

**GAO**

Report to the Chairman, Committee on  
Governmental Affairs  
United States Senate

November 1986

# BRADLEY VEHICLE

## Army's Efforts to Make It More Survivable



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National Security and  
International Affairs Division

B-221733

November 4, 1986

The Honorable William V. Roth, Jr.  
Chairman, Committee on Governmental Affairs  
United States Senate

Dear Mr. Chairman:

As you requested in your letter of October 4, 1985, we have been reviewing certain aspects of the Army's Bradley Fighting Vehicle Program. These include the ongoing live fire testing of the vehicle's vulnerability, proposed operational tests, its original mission requirements, subsequent changes to those requirements, and the Bradley's ability to perform its role as a carrier of the infantry squad and supporter of troops and tank forces during combat. A more detailed analysis of these issues is contained in appendix I.

On February 14, 1986, we furnished you our report on the first of two phases of the live fire vulnerability testing held at the Aberdeen Proving Grounds, Maryland. The tests, completed in October 1985, showed that the Bradley, as presently configured, is highly vulnerable to all antiarmor weapons. These test results and Army vulnerability models further showed that ammunition stored inside the vehicle, when hit, was likely to be the major source of crew casualties and catastrophic vehicle losses.

The second phase of the live fire tests, begun in March 1986, was to evaluate two proposed modifications of the Bradley which would upgrade certain features to reduce its vulnerability to enemy fire. This phase was suspended, by the Army Chief of Staff, in April 1986 following a disagreement between the Army and the Office of the Secretary of Defense (OSD) official assigned to monitor the tests, over the test methodology and the selection and placement of shots to be fired. Originally scheduled to be completed in time for the Army to report the results to the Congress by June 1, 1986, it now appears that the test results will not be available until the summer of 1987.

Although the live fire tests will provide information on the effectiveness of the armor enhancements, these enhancements are only expected to protect against the lower end of the scale of enemy antiarmor weapons. While any weapon system is vulnerable to overmatching threat weapons, for the Bradley to achieve an acceptable level of survivability

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the Army is relying on the vehicle's mobility and firepower and on tactics that will allow it to avoid overmatching enemy weapon systems, whenever possible. The Army has not yet conducted operational tests to determine how the tactics designed to enhance the vehicle's survivability would affect its fighting capability. An operational test the Army planned to start in October 1986 has been postponed indefinitely while new instrumentation is developed for the proposed test site, the Army's National Training Center, at Ft. Irwin, California. This instrumentation will not be completed until mid-1988.

The conference report to authorize fiscal year 1987 appropriations for the Department of Defense (DOD) requires the Secretary of Defense to plan, and the Secretary of the Army to conduct, operational tests of the two modified versions of the Bradley. One version, which the Army calls the high survivability Bradley, would have reactive armor and a spall liner added to reduce its vulnerability. The second modified version, called the minimum casualty vehicle, would have most of its fuel and ammunition stored outside. However, no time limit was specified on when these test results should be submitted. While DOD intends to perform these tests, the tests will be delayed until the instrumentation at the National Training Center is developed, and the live fire tests of the two modified Bradleys are completed.

Our examination of mission documents and discussions with Army officials did not disclose any change in the Bradley's basic mission of transporting the infantry squad into battle and supporting the troops and tank forces during combat engagements. However, the tactics for carrying out its mission have evolved as the Army gained a better understanding of the vehicle's capabilities and limitations. The Army has refined the doctrine for its use accordingly.

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## Conclusions

Concerns about the Bradley's survivability require that new operational tests be conducted with particular emphasis on how well the tactics devised for it will offset its vulnerability, and at the same time, permit it to retain its combat effectiveness.

It does not appear prudent to wait more than a year for the improved instrumentation to be developed at the National Training Center for the operational tests because other test sites with suitable instrumentation can be made available sooner, and are already instrumented for operational tests. Also, it is not clear why operational tests are being postponed until the live fire tests are completed. Operational tests should

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demonstrate the extent to which the Bradley can avoid being hit by enemy antiarmor weapons, and thus survive to perform its missions. The live fire tests will demonstrate the vehicle's ability to withstand such weapons if hit. While both types of tests are necessary to determine survivability, they can be performed during the same time period. Because the outcome of operational tests could determine what survivability modifications are necessary, or even whether the Bradley production should continue, the tests should be conducted before the vehicle's production is nearly completed. The Bradley is still being produced without the proposed major survivability enhancements, and by the end of 1988, when operational tests at the National Training Center might be completed, over 5,000 of 6,882 vehicles in the total program are scheduled to be procured. To resolve the survivability concerns and minimize the extensive retrofit that may be necessary, the Army should proceed with the tests at an alternative test site.

