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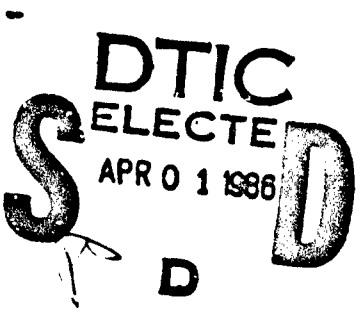
Report to the Chairman, Committee on Governmental Affairs, United States Senate

February 1986

BRADLEY VEHICLE

Concerns About the Army's Vulnerability Testing



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United States
General Accounting Office
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National Security and International
Affairs Division

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February 14, 1986

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

Dear Mr. Chairman:

In your letter of October 4, 1985, you requested us to monitor the Army's Bradley Fighting Vehicle vulnerability tests, which began in March 1985 and are to conclude by June 1986. The tests are being conducted at Aberdeen Proving Ground, Maryland.

You asked us to assess the test results for the vehicle's adequacy to meet the potential threat and fulfill its battlefield roles. You also asked for our observations on the validity of the tests, for information on whether the Bradley's mission requirements and its tactical use have changed significantly, and for the cost of enhancements the Army will make to improve the vehicle's survivability.

The tests have been divided into two phases—the first, with the Bradley as presently configured, and the second, with modifications derived from the vehicle's performance during the first phase. This is an interim report on the test results of the first phase completed in October 1985. We will more fully evaluate and report on all the results when the Army completes the second phase, scheduled to begin in March 1986. At that time, we will furnish you our assessment of the validity of the entire test program, as well as the other information you requested on the Bradley.

In December 1985, the Department of Defense submitted to the Congress a report on the Phase I testing. Subsequent statements by Army officials gave the impression that the test results showed the Bradley to be less vulnerable than the Army anticipated. In our opinion, the Phase I test results do not provide a realistic picture of the vehicle's vulnerability or of the number of casualties likely in combat, since, by themselves, they do not provide sufficient information to make such assessments. The Army used the Phase I test results to update its vulnerability models which predict the vehicle's vulnerability in combat, but only a limited amount of the updated vulnerability information obtained from the models was used in preparing the report submitted to the Congress. Not included in the report was information the models generated regarding

expected casualties and catastrophic kills given the probable frequency of missile or projectile hits on all the Bradley's vulnerable areas. This data would have helped to provide a more realistic assessment of the Bradley's vulnerability. Therefore, the Phase I test results, as reported to the Congress in the December 1985 report, leave a number of questions about the Bradley's vulnerability unanswered.

Also, the test conditions that the Army established influenced the outcome of the tests in such a manner that the results indicated less vulnerability than should reasonably be expected in combat. For instance, the Army avoided, in almost all cases, shots that could have directly penetrated stowed ammunition which it knew, with a high degree of certainty, could cause catastrophic losses. Furthermore, the simulated threat weapons fired at the Bradley were not, in all cases, typical of the latest Soviet weapons deployed and, therefore, were not representative of certain weapons likely to be encountered on a battlefield. Finally, only the cavalry version of the Bradley was tested. Since the cavalry version carries fewer troops than the infantry version, casualty rates would have been higher, on the average, had the infantry version been used, given the same number of hits in identical areas.

Objective, Scope, and Methodology

Our objective was to assess the results of the Phase I Bradley vulnerability tests. To do this we examined pertinent documentation prepared by the Department of Defense and the Army concerning these tests. We also held discussions with officials involved in the testing, including those in the Office of the Secretary of Defense (OSD); Army headquarters; the U.S. Army Ballistic Research Laboratory and the Army Materiel Systems Analysis Activity, Aberdeen Proving Ground; the U.S. Army Armor School, Fort Knox, Kentucky; and the U.S. Army Infantry School, Fort Benning, Georgia. We performed the review in accordance with generally accepted government auditing standards.

Background

The Bradley Fighting Vehicle comes in two versions—the Infantry Fighting Vehicle, or the M-2, and the Cavalry Fighting Vehicle, or the M-3. The M-2, whose mission is to support the tanks by suppressing enemy infantry and lightly armored vehicles, is designed to carry a nine-man infantry squad, which includes a driver, a commander, and a gunner. The M-2 has six firing ports, positioned along the sides and back of the vehicle, through which the six men in the rear of the vehicle can fire their weapons. The squad can, therefore, fight from within the vehicle, as well as dismounted.

