

GAO

Report to Congressional Requesters

July 1987

BRADLEY VEHICLE TEST PLANS

More Information Is Needed to Fully Assess Vehicle's Survivability



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**National Security and
International Affairs Division**

B-221733

July 23, 1987

The Honorable John C. Stennis
Chairman, Committee on Appropriations
United States Senate

The Honorable Jamie L. Whitten
Chairman, Committee on Appropriations
House of Representatives

The Honorable Sam Nunn
Chairman, Committee on Armed Services
United States Senate

The Honorable Les Aspin
Chairman, Committee on Armed Services
House of Representatives

The National Defense Authorization Act of 1987 required the Secretary of Defense to perform live fire and operational testing of the Bradley Fighting Vehicle. This legislation also required us to review the Department of Defense's (DOD's) test plans for both types of tests, to monitor and report on the tests, and to evaluate the Secretary's report to the Congress on the test results. This report presents our evaluation of the test plans. We will report our evaluations of the live fire and operational tests and of the Secretary's report when they are completed. A more detailed analysis of the issues concerning the plans for testing the Bradley is contained in appendix I.

We reviewed DOD's live fire and operational test plans as well as its plans for evaluating the results. The plans are extensive in scope and could lead to much useful information about the vehicle's vulnerability and survivability in combat. Some important analyses are not required by the plans to be included in the report to the Congress. However, Army officials have decided to include virtually all of the data in that report. These analyses, coupled with a proper evaluation of the test results, should provide the Congress with the information necessary for an understanding of the Bradley's vulnerability and potential for surviving.

Background

Because the Bradley is a lightly armored vehicle that carries explosive ammunition and flammable fuel inside, concerns for the safety of the infantry squad also inside the Bradley, should it come under attack,

have become an important issue in the program. These concerns have prompted the Army to consider some enhancements that could increase the vehicle's survivability in combat and reduce casualties. The purpose of the live fire and operational tests is to evaluate the effectiveness of these enhancements on two versions of the Bradley—the “high survivability” vehicle and the “advanced survivability test bed” vehicle.

The high survivability vehicle is a basic Bradley vehicle with certain survivability enhancements, including reactive armor superimposed on the vehicle's basic armor, spall liners around the interior of the area where the crew is located to protect them from flying fragments if the vehicle is hit, and restowage of some of the internal ammunition to less vulnerable areas inside the vehicle. The advanced survivability test bed vehicle is also a modified Bradley. It too has spall liners but, unlike the high survivability vehicle, it does not have the reactive armor. In the advanced survivability test bed vehicle, the fuel and TOW missiles are stored on the outside of the vehicle and some of its 25-mm ammunition is compartmentalized to lessen its susceptibility to a catastrophic loss, where the vehicle is damaged beyond repair and crew casualties are high. The thinking behind this modification is that if, when the Bradley is hit, the explosions and fire were to occur outside the vehicle, it may be that the damage to the vehicle would be reduced and the crew might have a better chance to survive.

Concerns With Live Fire Test Plan

The plan for evaluating the live fire tests does not provide for an analysis of the overall vulnerability of the Bradley to the full spectrum of likely threat weapons. This analysis is necessary because the number of live fire shots is too small to be statistically reliable and the majority of the test shots are the lower caliber RPG-7G missiles and 30-mm rounds. Differences in the two vehicles' armor could account for differences in their resistance to the various weapons fired against them. For example, the reactive armor of the high survivability vehicle could enable this vehicle to better withstand smaller caliber antiarmor weapons, like the RPG-7G missile and 30-mm round, than the advanced survivability test bed vehicle. On the other hand, because the high survivability vehicle has its explosive ammunition and fuel stored inside, it could be the more susceptible of the two vehicles to a catastrophic loss if it were hit by the larger caliber threat weapons, like the TOW missile or the 120-mm round, which could penetrate even the reactive armor.

Army officials told us that, although it is not specified in the evaluation plan, they intend to analyze the vehicles' overall vulnerability using Ballistic Research Laboratory models that were updated based on the live fire test results, and include the analysis in the DOD report to be submitted to the Congress. The Army has informed the Congress that it would also include in the report the probable results of several shots that were planned but were not fired because they would likely have resulted in a catastrophic loss to the high survivability vehicle and possibly heavy damage to the advanced survivability test bed vehicle. Also to be included in the final evaluation is data collected on the effects of toxic fumes, acceleration, flash, and overpressure on the crew. For this purpose, the Army has instructed the Walter Reed Army Institute for Research to provide information for the report on the crew's capacity to continue functioning after a hit penetrates the vehicle.