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## Recommendation

We recommend that the Secretary of Defense require the Army to begin the Bradley operational tests at a test site that is available for immediate use, using the Army's planned battle tactics for the Bradley and simulating, as necessary and feasible, the modified versions of the Bradley. The timing of the tests should be such that the results would be available to the Congress in time for its deliberations on the Army's fiscal year 1988 budget request for the procurement of Bradley vehicles.

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## Agency Comments and Our Evaluation

We requested and obtained official DOD oral comments on a draft of this report. DOD officials told us that several factors may delay the commencement of the operational tests. First, the officials emphasized that they cannot, in the near future, operationally test the Bradley at the National Training Center. They told us that this facility's instrumentation is unsuitable for testing and that new instrumentation will not be ready for this use until mid-1988, assuming a successful development program and adequate funding. Secondly, they stated that operational tests on the Army's proposed survivability enhanced Bradley and the minimum casualty vehicle could not be conducted until the live fire tests of these two versions are completed.

We believe that further delays of operational tests should be avoided because the vehicle continues to be produced with survivability questions unresolved. While the improved instrumentation planned for the National Training Center may permit a more precise operational test of the Bradley, in view of congressional concerns regarding its

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survivability, we do not believe it would be prudent for the Army to delay demonstrating the vehicle's survivability for at least two more budget cycles, during which time it is expected that funds will be requested for over 1,600 additional vehicles. This is particularly true when other sites are available. These other sites are already instrumented for operational tests, as evidenced by the fact that such tests are routinely performed at these sites. We do not believe that the operational tests of the Bradley present any unusual problems which require special instrumentation, since the Bradley has been instrumented in previous tests. The Army conducted Bradley operational tests in 1979 at Ft. Carson, Colorado, and in 1976 and 1977 at Ft. Benning, Georgia. Also, Bradley vehicles participated in the 1985 Sergeant York air defense gun operational tests at Ft. Hunter-Liggett, California, and were instrumented to allow for simulated combat.

Although the Army has not yet decided which survivability enhancements will be incorporated on the vehicle, a decision on the exact configuration of the vehicle is not a necessary precondition of the operational tests. The purpose of the operational tests is to demonstrate the vehicle's ability to avoid engagement by the enemy, and thus survive to perform its mission, while the live fire tests will demonstrate what level of antiarmor weapons the vehicle can withstand, if engaged. While mobility may be affected by any weight increase the proposed enhancements cause, this can be simulated during the tests by adding additional weight to the vehicle. As to the minimum casualty vehicle, Army officials told us that this is a concept vehicle, with many questions still unresolved concerning the final configuration and the vehicle's fightability. We believe operational tests of the high survivability Bradley should proceed without delay, with similar tests of the minimum casualty vehicle to follow as soon as possible.

DOD also suggested other changes in the report which we have incorporated, as appropriate.

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We examined pertinent documentation prepared by the DOD and the Army concerning the Bradley program. We also held discussions with officials involved in the program, including those in the OSD; Army headquarters; the U.S. Army Ballistic Research Laboratory and the U.S. Army Material Systems Analysis Activity, Aberdeen Proving Ground, Maryland; the U.S. Army National Training Center, Ft. Irwin, California; the U.S. Army Infantry Center, Ft. Benning, Georgia; and the U.S. Army

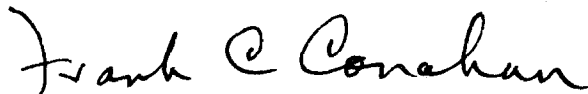
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Armor Center, Ft. Knox, Kentucky. We performed our work in accordance with generally accepted government auditing standards.

We will continue to monitor the Army's vulnerability and operational testing of the Bradley and will report the results of our review after the tests are completed.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of the report. At that time we will send copies to interested parties and make copies available to others upon request.