The M-3, which carries five troops, serves the armored cavalry units as a scout vehicle for purposes of reconnaissance and security missions, using its firepower mainly to defeat the lightly armored vehicles ahead of the enemy's main tank force. Both versions have a 25-mm. chain gun, which can use either kinetic energy rounds or high explosive rounds; a TOW antitank guided missile launcher; and a coaxial machine gun. Both versions are protected with aluminum armor, which can withstand up to 14.5-mm. caliber ammunition.

In November 1972, the Army awarded a development and production contract to the FMC Corporation. The Bradley entered production in 1980, and deployment began in 1983. Production is scheduled into the 1990's for a total of 6,882 vehicles, about 3,500 of which are M-2's. Production is now running at about 55 units per month, and about 2,000 have been delivered. The total program acquisition unit cost is estimated at about $1.7 million, in 1986 dollars.

Vulnerability Concerns

When the Bradley was approved for development, attention was focused on its superior mobility, firepower, and armor over the M113 armored personnel carrier it was to replace. With these attributes, it was to provide vital protection for tanks in the close combat mission. The M113 is used mainly to carry the infantry squad into battle. It does not have any heavy armament and serves as a vehicle to transport the troops rather than as a fighting vehicle.

Concerns have surfaced about the Bradley's vulnerability and its ability to perform both its fighting and troop-carrying missions in a combat environment. The vehicle is designed to withstand 14.5-mm. munitions but contains a highly explosive cargo of 25-mm. ammunition and TOW missiles. Thus, threat munitions that penetrate the armor and hit either the TOW missiles or the 25-mm. ammunition could cause a catastrophic loss of the vehicle and the entire crew. There has also been some speculation that the Bradley with its aluminum armor might be more susceptible than steel-armored vehicles to "vaporifics effects," i.e., dangerous pressures and toxic vapors inside the vehicle which result when the vehicle's armor is penetrated by certain threat weapons. Adding to the criticality of the vehicle's survivability is the presence on board of the TOW antitank guided missiles, which may make it a high-value target. Since the Bradley carries as many as nine troops, casualties, in the event of a hit in its more vulnerable areas, could be high.

Because of concern about the survivability of many U.S. weapon systems, including the Bradley, OSD, in 1983, set up a live-fire test program in which the services were to test the lethality of several of their weapons against Soviet vehicles and to determine and correct the vulnerabilities of U.S. vehicles to the Soviet systems. Subsequently, OSD approved an Army request to test the Bradley vehicle and several other Army systems separately from the systems that were being tested under the OSD program. The Congress, on June 19, 1985, directed the Secretary of Defense to provide it a report on the Bradley test results.

Phase I Test Objectives and Results

According to Army officials, Phase I tests were designed to develop data on areas of uncertainty affecting the Bradley's vulnerability to overmatching threat munitions, i.e., munitions with calibers greater than the 14.5-mm. which the Bradley was designed to withstand, in order to

- update the Bradley's vulnerability models that the Army uses to determine the vehicle's susceptibility to damage from enemy fire and
- help develop improvements to enhance the vehicle's survivability, such as increased armor protection.

The tests were also to provide information on

- the performance of the automatic fire suppression system in extinguishing fires within the vehicle;
- the likelihood of secondary fires within the vehicle;
- the effect of spalling (breaking off of armor fragments) on personnel, vehicle components, and stored ammunition;
- the effect of overpressure and heat on both personnel and the vehicles; and
- the adequacy of the predictions made by the current vulnerability models.

In Phase I, the Army used the following three series of tests to address the vulnerability issues:

- Eight shots were fired into a ballistic hull and turret representative of those on the Bradley, loaded with inert ammunition, i.e., ammunition with propellant and powder removed so it would not explode.
- Thirty-six shots were fired into an M-3 loaded with inert ammunition.
- Ten shots were fired in 3 M-3's loaded with live ammunition.

Also, included in the report to the Congress, though not part of the Phase I tests, were the results of 14 shots fired into a ballistic hull and turret containing live ammunition.

The Army did not test the infantry version, the M-2, which carries nine troops as opposed to the M-3's five and therefore has greater casualty risk.

