DESIGNING THE NEXT INFANTRY FIGHTING VEHICLE

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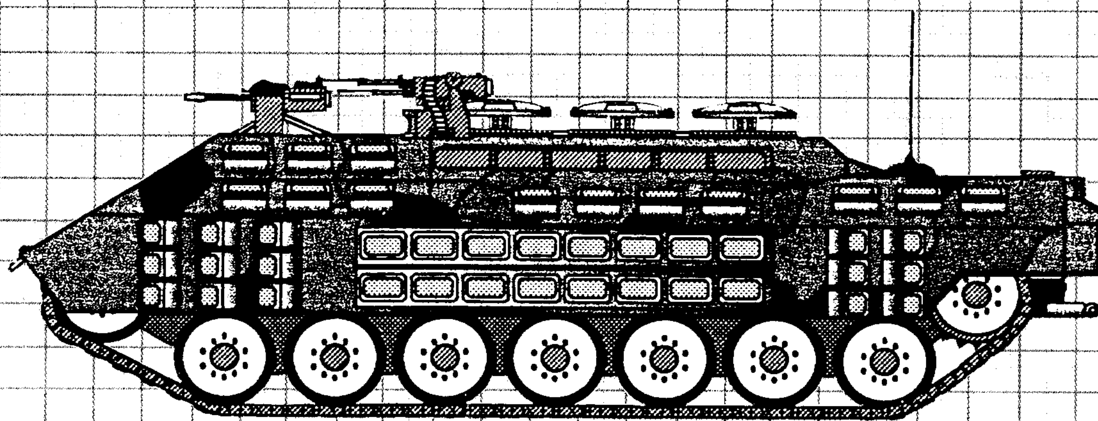

The design of armored vehicles for transporting infantry has been debated almost since the inception of armored warfare itself. Immediately after the introduction of tanks on the Western Front in 1917, attempts were made to transport infantry in compartments in the rear of some vehicles. These attempts were less than successful, and the debate over tank-infantry tactics and the required technologies continues today.

In many respects, this study represents the latest chapter in the long-running debate over the design of infantry fighting vehicles (IFVs). The end of the Cold War, instead of simplifying things, made IFV development more difficult, with more competing requirements than ever before. Compounding these new design parameters has been a series of design mistakes dating back to the early stages of the Cold War period. The cumulative result is current generation IFVs that are generally unsuitable in both low-intensity and high-intensity scenarios.

This study begins by examining requirements for current and next generation IFVs—not a simple task: Attributes that are seen as essential by those with combat experience are sometimes at odds with other requirements that have largely driven IFV development since the end of World War II. The addition of low-intensity conflict operational requirements adds to the already long list of attributes an IFV must have.

On the basis of IFV requirements, the study then examines existing or new designs for suitability. Finally, a candidate design is chosen, and the study looks briefly at the feasibility of such a system in terms of engineering and cost factors that would affect its development and deployment.

A clear understanding of the relationship between tactics and technology is important to any discussion of present-day IFV tactics, requirements, and candidate technologies.

In cases where revolutionary technologies are initially introduced, these technologies naturally drive tactics. In most other cases—including those that involve the development of revolutionary technologies—tactics generally drive that development. Put another way, *revolutionary* technologies drive tactics; *evolutionary* technology development should be driven *by* tactics. Tactical requirements drive the process of IFV development in most cases.

Once the relative primacy of tactics in IFV development is established, the next challenge involves differentiating valid tactical requirements from those that are unfounded. Although it is a problem that defies simple solution, most would agree that tactical requirements developed in combat tend to be "good requirements" far more often than those developed during peacetime. If it is not feasible to develop tactical requirements through combat experience, peacetime requirements generated by organizations or individuals with combat experience may be the next best thing. Finally, tactical requirements generated in peacetime and without significant input from those with relevant experience are generally the least effective pattern.

IFV development reflects a common weapon system development phenomenon—an evolutionary technology influenced by a revolutionary technology. The first modern IFV, the Soviet BMP-1, was a direct product (in terms of design) of the Soviet attempt to evolve in reaction to the atomic bomb. Subsequent IFV development in the East and West reflected the influence of the BMP-1 design, even after it was clear that the influence of atomic weapons at the tactical level was no longer an overriding consideration.

Worldwide IFV development in the 1960s, 1970s, and 1980s proceeded almost solely in peacetime and with less and less input from individuals and organizations with actual mechanized combat experience. The result is not surprising: Current generation IFVs are largely based upon a revolutionary influence (nuclear war fighting) that was overemphasized, to be used in a conflict that did not occur (the cold war), and requested by tacticians working largely without the benefit of combat experience.

One problem with using input from organizations and individuals with mechanized infantry combat experience is that extensive experience of this type is increasingly scarce. Moreover, much of the available data is of limited value, and it is also possible to draw incorrect conclusions from combat. Still, ample data is readily available in the form of various limited conflicts and contingency operations, many of which have involved mechanized operations of some kind.

In its analysis of tactical IFV requirements, this study depends heavily upon such conflicts—and the organizations and individuals involved. Significant weight is also given to combat experience gained during the closing months of World War II, whose massive mechanized operations can bring still relevant input to the discussion.

Without doubt, the Israeli Defense Force (IDF) has had more mechanized combat experience than any other military organization in the world today. Its experience in Lebanon in 1982 provides rare data on mechanized operations in a low-to-medium intensity environment.

If learning through failure is an effective source for tactical IFV requirements, the Russian Army and its Soviet predecessor can provide significant data from experience in Afghanistan and more recently in Chechnya. Chechnya, in particular, provides invaluable data on the effectiveness of current generation IFVs and future tactical requirements. And the Soviets turned tank-infantry tactics into an art form in the World War II campaigns of 1944 and early 1945.

U.S. experience with mechanized warfare since the end of World War II has been somewhat limited, in spite of an impressive list of campaign credits. Although operation *Desert Storm* lacked the effective opposition to put U.S. Bradley IFVs to a real test, the conflict still provides valuable data.

U.S. experience in Operation *Restore Hope* in Somalia—the antithesis of *Desert Storm*—also provides clues to IFV requirements, despite the absence of U.S. IFVs during much of this unfortunate episode. U.S. operations in Northern Europe during 1944 and early 1945 yield relevant data on mechanized operations in a high-intensity conflict environment. (This study uses only two conflict levels. In a non-nuclear environment, conflict is generally low or high; *medium* only confuses the issue.)

Several individuals have also contributed to this discussion:

Major General Michael Lynch (U.S. Army, Retired), a veteran of World War II, Korea, and Vietnam, may be the most experienced U.S. mechanized infantry officer alive today, having commanded mechanized forces in combat at levels from squad to brigade. General Lynch himself counts his mechanized experiences during World War II as among the most valuable.

Brigadier Richard Simpkin, who served more than 30 years as an officer of the British Royal Tank Regiment, was one of the few writers to seriously examine the role of IFVs on the modern battlefield during the period after World War II. His books *Mechanized Infantry* and *Tanks* represent the best in analytical literature in the field of IFV development during the past 40 years. (If a reader notes similarities between this article and the writings of Brigadier Simpkin, this is no accident—his work is inherently tactical in both its approach and its largely inevitable conclusions.)