Sincerely yours,

A handwritten signature in cursive script that reads "Frank C. Conahan".

Frank C. Conahan  
Assistant Comptroller General

# Army's Efforts to Make the Bradley More Survivable

## Background

The Bradley Fighting vehicle comes in two versions, the Infantry Fighting Vehicle (IFV), and the Cavalry Fighting Vehicle (CFV). The IFV's mission is to transport the infantry squad into battle and, once there, to support the squad and the accompanying tanks by suppressing enemy infantry and lightly armored vehicles. The CFV's mission is to perform reconnaissance for the armored cavalry. Both vehicles have a 25-mm. cannon, a TOW antitank guided missile launcher, and a coaxial machine gun. The IFV also has six firing port weapons, positioned along the sides and back of the vehicle, which the six men in the troop compartment can fire. The IFV and CFV are both armored to withstand up to 14.5-mm. ammunition.

Most of the concerns about the Bradley's vulnerability center on the IFV. The IFV's mission in support of the M-1 tank takes it into the heart of the battle, exposing it to antiarmor weapons that the CFV, a scout and reconnaissance vehicle dependent on stealth, might avoid. In addition, because the IFV carries the nine-man infantry squad while the CFV carries only five troops, the casualties would be greater if an IFV were lost than if a CFV were. Although many of the Bradley's vulnerabilities are common to both versions, we focused our work on the IFV because of the greater risks inherent in its mission.

The Bradley's highly explosive 25-mm. ammunition and TOW missiles are stored mainly in the troop compartment. If an antiarmor weapon penetrates the Bradley's armor and hits either of these types of ammunition, the ensuing explosion could cause the loss of the vehicle and crew. The Army refers to such an event as a "catastrophic" loss. Because the Bradley carries a large amount of this explosive ammunition within its troop compartment, there is reason to be concerned, particularly with the more exposed IFV, that this type of explosion could occur with unacceptable frequency during combat.

The Army has developed models which predict a vehicle's vulnerability based on data derived from tests and from estimates of a threat weapon's accuracy and lethality. These models show that, because of the highly explosive material stored in the troop compartment, the Bradley, if it were hit in that area, would be more prone to a catastrophic loss than its predecessor, the M113 armored personnel carrier, which does not carry the kinds or amounts of ammunition found on the Bradley. According to these models, the M113A3, an upgraded variant of the basic M113 vehicle, is not likely to suffer catastrophic kills when hit by two frequently encountered Soviet antiarmor weapons, the RPG-7 or the AT-P-5. The models show that casualties inside the M113A3 are



expected to be much lower in number than casualties suffered in the Bradley.

The Army is considering some enhancements to increase the Bradley's survivability, including (1) installing reactive armor to blunt the effect of some hits on the vehicle, (2) lining portions of the vehicle's interior with material to reduce damage to troops and key electrical components from spalling (armor fragmentation), and (3) relocating some of the ammunition to less vulnerable areas inside and outside the vehicle. While the live fire tests which will evaluate the effectiveness of these changes have not yet been completed, Army predictions of their effectiveness have been entered into their vulnerability models. If the changes enhance the vehicle's survivability as much as the Army expects, better protection will be provided against the smaller antiarmor weapon, the RPG class, than against larger antiarmor weapons, such as the AT-P-5. The latter would still overmatch the vehicle's enhanced armor.

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## Live Fire Tests Reveal the Bradley's Vulnerability

The first phase of the Bradley live fire tests did not resolve all concerns about its vulnerability. Indeed, the tests confirmed that the vehicle is very vulnerable to antiarmor weapons. Although the tests were constructed to preclude total loss of the test vehicles and, for the most part, shots fired directly into the ammunition were excluded, all antiarmor weapons penetrated the vehicle and caused considerable damage. Primary penetrator and spalling were the major sources of crew casualties and damage to vehicle components. The electrical system, in particular, was very vulnerable to damage from spalling, resulting in frequent losses of firepower.

