JAMES HASIK

Professional Grade

A working paper on recent fatalities in military vehicles in Iraq and Afghanistan

31 October 2006 (revision 3.1)

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Summary

Armoring existing trucks and Humvees makes sense, but the Army could use some serious, 'professional grade' vehicles.

Roadside bomb attacks on trucks and Humvees account for about 50% of fatalities in US Army vehicles.

For all the effort being directed at protecting armored vehicles from RPGs, rather few fatalities have been the result of RPG attacks. The fatality rate from traffic accidents is much higher.

Bradley fighting vehicles show the highest fatality rates amongst US Army vehicles in Iraq. While the Bradleys' aluminum armor provides good, lightweight protection against machineguns and medium-caliber cannons, these are not the typical weapons of insurgents. Roadside bombs are—and aluminum generally provides less blast-protection than steel.

While fatalities in Strykers have been the second-highest amongst US Army armored combat vehicles, the rate has been countercyclical with those of fatalities in other armored vehicles. Geographic and employment factors complicate what would otherwise seem to be an even comparison.

Trucks, Humvees, and (in particular) M113s have shown much lower fatality rates. This apparent survivability is partially explained by the more restricted employment these types experience. Anecdotally, no fatalities have yet been experienced in Cougar or Buffalo mine-protected armored trucks.

Fatalities in armored combat vehicles have been considerably outnumbered by fatalities in trucks and Humvees, but vehicle fatalities as a whole have represented only 10% of all US fatalities in Iraq. However, that percentage was steadily rising through 2005.

Funding for development of new armored assault vehicles in the Army's budget drastically outweighs that for new support vehicles, but buying more or stronger armored assault vehicles is not likely to suppress fatality rates amongst troops in Iraq. Buying support vehicles designed for blast resistance *ab initio* is more likely to help.

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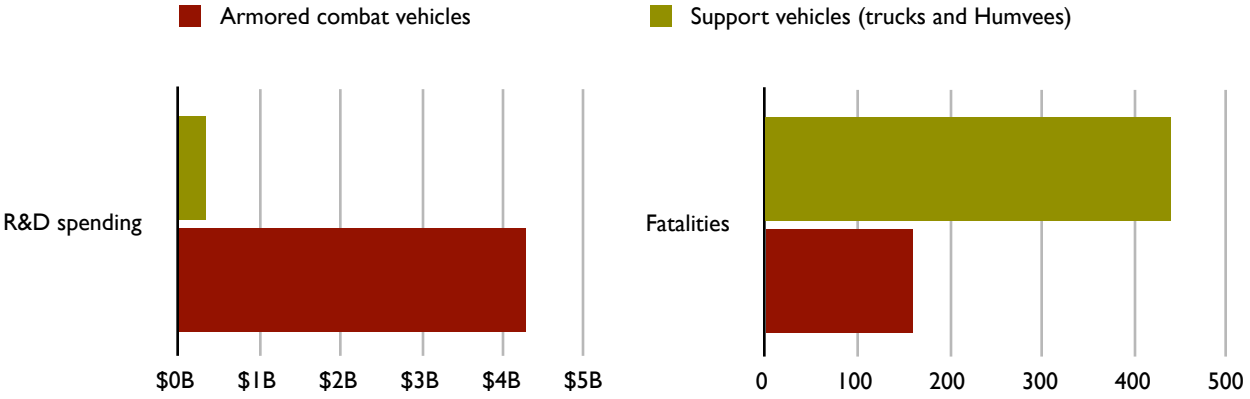
Introduction

The US Army's vehicle funding priorities do not match the primary sources of fatalities in military vehicles in Iraq

This study found its impetus in a review for a recent client of the US Army's vehicle spending plans in the Future Years Defense Program (FYDP). As shown in the chart below and to the left, the Army is planning to spend over four billion dollars in fiscal years 2006 through 2011 on research and development activities for the manned ground vehicles of the Future Combat System (FCS) and the Non Line of Sight Cannon (NLOS-C) vehicle. As of the date of last year's military appropriations act, the FYDP held less than one-tenth that much money for development of new trucks and associated automotive technologies.[1]

FATALITIES IN US ARMY MILITARY VEHICLES IN IRAQ, OCTOBER 2003 THROUGH SEPTEMBER 2006, AND RESEARCH AND DEVELOPMENT SPENDING ON US ARMY MANNED GROUND VEHICLES IN THE FYDP



Trucks and Humvees, however, are widely observed to be vulnerable targets for rocket-propelled grenades (RPGs), roadside bombs, car bombs, and automatic weapons fire.[2] This apparent fiscal dissonance lead me to review the Pentagon's casualty reports to determine just which vehicles appeared statistically most vulnerable to which types of attacks. As shown in the chart above and to the right, considerably more US soldiers have been killed in support vehicles (largely trucks and Humvees) than in armored combat vehicles such as Abrams tanks, and Bradley, Stryker, and M113 troop carriers.[3] A more detailed analysis follows. It begins on the next page with an outline of the method that I followed for collecting and classifying the data.

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[1] This excludes procurement funding, which will be used to buy (amongst other things, and as I note on the last page) another 250 Buffalo explosive ordnance disposal (EOD) team trucks from Force Protection of Charleston, South Carolina. Force Protection is funding its own development work, which is laudable, but the lack of official development funding probably says something about the Army's priorities.

[2] The Army uses the term *improvised explosive device* (IED) to describe roadside bombs, and *vehicle-borne improvised explosive device* (VBIED) to describe car bombs. Strictly speaking, IED may be more accurate than *roadside bomb*, since not all such bombs are laid by the side of a road. The emphasis on improvisation, however, may be part of the problem, as it downplays the organizational and material capabilities of the opposing force. *VBIED* is just awkward and silly. Accordingly, I use herein the term 'bomb' to describe all such explosives, including industrially-produced landmines, which serve the same purpose.

[3] As I will explain later, I excluded the other US military services' fatalities, particularly those of the US Marine Corps, to simplify the data collection process.

Methodology
The Pentagon's fatality reports are a valuable, if uneven, source of data.

While I consider the results which follow to be broadly reliable, I need to qualify them by describing the methodology (to include its limitations) that I used to analyze the fatality figures:

1. I collected all the Pentagon's electronic mail casualty reports for the thirty-six months between October 2003 and September 2006. The beginning point was spaced relatively far from the end of the initial fighting during the invasion from Kuwait. The ending point includes the upswing in fighting towards the end of 2005, and the subsequent *dénouement* in early 2006. The term *casualty report* is narrowly cast here: the Pentagon does not report the names of injured troops, only dead ones.

2. I limited the analysis to US Army fatalities in Iraq. The US Marine Corps has generally provided little explanatory detail in its fatality reports, beyond the oft-repeated boilerplate "died as a result of enemy action." While some US Navy and US Air Force troops have died in vehicles in Iraq, the numbers are sufficiently small to warrant exclusion from the analysis. I sorted the fatalities by the date of the incident; thus, a soldier who died in October 2005 from wounds received in August 2005 would be coded as an August 2005 fatality. This preserved the link between the death and its root cause. I later expanded the analysis to compare these rates to those of the British Army in Iraq and the Canadian Army in Afghanistan.

3. I then sorted the files automatically to capture those which indicated that the particular fatality occurred in a vehicle.

4. I further sorted the files by the type of vehicle indicated in the report: Abrams tank, Bradley fighting vehicle, Stryker Light Armored Vehicle-III (LAV-III), M113 armored personnel carrier (and its variants), Humvee, and truck.

5. I then analyzed the remaining files—a set of 129 individual fatalities in which the vehicle was identified only as a "vehicle." I analyzed the cases one-by-one, searching news reports for indications of the particular type of vehicle involved. In some cases, the identity of the unit involved indicated the type of vehicle: troops from light infantry units probably did not die in Bradley fighting vehicles, and troops from transportation units could be expected to have died in some sort of truck.

6. I then coded the entire set of 129 as *Humvees and trucks*, since most (though not all) of the vehicles could be demonstrated to be something other than an armored combat vehicle (such as a Bradley or Stryker). That is, I combined the Humvee and truck categories since distinguishing between the two in many of the reports could not be done reliably.

7. I counted both fatalities and fatal incidents in order to analyze whether particular methods of attacks or vehicles were associated with greater numbers of deaths per incident. In general, the fatality reports indicated clusters of deaths, but not always. Following the example above, if two soldiers were hit in the same attack in August, with one dying on the scene, but the other two months later in hospital, the cluster would need to be inferred from a match in the dates, locations, and units indicated in the report. In a few cases, troops from multiple units were killed in the same vehicle; here, matching deaths at different times from the same cause was somewhat challenging.