In addition, General Barry McCaffrey, as commander of the 24th Infantry Division during the Persian Gulf War, led his troops on the most rapid, far-reaching operational maneuver conducted by mechanized forces. More than any other commander on the scene, General McCaffrey was in a position to assess the effectiveness of current U.S. IFV systems and to draw conclusions regarding current and future requirements.

Establishing Requirements

The question of the *purpose* of an infantry fighting vehicle deserves far more intense scrutiny than it usually receives. Without an understanding of the functional role of an IFV, it is impossible to derive technology requirements from a focused perspective. While there are many potential operational requirements for an IFV, just two make up its functional role:

- To provide protected transport for infantry.
- To provide fire support for infantry during combat.

With these two fundamental requirements in hand, a careful analysis of various technologies will enable the developer to choose components that best satisfy these mission needs.

The primary components of an IFV design include *crew capacity, firepower, protection,* and *mobility.* From the standpoint of the dismounts, *spatial awareness* is another consideration that cannot be overlooked. The LIC environments encountered with increasing frequency in the 1990s have added yet another requirement to this group—*system flexibility.* Financial considerations add still another issue—*commonality of components.*

The four primary components—each heavily interrelated with the others—must be examined first, along with spatial awareness. Then the list of candidate technology requirements can be reviewed in light of flexibility and commonality.

Crew Capacity

Any analysis of IFV requirements must begin with a determination of appropriate crew size. As a start point for the discussion, Table 1 provides a sampling of current IFV capacities. Unfortunately, this table does not answer the most important question of how many dismounted infantrymen are necessary, and this must be addressed before any discussion of other characteristics can take place.

This study is a significant departure from generally accepted practice in that crew requirements determine vehicle capacity. The M113-to-Bradley evolution, like the armored personnel carrier (APC)-to-IFV evolution generally, illustrates the more conventional approach to this issue.

While the M113 APC carries 11 in addition to the driver and the vehicle commander, the M2 Bradley IFV carries six in addition to the two-man crew, resulting in an entirely new modified table of organization and equipment for the mechanized infantry squad organization. Anyone who might be tempted to criticize a decision leading to the downsizing of the mechanized infantry squad from 11 to 6 should first carefully evaluate dismounted infantry requirements.

While there is considerable variation in the crew sizes of various current generation IFVs, the difference between IFVs and APCs appears to lie with the intended functional role of the IFV in relation to its dismounted element. While an APC such as the M113 is too vulnerable to be of much help to dismounted infantry in combat, a new IFV such as the M2 Bradley is intended to function as an additional fire team. This accounts for the decrease in crew size from 10-12 in most APCs to an average of 6-8 among current IFVs. This also explains Simpkin's IFV design, which envisions a six-man dismounted element.

Unfortunately, while the six-man squad with an IFV acting as a second fire team seems reasonable, several factors undermine the validity of this approach. The loss of one or two members of a six-man squad in combat quickly renders it ineffective. In a more practical vein, day-to-day mission requirements typically reduce a six-man squad to four or five soldiers, or less, before operations even begin.

Finally, if the IFV is to provide the support of a second fire team, the vehicle must be survivable in this role, and most are not. Current generation IFVs such as the M2 Bradley and the BMP-3 are in many respects as vulnerable to antiarmor weapons as the M113 and BTR-60 APCs of 20 years ago. The end result, given current IFV design, is a squad that is often combat ineffective from the outset and a vehicle that is not survivable in the "second fire team" role.

In order to be most effective, an IFV and its dismounted infantry element must be both robust and survivable. While a six-man dismounted squad may work well in theory, operational considerations argue for an element of eight or more. At the same time, even this size requires that an IFV act as a supporting fire team, which in turn argues strongly for an IFV that can survive in this role. In terms of the dismounted element the IFV will carry and support, more is almost always better.

Firepower

Vehicle-mounted firepower is easily the most debated aspect of modern IFV design, and this distinction is well-deserved.

VEHICLE	ORIGIN	CREW SIZE
M2 Bradley	United States	2 Crew + 6 Dismounts
BMP 2	USSR/Russia	3 Crew + 6 Dismounts
Marder	Germany	9 (No Breakout)
AMX10P	France	3 Crew + 8 Dismounts
Warrior	United Kingdom	3 Crew + 7 Dismounts
Achzarit	Israel	3 Crew + 7 Dismounts

Table 1

Most design experts agree that the choice of a weapon system is a typical start point, because weapon size tends to drive most other critical vehicle dimensions. Technical design issues aside, most discussions focus on which tasks IFV-mounted firepower should accomplish on the battlefield.

Given the fundamental missions of an IFV—protected transport of infantry on the battlefield and fire support for dismounted infantry during combat—the key functions required of IFV armament include the following:

• Suppression of enemy infantry or antitank guided weapons (ATGWs) in the open or within soft cover.

• Suppression of infantry or ATGWs in hard cover or entrenchments.

• Suppression or defeat of soft transport and light armored vehicles.

Note that the ability to fight tanks is not on this list. As the body of this analysis will demonstrate, the belief that IFVs should be armed with weaponry designed to engage enemy main battle tanks (MBTs) is the single greatest misunderstanding of IFV mission requirements. As Simpkin and others have pointed out, engaging an enemy MBT with vehicle-mounted firepower places the dismounted element at avoidable risk. Tanks fight tanks. IFVs must be prepared to survive encounters with enemy tanks as they go about performing their primary tasks.

As with the analysis of IFV requirements in general, an examination of IFV armament options begins by establishing the legitimate tactical requirements. Then an analysis of the various armament options can be conducted.

General categories of IFV armament include the following:

High velocity gun/missile. Gun and missile designs, typified by the BMP-1, suffer from two deficiencies, both of which detract from primary IFV missions. The inclusion of both a gun and a missile system requires that the IFV carry large stocks of ammunition at the expense of space for infantry. Storing this ammunition close to the infantry squad is inherently dangerous (many of the BMP-1 kills during the Gulf War were catastrophic due to its thin armor and vulnerable ammunition stowage). Finally, the requirement for a large turret to house the cannon detracts from the vehicle's mobility, heightens its profile, and further decreases crew capacity.

Gun. In a perfect world, the development of an IFV with a 75mm-120mm gun would seem to represent an ideal hybrid between tank and IFV. Unfortunately, experience suggests that this combination falls short in one key area—crew capacity—and the ability to carry a full infantry squad into combat is essentially non-negotiable.

To date, the only army that has developed a gun-armed MBT/IFV is the IDF, and in this regard the Israelis have also come up short. Although the Merkava is an extremely innovative design with much to offer in both protection and firepower, its rear crew compartment is too small for more than five or six soldiers. Indeed, the Israelis do not use this compartment in an infantry carrier role but use it to stow additional supplies and ammunition. Simpkin takes an approach similar to the Israelis in his proposal for a gun—armed IFV, but his design suffers from the same flaw—it carries just six dismountable infantrymen because of the space taken by the turreted high-velocity gun.

Autocannon/missile. A combination of autocannon and missile systems is a step in the right direction. The autocannon provides both enemy infantry suppression and the ability to engage thin-skinned vehicle targets that an IFV might encounter in performing its infantry support mission. Because of the relatively small caliber of the weapon, considerable ammunition can be stored without an unacceptable loss of space for the infantry squad. Finally, the turret required to house the autocannon can be relatively small, or even nonexistent.