Concerns With Operational Test Plans

In reviewing the Army's evaluation plan and the operational test plans, we noted that the test scenarios did not portray any battles against a tank-heavy threat (i.e., a threat force in which tanks rather than infantry vehicles predominate), nor did they include threat helicopters. Army test officials told us that because of the large number of ground vehicles to be instrumented, insufficient equipment was available to instrument helicopters and more tanks, and still gather enough data on the Bradley vehicles being tested.

In lieu of introducing helicopters into the test, the Army intends to run computer simulations, using data collected in the operational tests, to "scale up" the battle and gain more insight into the larger battles. Army officials told us that these simulations will include helicopters and some battles on a European-like terrain. Although the evaluation plan is not clear on whether the simulation results with the helicopters included will be part of the final evaluation of the vehicles' survivability, Army test officials told us that they intend to include this information in the report on the tests.

We believe the computer simulations should also include a tank-heavy environment to properly evaluate the Bradley's survivability against the tank threat as well. These simulations, along with the extensive data being collected during the tests, would provide additional insight into the Bradley's operational performance and survivability that will be useful for a proper assessment.

Conclusion

Tests required by the test plans are sufficiently comprehensive. Together with some additional information not required by the test plans which, nevertheless, is to be included in the DOD report to the Congress, they should provide the basis for a realistic assessment of the relative survivability of the vehicles being tested. The additional information should include

- an analysis of the various vehicles' overall vulnerability using the Army's models to supplement the test results,
- the probable results of the shots that were deleted, and
- certain medical information concerning the crew's condition after a round penetrates the vehicle.

Army officials told us that the results of computer simulations of a helicopter threat will also be included in their analysis of the operational tests. We believe that information on the Bradley's performance in a tank-heavy environment is also needed to supplement the assessments of the test results and provide a more comprehensive picture of the Bradley's survivability.

Recommendation to the Secretary of Defense

We recommend that the Secretary of Defense require the Secretary of the Army to include in the Army's evaluation of the Bradley information on the vehicle's performance in a tank-heavy environment and that this information be included in the DOD report to the Congress. Although the operational tests did not portray this type of scenario, the Army can obtain this information from computer simulations.

Agency Comments and Our Evaluation

DOD officials agreed with our findings and our recommendation. They stated that information on the vehicle's performance in a tank-heavy environment will be included in future evaluations of the Bradley.

We believe that this information should not only be part of future evaluations but also should be included in the upcoming DOD report to the Congress so that this report can provide a comprehensive assessment of the Bradley's survivability and operational combat performance.

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

Objective, Scope, and Methodology

The objective of our review was to assess the realism and suitability of the Bradley vehicle's live fire and operational test plans for evaluating the survivability and likely combat performance of the vehicles. We examined pertinent documentation that the Army had prepared concerning the Bradley program. Also, we held discussions with officials involved in the tests, including those in the Office of the Secretary of Defense; Army headquarters; the Army's Operational Test and Evaluation Agency; the Army's Ballistic Research Laboratory; the Army Materiel Systems Analysis Activity; the Army's Test and Evaluation Command; the Army's Infantry Board and Infantry School; the Army Training and Doctrine Command's Combined Arms Test Activity and the Army's Combined Arms Center. We performed our work in accordance with generally accepted government auditing standards.

We are sending copies of this report to the Secretaries of Defense and the Army and other interested parties.

Sincerely yours,



Frank C. Conahan
Assistant Comptroller General

Evaluation of Bradley Live Fire and Operational Test Plans

The two current versions of the basic Bradley Fighting Vehicle are the Infantry Fighting Vehicle (IFV) and the Cavalry Fighting Vehicle (CFV). The IFV transports the infantry squad into battle and supports the squad and accompanying tanks by suppressing the enemy's armored vehicles. The CFV is the scout and reconnaissance vehicle for the armored cavalry. Both vehicles have a 25-mm cannon, a TOW missile launcher, and a coaxial machine gun. The IFV also has six firing port weapons, which the six men in the troop compartment can fire.

In addition to the basic Bradley, the Army is testing two modified versions. One, called the "high survivability" (HS) vehicle, has been outfitted with reactive armor superimposed on the regular Bradley armor. In addition, a spall liner has been added to this vehicle's interior to protect the crew from fragments that could result from a hit on the vehicle, and some ammunition has been restowed in less vulnerable areas. A second vehicle, referred to as the "advanced survivability test bed" (ASTB) vehicle, has been modified so that the fuel and TOW missiles are stored outside the vehicle, and some of the 25-mm ammunition inside the vehicle has been compartmentalized. This vehicle also has a spall liner but does not have the reactive armor.