8. I also classified the attacks into six categories: bombs (to include leftover landmines, carbombs, command-detonated mines, and the like), rocket-propelled grenades (RPGs), small arms (to include hand grenades), accidents, mortars, Molotov cocktails, and complex attacks involving more than one method.

I settled on this classification scheme to align the analysis with the protective demands of vehicle design. Protection against bombs calls for a strong, monocoque, rounded steel hull. Resistance to RPGs calls for standoff armor and possibly active interception systems. Limiting casualties from small arms calls for protected ingress and egress, firing ports, and remote weapon stations. Preventing accidents calls for (amongst other things) a low center of gravity, which could be at odds with the clearance needed for mine protection unless the vehicle is particularly well-designed for this role. Protection against mortar fire calls for a strong roof, which may be at odds with the desire to allow troops to fire from the top of the vehicle (as the Marines' AAV-7 amphibious tractors allow).

Some educated guesses were necessary in the coding process. This fatality report, for example, was not remarkably illuminating:

NEWS RELEASE from the United States Department of Defense

No. 1255-04

IMMEDIATE RELEASE

Dec 06, 2004

Media Contact: Army Public Affairs - (703) 692-2000

Public/Industry Contact: (703)428-0711

DoD Identifies Army Casualties

The Department of Defense announced today the death of two soldiers supporting Operation Iraqi Freedom. They died Dec. 4 in Mosul, Iraq, when their Stryker military vehicle received enemy fire during convoy operations. Both were assigned to the 3rd Battalion, 21st Infantry Regiment, 1st Brigade, 25th Infantry Division (Stryker Brigade Combat Team), Fort Lewis, Washington.

The 'enemy fire' could have been from assault rifles, RPG launchers, or even mortars. Since the report seems to suggest that the vehicle itself was the object of the attack, I coded this as an RPG attack, since mortar rounds (save from a direct hit) and assault rifle rounds would have little effect on a Stryker, except against its tires, which have run-flat inserts anyway.

I initially excluded from the analysis of US Army fatalities the Textron (Cadillac Gage) Armored Security Vehicle (ASV) of the military police, and the Cougar and Buffalo armored trucks that Army explosive ordnance disposal (EOD) teams have been using to disable those roadside bombs. This was for three reasons:

- There were apparently no recorded deaths which could be attributed to any of those vehicles during the period of analysis.
- There were initially relatively few of those vehicles operating in Iraq during the time in question.
- The employment profile of the vehicles—largely in explosive ordnance disposal (EOD)—differed considerably from that of Bradleys, Strykers, and Abrams. While this arguably was a more hazardous mission, it did complicate comparison.

I will return again on that in a later section, where I will discuss then RG-31 armored truck as well.[4]

Lastly, I should note that the validity of this entire exercise depends on the accuracy of the Army's fatality reports. I should also note that I have found little reason thus far to doubt them.

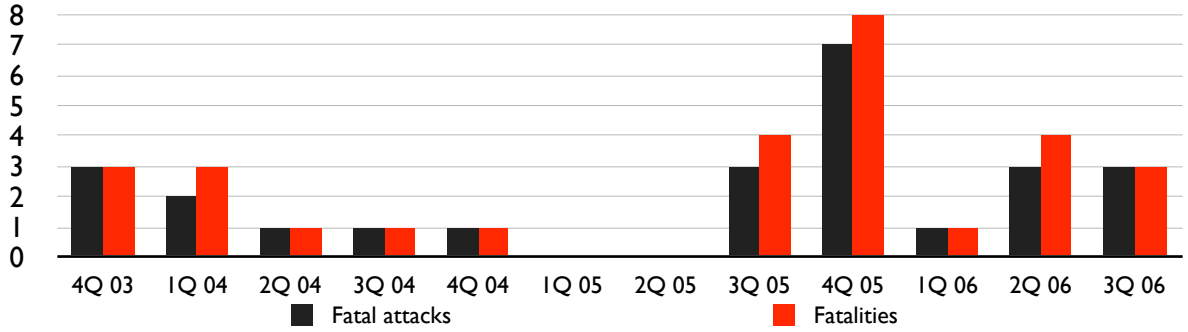
[4] I have been apprised of a single fatality in an ASV, but I have not been able to locate the casualty report in the Army's files. At least 25 military policemen died in military vehicles in Iraq during the reporting period, but some of these were merely identified in the fatalities reports as a "vehicle".

Abrams tanks

Fatalities in Abrams tanks increased sharply in late 2005, then fell off.

At over seventy tons in its heaviest, latest form, the M1 Abrams tank is not commonly considered a vulnerable vehicle. None of the losses of Abrams tanks in the 1991 campaign in Iraq were ever positively identified as the result of anything but friendly fire. This led to a perception (perhaps unwarranted) within the Army that the Abrams was essentially invulnerable. The chart below indicates that even Abrams tankers have suffered casualties in Iraq—the rate of successful attacks on Abrams tanks increased sharply during in late 2005.

FATALITIES IN AND FATAL ATTACKS ON ABRAMS TANK IN IRAQ SINCE THE INVASION



Even this chart does not tell the whole story. We do not have good figures on overall damage to the tank fleet, as the Army does not report tank losses or injuries to tankers, just deaths. For example, the somewhat mysterious, apparent RPG attack on an M1A1 in Baghdad on 28 September 2003 only slightly injured the crew, but started an internal fire that badly damaged the vehicle.[5] There have been varying reports on how many Abrams have been destroyed or damaged beyond repair. According to *Defense News*, through March 2005, roughly 27 Abrams tanks had been knocked out, and another 63 had suffered such serious damage that they were sent to the Anniston Army Depot in Alabama or Joint Systems Manufacturing Center (JSMC) Lima in Ohio for rebuilding—and full upgrading to the M1A2 Systems Enhancement Package (SEP) standard.[6] SEP upgrades (which restore the vehicle to essentially a zero-mileage condition) cost roughly $7 million each. The Pentagon's office of Program Analysis & Evaluation (OSD-PA&E) notes that many Abrams have been "maintenance washouts" in Iraq—which means that repair has deemed uneconomical—but that fewer than ten tanks have been knocked out in battle. If that is the case, then we may say that, fatalities aside, "Abrams tanks are very hard to destroy or even damage, but, if driven enough, need expensive rebuilding."[7]

Most successful attacks have come from two sources: remote-controlled roadside bombs and RPGs. RPG attacks are rarely fatal, but frequently punch through the lightly protected exhaust grill at the rear of the tank, destroying the gas turbine. This immobilizes the tank, and Iraqi insurgents have learned where to aim. It also results in, minimally, a half-million-dollar repair. Roadside bomb attacks seem to be increasingly

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[5] Frank Vizard, 'The Abrams Tank Mystery,' *Scientific American*, July 2004

[6] Greg Grant, U.S. Army's $7B Unfunded List Shows Costs of War, *Defense News*, 13 March 2006

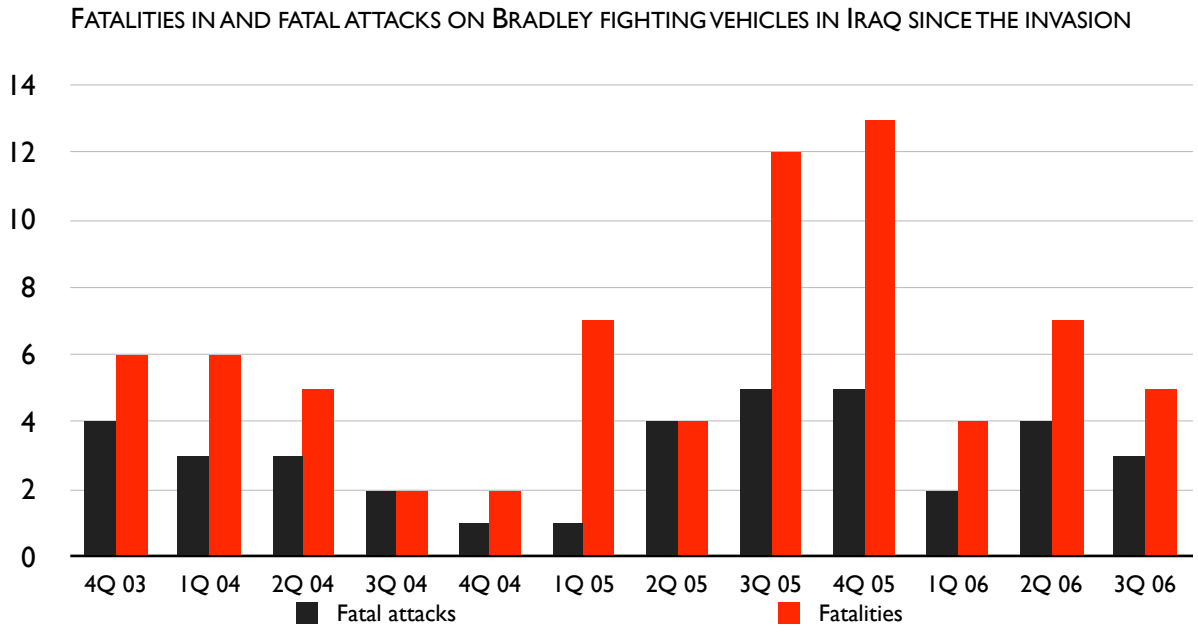
[7] Unclassified electronic mail message from OSD-PA&E, 30 May 2006

employing shaped charges, and larger ones, which is doing more damage to armored vehicles—even heavy tanks.

