Human Factors Analysis & Classification

Applying the Department of Defense system during combat operations in Iraq

By Jay Jennings

SAFETY AND COMBAT OPERATIONS appear to be incompatible. Bold, audacious, risk-taking is often the hallmark of successful military missions, a time-honored concept validated by the recent invasions of Afghanistan and Iraq. At first glance, it would appear the administrative restraints of safety have no place in a fluid combat environment.

However, an effective safety program in a war zone preserves the combat power of a military force. The Department of Defense Human Factors Analysis and Classification System (DOD-HFACS) provides an excellent analytical tool for developing and sustaining a proactive safety program. Using a fatal accident that occurred in Iraq in November 2005 for illustrative purposes, this article demonstrates how this system can be an effective taxonomy for minimizing or eliminating accidental losses in the most hazardous workplace—armed combat.

Each of the four U.S. military services and the Coast Guard has a safety center with the mission to reduce or minimize accidental losses or mishaps. The U.S. Army Combat Readiness Center/Safety Center trains soldiers, leaders and military safety professionals to integrate safety into all phases of military operations—including combat. This article focuses on the Army, as it is the service providing the majority of forces in Iraq and Afghanistan. The author has served as a full-time Army safety professional during separate tours of duty in Bosnia, Kosovo and Iraq. In January 2008, he deployed to Bagram Airfield, Afghanistan, with the 101st Airborne Division, where he serves as the Joint Logistics Command and 101st Sustainment Brigade Safety Officer.

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Systematic Analysis of Human Error

Using the framework of the DOD-HFACS, accident investigators may analyze the organizational and supervisory aspects of human error in a systematic manner. The system was adopted by the heads of the safety centers of all the military services in 2005 as the analytical model for human factors hazards in accident causation. The model builds on the solid foundations of Reason's "Swiss cheese" model (Figure 1) and Wiegmann and Shappell's (1998) extensive work in aviation accident causation and prevention, to include the first HFACS model. Although this article does not describe the system in great detail, it does provide a brief overview of the system and the two models upon which it is based.

Reason's Tiers of Human Error Analysis

Reason's work (1990) amplified Heinrich's domino theory of accident causation, which proposed that mishaps are the result of a sequence of errors. Reason's model focused not only on the active failures of operators involved in the mishap, but also on human error in the management and supervisory realms. His integration of latent failures or conditions into accident causation provided a more complete framework for investigators to identify and mitigate future accidents.

In addition to the first tier of analysis—unsafe acts of operators—Reason added three levels, each focused on the organizational influences on errors. The second, third and fourth tiers—titled preconditions for unsafe acts, unsafe supervision and organizational influences, respectively—analyze the latent failures or conditions that may lie dormant or remain undetected until circumstances are right. Conditions such as fatigue, stress or complacency may lead to a mishap, but they are not specific actions by an operator, they are preconditions that set the stage for an accident. Unsafe supervisory errors can prompt unsafe acts by operators; poor crew pairing or matching is an example of this failure. The final analytical tier, organizational influences, considers factors such as funding and corporate culture to identify latent failures that lead to accidents. An effective and thorough investigation considers factors at all four levels.

The investigation process seeks to find the holes, or hazards, in the four levels (Figure 1). When they are aligned, the holes in the process set the stage for a mishap. Unlike the domino theory in which each domino bumps the other, the holes may not always line up; latent failures or conditions may not always be present.

Creating a Unified Framework

Wiegmann and Shappell (1998) recognized the value of a unified framework for analyzing human error perspectives at all levels of the organization. However, they recognized that the specific nature of the holes was ill-defined. If one could identify the failed or absent defense, the hole could be plugged and the mishap prevented.

Wiegmann and Shappell developed the HFACS to define the latent and active failures identified in Reason's model. After extensive analysis of hundreds of accident reports and thousands of human causal factors, they designed the system for use in aviation accident investigation. Analogous to Reason's model, HFACS also defined four levels of failure, each of which corresponds to one of Reason's four layers (Figure 2).

The Department of Defense Safety Goal

On May 19, 2003, alarmed by the rising number of accidental losses in DOD, Secretary of Defense Donald Rumsfeld established a goal of 50% reduction in accidental losses in the following 2 years (DOD, 2003). The Defense Safety Oversight Council was formed to provide a forum for developing and implementing strategies to achieve the reduction.

