

# Inspector General

United States  
Department of Defense



Live Fire Testing of Light Tactical Wheeled Vehicles  
was Effective for the Portions Completed

# Report Documentation Page

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## Acronyms and Abbreviations

ARL	U.S. Army Research Laboratory
ATEC	U.S. Army Test and Evaluation Command
C-4	Composition-4
DOT&E	Director, Operational Test and Evaluation
FSP	Fragment-Simulating Projectile
FUSL	Full-Up System Level
HMMWV	High Mobility Multi-Purpose Wheeled Vehicle
IED	Improvised Explosive Device
IG	Inspector General
LFT&E	Live Fire Test and Evaluation
TNT	Trinitrotoluene



INSPECTOR GENERAL  
DEPARTMENT OF DEFENSE  
400 ARMY NAVY DRIVE  
ARLINGTON, VIRGINIA 22202-4704

November 24, 2010

MEMORANDUM FOR DIRECTOR, OPERATIONAL TEST AND EVALUATION  
AUDITOR GENERAL, DEPARTMENT OF THE ARMY

SUBJECT: Live Fire Testing of Light Tactical Wheeled Vehicles was Effective for the Portions Completed (Report No. D-2011-019)

We are providing this report for your information and use. We determined that the Army's live fire testing of the up-armored High Mobility Multi-Purpose Wheeled Vehicle was effective for the portions completed. We also found that DOD oversight of the live fire test and evaluation was effective for the portions of the oversight process completed. We are making no recommendations and do not require a written response. Therefore, we are publishing this report in final form.

We appreciate courtesies extended to the staff. Please direct questions to me at (703) 604-9201 (DSN 664-9201).

A handwritten signature in black ink, appearing to read "Richard B. Jolliffe", is positioned above the typed name.

Richard B. Jolliffe  
Assistant Inspector General  
Acquisition and Contract Management





# Results in Brief: Live Fire Testing of Light Tactical Wheeled Vehicles was Effective for the Portions Completed

## What We Did

We determined whether the Army effectively planned, executed, and evaluated High Mobility Multi-Purpose Wheeled Vehicle (HMMWV) live fire testing and whether DOD exercised adequate live fire test and evaluation oversight of the Army's HMMWV Program. This report is the second in a series of reports on the Army's efforts to develop, test, and acquire armor solutions for light tactical wheeled vehicles.

## What We Found

The U.S. Army Test and Evaluation Command's (ATEC) live fire testing of the up-armored HMMWV was effective for the portions completed. Specifically, ATEC planned a live fire test strategy for the HMMWV Program that identified required documents needed to determine system and crew survivability. ATEC provided the required live fire planning documents to the Office of the Director, Operational Test and Evaluation, for approval and ATEC executed tests in accordance with the approved live fire test plans. ATEC has not yet completed the up-armored HMMWV live fire test and evaluation report but will provide it, upon completion, for the Director, Operational Test and Evaluation's evaluation of the up-armored HMMWV live fire test and evaluation.

The Office of the Director, Operational Test and Evaluation's live fire test and evaluation oversight of the Army's up-armored HMMWV was effective for the portions of the oversight process completed.

Specifically, the Director, Operational Test and Evaluation, placed the up-armored HMMWV on the Office of the Secretary of Defense Test and Evaluation Oversight List in 2006 for live fire oversight and has reviewed, as required, the Army's up-armored HMMWV live fire test planning documents. The Director, Live Fire Test and Evaluation, stated that the Director, Operational Test and Evaluation, will publish a HMMWV live fire test and evaluation report by the end of 2010.

## What We Recommend

The report contains no recommendations.

## Management Comments

We do not require a written response to this report.

### M1151-Model HMMWV With Fragmentation Kit #7



Source: <http://www.army.mil>



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# Introduction

## Audit Objectives

Our objectives were to determine whether the Army effectively planned, executed, and evaluated High Mobility Multi-Purpose Wheeled Vehicle (HMMWV) live fire testing and whether DOD exercised adequate live fire test and evaluation (LFT&E) oversight of the Army's HMMWV Program. See the appendix for a discussion on scope and methodology and prior coverage related to the audit objectives.