Bradley fighting vehicles

Fatalities in Bradley fighting vehicles also surged in late 2005.

The same insurgent offensive led to a sharp increase in the fatality rates for Bradley fighting vehicles. Note that the scale in the chart below is stretched for better visual comparison to the other armored combat vehicle fatality charts.



One notable difference is that the upswing in fatal attacks has been slightly less pronounced in terms of vehicles, but more pronounced in terms of fatalities. While the Abrams carries a crew of four, the Bradley carries a crew of three and up to seven passengers, so more troops are generally at risk in each attack. Of course, the Bradley's mission (at least that of the M2 *infantry* fighting vehicle version) is to carry troops, so going in harm's way is what is to be expected. In several cases, the data again suggest that the insurgents are using larger and more sophisticated charges in their mines, which is broadly confirmed by news reports. For example, in one particularly large roadside bomb attack on 15 October 2005, fully five soldiers from the 2nd Battalion of the 69th Armor Regiment were killed in their M2A2 infantry fighting vehicle.

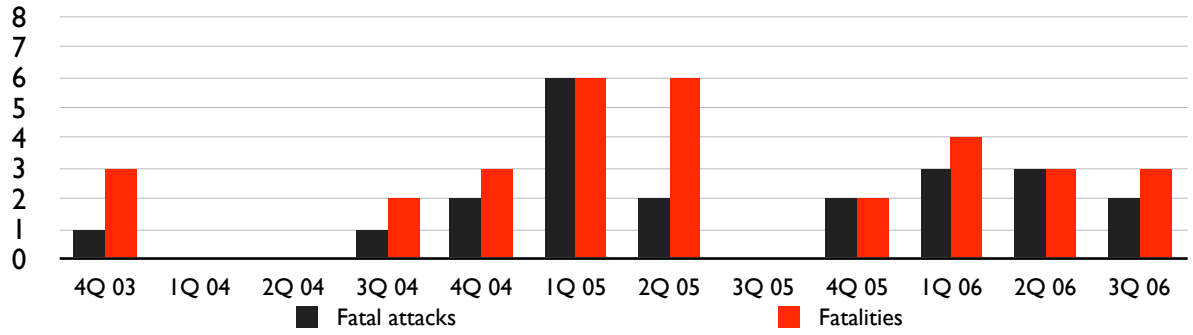
Unless the Army is successful in finding ways to better suppress this threat, we can thus also expect to continue to see Bradleys returning to the US (particularly the Red River Army Depot in Texarkana, Texas) with greater damage. The trouble is that if large remotely-controlled mines can penetrate Abrams tanks, they can also penetrate the comparatively less well-armored Bradleys. While more Bradley troopers than Abrams tankers have been killed in RPG attacks, the RPG is not a major killer of armored vehicle crewmen in Iraq. Traffic accidents are a bigger problem.

Stryker wheeled armored vehicles

Fatalities in Stryker armored vehicles have been countercyclical with those in Abrams and Bradleys

The Army's new Stryker wheeled armored vehicles (a version of General Dynamics' fast-selling Light Armored Vehicle III) have a long record of service in the land forces of now more than a dozen countries. The vehicle has also suffered comparatively fewer fatalities in Iraq than the preceding two vehicles. As I will note below, that is at least partly because there have been simply fewer Strykers in Iraq than either Abrams or Bradleys. During the period in question (again, October 2003 through September 2006), the Army had slightly more than 300 Strykers in Iraq, but roughly 400 Abrams and over 600 Bradleys.[8]

FATALITIES IN AND FATAL ATTACKS ON STRYKERS IN IRAQ SINCE THE INVASION



Notably, the resident Stryker brigade in Iraq (one brigade from the home base at Fort Lewis, Washington was always in Iraq during the period in question) suffered no fatalities at all in its combat vehicles during the third quarter of 2005—a time period during which other, heavier armored brigades were experiencing sharp increases in fatality rates. Since the Strykers have been deployed to different provinces than brigades equipped with Abrams and Bradleys, this is probably because the patterns of insurgent activity have shifted over time. The opposing cycles off violence indicate why comparing fatality rates between vehicle types is not as reliable as the figures would seem to suggest. This is particularly true of the record of the M113.

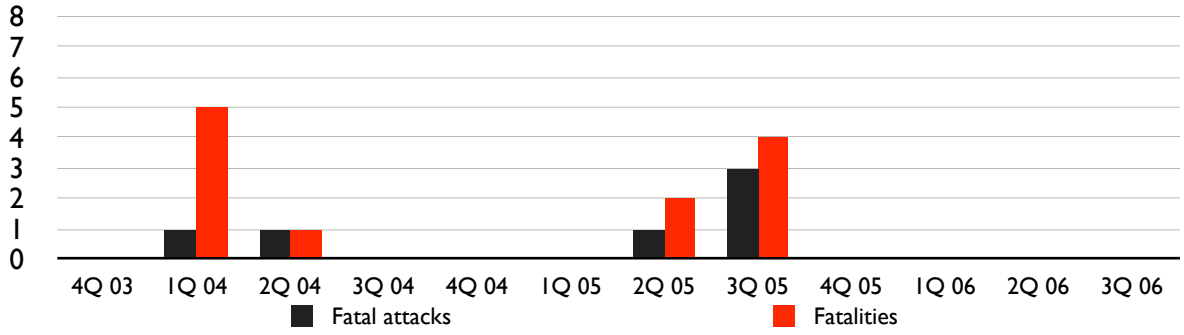
[8] Gina Cavallaro, 'Abrams still relevant in urban warfare, says top brass,' *Army Times*, 22 May 2006. Cavallaro quotes Vice Chief of the Army Staff General Richard Cody. The number of Abrams and Bradleys in Iraq roughly correspond to the number that would be expected, according to the Army's tables of organization and equipment, for seven heavy armored brigades. This is indeed the number that was rotating through the country from late 2003 through early 2006, so we can have some confidence in the figures.

M113 armored personnel carriers

M113 have experienced rather few fatalities, and in roughly the same pattern in time as the Abrams and the Bradleys.

The somewhat venerable M113 appears to be a relative success story in Iraq: only twelve soldiers died in the vehicles during the period in question. With roughly 1,500 US Army M113s in service in Iraq[9], the vehicle is widely deployed and used, so the low rate of casualties is notable, as I will discuss later. As shown in the chart below, the casualty pattern over time has broadly followed that of the Abrams and Bradleys—and indeed, roughly 100 M113s accompany each heavy armored brigade in a variety of roles. These facts suggest that there may be something different about the old vehicle, but I will get to that.