One joint committee, the Human Factors Working Group (HFWG), had a charter to "identify data-driven, benefit-focused, human-factor and human-performance safety strategies designed to identify hazards, mitigate risk and reduce aviation mishaps inherent in aircraft operations throughout DOD." More than 80% of military aviation accidents are deemed to be caused by human error, a percentage that mirrors civil aviation. Among its goals, HFWG set out to:

•promote common human factors taxonomy, investigation and analysis system for DOD-wide implementation;

•recommend standardization of human factor and human performance terminology.

The military services had been collecting human factors data using many different models, causing a disparity in methodologies and making it difficult to create group approaches to mitigating the human factors hazards present in most mishaps. Following a May 5, 2005, meeting, the safety directors from all military services and the Coast Guard recommended that a version of HFACS be modified and adopted. DOD-HFACS is this jointly created taxonomy.

The DOD-HFACS is nearly identical to the Wiegmann and Shappell model. Some categories were modified to accommodate the human factors analysis of ground accidents as well as aviation mishaps. The U.S. Army Combat Readiness Center/Safety Center developed a foundational training program.

When the accident investigator analyzes human error using the framework of the DOD system, supervisory and organizational factors (the holes in the cheese) begin to take shape. A practical application of the model is the most effective method of demonstrating its effectiveness.

The mishap and fatality described occurred near Tal Afar, Iraq, in November 2005. The names, units and specific location are omitted for security reasons, but the circumstances leading up to this event provide an excellent framework to apply the DOD-HFACS.

Case Study: Mishap in Iraq

Nov. 17, 2005, was a typical late fall day in Iraq. Temperatures were in the mid-80s, visibility was unlimited and the warm desert air was free of dust storms. At 8:30 a.m., four desert-tan, armored high mobility multipurpose wheeled vehicles (HMMWVs) departed a forward operating base (FOB), a fortified American military base camp, bound for a larger FOB 50 km to the south. The reason for the mission (regardless of the purpose, they are all termed "missions," as one is in harm's way) was to take a soldier on the first leg of his trip home on rest-and-recuperation leave and to replenish the supply stocks of multiple commodities on the smaller facility.

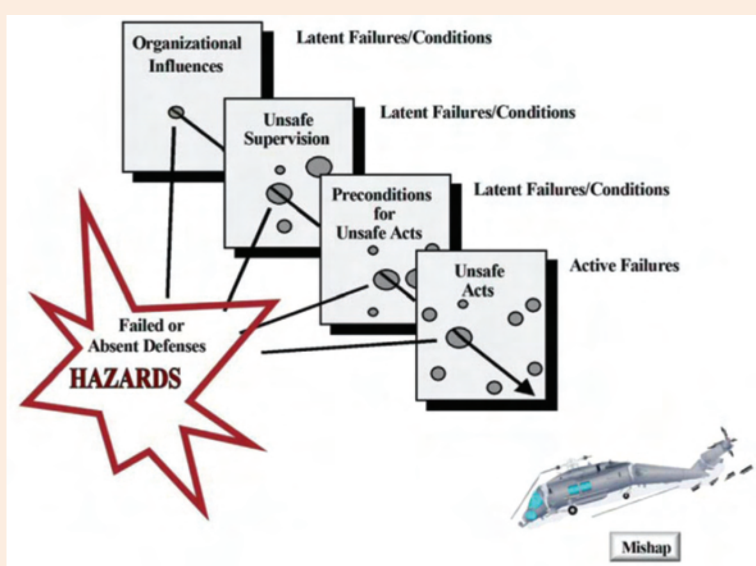
The potential for enemy activity on the route was considered low for the first 30 to 35 km, but the convoy would eventually pass through the northern Iraqi city of Tal Afar, a hotbed of insurgent activity. Three vehicles from the FOB's combat unit and a fourth from a tenant combat support element departed at 8:30 a.m. The support unit HMMWV was in the second position in the convoy.

Forty-five minutes into the trip, 4 km north of Tal Afar on a paved asphalt road, the driver of the second HMMWV wildly swerved on a curve and lost control of the vehicle. The HMMWV rolled over, the left rear door opened and the soldier seated behind the driver

Abstract: *Using a fatal accident that occurred in Iraq in November 2005 for illustrative purposes, this article demonstrates how the human factors analysis and classification system developed by the Department of Defense can be an effective taxonomy for minimizing or eliminating accidental losses in the most hazardous workplace—armed combat.*

Figure 1

Reason's "Swiss Cheese" Causation Model



Note. *Adapted from* Managing the Risks of Organizational Accidents *by J. Reason, 1990, Cambridge, U.K.: Ashgate.*

Photos 1 and 2: The unsecured soldier seated behind the driver was thrown out of the rear passenger door when it opened during the rollover.

was thrown out. He struck the ground with sufficient force to kill him immediately upon impact. The driver and truck commander in the front right seat suffered minor injuries, as they were secured in place by their seatbelts. The third HMMWV came upon the wreckage moments later and initiated an immediate call for an aeromedical evacuation for the injured soldiers and a maintenance team to recover the overturned vehicle. The convoy never reached its destination and the support unit mourned the loss of a soldier.