## Background

This is the second in a series of reports on the Army's efforts to develop, test, and acquire armor solutions for light tactical wheeled vehicles. The first report in the series, DOD Inspector General (IG) Report No. D-2010-039, "Recapitalization and Acquisition of Light Tactical Wheeled Vehicles," January 29, 2010, addressed the Army's efforts to develop and acquire the Risk Reduction Vehicle, or XM1166, and the Next Generation Expanded Capacity Vehicle, or ECV2. We initiated these audits as a result of information gathered while conducting the audit that led to DOD IG Report No. D-2009-030, "Marine Corps Implementation of the Urgent Universal Needs Process for Mine Resistant Ambush Protected Vehicles," December 8, 2008. Specifically, we were presented with information that led us to question the survivability testing of the HMMWV against mines and improvised explosive devices (IEDs).

## *Live Fire Test and Evaluation*

LFT&E is a test process to evaluate the vulnerability and lethality of a conventional weapon or a conventional weapon system. LFT&E provides insights into a weapon system's ability to continue to operate or fight after being hit by enemy threat systems. Live fire testing provides a way to examine the damage inflicted on materiel and personnel and an opportunity to assess the effects of complex environments that crews are likely to encounter in combat. Conducting live fire tests is very complex, and many factors have to be considered in the LFT&E of tactical wheeled vehicles. Those factors include, but are not limited to: the type of munition used, standoff distance of the vehicle to the explosive, projectile orientation angle, shotlines, the size of the fragment-simulating projectile (FSP),<sup>1</sup> where to fire FSPs at the vehicle, soil conditions, whether to conduct a test that would cause catastrophic or significant damage to the vehicle, and differences between the individual vehicles.

## *Test Methodology Concerns*

During the audits of the "Marine Corps Implementation of the Urgent Universal Needs Process for Mine Resistant Ambush Protected Vehicles" and "Recapitalization and Acquisition of Light Tactical Wheeled Vehicles," we interviewed vehicle survivability subject matter experts who expressed concerns about the U.S. Army Test and Evaluation Command's (ATEC's) live fire testing methods.

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<sup>1</sup> An FSP is a specific fragment simulator type based on a standardized cylindrical projectile with a chiseled nose. It is designed to be fired from a gun to simplify armor testing.

Specifically, the subject matter experts were concerned that ATEC personnel:

- used FSPs to test armored vehicles that did not accurately represent fragments from IEDs detonated close to a vehicle,
- incorrectly used composition-4 (C-4) as an explosive equivalent to trinitrotoluene (TNT), and
- performed IED tests to evaluate vehicle armor protection in soil that did not represent the soil found in theater operations.

## **Results**

To address the vehicle survivability subject matter experts' concerns about ATEC's live fire testing methods, we reviewed ATEC's LFT&E planning and execution, use of FSPs, use of C-4 in lieu of TNT, and whether the soil used in live fire testing was representative of the soil found in theater operations. We also evaluated Director, Operational Test and Evaluation's (DOT&E's) LFT&E oversight of the HMMWV Program.

### ***Planning and Execution of Up-Armored HMMWV Live Fire Test and Evaluation was Effective for the Portions Completed***

ATEC's live fire testing of the up-armored HMMWV was effective for the portions completed. Specifically, ATEC planned a live fire test strategy for the HMMWV Program that identified required documents needed to determine system and crew survivability. ATEC provided the required live planning documents to the Office of the DOT&E for approval and ATEC executed tests in accordance with the approved live fire test plans. ATEC has not yet completed the up-armored HMMWV LFT&E report but will provide it, upon completion, for DOT&E's evaluation of the up-armored HMMWV LFT&E.

### ***Fragment-Simulating Projectiles***

Data collected by the U.S Army Aberdeen Test Center and the U.S. Army Research Laboratory (ARL) revealed that the tactic of employing artillery shells as surface-laid IEDs, as opposed to an airburst detonation, resulted in an increase in the number of the bigger fragments threatening a vehicle. An ARL representative stated that the 20mm FSP represents the 97<sup>th</sup> percentile of fragments, by mass, from a surface-laid 152mm artillery shell detonation. Based on ARL's test data, we confirmed that the 20mm FSP represents the 97<sup>th</sup> percentile of fragments, by mass, from a surface-laid 152mm artillery shell detonation. The Army used a combination of FSP tests, full-up system level vulnerability tests,<sup>2</sup> and modeling and simulation<sup>3</sup> to determine the up-armored HMMWV's capabilities and limitations against surface-laid artillery shell-based IED threats and other threats.