Unfortunately, the inclusion of a vehicle-mounted antitank missile system reflects an imperfect understanding of IFV mission requirements. The desire to give the IFV the ability to engage tanks is based upon two concepts that combine to render IFV-mounted missile technology inappropriate, even dangerous: the tactical IFV-MBT relationship and gun-missile engagement characteristics.

The tactical disconnect behind IFV-mounted missile technology is relatively simple. AirLand Battle doctrine dictated that IFVs operate with tanks. Among other implications, this means that friendly tanks deal with any enemy tanks encountered. The disconnect occurs in those unusual situations where IFVs operating *without* tanks encounter enemy MBTs; if these tanks stand in the way of accomplishing the infantry missions, the dismounted squad, not the vehicle, tackles the threat with antiarmor systems. Placing the antiarmor system on the IFV just encourages the vehicle commander to engage the tank, possibly disregarding the IFV's primary missions. As Simpkin points out, "It is quite simply that moving or siting the IFV to make use of its vehicle-mounted firepower puts the maneuver team at avoidable risk."

The division of labor is much the same as the MBT/IFV interrelationship—IFVs get the infantry where it needs to go and provide suppressive fire once it dismounts. As its contribution, infantry helps provide suppressive fire for the IFV while on the move, fights the enemy infantry threat when dismounted, and uses its specialized antiarmor systems to defeat the occasional armored threat.

The Israelis have come to grips with this essential IFV philosophy. In a largely desert environment (with engagement ranges that might suggest a TOW system), they have opted for an IFV with no significant antiarmor capability. The division of labor between infantry and IFV is critical; trying to make an IFV capable of all things makes it incapable of most.

The second and most compelling argument against an IFV-mounted missile lies in its engagement characteristics. While the range and accuracy of missiles such as the TOW IIB are obvious, their value in tactical combat is open to question. The single greatest advantage the IFV gets from a TOW launcher is the ability to destroy enemy armor at ranges beyond 3,000 meters. Indeed, because of the guided missile's classification as a "slow firer," this range advantage is the only engagement "envelope" that gives the IFV any chance of surviving such an engagement, let alone winning it.

Unfortunately, many gun and missile engagements take place at ranges of much less than 3,000 meters. In fact, most engagements actually take place at 500 to 1,000 meters. While a number of long-range kills were made in the Gulf War, desert terrain is not necessarily representative of future operating environments. Future conflict scenarios suggest the Balkans or the Korean peninsula as likely and far more constrained operational areas. Finally, because a missile is a slow firer, launching at maximum range in a restrictive environment is worse for the IFV, in that it gives the enemy tank the greatest opportunity to return fire. From the perspective of range-based engagement characteristics, missile technology is appropriate in relatively few cases.

Once engagement range constraints are understood, the IFV-tank engagement problem is clear: A tank lying within effective range of the IFV will probably fire back, with predictable results. In short, if an IFV intends to engage a tank in a doctrinally appropriate environment, it must be capable of "fast firing" and of surviving return fire. Current IFVs armed with autocannon and missile do not meet these critical requirements.

Autocannons are an appropriate IFV armament for a variety of reasons. The turret space required is significantly less than that of a larger gun. Ammunition storage requirements are also reduced, and there are other benefits as well. Ironically, one important advantage is that the autocannon eliminates the temptation to engage a tank with a TOW at 2,000 to 3,000 meters. Most important, the autocannon provides effective suppressive fire for dismounted infantry, which speaks directly to the second fundamental IFV requirement—fire support for infantry during combat.

Automatic grenade launcher (AGL). Of all the weapon options available as IFV armaments, the AGL may be the most suitable. It occupies the least space of all the options except the machinegun. At the same time, AGLs—typified by the U.S. Mk 19—have rounds capable of engaging troops, lightly armored vehicles, and various fortifications and other hard targets with highly satisfactory results. One subtle but important advantage of AGLs is their relatively low muzzle velocity; this allows them to engage troops in dug-in positions largely immune to higher velocity weapons with flatter ballistic trajectories. Finally, AGLs can place smoke more effectively and efficiently than any of the other options, an often overlooked yet vital aspect of the infantry mission.

Machinegun. The machinegun is also a very appropriate

AUTHOR'S NOTE: This article is based on an extensive study of infantry fighting vehicles. The research and analysis and the resulting proposal for a future vehicle are my own. I welcome any comments, suggestions, ideas, or counterarguments. I can be reached through E-mail: gpickell@aol.com; FAX (703) 354-5951; or phone (703) 354-6825.

form of IFV armament. Selecting the machinegun over an autocannon is a tradeoff between space and suppressive firepower. The Israelis, in mounting a single 7.62mm machinegun on their revolutionary Achzarit heavy infantry fighting vehicle (HIFV), have clearly chosen more crew capacity at the expense of firepower, perhaps because of the relatively limited space available in the T-55 chassis that is the basis for the vehicle. The German Marder IFV represents an opposing point of view, with firepower taking relative precedence over crew space. Both cases are essentially appropriate; discussions regarding crew size demonstrate that so long as a dismount element of at least eight soldiers can be accommodated, the choice between machinegun and autocannon is best left to the engineers and the physical characteristics of the vehicle chassis itself.

Protection

Protection can be classified as either passive or active:

Passive Protection. Passive protection refers to the survivability offered by conventional, non-reactive armor systems. These systems—which include ceramics, composites, titanium, and other materials—can be qualified in terms of the equivalent protection they provide in millimeters of rolled homogenous armor (RHA). As an example, Chobham composite/ceramic armor (along with depleted Uranium) provides the U.S. M1A1 tank with about 1,300mm RHA equivalent protection against high-explosive antitank (HEAT) rounds. Passive armor protection is the primary protection afforded an IFV.

The degree of passive armor protection an IFV offers its internal infantry squad is a central factor in mission capability. If, for example, an IFV is designed for a tactical exploitation role in a nuclear environment—as was the case with the Soviet BMP-1—it requires a minimum of protection. Similarly, if an IFV is dedicated to performing rear area security functions, protection against small arms fire may be enough. On the other hand, if an IFV must operate in a more dangerous environment, more protection is needed. In each case, armor protection should be commensurate with the IFV's anticipated mission profile.

U.S. AirLand Battle doctrine was clear in its implications for IFV protection. It described a high-intensity environment in which MBTs and IFVs operate together to apply fully synchronized combat power against an opponent. This intimate tactical operating relationship is not new. U.S. combat formations have been operating in a functionally similar manner since the formation of the first U.S. armored divisions before World War II. U.S. doctrine explicitly requires that IFVs operate close to the tanks they support and are supported by.

It follows then that IFVs acting in this role should be protected to the same degree as tanks. Simpkin noted in his landmark study *Mechanized Infantry* that "if the IFV is to lead and stand a high chance of survival in a tank versus tank engagement, it must have the same protection as the tank over its frontal arc." The IDF has embraced this concept, adding an estimated 14 tons of armor to its HIFV. Finally, the Russians, smarting from their experience in Chechnya, have noted the requirement for an IFV with MBT—level protection. From the perspective of those with recent experience, the requirement is obvious, even fundamental.

From a broader perspective, however, the protection requirement is far from fundamental. Added protection means added weight, which in turn brings the up-armored IFV into conflict with a variety of competing requirements—ground mobility, air transportability, and swim capability. Before any protection requirement can be generated, the added armor the tacticians advocate must be reconciled with the mobility requirements viewed as necessary for broader military missions.