At first glance, the causation appears relatively simple; however, an analysis through DOD-HFACS reveals a series of latent human errors. The model provides a tool to eliminate systemic shortcomings and, more importantly, prevent future accidental losses from the same causes.

Analyzing the Mishap

Categories of Unsafe Acts

The primary act that caused the mishap was the driver's failure to control the HMMWV in the curve. Although there was gravel on the road, it was a gentle turn on a smooth, dry, level road surface. The additional action that directly led to but did not cause the death of the passenger in the rear was his failure to comply with the requirement to wear a safety belt while the vehicle was in motion.

These two operator errors—one of commission and one of omission—were the active failures in this sequence of events. Army Regulation 385-55, Prevention of Motor Vehicle Accidents, outlines specific requirements for vehicle control and requires that passengers wear restraints at all times. Within DOD-HFACS, these fall into different categories under the acts tier (Figure 3). The unintended, improper operation of the HMMWV is classified as an error, specifically a skill-based error. The driver failed to execute a commonly practiced skill. Conversely, the passenger's failure to secure his seatbelt is classified as a violation, as he displayed a lack of discipline in his disregard of a known standard.

Categories of Unsafe Supervision

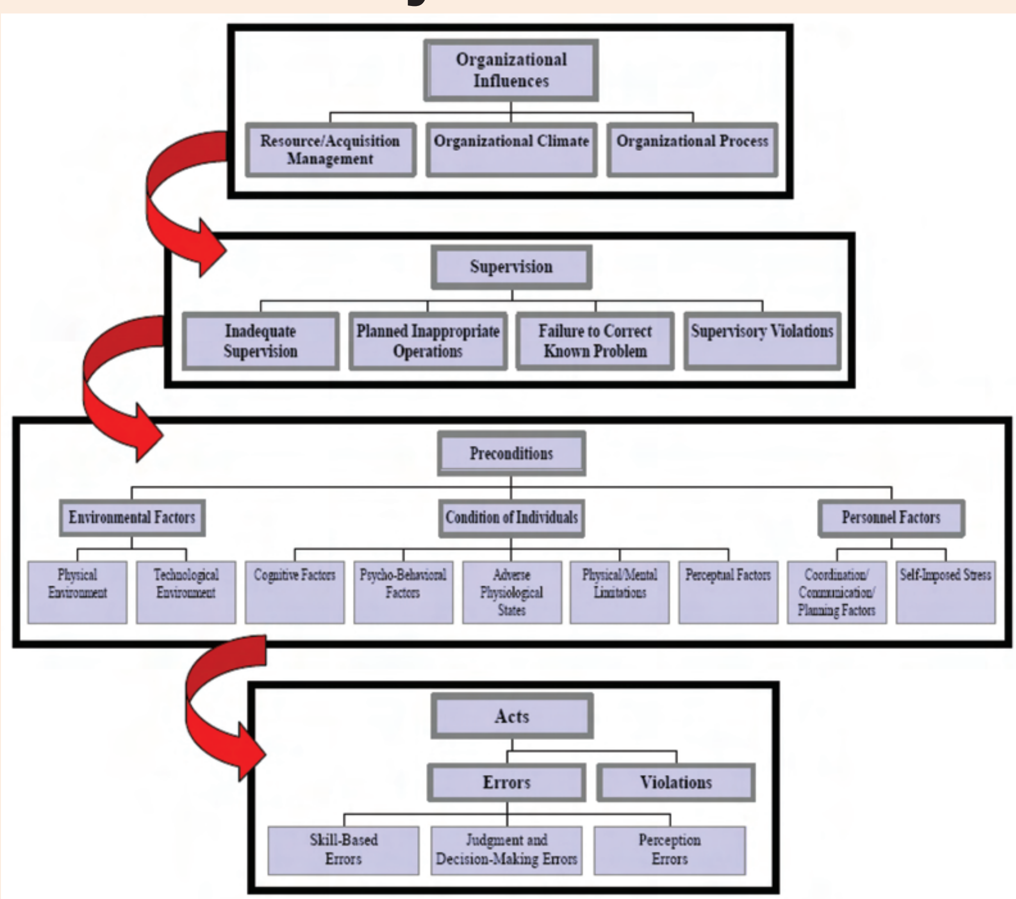
Without a systemic way to perform causal analysis, many accident investigators would stop here. However, the three additional tiers for analysis in DOD-HFACS provide a framework for focusing on management responsibility in the sequence of events and causation. Within the U.S. military structure, management is the chain of command.