In its report, the Department of Defense summarized the test results in the following way:

- The automatic fire suppression system extinguished fuel fires, although it had a high rate of false alarms.
- Secondary fires were not a problem.
- Spalling did not set off the stored ammunition, although it was a major source of crew casualties and damage to vehicle components.
- The vaporifics effects did not result in casualties.
- There was reasonable agreement between what the Army's vulnerability models predicted and what actually happened. Necessary improvements to current vulnerability models were identified, and the models have been updated.

Our review of the test results clearly indicated that the Bradley, as it is presently configured, is highly vulnerable to antiarmor weapons, all of which penetrated the Bradley's armor in the Phase I tests. Certain test conditions precluded total loss of the vehicles. In most cases, the Army avoided shots where it knew catastrophic loss would result and did not simulate some of the more current threat antiarmor weapons capable of greater armor penetration. Had these been fired, they would have indicated the extent of damage the vehicle would sustain from the newer weapons.

Most of the shots into an M-3 loaded with ammunition and fuel caused serious damage to the vehicle. According to the Department of Defense report, a considerable percentage of the crew in these tests would have been wounded, most of them from spalling. The electrical system was also very vulnerable to spalling damage, and since the turret and main armaments are electrically operated, this typically caused major degradation in firepower. Also, although the automatic fire suppression system extinguished fuel fires effectively, it was not effective against ammunition fires.

The testing provided the Army with information to improve and update its vulnerability models. These models could have provided data on casualties and vehicle damage likely to result from hits on the Bradley's more vulnerable areas. However, only some of this data was used in preparing the report to the Congress.

Test conditions influenced the test results making the vehicle seem less vulnerable and the casualty rate lower than might actually be the case under combat conditions. Most of the 10 live-fire test shots were aimed to deliberately avoid striking the explosive elements of the stored ammunition. According to the Army, this was because the effect of such shots—total loss of the vehicle and the entire crew—was already well known. The Army stated that those shots would yield no useful data due to the high level of destruction and would further reduce the already limited number of vehicles needed for the tests. Had shots reflecting the combat distribution of hits been fired, the vehicle loss rate and estimated crew casualty rate might have been much higher. The vehicle is heavily loaded with TOW missiles and 25-mm. rounds, which fill a sizable percentage of the area the enemy can see when the vehicle is exposed. If a shot from a high-caliber warhead penetrated the armor (which the tests show to be likely) and hit one of these areas (which also appears highly probable, given the percentage of the total exposed area they represent), total loss of the vehicle would likely have resulted.

In addition to the testers firing mostly at the Bradley's less vulnerable areas, not all the planned shots, as table 1 shows, were fired.

Table 1: Phase I Shot Summary

	Number of shots	
Munition	**Planned**	**Actual**
RPG-7G round	22	19
TOW antitank guided missile	21	14
120-mm. high explosive antitank round	21	2
ROCKEYE II artillery bomblet	10	7
M718 land mine	5	6
30-mm. kinetic energy round	10	5
3.2-inch high explosive round	0	1
Total	**89**	**54**

The Army's rationale for not firing all planned 120-mm.rounds and TOW missiles was that these weapons overmatch the vehicle to such a degree that further evidence of this was not necessary. During the test, two 120-mm. rounds were fired into the engine compartment. None were

fired into the crew area. Seven TOW rounds were not used because, according to the test director, sufficient data had been collected from the 14 shots already fired.

Army intelligence reports show that threat rounds with more armor penetration than some of those used or simulated in Phase I testing could be encountered on the battlefield. Table 2 shows some of those munitions.

Table 2: Munitions Comparison

Munitions fired in Phase 1	More powerful threat munitions deployed
Hand-held high explosive antitank rounds:	
RPG-7G	RPG-18, RPG-22
Antitank guided missile:	
TOW	AT-5, AT-7, AT-P-4 AT-P-5

The remaining munitions used, i.e., 30-mm. kinetic energy rounds, 120-mm. rounds, the ROCKEYE II artillery bomblet, and the M718 mine, are representative of the class of threat munitions more likely to be encountered on the battlefield.

OSD Test Official's Assessment

Subsequent to our receiving your letter, we agreed, in discussions with your office to obtain and compare the evaluation prepared by the official who monitored the Bradley tests for OSD with the December 1985 report that the Department of Defense provided to the Congress.