Ground mobility with regard to weight boils down to the ability of heavy vehicles to use the bridges and roads in an area of operations. The Soviets have long recognized this important issue, designing MBTs weighing less than 50 tons. In contrast, NATO countries have accepted the limitations imposed by much heavier designs, rationalizing this approach in part on the axis of the well-developed roads and bridges of Western Europe.

While the wisdom of these different approaches is open to debate, operations in areas with less developed roads and bridges require that an IFV weigh much less than the 60+ tons of many western MBTs. Such a reduction in weight is clearly feasible—a limit of perhaps 50 to 55 tons for an up-armored IFV still offers significant design flexibility in view of current IFVs weighing 20 to 30 tons. While constraints imposed by ground mobility must be recognized as an important factor in IFV design, there is still considerable flexibility within these constraints.

The single greatest force behind IFV weight restrictions may derive from the requirement that IFVs be air transportable. U.S. strategic planning is predicated to a large extent upon the number of C-141 equivalent aircraft sorties required to deliver specific force packages to various destinations. Organizational as well as technological weapon system decisions are often driven by aircraft sortie restrictions instead of any tactical requirement.

Given the apparent importance of this competing requirement, the issue of sufficiency must be addressed from a strategic lift perspective to derive realistic airlift-driven weight restrictions. Notably, top-end weight is not an issue. Aircraft, including the U.S. C-5 and C-17, are capable of transporting 67-ton M1A1 tanks and even heavier loads. The issue is numbers: How many IFVs does one *plan* to airlift? This is extremely important, in that it allows a determination of weight restrictions to be based on real-world strategic requirements.

The answer to the "how many" question is, in short, *few if any*. IFVs and tanks are rarely transported by airlift, and in cases where they are, the numbers are extremely limited. Evidence of this can be found in the numerous U.S. contingency operations of the past 40 years. At no time during this period has armor been air transported in significant quantities. Even during the earlier stages of the Gulf War, when the need for armor of any kind was greatest, other priorities were deemed more important. In Somalia, armor was airlifted after the fight in Mogadishu, but in small quantities. Notably, the unwillingness to airlift armor applies to *all* armor; strategic deployment planners are no more willing to ship 25-ton M2 IFVs than 67-ton M1A1 tanks. In short, airlift-based restrictions on IFV weight and protection are largely inappropriate, if not entirely irrelevant.

The requirement that IFVs be capable of swimming water obstacles may be the least valid of the mobility-based weight restrictions, from both doctrinal and practical standpoints. U.S. AirLand Battle suggested that IFVs act in concert with tanks, and tanks cannot swim. As Simpkin noted, "Swimming is super, but too bad if IFVs and tanks have to cross at widely separated sites because one swims and the other snorkels or needs bridging."

Another strong argument against this requirement is the fact that it is rarely used. From the standpoint of both doctrine and practice, a swim capability is unnecessary and, if used as envisioned, could separate the IFVs from the tanks with which they are teamed.

In summary, then, the level of passive armor protection in IFV design is of paramount importance in mission capability, and given the relative lack of importance of both air transportability and a swim capability, this protection should take precedence in any analysis of relative value. In addition, trafficability in less developed areas requires that weight be restrained because the bridges are often rated at 50 tons or less. At the same time, the level of protection should be at or near that of the MBTs with which IFVs operate. For the U.S. Army, this means a weight of 50 to 55 tons with protection at or near that of the M1A1 tank.

Active Proximate Protection. Active proximate protection refers to measures taken to defeat threats near the vehicle. This relatively new field includes two primary technologies: reactive armor and proximity defense systems.

Reactive armor technology uses exploding armor blocks to defeat both chemical energy and, to a lesser extent, kinetic energy penetrators. Reactive armor explodes upon contact with the incoming round, deflecting the energy stream or kinetic penetrators and degrading penetrator effectiveness enough that it can be defeated by the conventional armor to which it is attached. Initially developed by the IDF, this technology is quite effective against chemical energy rounds.

Most current generation MBTs do not use reactive armor. They rely instead on compound armor, which embodies many of the properties of reactive armor blocks, though at a much higher cost in weight. IFV weights are often significantly less because they use aluminum or RHA with reactive armor added as needed. Even this is an imperfect solution—reactive armor provides imperfect coverage and can add as much as 10 tons to vehicle weight, as in the case of the M2A1 Bradley.

Proximity defense systems (PDSs) are an important innovation in active armor protection. They consist of command-detonated antipersonnel devices fixed to the sides, front, and rear of an IFV for protection against dismounted infantry. While the requirement for such protection has existed since the inception of armored vehicles themselves, the end of the Cold War and the resurgent LIC environment have lent renewed urgency to the need. Chechnya provides graphic evidence of such a requirement, as do the photographs of the destroyed German-made Condor APCs in the aftermath of the fighting in Mogadishu. The need for such a system has not gone entirely unnoticed; it is believed that the IDF is experimenting with a rudimentary PDS by affixing claymore antipersonnel mines to the sides of their MBTs and IFVs.

Mobility

From a tactical perspective, mobility requirements for IFVs are generally based on the speed of the MBTs with which they operate. Performance requirements for the M2 Bradley were based in part on a requirement to keep up with the M1A1 tank. Notably, the requirement was not purely based on miles per hour—even the M113 is capable of relatively high speeds in favorable terrain. The Bradley mobility requirement centered instead upon equivalent speeds over broken terrain in an operational environment, something far beyond the capabilities of the M113. This requirement was further validated in view of the AirLand Battle doctrine outlined earlier.

While cross-country IFV mobility is certainly important, little attention has been paid to the question, "How much is enough?" During Operation *Desert Storm,* the 24th Infantry Division advanced 75 miles on the first day of the ground war, "traveling at sustained speeds of 25-30 mph against light opposition" (according to the Defense Department's final report to Congress). Even disregarding the discrepancy between "sustained speeds" and 75 total miles (25mph in 12 hours equals 300 miles), the actual sustained speed of the division was significantly less than the rated speed of either the M1A1 MBT or the M2 Bradley. Other evidence bears out the idea that the relevant speed requirement for heavy mechanized forces is that required *off-road and in formation.*

The objective in establishing a relative speed benchmark is to allow an analysis of available power plants for use in a given IFV design. Notably, it is almost as serious an error to overpower an IFV as to underpower it. In addition to the tactical dangers noted by Simpkin, a power plant that generates horsepower significantly in excess of power-to-weight requirements probably detracts from an optimum vehicle design, in both excess weight and space requirements. The most favorable power plant is one that provides the required power-to-weight ratio and resultant mobility while reducing powerplant space and weight.

Determination of the required speed and the ratio of horsepower to weight for a U.S. IFV is relatively clear: The IFV must have speed and maneuverability comparable to those of the M1A1 tank it will accompany. The standard M1A1 has off-road speed rated at 30.18 mph, thereby providing a benchmark comparable to the 25 to 30 mph noted earlier. A power-to-weight ratio comparable or identical to the M1A1 is not necessary; the M2 Bradley has essentially equivalent mobility characteristics while generating just 20.8 HP per ton compared to the M1A1's 27 HP per ton. With a benchmark of 20 to 22 HP per ton needed to generate the required mobility characteristics, and a vehicle weighing 50 to 55 tons, a power plant in the 1,100 HP class is enough.