If active and/or latent preconditions result in human error or an unsafe situation, preconditions may be causal factors in a mishap. These latent factors are not actions, but circumstances that compromise human performance. They comprise preconditions, the second DOD-HFACS tier (Figure 4).

This rollover and fatality occurred in the most stressful imaginable operational

Figure 2

DOD Human Factors Analysis & Classification System



work environment—armed combat. Combatants in Iraq are subject to hostile actions at all times because there are no traditional front lines. Mortars and rockets drop at random on FOBs and convoys are routinely peppered by bullets and rocket-propelled grenades. However, the low-tech weapon of choice for insurgents is the improvised explosive device (IED)—or the roadside bomb. The constant threat of IEDs creates conditions in which every convoy is a high-stress, life-threatening event.

On the day of the mishap, the crew of the second HMMWV had been in Iraq for less than 2 months and the vehicle operator had driven through Tal Afar on only one previous occasion. In addition, unlike the three vehicles from the combat unit, the vehicle from

Figure 3

DOD-HFACS Tier 1: Categories of Unsafe Acts

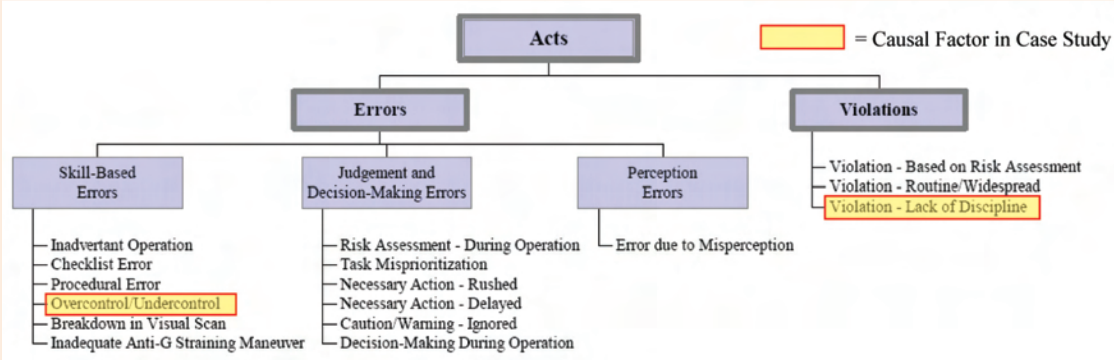


Figure 4