The basic vehicle's highly explosive 25-mm ammunition and TOW missiles are presently stowed mainly in the troop compartment. Thus, if an antiarmor round were to penetrate the vehicle's relatively light armor and strike this stowed ammunition, a loss of the vehicle and crew could result. The live fire tests, which began in March 1985 and ended in May 1987, were designed to test the vulnerability of the basic vehicle and the two modified versions to certain types of antiarmor weapons. The operational tests, which began in March 1987 and ended in May 1987, were designed to compare the survivability of the three versions in an operational environment. Although the Bradley is highly vulnerable to many antiarmor weapons, the Army maintains that the vehicle's survivability will depend also on its mobility and firepower and on the tactics to be used in combat. The operational tests should demonstrate whether modifications, such as the enhanced armor, have reduced potential damage from some antiarmor weapons without significantly decreasing the vehicle's combat effectiveness due to the added weight.

Live Fire Test Plans

During the live fire tests, shots representing Soviet antiarmor weapons were fired into Bradley vehicles that were carrying their full load of ammunition and fuel. These tests indicate how vulnerable the vehicle is

to these weapons and what vehicular damage and crew casualties would likely result from such weapons hitting the Bradley.

Phase 1 of the tests was completed in October 1985. At the conclusion of these tests, we reported¹ that even though the tests were structured to avoid catastrophic losses of the vehicles, they showed the basic Bradley was highly vulnerable to all antiarmor weapons. The purpose of the Phase 2 tests is to determine if the vehicle's modified versions are less vulnerable to these weapons.

The Phase 2 tests, which were begun in March 1986, were suspended in April 1986 because of a controversy between the Army and the Office of the Secretary of Defense's (OSD's) official monitoring the tests over the selection of shots to be fired. The Board of Army Science and Technology was asked to recommend a methodology to be used in selecting shots for these tests. The Board's methodology reflected a compromise between the Army's preferred method of selecting shots to provide information on unknown effects and the OSD official's desire for mostly random shots. The Army followed the Board's recommendations in choosing the Phase 2 shots. With OSD's approval, the Army did not fire certain planned shots that would likely have caused catastrophic loss of the vehicle. The Army believed that no useful information could be gained from these shots and that expensive test vehicles would be lost. The Army will report the omitted shots as a catastrophic loss involving total crew casualties.

The Army's test plan called for the Phase 2 live fire tests to be divided into two sections. During the first section, Phase 2A, 32 shots were fired into fully-loaded HS vehicles and 14 shots were fired into fully-loaded basic Bradley vehicles to generate data for comparison. Weapons fired included the smaller caliber RPG-7G missiles and 30-mm rounds, the larger caliber 120-mm high explosive (HE) and kinetic energy (KE) rounds, and the TOW and TOW 2 missiles. One mine was also used. The number of shots by threat weapons, and the vehicles at which they were fired, is shown in table I.1.

¹BRADLEY VEHICLE: Concerns About the Army's Vulnerability Testing (NSIAD-86-67, Feb. 14, 1986).

**Appendix I
Evaluation of Bradley Live Fire and
Operational Test Plans**

Table I.1: Shots Fired During Phase 2a

Threat weapon	Bradley (Basic)		IFV	CFV
	IFV	CFV		
RPG-7G missile	3	8	1	12
30-mm round	0	2	0	6
TOW missile	1	0	0	1
TOW 2 missile	0	0	3	4
120-mm HE round	0	0	0	3
120-mm KE round	0	0	0	1
Mine	0	0	1	0
Total	4	10	5	27

The plan also called for a number of subtests to be done in Phase 2A, including tests to determine the effect of shots on the 25-mm ammunition boxes and to measure the effect of Halon discharged from the automatic fire suppression system when it interacts with burning fuel. The Army also collected data from these shots on the effect of the resulting toxic fumes, flash, acceleration, and overpressure on the crew.

Test results from the second part, Phase 2B, were to be used to compare the ASTB vehicle with the basic Bradley and the HS vehicle. Twenty seven shots were fired into the ASTB vehicle to determine if its vulnerability is reduced by storing fuel and TOW missiles on the outside of the vehicle and by compartmentalizing the 25-mm ammunition. Four additional shots—two into an HS vehicle and two into a basic Bradley vehicle—were also fired. Phase 2B shots were as shown in table I.2.