Spatial Awareness

Spatial awareness refers to an awareness of surroundings in a given environment. In the case of an IFV, it is critical that a dismounting infantry squad be able to orient rapidly to its surroundings upon leaving the vehicle. This requirement may not be clear outside the user community, but among those with experience, it is critical. Taking this requirement into account, the Israeli Achzarit provides for excellent fields of fire for infantrymen riding inside. At the same time, conventional IFV spatial awareness allowances range from marginal for the Bradley to little or none for the Condors that saw action in Mogadishu. A tactically appropriate IFV design must include excellent fields of fire for mounted infantry, allowing these personnel to retain awareness while riding "buttoned up."

As anyone who has ridden in a buttoned-up IFV will attest, the awareness provided by vision blocks is limited at best. Closed-circuit video devices, built into the IFV hull, can give the vehicle commander and the leader of the dismounted element excellent 360-degree visibility. Integration with night vision technology and thermal imaging systems would further enhance this important aspect of IFV design. Such technology does not, however, obviate the need for vision blocks.

Finally, General Lynch adamantly argues that true spatial awareness can be achieved only by operating without either vision blocks or high technology video. He points out that the risks of operating with open hatches in the crew compartment are more than justified by the significantly increased effectiveness of the mounted infantry. NBC protective requirements do not rule against such an approach. When operating in a contaminated environment, the infantry squad in question typically dons protective gear while inside the vehicle in any event. The development of hatches used in the Merkava series of vehicles contributes to the feasibility of this idea, allowing soldiers to operate completely unbuttoned, partially covered, or fully buttoned up as the situation requires (Figure 1).

System Flexibility

The single greatest impetus for change in tactical IFV requirements results from the end of the Cold War. Flawed as many Cold War IFV development requirements may have been, the U.S.-Soviet confrontation resulted in an essentially one-dimensional conflict pattern that drove all IFV development. The end of the Cold War and the dramatic reemergence of "small wars"—variable intensity conflicts such as Somalia and Bosnia—have resulted in numerous competing requirements, each valid for a given intensity level. Recent experience strongly argues for flexible designs that can rapidly adapt to changing levels of conflict. The evidence also strongly suggests that current IFVs do not always measure up to these new requirements.

There is clearly a requirement that the IFV of the 21st century be capable of operating effectively in low and high intensity conflict. A more subtle requirement is that this IFV be capable of rapid reconfiguration to meet the requirements of high-intensity "spikes" within low-intensity conflict. These spikes represent the inevitable bursts of violence that naturally occur in a counterinsurgency environment. Failure to consider these spikes will result in the design of equipment well suited to low-end violence but utterly vulnerable to bursts of intense combat. Attention to this vital aspect of LIC will result in an IFV that boasts a degree of reconfigurability not seen in conventional IFV design.

The U.S. experience in Somalia is an excellent example of an intensity spike, as well as the hazards of confronting such a spike with inappropriate technology. *Operation Restore Hope* was, by any contemporary description, a low-intensity conflict over 99 percent of its duration. Unfortunately, the 18 hours that made up the other one percent were clearly high-intensity.

The armored vehicles available were designed for low-end violence. The Malaysians' Condor APCs unquestionably saved the day for the U.S. troops involved, but only at grievous cost to the vehicles and crews. The battle was nearly lost in spite of these vehicles. The APCs' nemesis was the RPG-7, a system just as lethal to most current generation IFVs in a built-up area like Mogadishu. IFVs will often represent the high end of ground combat capability in low-intensity conflict; they must be designed to be adaptable to multiple intensity levels.

The requirement subset that includes low-intensity conflict centers primarily on protection and firepower as they pertain to appropriate threat scenarios. In low-intensity conflict, armor must be proof against 7.62mm small arms, up to 23mm KE/HE heavy weapons, and chemical energy up to 100mm HEAT. During a high-intensity spike, armor must protect against heavy weapons up to 125mm KE/HE and chemical energy up to 150mm tandem charge HEAT.

The importance of political considerations in LIC provides an interesting case in point for flexibility. While it may be attractive to deploy heavily armed combat vehicles in anticipation of a high-intensity spike, political considerations can and often do prevent such measures. U.S. intervention in Haiti saw limited use of heavy armor, with M2 Bradley IFVs but no tanks visible during the critical early days of the intervention. UN protective force deployments in Bosnia may represent the logical extreme in this dangerous game, with lightly armed IFVs operating in a scenario with frequent high-intensity spikes, due to political considerations. U.S. experience in Somalia is an example of the political dimensions of decisions whether or

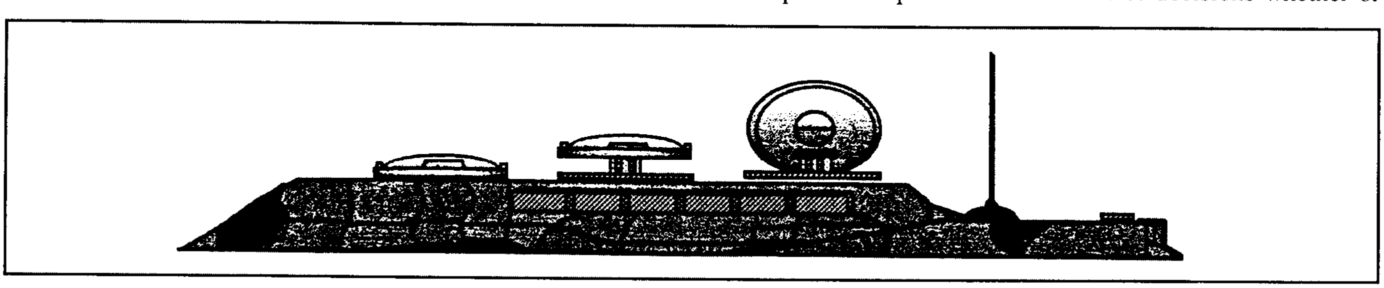

Figure 1. Hatches like these allow 360-degree view for dismount element.