DOD-HFACS Tier 2: Categories of Preconditions for Unsafe Acts

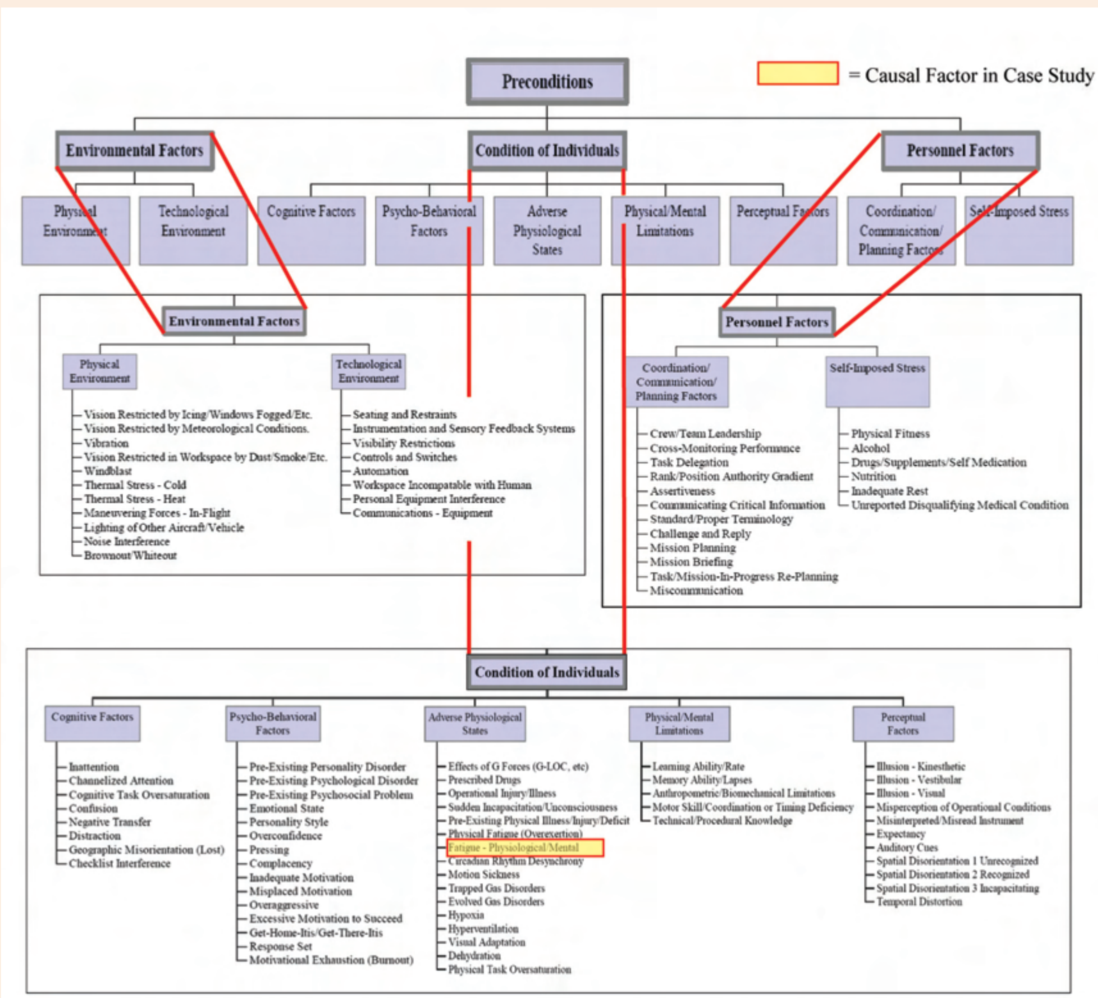
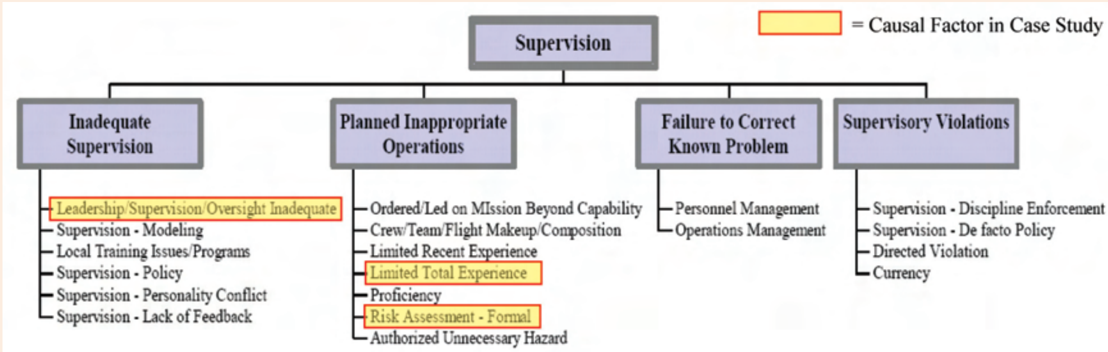


Figure 5

DOD-HFACS Tier 3: Categories of Unsafe Supervision



the support unit had no radio. This was not an oversight or error; there simply were not enough radios available to equip all vehicles in the convoy.

This additional analysis helps complete an emerging picture of a significant latent precondition, an exceptionally high-stress environment. The driver, a recent arrival to Iraq with little experience driving an HMMWV, drove through a dangerous area with which he was unfamiliar and he had no means to communicate with the lead vehicle.

Inadequate supervision often plays a role in mishap causation. Latent human supervisory errors occurred leading to this incident, including factors from two of the four categories under the third classification tier, supervision (Figure 5). The senior occupant of an Army vehicle is responsible for enforcing all policies and procedures relating to its safe operation. These responsibilities include the use of restraints. Although the rear passenger failed to buckle his seatbelt, the truck commander, as senior occupant, failed to check and enforce compliance. The DOD-HFACS model categorizes this deficiency as inadequate supervision.