Table I.2: Shots Fired During Phase 2b

Threat weapon	ASTB (CFV)	ASTB (IFV)	HS (IFV)	Basic (CFV)
RPG-7G missile	11	5	2	0
30-mm round	7	1	0	2
TOW 2 missile	1	0	0	0
120-mm HE round	1	0	0	0
Mine	0	1	0	0
Total	20	7	2	2

The Phase 2A and Phase 2B tests have been completed, although the analysis of the data has not yet been done.

Data Needed to Supplement Live Fire Test Results

The live fire test plan does not specify whether information from the Army's vulnerability models or from the analysis of certain medical data being gathered should be included in the test evaluation. Also, the plan does not require the Army to report the results of the shots that were deleted due to the likelihood of catastrophic losses. However, Army officials told us this information would be included in DOD's report to the Congress. Its inclusion is needed for the Congress to have a good understanding of the vehicle's vulnerability and its potential for survival in combat.

The comparison of the HS vehicle and the ASTB vehicle cannot be based solely on the test shots. Additional analysis, using the Army's vulnerability models, is necessary since, according to the Board of Army Science and Technology, the number of live fire shots is too small to provide a statistically reliable sample. The models, which are being updated based on the live fire test results, are used to predict expected casualties and vehicular damage given hits on the various vehicles' vulnerable areas.

Also, since most of the projectiles fired were RPG missiles and 30-mm rounds, they could cause more damage to the ASTB vehicle which, unlike the HS vehicle, does not have the reactive armor. The ASTB vehicle's theoretical benefit is that by putting the potentially explosive ammunition and fuel outside the crew compartment, it may prevent excessive casualties inside the vehicle (and catastrophic loss of the vehicle) should an antiarmor projectile, such as a TOW missile or 120-mm round, penetrate. Thus, RPG missiles and 30-mm rounds could cause more damage to the ASTB vehicle than to the HS vehicle, while TOW missiles and 120-mm rounds could cause damage to both types of vehicles, but perhaps less casualties on the ASTB vehicle. The Army has not yet completed its analysis of the test data.

In the absence of a large enough sample, the Army will have to rely on its vulnerability models to provide the missing information. Although there is some concern² that the models have not been adequately validated, Army officials told us that the models can be used to determine major differences in the vehicles' vulnerability. Data derived from the models and the live fire tests, combined with the operational test results that will indicate the distribution of hits on the Bradley under combat conditions, should help determine the expected survivability of the vehicle and crew.

²Another GAO review of DOD's live fire test methodology indicated that DOD's vulnerability models have not been adequately validated. That report is scheduled to be issued soon.

During Phase 2A, the Army collected data on the effects of toxic fumes, acceleration, flash, and overpressure on the crew. Although the test plan did not require the data to be analyzed for inclusion in the DOD report, the Army, in April 1987, asked the Walter Reed Army Institute for Research to provide an overall assessment of the crew's capacity to continue functioning inside the vehicle following a hit that penetrated. The data will be necessary to determine the number and severity of crew casualties and also may be important if the Army concludes that the crew could extinguish certain slow starting fires. These fires usually start when hot material lands on the crew or combustibles (bed rolls, chemical suits, etc.) within the vehicle. Army test officials believe the crew could brush these hot items away or throw them out of the vehicle. However, it is important that the medical data also be analyzed and included in the evaluation of the live fire tests to be certain that the crew was not incapacitated and could extinguish the fires.

In a January 16, 1987, letter to the Chairman, the Army informed the Subcommittee on Procurement and Military Nuclear Systems, House Committee on Armed Services, that it would include in DOD's report to the Congress the probable results of shots deleted from the tests because they would have probably resulted in catastrophic losses. Without this information, the vehicles' vulnerability could be understated. The Army will score the shots deleted from the HS vehicle tests as catastrophic losses of the vehicles. Comparable shots deleted from tests of the ASTB will not automatically be considered catastrophic losses. Rather, the Army will attempt to determine casualties and vehicle damage from such shots by reference to its vulnerability models. The Army will report the probable results of the deleted shots, using the shot-by-shot comparison of the two vehicles, when it reports the results of the live fire tests.

Operational Test Plans

The Army's Operational Test and Evaluation Agency (OTEA) is in charge of the operational tests and has developed an evaluation plan. For their portions of the tests, the Training and Doctrine Command's (TRADOC's) Infantry Board and the Combined Arms Test Activity (TCATA) developed detailed test plans that were based on OTEA's evaluation plan. OTEA's plan enumerated seven issues to be evaluated. The Infantry School at Fort Benning is the Bradley IFV proponent and provided the tactics and composition of the U.S. forces to be portrayed and some analysis of the threat force.