FATALITIES IN AND FATAL ATTACKS ON M113S IN IRAQ SINCE THE INVASION



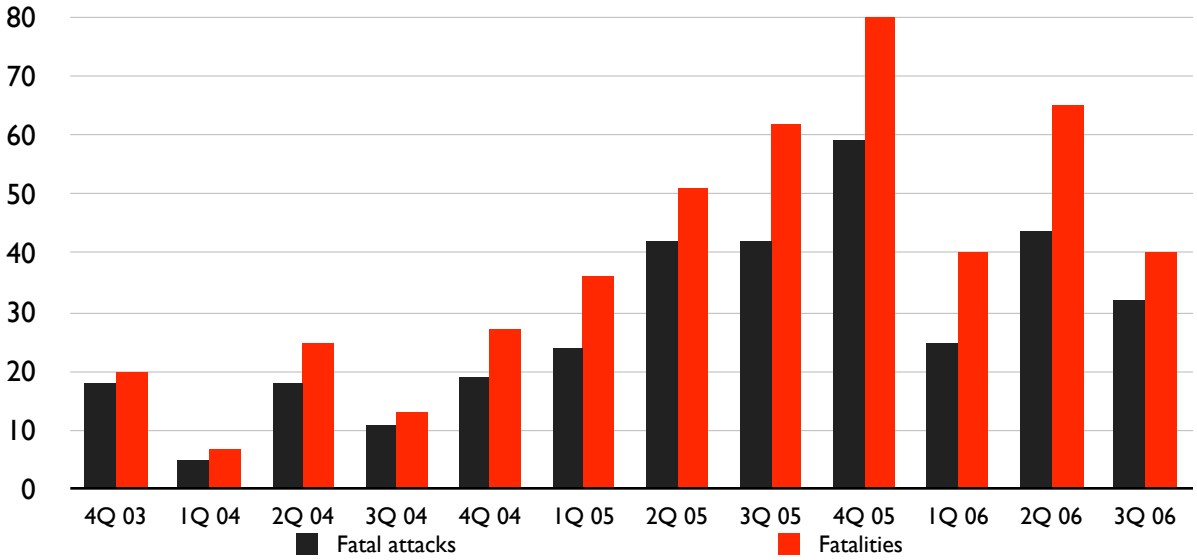
Humvees and Trucks

The fatality rate in Humvees and trucks was steadily increasingly until early 2006, and roadside bombs continued to be the primary killer

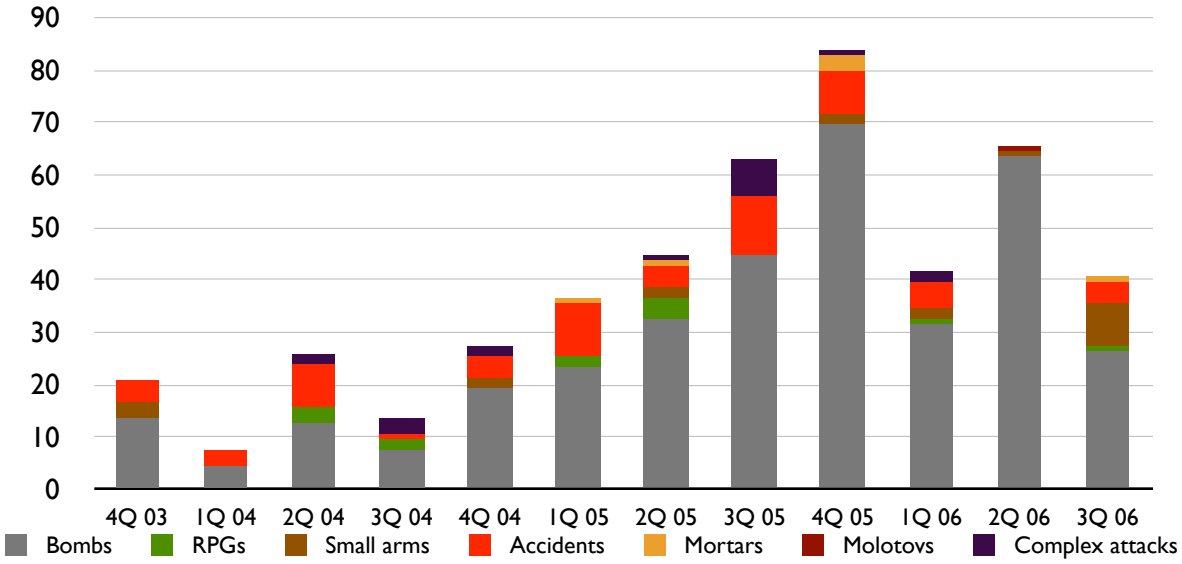
In gross terms, however, all of this is rather small beer compared to the fatality rates in trucks and Humvees (hereafter sometimes called just *trucks*). The chart on the next page shows how fatality rates accelerated throughout 2005, only falling off with the *relative* calm of the first few months of 2006. Identifying the source of the problem is not difficult: a more thorough review of the Army's fatality reports confirms that roadside bombs (and the like) are the primary killer of troops in trucks. The ubiquitous RPGs, if the Army's reports are accurate, were at least for a long while a smaller problem overall than traffic accidents. If this has changed, it is because the overall rate of traffic accidents was much lower in 2006 than in the preceding years.

[9] The figure 1500 is drawn from Elaine Grossman, 'Countering the insurgency: Army Approval for Heavier Armor in Iraq Delayed Until Last Month,' *Inside the Pentagon*, 20 January 2005, page 1. The Iraqi Army has its own M113s, but I did not include these in the analysis since that service apparently has no easily accessible, reliable fatality database.

FATALITIES IN AND FATAL ATTACKS ON HUMVEES AND TRUCKS IN IRAQ SINCE THE INVASION



FATALITIES IN TRUCKS AND HUMVEES BY CAUSE



Comparing fatality rates

Differences in fatality rates amongst Abrams, Bradleys, Strykers, and M113s are partially explained by geography and employment.

One could expect vehicle fatality rates to correspond broadly to the weight of the vehicles' armor. Abrams tanks are designed to withstand all but very large shaped charges and kinetic energy rounds. Bradleys are designed (since the -A2 modification) generally to withstand frontal impacts from 30 mm rounds. Strykers are designed to withstand front impacts from 14.5 mm rounds and side impacts from 12.7 mm rounds. The latest M113A3s have a comparable level of protection (from penetrating rounds) as the Stryker. However, as shown in the table on the next page, this logic is not completely supported by the data: Abrams do have a lower fatality rates than Strykers, but Strykers have a lower fatality rate than Bradleys, and M113s show a much lower rate than any.

More specifically, the fatality rate in Strykers was about 38% higher than that in Abrams: 0.033 deaths per Stryker annually, vice 0.024 deaths per Abrams annually. However, that gap is rather narrower than might be presumed, as the Stryker has far less armor that the Abrams. The nature of the Abrams' design is notable in this case: the tank was not designed to resist attacks from large carbombs and command-detonated mines buried in roadways. Additionally, several tankers have been killed trying to engage the enemy after their vehicles have come under fire: popping the hatch to fire the commander's machine fun has not always proved to be the right answer. As a result, the Army added a remotely-controlled 12.7 mm machinegun to its Tank Urban Survival Kit (TUSK) upgrade for vehicles in Iraq.

FATALITY RATES AND CAUSES OF FATALITIES IN US ARMY VEHICLES IN IRAQ

Vehicle	Approx. # in Iraq	Bombs	RPGs	Small arms	Accidents	Mortars	Complex attacks	Total	Annual rate per vehicle
Abrams	400	21	1	3	4	---	---	29	0.024
Bradley	600	59	6	1	5	6	3	80	0.044
Stryker	300	18	3	3	6	---	---	30	0.033
M113	1500	12	---	---	---	---	---	12	0.003
Trucks	20000	320	13	20	62	6	20	441	0.007

In the case of the Bradley and the Stryker, some of the difference may reside in their differences in construction. The Bradley has an aluminum hull, but the Stryker has a steel hull. Aluminum armor is rather good at stopping penetrations from small and medium-caliber projectiles, but steel is " best for blast."[10]

The performance of the M113 seems quite remarkable. While twenty-six troops were killed in Strykers during the thirty months in question, only twelve troops were killed in M113s. More so, while the Army consistently operated slightly more than 300 Strykers in Iraq during this period, it operated roughly 1,500 M113s. This works out to an annual fatality rate of 0.033 deaths for the Stryker, but just 0.003 deaths for the M113. On the surface, the comparison suggests that the M113 has been about eleven times safer a ride for the troops than the Stryker.

[10] Conversation with Dr. Vernon Joynt, Chief Scientist at Force Protection Industries, 7 June 2006

The straight comparison, however, does not reveal the whole story. Even though the Stryker and the M113 are both troop carriers with multiple variants, the Army has used them quite differently in Iraq. In short, the Army has used the Stryker more broadly, in almost all the combat roles of its medium-weight brigades, including bringing dismounting infantry and cavalry soldiers directly into direct contact with the enemy. M113s, however, have almost entirely equipped engineering, artillery, mortar, logistics, and command units. An even comparison of the fatality rates for both vehicles would compare the rates from comparable unit types, since different unit types tend to have different casualty rates. In particular, mortar, engineering, and headquarters companies should experience lower casualty rates than infantry companies and cavalry troops, since the former tend to spend less time in direct contact. As the Army tends to identify troops in fatality reports by battalion, and not company, separating the troops assigned to headquarters and mortar companies proved infeasible.