The planned survivability enhancements will be tested in the second phase of the Bradley live fire tests. Then, tests of another version of the Bradley with most of its ammunition and fuel stored outside (referred to as the minimum casualty vehicle) will be conducted. The Army Chief of Staff suspended these tests from April 1986 to October 1986 because of a disagreement between the Army and the OSD official monitoring the test over test methodology and shot placement. Because of the delays in the tests, which were originally scheduled to be completed by June 1986, the effectiveness of these enhancements will not be known until the summer of 1987.

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## Original Mission Requirements

We examined the question of whether the Army has significantly changed the Bradley's mission requirements since production began in order to compensate for the vehicle's survivability shortcomings. We reviewed congressional testimony by Army officials and various Bradley mission documents dating from before production and compared them with more recent testimony and mission documents. The Bradley's basic mission of transporting the infantry squad into battle and supporting the troops and tank forces during combat engagements has remained unchanged. However, the tactics for carrying out these missions have evolved as the Army gained a better understanding of the vehicle's capabilities and limitations. The differences between previous and present tactics appear to be the result of inexperience with this type of vehicle, and the lack of fully developed doctrine at the time of production. The Army is now placing more emphasis on tactics which it believes can increase survivability. This appears to have resulted from the Army's better understanding of the vehicle's capabilities and limitations as it acquired more experience with the Bradley.

Most of the controversy surrounding how the IFV's mission might have changed focuses on its use on the battlefield with the M-1 tank. During hearings before the House Armed Services Committee in April 1978, the Bradley program manager stated that the infantry and cavalry fighting vehicles would be fighting side by side with the M-1 tanks. Later in the same hearing, a Training and Doctrine Command representative corrected this, stating that the Bradley would operate in proximity to the tanks but not side by side, because of the vehicle's inability to survive enemy tank fire in that situation. Confusion about the Bradley's mission has resulted, in part, because when production started, Army doctrine was not clear about the vehicle's use with the M-1 tank. In a report<sup>1</sup> before the vehicle was approved for production, we stated that a tactical doctrine for the Bradley working with the M-1 was lacking, and that it was unclear whether the Bradley would be used alongside the tank or at some undetermined distance from the tanks. Army officials at that time told us that the tactics for the Bradley would be refined as the soldiers trained with the vehicle.

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## Combat Effectiveness of the Bradley

The test results have shown the vehicle to be very vulnerable to all classes of antiarmor weapons. The Army contends that the tests alone should not be used to draw conclusions about the vehicle's survivability on the battlefield. Army officials maintain that the capabilities of the

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<sup>1</sup>The Army's Proposed Close Combat Armored Vehicle Team (PSAD-78-11, Dec. 12, 1977).

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vehicle, such as its mobility and firepower, and the proper use of tactics it has devised, will enable an acceptable level of survival in a combat environment.

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## Current Doctrine and Tactics

Army doctrine does not encourage the use of the Bradley "side by side" with the M-1 tanks. The Bradley and the tanks will be dispersed as much as is feasible on the battlefield to enhance their survivability. Still, Army doctrine specifies that the Bradley is an integral part of the combined arms team, traveling with the tanks and occupying the same areas of the battlefield. The Bradley was developed to fight with and support the tanks. In this capacity it will face the same combinations of threat weapons as the M-1 tank will face.

To take and hold ground, the Army considers the M-1 and the Bradley to be the most indispensable elements of the combined arms team. In movement to combat, when enemy resistance is not expected and speed is essential, the IFVs would follow 200 to 400 meters behind the tanks or closer, if necessary, to protect the tanks. At times when enemy contact is possible, but not likely, a technique called traveling overwatch is used. Here the trailing element, usually the IFVs, moves at variable speeds, separated again by 200 to 400 meters from the tanks in the lead or closer, if necessary, to protect the rear and flanks of the tanks if they are attacked. Another technique, bounding overwatch, is used when enemy contact is expected. Here, the tank element and the IFV element move by bounds, with one element always halted to provide overwatching protection to the other element. For instance, the IFV would halt to protect the rear and the flanks of the tanks from antitank weapons.

Army doctrine, in both offensive and defensive operations, calls for the IFV to control and pin down the enemy while the tanks maneuver against them. The IFVs support the tanks with their TOW missile system and their 25-mm. cannon. Army doctrine calls for the infantry squad to dismount whenever moderate to heavy resistance is expected, and generally, during an engagement.