OTEA's evaluation plan calls for the Infantry Board to conduct mobility testing of the basic and HS vehicles and crew drills to determine what effect the vehicular modifications will have on the crew. The Infantry Board also conducted some platoon level force-on-force exercises to determine the contribution of tactics, mobility, and firepower to survivability. The Infantry Board is the primary tester for the following OTEA evaluation issues:

- Essential mission functions performed by the squad (such as loading and reloading of weapons, dismounting the vehicle, stowage, and installing and removing the armor tiles).
- Operational mission performance (such as mobility and weapons accuracy).
- Logistics.
- Transportability.
- Training.
- Soldier performance and safety.

OTEA's evaluation plan called for TCATA to test the main issue—whether the survivability modifications provide an increase in vehicle and personnel survivability in an operational environment. According to the plan, TCATA was first to run large scale exercises using the basic vehicle in combined arms battles. These battles included attack, defense, and movement to contact scenarios. When in the attack phase, a blue (U.S. forces) battalion task force would attack a red (Warsaw Pact) company. When on the defense a blue company would defend against an attacking red battalion. In the movement to contact phase, a blue company would meet a red company. The red force portrayed represented a near term Warsaw Pact threat and consisted of U.S. weapons modified to represent the threat and U.S. troops with some training in Soviet tactics. From these battles, TCATA gathered data on a number of areas, including engagement ranges, aimpoints, whether troops were on board when the vehicle was hit, and target types. Table I.3 presents a breakdown of the systems involved by type of battle.

**Appendix I
Evaluation of Bradley Live Fire and
Operational Test Plans**

**Table I.3: Systems Involved in
Operational Tests**

Attack by U.S. forces

Blue	Red
28 Bradley IFVs	13 Bradley IFVs
14 M1 tanks	4 M1 tanks
6 M3 Bradley CFVs	3 Improved TOW vehicles

Movement to Contact

Blue	Red
9 Bradley IFVs	13 Bradley IFVs
4 M1 tanks	4 M1 tanks
6 M3 Bradley CFVs	3 Improved TOW vehicles
2 Improved TOW vehicles	

Defense by U.S. Forces

Blue	Red
9 Bradley IFVs	27 Bradley IFVs
4 M1 tanks	13 M1 tanks
2 M3 Bradley CFVs	3 M3 Bradley CFVs
4 Improved TOW vehicles	3 Improved TOW vehicles

After these large exercises, smaller scale drills were run using the basic Bradley, HS, and ASTB vehicles in platoon-on-platoon exercises to determine the difference in combat performance between the various versions of the vehicles.

**Data Needed to
Supplement
Operational Test
Results**

The operational test evaluation plan is ambitious in scope and should lead to useful information about the vehicle's performance and survivability in combat. The operational test scenarios do not, however, portray any battles against a tank-heavy threat nor do they include the helicopter threat.

The ratio of tanks to infantry fighting vehicles deployed with the red forces in the operational scenarios was about 1 to 2 when the red forces were attacking and about 1 to 3 when they were moving to contact or defending. No scenarios were planned in which tanks rather than infantry fighting vehicles dominated the red forces. Neither did the scenarios include the helicopter threat. According to Army officials, they could not instrument additional vehicles or helicopters because the large number of vehicles already being instrumented for the tests was taxing the available resources. Because they wanted as much data on the Bradley as possible, they focused on the ground battle and, within this

ground battle, on scenarios in which the mechanized infantry, rather than tanks, would play a prominent role. These scenarios did not represent the main Soviet thrust, which would employ heavy concentrations of tanks and helicopters. Although the scenarios tested should yield useful information, we believe that some measure of the Bradley's performance is needed in battles that use these heavier concentrations of tanks and include the use of helicopters.

After the tests, TRADOC's Analysis Command and Infantry School will run computer simulations using the data collected in the operational tests to update these simulations. They plan to transfer the results of the battle on Fort Hood terrain to a European environment and will include some helicopters in these simulations, although the scenarios will still portray mechanized infantry battles rather than tank battles. The evaluation plan does not indicate whether the results of simulated battles using helicopters will be part of the final analysis of the basic Bradley and its variants, but test officials told us that they intend to make this part of the report to the Congress.

Since the scenarios for these simulations can be altered by the analysts, the Army could also run the simulations with a main battle scenario, that uses more tanks. We believe that these tank-heavy simulations should be run and that the results of this analysis should be included in the report to the Congress. This information is needed to fully assess the vehicles' performance and survivability and to provide a comprehensive comparison of the various Bradley versions.



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