A second category under supervision, planned inappropriate operations, addresses two additional supervisory shortcomings from this mishap. The driver had little experience at the wheel of an up-armored vehicle, which provides greater protection from IEDs. He had driven the vehicle once during his precombat training in Kuwait and to the FOB when his combat support unit initially set up operations. He had not driven a heavier HMMWV since his arrival. The supervisor's choice to have him drive conflicted with Army guidance that new vehicle operators should never gain initial experience on equipment in combat.

In addition, a second supervisor, the convoy commander in the first vehicle, planned inappropriate operations that led to the accident. The convoy consisted of four vehicles—three from the combat unit and one from the support unit. The officer in charge of the convoy was from the combat unit. He opted to bypass standard convoy procedures, which require a predeparture convoy briefing with all participants present and the completion and approval of a risk assessment for the operation.

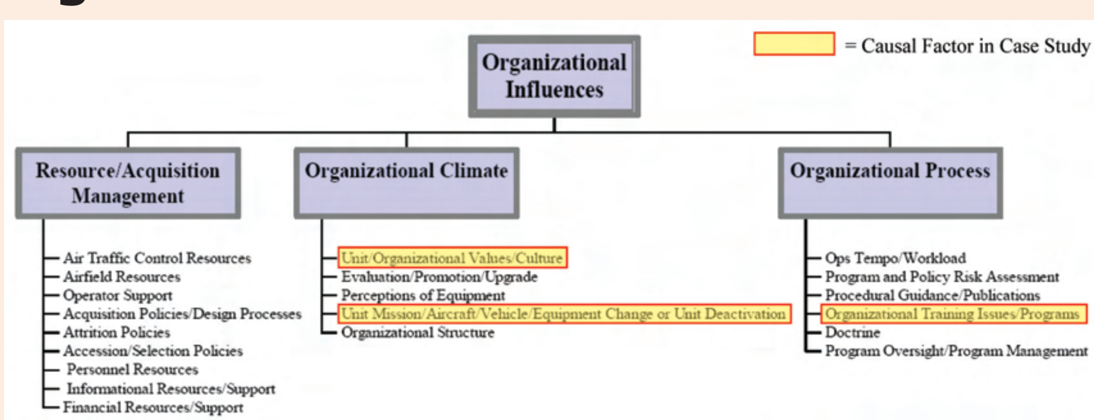
These omissions denied the support unit HMMWV driver a map review of the route. The convoy commander also missed an opportunity to reinforce the requirement to wear restraint systems. In addition, this officer failed to check the driver's experience level. Had he followed standard supervisory procedures, he might have selected a different vehicle operator whose capabilities were more suitable for the mission.

Categories of Organizational Influences

Supervisory practices are heavily influenced by

Figure 6

DOD-HFACS Tier 4: Categories of Organizational Influences



organizational pressures (Figure 6), especially in rigid hierarchical structures such as the military services. The Nov. 17, 2005, mishap was no exception. The legacy of changing standard practices during the first 3 years of Operation Iraqi Freedom, the evolving combat role of the HMMWV and the standards of the Army-level vehicle licensing program all played a role in shaping the decisions of the driver, passenger and first-line supervisor.

In the author's opinion, the U.S. Army was not fully prepared to combat the insurgency that erupted in the wake of the 2003 invasion of Iraq. Most units were equipped with the M-998 HMMWV, a stripped-down, generic variant of the Army's workhorse vehicle. The M-998 had canvas doors, sides and top. It had no armor plating and, in many cases, no structural platform on which to mount an automatic weapon. It provided occupants with little to no protection from bullets, shrapnel and other combat hazards. In addition, the two-point seatbelts were flimsy, extremely difficult to reach and often not long enough to reach around the torso of a soldier wearing Army-issued body armor.

The Army issued a maintenance work order in 1999 to install a longer, three-point seatbelt system in all HMMWVs. However, this upgrade was not a high priority, as the deadline for completion was 2005, 6 years after the work order. As a result, many HMMWVs were sent to Iraq with the short, two-point belt.

On Dec. 9, 2004, when Secretary Rumsfeld stated, "You go to war with the Army that you have," it was a response to a concern about the lack of armor protection on HMMWVs. Blasted by IEDs, small arms fire and other dangers, soldiers improvised, adding metal plating to the top and sides of the vehicle and placing sandbags to the floor. This plating, often of dubious quality, was made of every imaginable shape and size of metal. The different materials often spalled when struck by enemy bullets and created flying fragments that endangered vehicle occupants. In addition, the greater weight, especially to the top of the vehicle, raised its center of gravity.