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## Survivability Is Enhanced by the Vehicle's Capabilities

According to the Army, the live fire vulnerability tests being conducted at Aberdeen Proving Ground cannot be considered tests of the vehicle's survivability. Survivability in combat will depend on a combination of factors, including using

- the vehicle's mobility and the battlefield's terrain features to evade the enemy,
- its weapons to destroy or suppress the enemy, and
- tactics which keep the vehicle out of the range of overmatching threat antiarmor weapons, whenever possible.

The live fire vulnerability tests furnish insight into the vehicle's vulnerability and suggest areas of needed improvements, but its survivability cannot be judged solely by shots fired at the fully exposed Bradley from short range.

According to the Army, drivers of the Bradley will be expected to use terrain features to provide cover and concealment, shielding the vehicle from enemy fire. The terrain in Central Europe is one of rolling hills and considerable vegetation, and the Bradley squads will be urged to take advantage of these features, whenever possible, to protect themselves. They will not be trained to move across open ground against a prepared enemy but, rather, to take advantage of the terrain to move inconspicuously. When not moving, the driver will be expected to seek cover to keep the vehicle hidden as much as possible. Onboard smoke grenade launchers will also provide cover in some situations.

The Army points out that the Bradley's mobility will also permit it to evade the threat, and make it harder to hit. They say that its speed and ability to cross rough terrain will allow it to move quickly from one sheltered firing position to another, thus minimizing its exposure to threat weapons.

In addition to its ability to avoid detection, Army officials believe that the Bradley's survivability is improved by its firepower. They say that this adds to the combat effectiveness of the force, thus making the whole force more survivable. They also say that the Bradley's TOW weapon system is an effective tank killer and a large contributor to force effectiveness, and that its 25-mm. cannon can defeat lightly armored vehicles such as the Soviet counterpart to the Bradley, the BMP, and enemy infantry in dug-in positions. Because of its stabilized turret, the gunner can shoot the cannon while on the move.

Army officials also told us that the planned tactical employment of the IFV will add to its survivability. When moving to contact with enemy forces, the IFVs will be with the tanks and the Army expects the IFVs to benefit from the tanks' protection. The vehicle will often be employed in an overwatch mission, where it will be used to provide fire support to

armor or infantry from a sheltered position to the rear or side of the force. Because of the ranges of its weapons, 3,750 meters for the TOW, and 2,000 meters for the 25-mm. cannon, Army officials believe the IFV will, in many situations, be beyond the range of the threat antitank weapons.

Dismounting the troops is another tactic that may increase the survivability of the infantry squad. Present Army tactics call for dismounting when enemy resistance is moderate to heavy, or when it is necessary to clear obstacles, such as forests or urban areas, of enemy infantry. Thus, once the vehicle reaches the battle, the squad will generally not remain inside the vehicle. Therefore, although antiarmor weapons which penetrate the Bradley's armor and hit the 25-mm. ammunition or TOW missiles may cause loss of the vehicle, the loss of the entire squad will not result from such a hit if the squad has already dismounted.

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## Evaluation of Bradley's Survivability Is Necessary

Although the Army believes that the mobility, firepower, and tactical employment of the Bradley will offset its vulnerability to antiarmor weapons, this has not been demonstrated in a realistic operational environment. The Bradley is a new type of system for the Army, since its predecessor, the M113, was merely an armored personnel carrier and not a fighting vehicle. The Bradley has capabilities, in its TOW missile system and 25-mm. gun, that the M113 does not have, but the price paid for these capabilities may be a greater susceptibility to catastrophic loss.

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## Tests Have Not Evaluated the Bradley's Survivability

In the last 10 years, the Army has conducted various operational tests of the Bradley, but survivability, as a function of mobility, firepower, and armor protection, has not been evaluated during these tests. Early operational tests, in 1976 and 1977, looked at survivability mainly in terms of the vehicle's detectability. The tests found that the vehicle was more susceptible to engagement by direct fire antiarmor systems because it was easier to detect and recognize than the smaller M113, and because the threat force realized that it had greater capability to destroy threat systems.

Operational testing on the vehicle in 1979 again examined survivability only in terms of the vehicle's detectability. This test found that the vehicle's size did not increase its detectability, contradicting the results of the earlier operational tests.