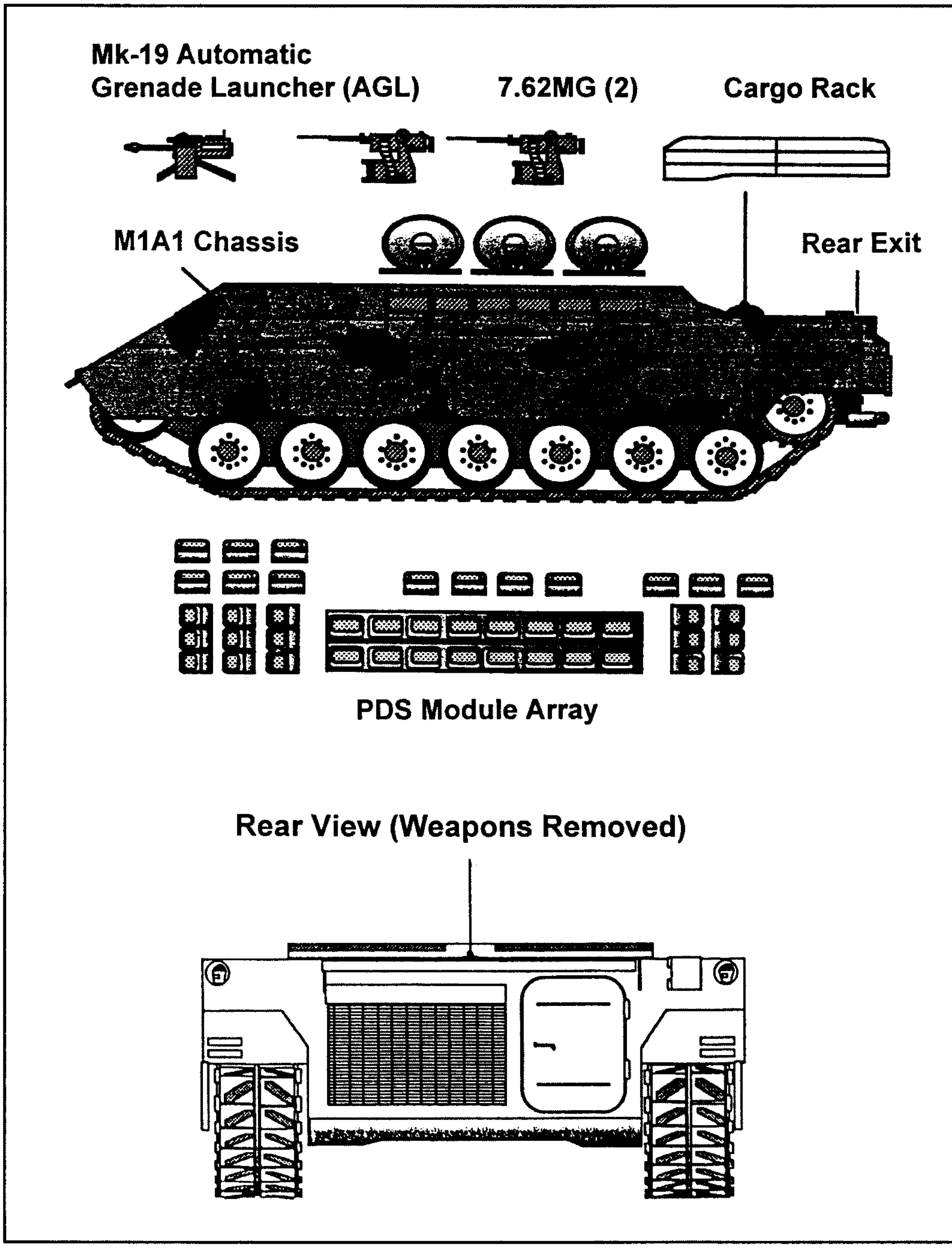

Figure 2. XM4 Candidate RIFV System Components.

not to deploy heavy armor and the disaster that can result. Interestingly, the single greatest determinant in these deployment considerations is in appearance: Tanks connote a high-intensity combat environment that political issues cannot allow, while IFVs seem to imply a gentler form of conflict.

Firepower in humanitarian assistance (HA) is an often-ignored issue that is far from contradictory; many missions that begin this way end as LIC scenarios. Most HA missions retain at least the possibility of open conflict, as demonstrated during Operation *Provide Comfort* in Iraq and the Rwandan relief mission in Central Africa. In such missions, it is often better to provide vehicles without significant firepower of any kind. At the same time, the vehicle must be able to protect passengers and support them with heavier firepower when necessary. In short, the truly flexible IFV must be reconfigurable, with armament that can be upgraded or downgraded as the situation requires.

Component Compatibility

The compatibility of MBT and IFV components offers many obvious advantages in cost as well as logistics. An IFV based on an MBT hull significantly reduces the developmental costs of new vehicle design. Once the vehicles are deployed, the commonality of components can greatly reduce the logistical burden imposed on combat and combat support formations.

Despite these advantages, however, the development of common-chassis MBTs and IFVs has not taken place. In a notable exception, the IDF experimented in this area using a de-turreted Merkava for its design. Although the result may be the best IFV ever designed, the expensive chassis forced the IDF to look elsewhere to meet its IFV requirements. The eventual development of the Achzarit IFV, based on a surplus T-55 hull, represented the best low-cost solution available to the Israelis. For other Western armies that do not suffer from the same tremendous budget constraints, IFV development using chassis or other components common to indigenously produced MBTs offers significant savings over specialized, noncompatible designs.

Before examining candidate systems, a summary of technology requirements generated by this tactical analysis is in order. The following are the tactically derived requirements for the next generation U.S. infantry fighting vehicle:

Crew Capacity: Minimum eight dismounted personnel.

Armament: Automatic grenade launcher and machinegun (7.62mm-12.7mm).

Passive Protection: 1,300mm against chemical, 600mm against kinetic penetrators over frontal arc.

Weight: 50 to 55 tons.

Proximity Protection: Reactive armor and PDS.

Ground Mobility: Maximum speed 30 mph off-road, 45 mph on-road.

Spatial Awareness: 360-degree field of view for vehicle commander and dismount commander. Partial view for each infantryman when operating buttoned-up.

Component Commonality: MBT component compatible.

System Flexibility: Reconfigurable for multi-level conflict intensity.

Existing Technology Options

Few, if any, existing IFVs meet these technology requirements. A summary of these requirements along with the latest U.S. IFV, the M2 Bradley, illustrates the point (Table 2).

At present, only one IFV in existence satisfies most of the requirements outlined in this study. The newly revealed Israeli Achzarit is an innovative answer to an up-armored IFV requirement. While it does not necessarily fit U.S. needs, it does provide an excellent conceptual starting point for any U.S. design (Table 3). The Achzarit, with its excellent protection, appropriate firepower, and adequate crew capacity—is presently the only true HIFV in existence.

	CANDIDATE IFV	BRADLEY IFV
Crew	Minimum 8 Dismounts	6
Armament	MG Autocannon	Autocannon Missile
Passive Protection[1]	600mm - KE 1300mm - CE	30mm - KE 500mm - CE[2]
Ground Mobility		
Road:	45 mph	41 mph
Ground Pressure:	.96 kg/cm(sq)	.54 kg/cm(sq)
Weight :	50 tons	22.5 tons
Spatial Awareness	360-degree field of vision	Limited
System Flexibility	Reconfigurable for HA/LIC/HIC	None
Component Commonality	M1A1 Compatible	Limited

[1] The first value refers to protection against kinetic energy penetrators, the second value to chemical energy penetrators, both over vehicle frontal arc. (From *Desert Shield Factbook*, by Frank Chadwick, p. 19.)

[2] From *Desert Shield Factbook*, p. 19.

Table 2

	CANDIDATE IFV	ACHZARIT HIFV
Crew	Minimum 8	8
Armament	MG Autocannon	7.62mm MG
Passive Protection	60mm - KE 1300 mm - CE	Approx. 14 tons RHA*
Active Protection	Reactive/PDS	Blazer/Claymore
Ground Mobility		
Road:	45 mph	41 mph
Off-road:	30 mph	??
Ground Pressure:	.96 kg/cm(sq)	.54 kg/cm(sq)
Weight:	50 tons	44 tons
Spatial Awareness:	360-degree field of vision	360-degree field of vision
System Flexibility:	Reconfigurable for HA/LIC/HIC	None
Component Commonality	M1A1 Compatible	None

Table 3

*Precise RHA equivalent unavailable.