### ***Explosive Equivalency***

An ATEC representative stated that, from May 2004 to November 2006, ATEC used the C-4 explosive conversion as a substitute for a TNT mine explosive when performing underbody tests

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<sup>2</sup> Full-up system level vulnerability tests are tests conducted on a complete system loaded or equipped with all the dangerous materials that normally would be on board in combat (including flammables and explosives) and with all critical subsystems operating that could make a difference in determining the test outcome. These tests use munitions likely to be encountered in combat.

<sup>3</sup> We did not evaluate the models or simulations the Army uses in the live fire test and evaluation process.

of the HMMWV variants. ATEC used C-4 to support the HMMWV requirement to provide underbody protection against mine blasts to the HMMWV variants. The C-4 conversion used by ATEC created smaller sized craters during the test events than the crater sizes created by TNT mines in theater. ATEC representatives stated that they used the C-4 explosive substitute because it was the best they could do at the time. Although ATEC incorrectly used C-4 as an explosive equivalent to TNT when performing underbody mine testing, the TNT mine weight requirement in the September 2004 HMMWV Operational Requirements Document was less than two-thirds of the mine explosive weight experienced in theater operations.

By 2008, ATEC changed the testing methodology from using the C-4 explosive equivalent as a substitute for the TNT underbody mine threat to using a cast TNT mine. ARL developed cast TNT mines as threat surrogates for the actual mine. As documented in its live fire test planning documents, ATEC plans to use an approved threat surrogate during live fire testing instead of the C-4 explosive conversion in its underbody mine blast testing.

### ***Soil Testing***

An ARL representative stated that he discussed with officials from Developmental Test Command<sup>4</sup> the possibility of conducting a study to determine whether test procedures in a new soil would be repeatable. He stated that ARL can complete this type of study. Further, the representative stated that current tests conducted in consistent soil retain a 10 to 25 percent variability in blast effect from shot to shot. ARL is also in the process of developing a comparison of the different types of soil that range from dense, saturated clay to loose, sifted sand. From this comparison study, ARL is working on a rough conversion factor that would allow testers to take real observed test results done in one soil condition and use that data to estimate probable results of the same test as if it had been done in another soil type. Results of tests would still need to be compared to older vehicle tests done in the current standard test soil.

A representative from the U.S. Army Corps of Engineers Engineer Research Development Center provided a 2009 report which examined the detonation of explosives in soil. He also stated that the Center is in the process of conducting a soil study that will focus on the tactical implications of differences in soil conditions. The study will identify how soil conditions affect ground radar used in IED detection systems and how the depth of an IED affected the blast to vehicle underbellies. The U.S. Army Corps of Engineers Engineer Research Development Center surveyed 10 to 11 sites, and the United Kingdom team members are gathering data from 5 additional sites.

### ***Effective Oversight by the Director, Operational Test and Evaluation Oversight***

The Office of the DOT&E's LFT&E oversight of the Army's up-armored HMMWV was effective for the portions of the oversight process completed. The up-armored HMMWV was added to the Office of the Secretary of Defense Test and Evaluation Oversight List in 2006, and the vehicle remained under DOT&E oversight for live fire testing in 2010. DOT&E reviewed and approved up-armored HMMWV test planning documents, as required. As a part of its

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<sup>4</sup> Developmental Test Command is a part of ATEC and is responsible for planning, conducting, and reporting developmental tests.

assessment of the survivability of the up-armored HMMWV, DOT&E originally planned to use ATEC's HMMWV Live Fire Report. However, on April 23, 2010, DOT&E issued a memorandum to the Service test community stating that DOT&E will publish an independent report before the completion of the test agency report, if necessary to ensure the timely reporting of operational and live fire test results. Therefore, DOT&E will start its assessment of the survivability of the up-armored HMMWV whether or not ATEC has provided its HMMWV LFT&E report. The Director, Live Fire Test and Evaluation, stated that DOT&E will publish a HMMWV LFT&E report by the end of 2010.

## **Appendix. Scope and Methodology**

We conducted this performance audit from October 2009 through October 2010 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

The objectives of the audit were to determine whether the Army effectively planned, executed, and evaluated HMMWV live fire testing and whether the DOD exercised adequate live fire testing oversight of the Army's HMMWV Program.