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**Further Operational Testing  
Needed to Resolve  
Survivability Concerns**

The live fire tests at Aberdeen Proving Ground cannot, by themselves, answer all the questions about the vehicle's survivability in combat. These tests can show the probability of a vehicle kill given certain shots at certain impact points, but the vehicle's survivability can only be demonstrated when it can maneuver, using its agility to avoid the threat and its firepower to defeat it.

The Bradley has firepower capabilities which derive from its antitank weapon, the TOW missile system, and its 25-mm. cannon. These weapons are expected to make the Bradley a prime target on the battlefield, and cause concerns about the risk of carrying troops to the battlefield in a vehicle that may not have an acceptable survival rate if it comes under enemy fire.

Earlier this year, the Army began planning what they called a "limited operational assessment" to evaluate the Bradley's survivability. For this assessment, the Army intended to conduct operational tests of the vehicle, using it as it would be used in combat, that is, dismounting the infantry squad when the situation calls for it, using terrain features to mask the vehicle and decrease its detectability, using its mobility to evade the enemy forces, and employing its firepower to defeat them. Army officials expressed confidence that these tests would conclusively demonstrate the survivability of the vehicle and its combat effectiveness.

The test was tentatively scheduled for completion by October 1986. However, it has now been indefinitely postponed until new test instrumentation can be developed for use at the Army's National Training Center where the tests are to be held. The Army hopes this instrumentation will allow them to determine more precisely where hits occurred on the vehicles, and which weapons hit them. This instrumentation will not be available until 1988, by which time most of the 6,882 Bradley vehicles will have been procured. The conference report to authorize fiscal year 1987 appropriations for the DOD directed the Secretary of Defense to submit a plan for operational combat performance tests of the high survivability Bradley, and of the minimum casualty vehicle. It also required the Secretary of the Army to test both versions in accordance with this plan. However, no time limit was specified for performance of these tests or submission of the results to Congress.

Several questions regarding the tactics to be employed for the Bradley to have an acceptable level of survival and how these tactics might

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inhibit its fighting capability have not been examined in previous operational tests. We believe that operational tests are necessary to determine if the vehicle will be sufficiently survivable to perform its missions.

First, there is the question of whether the vehicle can get close enough to use its 25-mm. cannon in combat while still avoiding enemy antiarmor weapons. The TOW system's range is over 3,700 meters and with it the Bradley can defend itself against an enemy antiarmor threat from a distance outside the range of most threat antiarmor weapons. However, when performing the overwatch mission with the 25-mm. cannon, the IFV cannot stand off as far, since the cannon's range is no more than 2,000 meters. At this distance, the vehicle is within range of more of the overmatching threat weapons, such as the BMP's antiarmor missiles and its 30-mm. gun. Operational tests have not yet demonstrated the vehicle's ability to survive when it is required to get close enough to bring its cannon into play.

A second major question, is whether the IFV can perform its various missions of delivering troops to locations where they are to dismount, supporting them at these positions and furnishing adequate overwatch protection to the tanks. Short overwatch of the infantry squad is usually conducted within 500 meters of the dismounted troops. Long overwatch, where the IFV would use its TOW to protect the tanks, is usually done within 1,500 to 3,000 meters of the tanks being supported. The Army has not yet demonstrated how it will maneuver the IFVs to protect the squad and the tanks, or which mission takes precedence since they cannot both be performed at once. The TOW missiles are not as effective in the close-in battles, so in these situations the TOW weapon, which is the Bradley's most effective weapon against enemy armor, would not be fully utilized in the engagements.

Finally, the Army has yet to demonstrate how effectively the vehicle can use cover and concealment to enhance its survivability. Earlier Army studies and tests have shown mixed results on whether the Bradley runs the risk of relatively easy detection because of its size. Army officials told us that the vehicle's size will not make a difference, as the battle environment will afford many opportunities for concealment, even for a vehicle of this size. However, while the use of terrain masking will lessen any vehicle's likelihood of being hit, it may also decrease its ability to acquire and destroy targets. Earlier operational tests evaluated the IFV's effectiveness against stationary and moving targets, but have not evaluated the system's effectiveness in a force-on-force context where its survivability is also evaluated.





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