Insurgent activity began after the invasion of Iraq was complete and the Iraqi Army melted into the civilian population. When attacked, soldiers dismounted from the vehicles and pursued the enemy on foot, usually to no avail. In this environment, many soldiers viewed the seatbelt as a liability, an obstacle to a swift dismount under fire. As a result, commanders in many units specifically ordered soldiers *not* to wear seatbelts in HMMWVs.

The results were somewhat predictable. Although troops were not delayed by entanglement in their restraint systems while responding to enemy attacks, injuries from both major and minor HMMWV accidents caused hundreds of casualties. Operated at higher speeds to reduce exposure to the IED threat, HMMWVs with nonstandard armor and a corresponding increase in the vehicle's center of gravity, began to roll over at an alarming rate. Young, inexperienced drivers under great stress were unprepared to safely operate the vehicles at 80 to 100 mph, even on paved roads. It was not uncommon for a driver to rapidly overcorrect with the steering wheel in a panic, initiating a rollover.

Because of mounting losses from small arms fire and shrapnel and public outcry with accompanying congressional pressure, the U.S. Army directed substantial resources to providing greater protection for soldiers in HMMWVs. Engineers from the Army's Tank and Automotive Command immediately began to design standardized templates and an approved materials list for armor plating.

Using guidance and materials in the newly developed and implemented Add-On Armor (AOA) program, soldiers and contractors on FOBs began upgrading nonarmored M-998 HMMWVs. The addition of more than 1,000 lb of armor plating required that the suspension system, door hinges and windows be upgraded. In addition, sealing the metal cab created an oven on wheels, so air conditioners were added—not as a creature comfort measure, but to keep soldiers from suffering heat injuries inside the vehicles, where air temperatures sometimes exceeded 130 °F.

The up-armored HMMWVs dramatically improved survivability. Simultaneously, newly fielded electronic countermeasure devices decreased the effectiveness of remotely detonated IEDs. As a result, the Army's standard tactical response to an IED attack changed. Rather than stopping, dismounting and pursuing an elusive enemy, convoy commanders were directed to push through the IED "kill box" and leave the danger area as soon as possible. All soldiers stayed inside vehicles, as it was now the safest place to be during an attack. Entanglement in a seatbelt was no longer a major concern since occupants were not required to dismount. Longer, three-point seatbelts with large, robust, easily accessible buckles were installed.

With seatbelts that were readily available and offered a good fit, soldiers had no logical reason to avoid wearing them. However, getting them into the habit of buckling up proved a significant challenge. Two major obstacles hindered compliance: the legacy of "no-seatbelt" orders and the lingering perception that seatbelt use is an administrative requirement not applicable to combat.

As soldiers return for their second, third and fourth tours of duty in Iraq and Afghanistan, the advice of the grizzled veteran (who is often 22 years old) can be counterproductive to safe vehicle operation. The "that's the way we do it here" mindset familiar to

Photo 3 (top): The canvas-covered M-998 HMMWV with "soft-skinned" top and sides provides little protection from IEDs, shrapnel and bullets.

Photo 4: (Large photo) An up-armored M-998 HMMWV. Note the ballistic windshield and armored doors added in Iraq. The inset photo shows 2-in. thick ballistic glass that can withstand a direct hit from IEDs and machine-gun fire.

SH&E professionals in the public and private sectors can undermine standardization and change in any organization. In the initial stages of a deployment, new soldiers naturally look up to the experienced soldiers who have served a combat tour or two. Anecdotal evidence indicates that the old-timer often discourages the newcomers from wearing seatbelts, because "I survived without them on my first tour."

Despite the fact that tactics have changed and occupants no longer dismount and counterattack, distain for the seatbelt persists. In many respects, this is a function of the Army organizational culture, which encourages bold, audacious and decisive action. In this culture, seatbelts are often perceived to be a device for training only—and a hindrance to real soldiering.

As noted, the administrative element of buckling up is yet another organizational human factor that discourages adherence to safe practices. Despite predeployment presentations showing that survival in a rollover is linked to seatbelt use, skepticism remains. This is also a function of the population of the Army today, primarily 18 to 24-year-old males, a demographic group that typically has a sense of invincibility and immortality. The greatest successes improving individual compliance with use of restraints have been directly tied to constant command emphasis from the top of the organization.

Investigators of the 2005 mishap could never confirm whether the soldier's decision to violate the seatbelt regulation was influenced by these two organizational factors. However, other soldiers in Iraq in 2005 indicated that securing seatbelts was not part of a standard premovement check. And, as noted, the truck commander did not enforce the requirement.