In our review, we included the HMMWV variants that were part of the Office of the Secretary of Defense Test and Evaluation Oversight List from 2006 to 2010. The HMMWV variants on the Oversight List consisted of the M1151 family of vehicles.\*

We did not include the Next Generation Expanded Capacity Vehicle, or ECV2, in our review of DOD's live fire testing oversight of the HMMWV Program. The Army considered the Next Generation Expanded Capacity Vehicle as a part of the HMMWV Program and merely an upgrade to the existing HMMWV. Therefore, DOT&E listed the Next Generation Expanded Capacity Vehicle as "HMMWV ECV2" on its Office of the Secretary of Defense Test and Evaluation Oversight List. However, as discussed in DOD IG Report No. D-2010-039, "Recapitalization and Acquisition of Light Tactical Wheeled Vehicles," we do not agree that the Next Generation Expanded Capacity Vehicle is a HMMWV because it had less than 30 percent of parts in common with the Expanded Capacity Vehicle-model HMMWV and would be built on a separate production line.

To accomplish the objectives of the audit, we reviewed the Office of the Secretary of Defense Test and Evaluation Oversight Lists from 2006 through 2010; live fire test planning documents, such as the HMMWV Live Fire Test and Evaluation Strategy, Detailed Test Plan, Event Design Plan, and Pre-Shot Prediction Report; the HMMWV Operational Requirements Document; and various DOD studies and reports from January 1973 through March 2010.

We contacted staff in the Offices of the Director, Operational Test and Evaluation; Joint Improvised Explosive Device Defeat Organization; U.S. Army Test and Evaluation Command; and U.S. Army Research Laboratory.

### **Use of Computer-Processed Data**

We did not use computer-processed data to perform this audit.

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\* The HMMWV M1151 family of vehicles includes the M1151, M1152, and the M1165.

## **Use of Technical Assistance**

The Technical Assessment Directorate, Office of the Deputy Inspector General for Policy and Oversight, assisted the audit team by analyzing data related to the U.S. Army Test and Evaluation Command testing methodologies used during the live fire test and evaluation of the HMMWV Program.

## **Prior Coverage**

During the last 5 years, the Government Accountability Office (GAO), the DOD IG, and the Army Audit Agency have issued eight reports discussing the HMMWV; add-on armor for tactical wheeled vehicles; production, delivery, and installation of truck armor; tactical wheeled vehicle strategies; and recapitalization and acquisition of light tactical wheeled vehicles.

Unrestricted GAO reports can be accessed over the Internet at <http://www.gao.gov>. Unrestricted DOD IG reports can be accessed at <http://www.dodig.mil/audit/reports>.

Unrestricted Army reports can be accessed from .mil and gao.gov domains over the Internet at <https://www.aaa.army.mil/>.

### **GAO**

GAO Report No. GAO-06-274, “Defense Logistics: Lack of a Synchronized Approach between the Marine Corps and Army Affected the Timely Production and Installation of Marine Corps Truck Armor,” June 22, 2006

GAO Report No. GAO-06-160, “Defense Logistics: Several Factors Limited the Production and Installation of Army Truck Armor during Current Wartime Operations,” March 22, 2006

### **DOD IG**

DOD IG Report No. D-2010-039, “Recapitalization and Acquisition of Light Tactical Wheeled Vehicles,” January 29, 2010

DOD IG Report No. D-2009-046, “Procurement and Delivery of Joint Service Armor Protected Vehicles,” January 29, 2009

DOD IG Report No. D-2009-030, “Marine Corps Implementation of the Urgent Universal Needs Process for Mine Resistant Ambush Protected Vehicles,” December 8, 2008

DOD IG Report No. D-2008-089, “Planning Armor Requirements for the Family of Medium Tactical Vehicles,” May 9, 2008

DOD IG Report No. D-2007-107, “Procurement Policy for Armored Vehicles,” June 27, 2007

### **Army**

Army Audit Agency Report No. A-2007-0234-ALM, “Tactical Wheeled Vehicle Strategy, Deputy Chief of Staff G-8 and Program Executive Office Combat Support and Combat Service Support,” September 26, 2007



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