The Candidate Reconfigurable IFV

Given the inability of most existing systems to meet the tactics driven specifications for a candidate reconfigurable infantry fighting vehicle (RIFV), one must look elsewhere to satisfy these requirements. The XM4 system shown in Figure 2 is one potential design that meets the technical requirements outlined. This system, based on a de-turreted M1A1 chassis, provides the mobility, crew capacity, protection, and weapon systems to handle a variety of threat scenarios.

It accommodates a maximum of 10 soldiers (two crewmen, eight dismounts). It is armed with two 7.62mm machineguns and a 40mm automatic grenade launcher.

The XM4 uses a new type of PDS that combines the functions of conventional reactive armor with antipersonnel capability. The tiles are mounted on the sides, rear, and top of the vehicle to provide CE protection in areas that lack compound armor protection. The primary role of PDS tiles is antipersonnel, offering a capability equivalent to an enhanced claymore antipersonnel mine. PDS elements are mounted in rows with individual rows angled to provide high-angle and low-angle coverage.

The XM4 power plant is a 12-cylinder Detroit Diesel engine that develops 1,200 HP. With an estimated vehicle weight of approximately 50 tons, this results in a very satisfactory power-to-weight ratio of 24 HP per ton and ground pressure of slightly less than that of the M1A1. Speeds are compatible with M1A1 performance at about 45 mph on-road and 30 mph off-road. The diesel was chosen over the turbine because of the turbine's excessive space requirements and fuel consump-

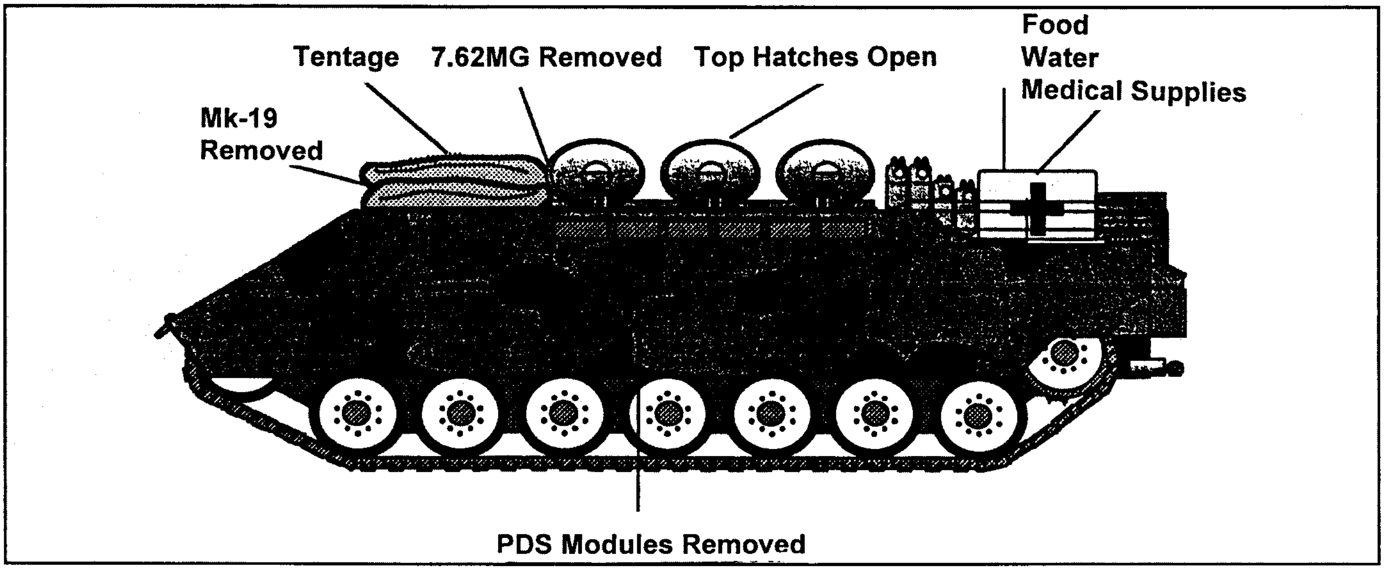

Figure 3. XM4 Humanitarian Assistance Configuration.

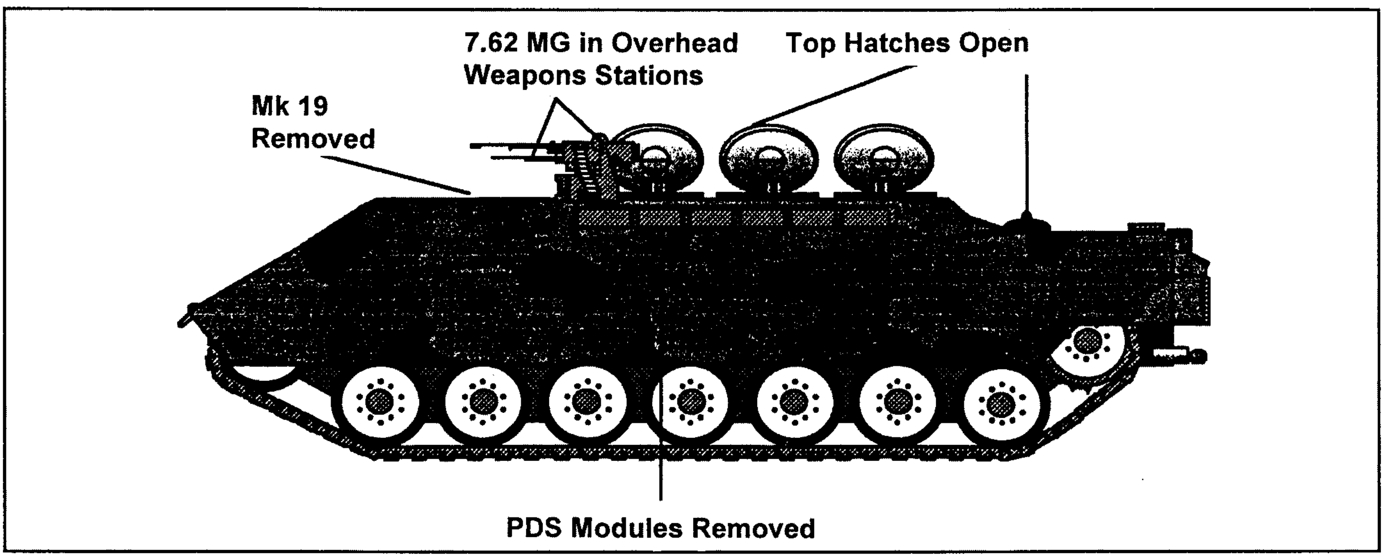

Figure 4. XM4 Low-Intensity Conflict Configuration.