FATALITIES IN M113S AND STRYKERS ASSIGNED TO ENGINEERING UNITS IN IRAQ[11]

Rank	Name	Date	Unit	Location	Vehicle
Staff Sergeant	C. Morningstar	5 Feb 2006	562nd Engineer Company	Al Husayniyah	Stryker
Sergeant	J. Boehmer	5 Feb 2006	562nd Engineer Company	Al Husayniyah	Stryker
Sergeant	B. Luckey	29 Jun 2006	562nd Engineer Company	Mosul	Stryker
Specialist	M. Gibbs	3 Aug 2005	348th Georgia Engineer Battalion	Baghdad	M113
Sergeant	L. Arnold	11 Jun 2005	155th Mississippi Engineer Battalion	Owesat	M113
Specialist	T. Lee	11 Jun 2005	155th Mississippi Engineer Battalion	Owesat	M113
Specialist	D. Morgan	17 Apr 2004	153rd South Dakota Engineer Battalion	Iskandariyah	M113
1st Lieutenant	D. Hufstedler	31 Mar 2004	1st Engineer Battalion	Habbaniyah	M113
Specialist	S. Mitchell	31 Mar 2004	1st Engineer Battalion	Habbaniyah	M113
Specialist	M. Karr	31 Mar 2004	1st Engineer Battalion	Habbaniyah	M113
Private First Class	C. Raney	31 Mar 2004	1st Engineer Battalion	Habbaniyah	M113
Private First Class	B. Davis	31 Mar 2004	1st Engineer Battalion	Habbaniyah	M113

Engineering units, however, have their own 'cap badges', so to speak, so their regimental identity (whether by battalion or company) comes through in the casualty announcements. As shown in the table above, a comparison of fatalities *within engineering units* of troops lost in M113s to those lost in Strykers is much closer. [National Guard units are identified by both their number and their home state.] At any given time during the period of analysis, the US Army had in Iraq roughly one engineering company equipped with Strykers and seven equipped with M113s. With roughly fourteen engineering vehicles per company, the annual fatality rates are 0.071 for the engineering Stryker and 0.031 for the M113. The result is far from statistically significant, so it cannot be used to argue that the degree of protection afforded by the M113 is higher than that afforded by the Stryker.

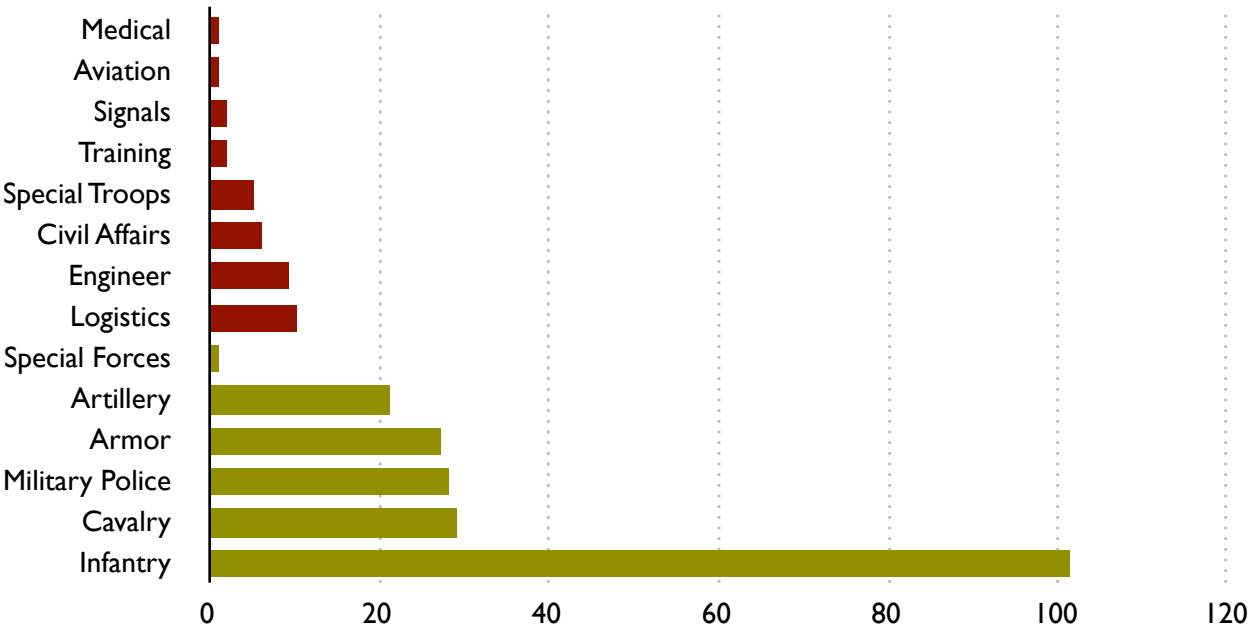
[11] In its press release on Sergeant Luckey's death, the Army described him as having been "shot by enemy forces while on a mounted patrol." His company possessed Humvees and engineering versions of the Stryker that might have been used for patrol. While I could not find a press report that described his vehicle, I coded it as a Stryker because I thought it more likely that the company would have gone patrolling in a heavier vehicle which was arguably more suited to its mission.

Comparing unit types

Most fatalities in soft-skinned vehicles are found in combat, not support, units.

One would normally expect that direct combat units—infantry, cavalry, armor, and artillery—would suffer more casualties in battle areas than support units. The news from Iraq over the past few years may have suggested something else, by implying that most of the casualties in soft-skinned vehicles have occurred amongst logistics units in road-bound convoys. The Army's fatalities reports, however, indicate that 207 of 248 fatalities in Humvees and trucks have occurred amongst combat units, which are shown in green in the chart below. [12]

FATALITIES IN TRUCKS AND HUMVEES BY UNIT TYPE IN IRAQ
OCTOBER 2003–SEPTEMBER 2006



In particular, engineer units suffered only fourteen fatalities in soft-skinned vehicles during the period in question. This suggests that—outside their rather dangerous bomb-disposal operations—engineer units are not frequently employed in direct combat. Engineer units suffered nine fatalities in M113s during the period in question. Since engineer units have considerably more trucks than M113s, this further supports the view that much of the safety of the M113 derives from its relatively restricted employment, and not any extraordinary protective qualities.

The other obvious conclusion from this analysis is that combat units in Iraq could use better armored support vehicles, or just more armored vehicles, since many of the infantry units in question are 'light', or non-mechanized, battalions.

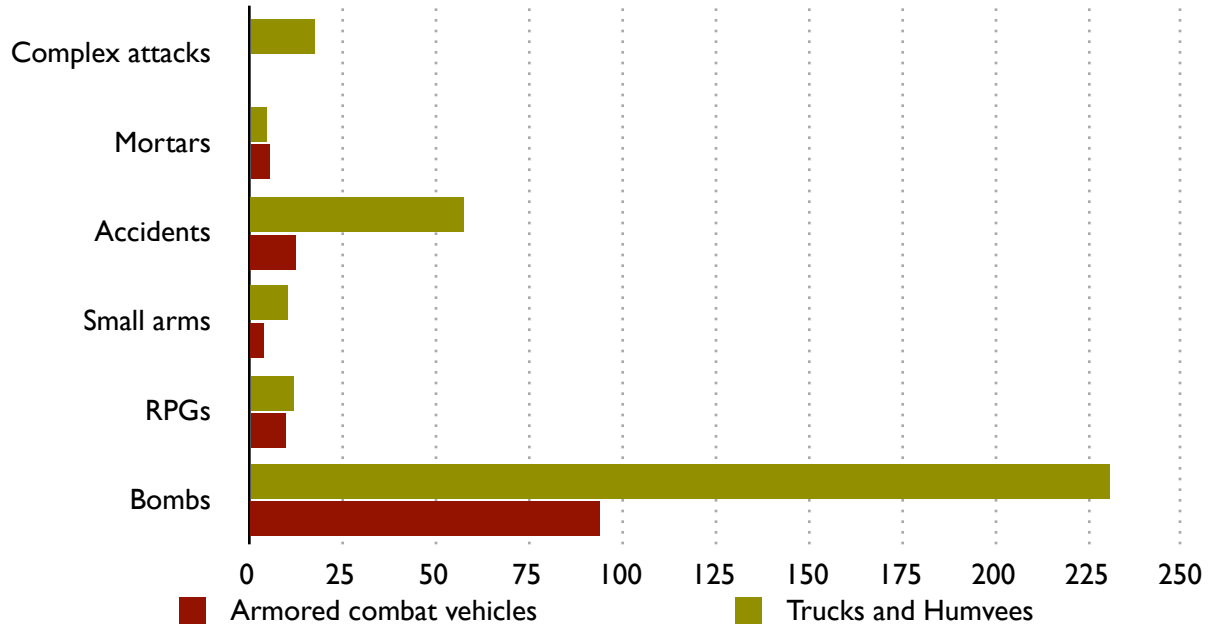
[12] I have classified the one death in an aviation unit as a 'support unit' fatality, since the trooper in question was most likely not an aircrewman or forward observer. Even if this is inaccurate, the error would not much affect the conclusion.