For the most part, the report to the Congress and this official's evaluation did not disagree on the events that had occurred during testing. In some areas, however, there were differences in the treatment of particular events in the report and in the test official's evaluation. The OSD test official emphasized that most antiarmor weapons inflicted considerable damage on the Bradley and that ammunition stored on the vehicle would present a major hazard to the crew. He also emphasized that for the most part, the Army had avoided catastrophic loss of the test vehicles by aiming shots away from critical areas. The report contradicted neither of these facts but did not emphasize them. Also, the OSD test official used numbers of casualties per shot as the primary vulnerability measure in contrast to the report's emphasis on vehicle damage and attendant loss of mobility and firepower.

There were two other major differences between the Department of Defense report and the OSD test official's assessment of the results. First, the report contended that the vaporifics effect of the aluminum armor had not produced casualties, whereas the OSD test official questioned whether the Army had used an accurate criterion to determine if casualties would result from this phenomenon. Second, while the report acknowledged that the fire suppression system's false alarms were excessive, it did not characterize the system's subsequent discharge of Halon gas as a hazard to the troops inside the vehicle. The OSD test official, on the other hand, questioned whether the vehicle would be habitable after this discharge, even if the troops donned their protective masks.

Conclusions and Recommendations

The results of the Phase I tests by themselves cannot be used to determine the Bradley's vulnerability in actual combat conditions. In evaluating statements by Army officials that the Bradley performed better than expected in the tests, it should be recognized that (1) certain shots, which could have caused severe damage to the vehicle and crew, were avoided, (2) some of the most current threat simulants were not used, and (3) the infantry version, which is more susceptible to larger numbers of casualties, was not tested.

Although the tests provide insight into the Bradley's vulnerability, key questions remain that cannot be answered by the test results alone. Critical data from the Army's vulnerability models is also needed to properly assess the Bradley's vulnerability. This data was available after Phase I tests but only a limited amount was used in preparing the Department of Defense's report. The Army informed us that more updated vulnerability information on the Bradley will be furnished to the Congress after the second series of tests.

We recommend that the Secretary of Defense, in his report to the Congress on Phase II tests, include

- an evaluation of the Bradley's vulnerability, based on a combination of the live-fire tests and the Army's vulnerability models, using the more current threat simulants available, in sufficient numbers to answer the questions about the Bradley's vulnerability, and
- vulnerability data on both the M-2 and M-3 vehicles.

This information would be essential for a comprehensive evaluation of the effectiveness of the enhancements to be adopted for these tests.

Views of Army Officials

We did not obtain official agency comments on this report. However, we discussed a draft of the report with cognizant Army officials and have incorporated several of their comments in the report where appropriate.

The Army officials disagreed with our observation that had shots reflecting an anticipated combat distribution of hits been fired, vehicle and crew losses might have been much higher. They stated that, while more shots might have caused more catastrophic losses, some of the additional shots might have caused only minimal damage.

These officials also stated that they fired a lesser number of shots than was originally planned because of time constraints brought on by the requirement to report the test results to the Congress in December 1985. Since they already knew that the 120-mm. round and the TOW missiles could defeat the Bradley's armor, they eliminated some of these planned shots in order to meet this deadline. In addition, the Army officials told us that they had not used the more powerful threat simulants because the antiarmor weapons used in the tests overmatched the vehicle and nothing would have been learned from firing the more powerful weapons. They also said more powerful simulants were unavailable. While a shortage or lack of weapons for test purposes is often a problem, we believe that, especially in the case of the Soviet antitank guided missiles, some U.S. systems with similar capabilities, like the TOW II were available for these tests and could have been used.

If the Army wants to test the efficacy of the enhancements planned, it should use more powerful weapons during the second series of tests. While we agree that little would be gained from extensive testing of munitions which clearly overmatch the vehicle, it is important to determine the extent to which the planned enhancements will improve the vehicle's survivability against more powerful munitions.

While Army officials agreed that the number of casualties would have been greater for the M-2 vehicle than for the M-3 version, they said the effect of the greater number of casualties would have been partially mitigated by the fact that the M-2 carries less ammunition and so presents less area that is vulnerable to catastrophic hits.

Finally, they disagreed with the OSD test official's reservations about the crew's reduced ability to function if the fire extinguishers were to discharge. They said the Army Surgeon General had determined that the troops could remain in the vehicle without injury if they used their protective masks.

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,

for Frank C. Conahan
Director