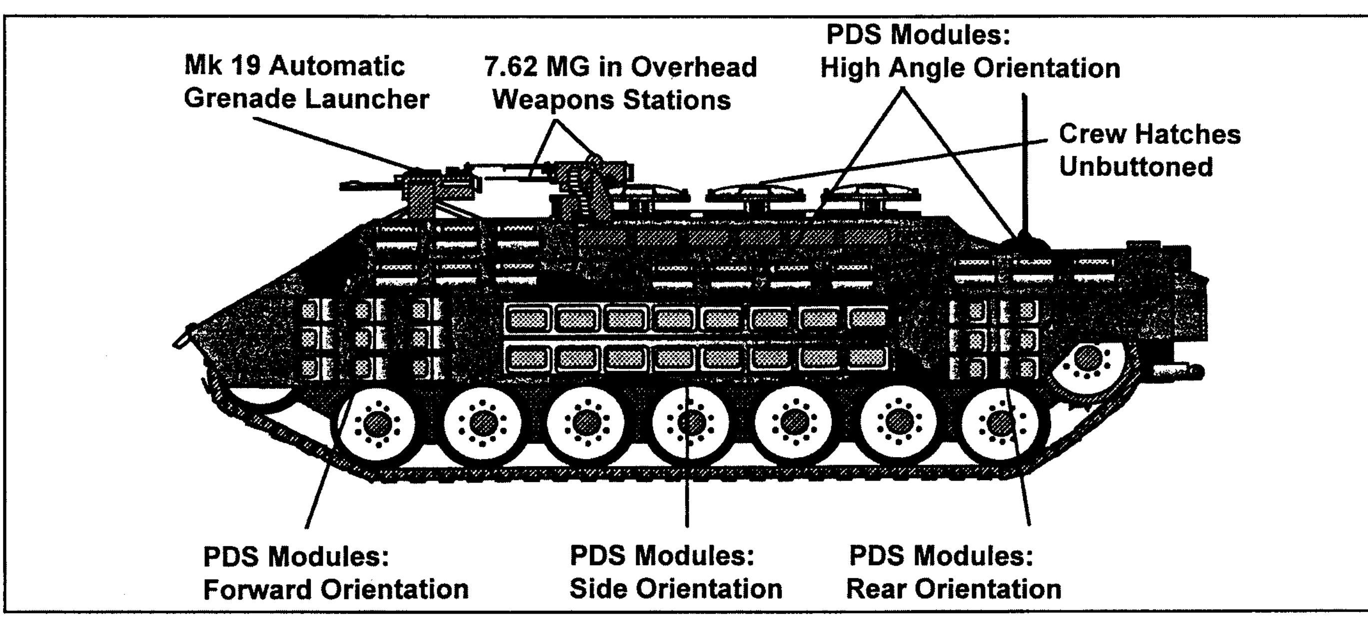

Figure 5. XM4 High-Intensity Conflict Configuration.

tion. Replacement of the turbine with the diesel enables developers to design the vehicle's rear exit.

The XM4 offers unsurpassed spatial awareness for vehicle-mounted infantry and crew. Inexpensive TV technology allows excellent flexible views for crew members and infantrymen operating buttoned up. Additional options available using this technology include integral night-vision and even thermal devices. Finally, back-up vision blocks allow 360-degree vision for the mounted infantry.

The XM4 is fully reconfigurable for HA, LIC, and HIC missions (Figures 3, 4, and 5). It is approximately 75 percent M1A1 compatible. Chassis components are fully interchangeable. (The engine plant is a primary contender for the U.S. Marine Corps advanced amphibious assault vehicle.)

XM4 Tactical Impact

While the flexibility of the XM4 design affects all threat levels, its most significant tactical effect lies in a high-intensity environment (as well as high-intensity spikes in other scenarios). The primary debate concerning conventional IFVs focuses on the internal infantry squad's dismount point relative to the objective, which is necessary for a vehicle that is vulnerable to antiarmor weapons. With the XM4, this discussion is no longer necessary—the infantry element dismounts *on* the objective, shortly after the surrounding area is saturated by PDS antipersonnel devices.

Viewed from the enemy's perspective, the XM4's advantages are striking: At long range, the vehicle is almost impervious to conventional antiarmor weapons. At close range—long the domain of the well-trained soldiers who wield sophisticated portable antiarmor systems—the enemy is faced with a withering hail of fragments from claymore-like devices, detonated at irregular intervals as the XM4s work their way to the objective. Psychologically, the effect is devastating; even the best enemy infantry will not stand against armor that they believe cannot be defeated.

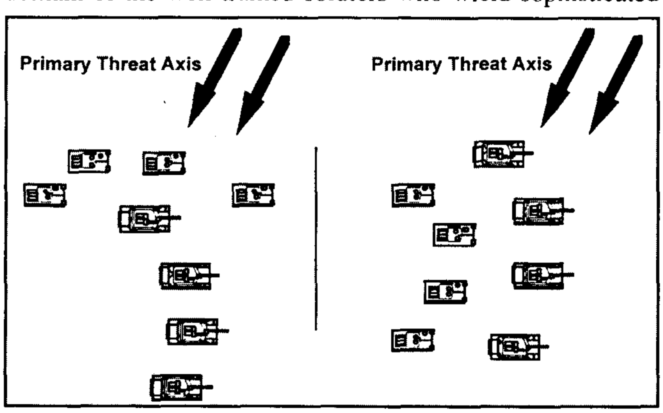

Figure 6. Tactical flexibility of the XM4 compared to that of the Bradley M2.

The tactical flexibility provided by the XM4 is just as striking when it is acting with the MBT because it has equivalent protection. Heavily armored IFVs such as the XM4 are capable of escorting MBTs on the primary threat axis (Figure 6). Conventional IFVs cannot provide this protection without extreme risk. Instead, U.S. doctrine has M2 Bradleys traveling under the protection of the M1A1s they are supposedly supporting. Worse still, if conventional IFVs attempt to provide primary threat axis security, the infantry squad ends up providing protection to its own IFV instead of the tanks. Paradoxically, current IFVs can provide added antiarmor capability in the non-threat axis configuration but are of relatively little use in suppressing enemy infantry in this role.

Unfortunately, organizational considerations and overall budget constraints would probably rule out the deployment of XM4s in large numbers. The Bradley, while lacking much of the XM4's flexibility, still has significant capabilities in all but the highest intensity scenarios. Additionally, the large fleet of Bradley IFVs is relatively new and represents an enormous financial and logistical investment.

The potential integration of XM4s in a heavy division structure might see one of the Bradley battalions designated the divisional RIFV battalion and refitted with XM4s. Other divisional mechanized battalions would retain the M2s. The RIFV battalion would fulfill the assault role, acting with one or more armor battalions to effect breakthroughs and stiffen defenses where needed. Bradley-equipped battalions would act in a tactical and operational exploitation role and provide essential rear battle support as well.

XM4 development and acquisition would benefit from existing component commonality, but the costs associated with the deployment of such a vehicle would be considerable. The principal contributors to cost would be the integration of a diesel power plant, redesign of the vehicle interior, development of a rear exit, and integration of the modular 25mm weapon system.

The cost could be expected to approach that of a conventional M1A1, although perhaps not that of an M1A2. Given the current and projected budget climate, it seems unreasonable at present to expect a complete transition from the Bradley IFV to the XM4 design. Fortunately, the organizational considerations outlined earlier do not point to such a requirement. A limited number of XM4 RIFVs, concentrated in divisional battalions, would provide the requisite capability without excessive cost.

The most important aspect of the IFV requirements developed in this study may be that it began without preconceptions or preconditions. First, the preeminence of tactical rather than technological requirements was established at the outset, allowing the design to proceed from a firm conceptual perspective. Using available combat experienced organizations and individuals as resources has allowed system attributes to be derived without interference from various competing technologies. Finally, once system requirements were firmly and legitimately established, available technologies could be analyzed. The result of this process, the conceptual XM4, is the most survivable and operationally flexible infantry fighting vehicle in the world.

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