Combat Vehicles versus Support Vehicles versus Dismounted Troops

The Army's current armored combat vehicles (whether Abrams, Bradleys, Strykers, or M113s) are not the problem

Whether the Army transports assault troops in Bradleys, Strykers, or M113s, the data do not indicate that casualty rates would be significantly higher in operations against insurgents. To many differences in geography and employment cloud the analysis. The overall cause of the casualties, however, is quite clear from the Army's own fatality reports, and it is widely known to be roadside bombs. The chart below shows the causes of fatalities in vehicles by cause and (broad) type.

CAUSES OF FATALITIES IN ARMORED COMBAT VEHICLES AND IN TRUCKS AND HUMVEES



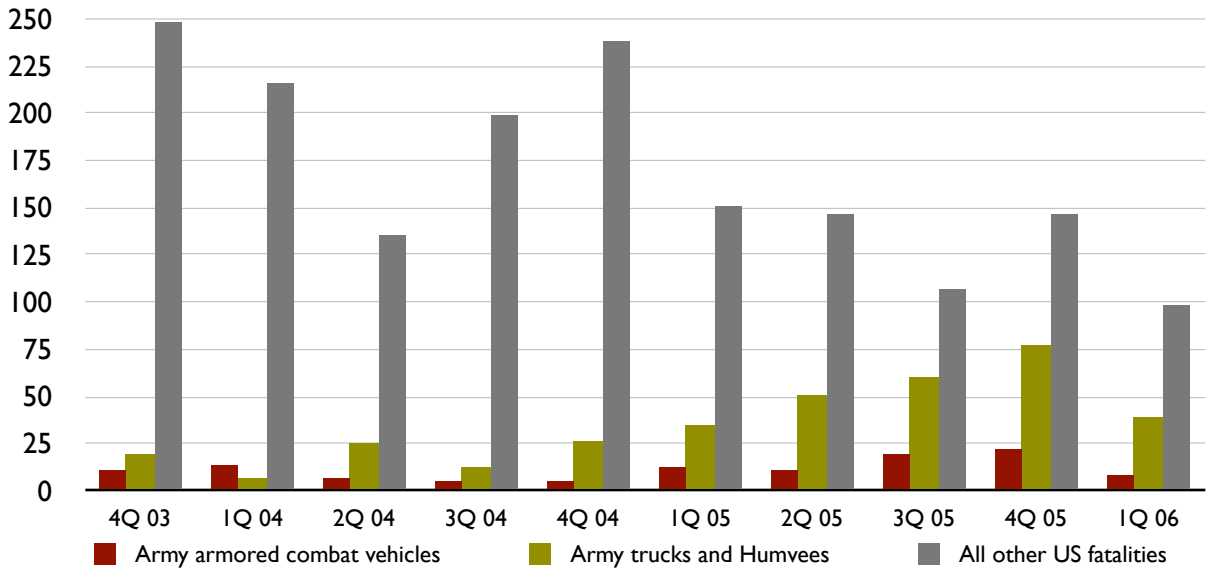
Roadside bomb attacks on trucks and Humvees account for just about half of all US Army fatalities in vehicles in Iraq. On the other hand, with roughly 20,000 Army trucks and Humvees in Iraq, the fatality rate is actually quite low comparatively: just 0.006 deaths per vehicle per year. That is twice the fatality rate for M113s (which serve in similar support roles), but the M113 is much better armored than even the strongest 'up-armored' Humvee or cargo truck.

The aspects of the Army's armoring program that are designed to combat bomb blasts are thus certainly understandable. Less clear is the emphasis on protecting against RPGs. For all the effort being directed at stopping RPG attacks, the casualty rate from RPG attacks on vehicles (that is, excluding complex attacks involving RPGs) in Iraq has been just 8.8 deaths annually. The fatality rates for bomb attacks on armored vehicles and (as noted) *even traffic accidents* have been much higher. So, either the slat armor and reactive tiles that have been fitting to armored assault vehicles (the Bradley, Stryker, and M113) are very effective,

or they are not extraordinarily necessary. Since the data do not generally identify the degree of armor on the attacked vehicle, I cannot make any progress with that question.[13]

Considering all US fatalities in Iraq provides yet another view. The rising series of green bars indicates that at some point between late 2004 and early 2005, the insurgents collectively learned that attacks on Humvees and trucks would lead to more US fatalities than attacks on harder targets. They also may have decided that burning out vehicles made better spectacles than killing soldiers walking about, since the overall fatality rate was dropping at this point.[14]

ARMY FATALITIES IN ARMORED COMBAT VEHICLES, TRUCKS AND HUMVEES, AND ALL OTHERS



[13] Some of the Army's fatality reports note that a Humvee was actually an *up-armored* Humvee, but I am yet to find one that identifies the vehicle as lacking additional armor. Given the relative public relations value of the two statements, I cannot express any surprise.

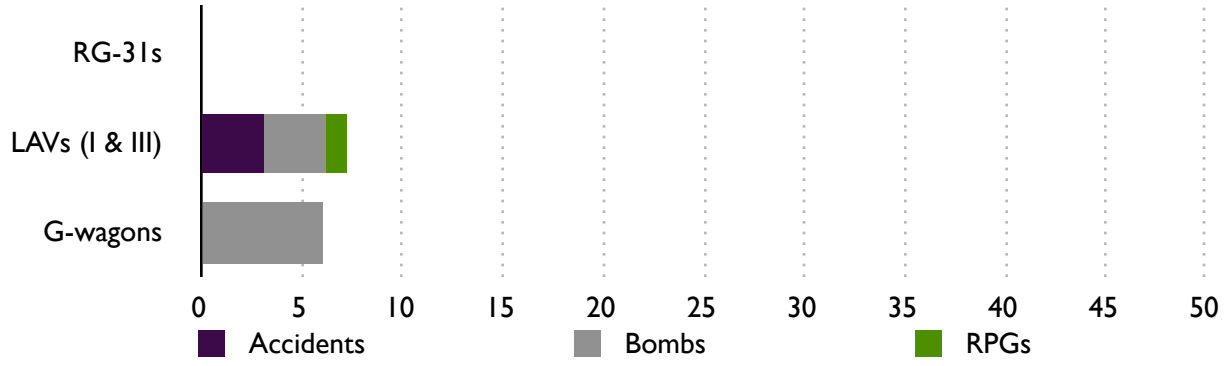
[14] Actually, the gray bars include all US fatalities in Iraq, so a proper comparison would show slightly lower non-vehicle totals. This is a working paper, after all, but I will need to parse those out in a subsequent revision.

The Canadian Experience in Afghanistan

Relatively few Canadian casualties have been caused by RPGs: as with the US experience in Iraq, the problem is bomb blasts.

Before moving on, it will be useful to compare the US Army's experience to that of allied forces. First, the Canadians: a Canadian battlegroup has been deployed with armored vehicles to the vicinity of Khandahar for the past year, and its troops have been under periodic attack by the Taliban. The nature of those attacks—at least the relatively successful ones—is captured in the charts below. Blasts, largely by roadside bombs and suicide car bombs, have been the biggest killer, accounting for nine of the thirteen fatalities over the past year in military vehicles.

CANADIANS KILLED IN MILITARY VEHICLES IN AFGHANISTAN
OCTOBER 2005–SEPTEMBER 2006, BY CAUSE AND VEHICLE



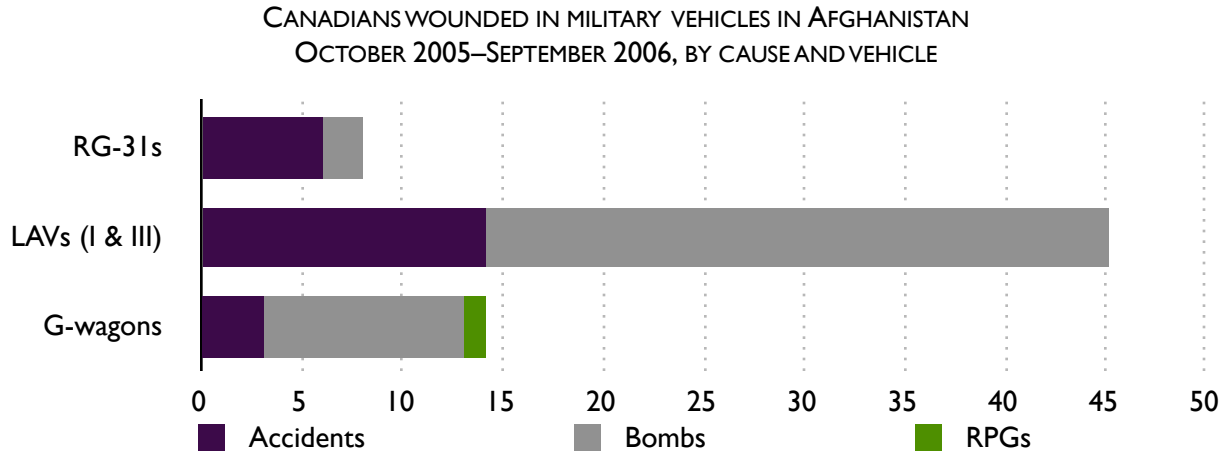
Six of the nine have been killed in *Geländewagens*, or G-wagons, which are 4-x-4 off-road vehicles from Mercedes-Benz rather akin to Land Rovers. With bolt-on armored plates and ballistic blankets on the floor boards, the G-wagons are not exactly built from the start to resist blast. The remaining three were killed in LAV-series vehicles from General Dynamics—two in an LAV-I Bison, and one in an LAV-III. No Canadian troops were killed in the period in question in an RG-31.

RPGs were notable for their relatively lack of lethality overall: only one Canadian was killed by an RPG in the period in question: Captain Nichola Goddard of the 1st Royal Canadian Horse Artillery, inside an LAV-III, while directing artillery fire on 17 May 2006 about 24 kilometers west of Khandahar. As noted in the chart on the next page, RPGs have also been only a minor source of non-fatal injuries. The Canadian experience in Afghanistan, in this regard, parallels that of the US Army in Iraq: traffic accidents have been a much larger source of casualties than RPGs.

It is notable that the number killed in LAVs is only slightly higher than the number killed in G-wagons, but that the number wounded in LAVs is much higher than the number wounded in G-wagons. The reason may be that LAVs carry so many more people: G-wagons are well-loaded with four soldiers, but LAVs easily carry eleven.

What may be more notable is the low rate of casualties due to RPG attacks on G-wagons. Without details on the full set of attacks, it is difficult to draw conclusions. Stephen Priestly of Simon Fraser University in British Columbia has written that "this may have more to do with fairly good luck", because "in

contrast with US armour, [Canadian Forces] vehicles have not been fitted with RPG cages."[15] Still, the nature of the terrain and the opponents may hold some explanatory value. The area around Khandahar is relatively free of dense vegetation, so challenging a convoy of vehicles in small groups with rocket grenades could be a hazardous undertaking. The insurgency in Iraq is more urban, and buildings sometimes provide better cover for RPG attacks. Roadside bombs, on the other hand, provide much greater stand-off distance if command detonated, and complete separation if triggered by the passing vehicles themselves.



Replacement of the G-wagons in the patrol role with RG-31s has been made a top priority by Minister of National Defense Gordon O'Connor (himself a retired brigadier general)

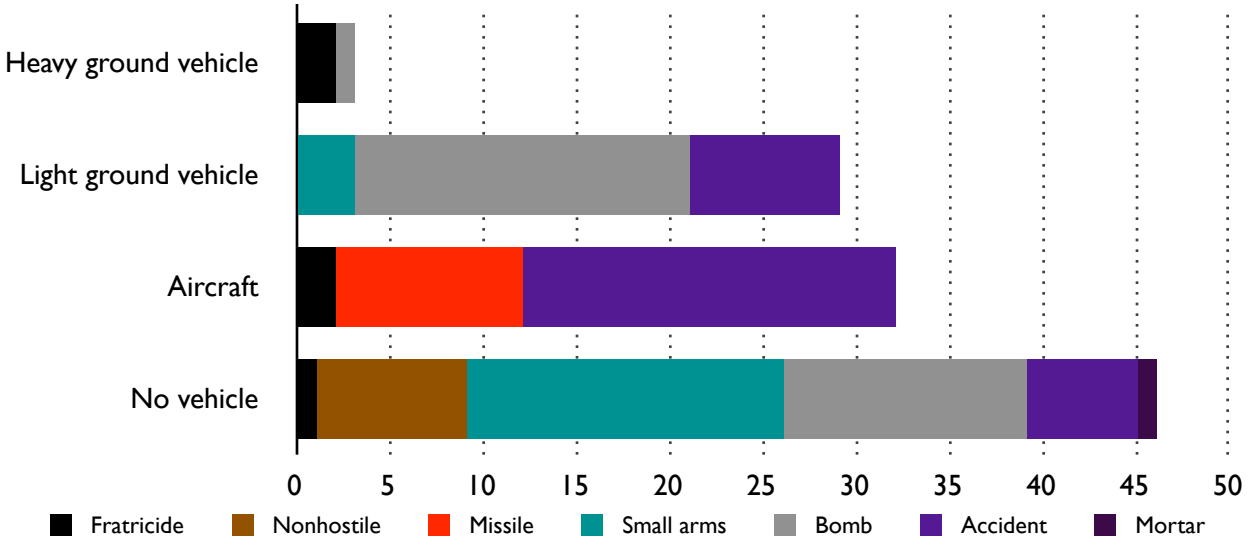
[15] Stephen Priestly, Hard Numbers: CF Afghanistan Casualties vs. Vehicles Type, *Canadian-American Security Review*, August 2006 (http://www.sfu.ca/casr/ft-vehicle-casualties.htm)

The British Experience in Iraq

Ground vehicles have not been the only problem, and accidents have been an even larger problem than bomb blasts.

The British Ministry of Defense publishes considerable detail on each fatality suffered amongst its troops in both Afghanistan and Iraq, including accidental deaths, suicides, and those due to illnesses.[16] In parallel with the American experience (shown in the column chart on page 14), significantly more British troops have been killed on foot than in vehicles.

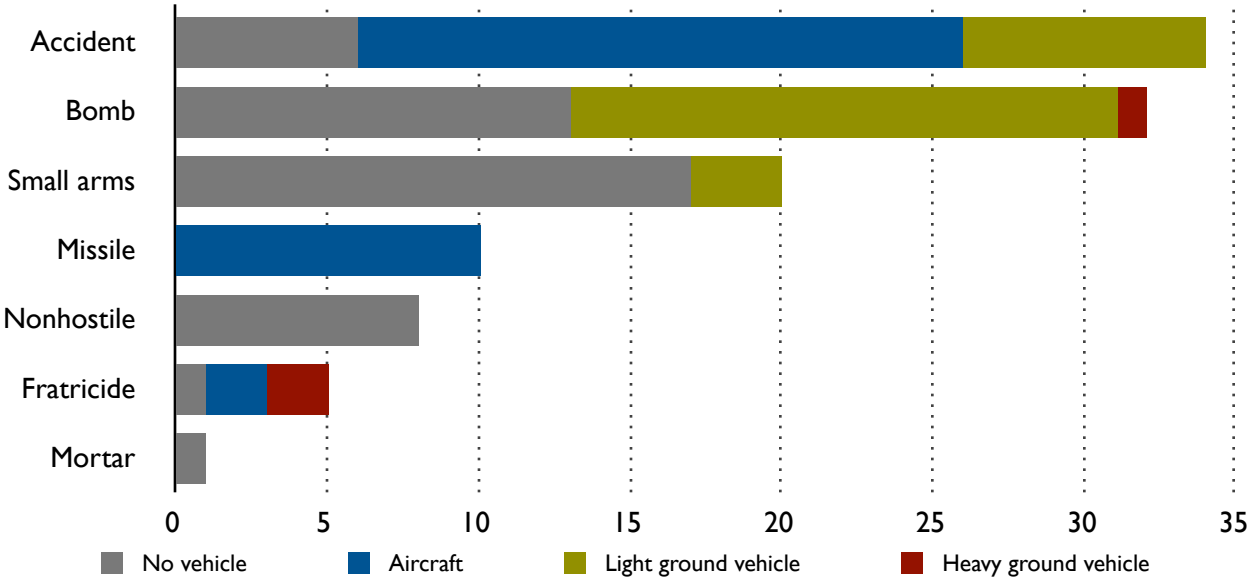
BRITISH FATALITIES IN IRAQ, MARCH 2003 THROUGH SEPTEMBER 2006, BY VEHICLE TYPE, THEN CAUSE



Again, bomb blasts have been a major killer, particularly of troops in light vehicles, such as Land Rovers, but notably also of troops on foot patrols.

BRITISH FATALITIES IN IRAQ, MARCH 2003 THROUGH SEPTEMBER 2006, BY CAUSE, THEN VEHICLE TYPE

16 See http://www.mod.uk/DefenceInternet/FactSheets/OperationsFactsheets/OperationsInIraqBritishFatalities.htm and http://www.mod.uk/DefenceInternet/FactSheets/OperationsFactsheets/OperationsInAfghanistanBritishFatalities.htm


Accident
Bomb
Small arms
Missile
Nonhostile
Fratricide
Mortar
0
5
10
15
20
25
30
35
No vehicle
Aircraft
Light ground vehicle
Heavy ground vehicle

Observations

The US Army and Marines need some more blast-protected trucks—a lot more.

The last chart makes clear that the US Army experience a serious upswing in vehicular fatalities in the latter half of 2005, and that the percentage of fatalities experienced in vehicles remained relatively high through the beginning of 2006. The preceding analysis indicates how understanding the causes of fatalities is important to developing ways to limit them. Further efforts to combat the RPG-7 are probably overkill, since current measures appear to be sufficient. That said, the new tandem warheads for weapons like the RPG-29 are another matter.

Three mine-protected, armored trucks in US service: from top to bottom, BAE Systems' four-by-four RG-31, Force Protection's four-by-four Cougar (also available in a six-by-six), and Force Protection's six-by-six Buffalo with its spork.

Rather, press reports broadly indicate that the reason is larger, more sophisticated, and better-placed roadside bombs. The Army's own fatality reports support this.

The question, then, is how to limit fatalities by equipping the troops with better armored transport, while still preserving their ability to undertake their missions. For mounted troops, the mechanism is obvious: troops riding in trucks and Humvees present more enticing targets than troops on foot, since they are necessarily clustered but relatively unprotected (even if 'up-armored'). Dismounted troops could also experience the benefit if better armored transport meant that they would dismount closer to their objectives, or in some cases, not at all. It is reasonable to suggest that many of the fatalities amongst light infantry and cavalry units in Iraq occur because the troops must dismount rather far from their objectives, since Humvees and trucks are not very bullet- or blast-resistant.

However, it is also arguable that infantry in Iraq are as often targets as effective combatants. The fight in Iraq today is substantially against bomb-makers, and disarming their bombs is generally better done from the safety of an armored EOD vehicle, such as Force Protection's Buffalo. Thus, sending more Abrams, Bradleys, or M113s to Iraq may not be the answer. These vehicles were not designed *ab initio* to protect against bomb blasts from below, but penetrating projectiles from the front and side. Against the latter, they are doing a good job—so good, in fact,

that traffic accidents appear to be a considerably larger problem for troops in Iraq than RPGs. The Stryker, with its steel armor, may provide better protection against car bomb blasts and the like, but that analysis requires more complete, case-by-case data from the Army (and those data are almost certainly classified).

No fatalities, however, have were reported during the period of analysis in the growing number of Cougar, Buffalo, and RG-31 armored trucks in Iraq. There are over 300 of these vehicles in use now in Iraq by the US Army, the USMC, and the British Army, and the vehicles have incurred rather few fatalities. All have occurred rather recently, and in RG-31s:

FATALITIES IN RG-31 MINE-PROTECTED VEHICLES ASSIGNED TO ENGINEERING UNITS IN IRAQ

Rank	Name	Date	Unit	Location	Cause
Staff Sergeant	O. Flores	8 July 2006	54th Engineer Battalion	Ar Ramadi	Bomb
Sergeant	A. Floyd	8 July 2006	54th Engineer Battalion	Ar Ramadi	Bomb
Specialist	T. Linden	8 July 2006	54th Engineer Battalion	Ar Ramadi	Bomb
Specialist	J. Micks	8 July 2006	54th Engineer Battalion	Ar Ramadi	Bomb
Specialist	M. Hermanson	23 May 2006	164th North Dakota Engineer Battalion	Al Abayachi	Complex
Private First Class	A. Gaylord	5 May 2006	110th Missouri Engineer Battalion	Qasr Ar Riyy	Bomb
Staff Sergeant	G. Reinke	4 May 2006	5th Engineer Battalion	Baghdad	Bomb
Specialist	B. Quinton	4 May 2006	5th Engineer Battalion	Baghdad	Bomb
Private First Class	C. Lufkin	4 May 2006	5th Engineer Battalion	Baghdad	Bomb

NB: all these fatalities were incurred after the period of analysis

It is important to note that the RG-31, which is built in South Africa by BAE Systems, is a *mine*-protected *troop carrier*. It is not purpose-built as an EOD vehicle in the same way as Force Protection's Buffalo, with its long, armored, bomb-grasping spork, and it is also designed specifically to provide blast protection from beneath, not the side. Each type of vehicle has its purpose, but neither will be equally effective at the other. In any case, while these casualties are unfortunate, their limited number serves to illustrate the value of this type of vehicle, both for mine-protected troop transport and bomb disposal. In the summer of 2005, insurgents in Baghdad began spraying walls with the Arabic equivalent of the graffiti message "Kill the Claw"—the spork at the end of the Buffalo armored truck was rather disrupting their bombing campaign.[17]

Unsurprisingly, the US Army recently amended its vehicle procurement plans to add another 250 Buffalos between 2007 and 2009, and the Senate Armed Service Committee in early May voted to add $100 million to the Navy Department's budget to buy up to 150 Cougars and Buffalos for the Marines.[18] Assuming that the plans hold, these purchases will bring the total number of armored trucks in US service to over 600. That is a good start. Just as significant are the Iraqi Army's plans: on its behalf, the US Army re-

[17] Greg Grant, 'An Answer to IEDs,' *Defense News*, 12 September 2005

[18] Roxana Tiron, 'Graham and Levin lead fight on Cougar,' *The Hill*, 11 May 2006.

cently awarded a $450 million contract to a team of BAE Systems, Force Protection, and chassis supplier Spartan Motors for 1,050 modified Cougar four-by-four troop carriers.[19]

Armored trucks are not the right vehicle for mechanized assault units, so neither the Army nor the Marines would be well-advised to abandon their Bradleys, Strykers, M113s, or Amtracks for them entirely. However, if the Army and Marines expect to continue engage in the sort of counterinsurgency that they are waging in Iraq, then supplementing the force—particularly infantry and EOD units—with a relatively large number of these vehicles will go far towards bringing the right vehicles to the battle at hand.

Next Steps
The analysis could use more data—a lot more.

While these results are intriguing, the paucity of information in the Army's fatality reports may limit the applicability of the observations. A more thorough study, which would require use of militarily sensitive information, would consider a wide range of factors in each fatal incident, including:

- vehicle speed when attacked
- the nature of the operation (*e.g.*, convoy, raid, patrol)
- the number and type of other vehicles in proximity
- the length of time that the unit had been in Iraq, and the number of previous deployments on which the driver and vehicle commander had served (as a proxy for experience)
- the presence, and if so, number of dismounted troops in proximity
- the nature of the terrain (open country, open road, city street, etc.)
- the estimated size of the explosive device or probable type of rocket
- the location of the penetration into the vehicle
- the range of the shooter, if a projectile weapon was used
- the proximity of the explosive to the vehicle, including directionality, if a bomb was used
- the type, level and manufacturer of any add-on armor on the vehicle
- the specific nature of the fatal injuries
- the nearest town to the attack (this is generally already available; I simply did not use the data)
- whether the vehicle or any other in proximity was jamming radio signals

The open source data, unfortunately, held too few fields for me to attempt anything more than a series of annotated bar charts. With the entire data set scrubbed again for inconsistencies and expanded in a formal and rich database, more sophisticated statistical tests would be possible, which may provide more significant insights into the patterns of armored vehicle protective performance.

[19] See U.S. Army Tank-Automotive & Armaments Command (TACOM) contract #W56HZV-06-D-VB01.