Qualifying Drivers in the Army

Like most well-run fleet management operations, the Army has a proven system for ensuring that drivers are qualified to drive safely, even in a combat zone. Every driver of an M-998 HMMWV is licensed by a unit master driver. This process involves a written examination and standardized road test. Electronic quality control prohibits a soldier from dispatching (military parlance for being handed the keys) a vehicle for which he is not licensed. If there is not an M-998 qualification entry beside the operator's name in the computer, he will not be given the keys to the vehicle.

However, in 2005, the Army's standardized vehicle licensing and quality control system failed to keep pace with the rapid upgrades to the M-998 HMMWV. As AOA kits were added, the weight and handling characteristics of the vehicle changed dramatically. Many unit motor sergeants and master drivers recognized this and provided drivers with refresher training on the heavier vehicles. However, this could not be provided during stateside predeployment training, as all up-armored HMMWVs were in Iraq where the need was greatest. Thus, the first time a soldier might drive the heavier variant was during a brief training period in Kuwait as the unit passed through on its way to Iraq.

Most HMMWV drivers did not gain an appreciation for the different handling characteristics and higher center of gravity of an up-armored HMMWV until they were on an FOB in Iraq executing the change-out with the departing unit. The operator of the vehicle in the fatal accident had driven an up-armored HMMWV once in Kuwait, yet the M-998 qualification on his vehicle license made him an approved operator. The 15 to 20% increase in the vehicle's weight with AOA should have prompted an additional nomenclature and a corresponding licensing procedure, refresher or upgrade, but this never happened. The conclusion of the postaccident investigation was that the Army's licensing system provided insufficient training for the task to be performed. In this case, the Army's licensing system failed the driver, who did not possess the proper skills to handle an up-armored vehicle.

Conclusion

This case study included specific unsafe actions of commission and omission by the operators. It is clear that management-level human factors also played a key role in the mishap causation. A comprehensive analysis using the DOD-HFACS framework identified both the hazards and the multiple management levels at which mitigating efforts can be focused. The rapid changes in supervisory and organizational dynamics during a fluid wartime environment create innumerable preconditions, supervisory challenges and organizational influences. To ignore these management human failures, even during a mishap in a combat zone, is to miss myriad latent causal factors. DOD-HFACS is an effective tool that can be used to identify and mitigate the accidental losses that can degrade the combat effectiveness of a military unit. ■

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Afterword: The Path to Fewer Rollovers

More than 2 years have passed since the fatal accident described. In the time since, the Army has solved some of the organizational human factor issues identified in the DOD-HFACS, but other management issues remain.

In 2005, the Army had not fielded enough factory-built up-armored M-1114 HMMWVs to equip all units in Iraq. The M-1114 has armor plating, bulletproof glass, heavy suspension, air conditioning and a roof weapons mount. It also requires a separate operator license. Since there were not enough M-1114s available, M-998 HMMWVs with AOA were used on convoys.

After the highly publicized remarks by Secretary Rumsfeld in December 2004, factory production and fielding of M-1114s increased dramatically, providing soldiers in Iraq with better protection from IEDs and enemy attacks. However, the pressing need to ship M-1114s to combat continues to deny Army units the opportunity to train on the heavier up-armored vehicles before deployment. Units must maximize the final train-up time in Kuwait—where M-1114s and M-998s with AOA are available—to ensure that vehicle operators gain driving experience in a controlled environment. Significant numbers of soldiers are returning for additional tours of duty; in some cases, more than 60% of unit personnel are on a return combat tour. This increases the experience base of HMMWV drivers and, in many cases, their first-person tales of rollovers and subsequent casualties.

The U.S.Army Combat Readiness Center/Safety Center has stated that command emphasis on the importance of seatbelts and reduction of convoy speeds is the key to increased compliance and supervisory enforcement. The improved survivability of the up-armored HMMWVs allows convoys to slow speed and decrease the potential for panic or rollovers caused by overcorrection. An in-depth analysis of accident statistics from calendar years 2005 to 2007 reveals a success story. In this 3-year period, the number of U.S. Army vehicle rollovers and rollover fatalities in Iraq has decreased significantly—with rollovers dropping 62% and rollover fatalities declining 75% (Figures 7 and 8). These reductions are further validated when placed in proper context—a rate incorporating the total annual miles driven in Iraq by all U.S. Army vehicles (Figure 9).

This measurable success story is encouraging and commanders at all levels are taking note. A decrease in accidental losses increases combat readiness and capability. Safe operating practices, a hard-sell during the early stages of the war, have become a key force protection measure. The recent inclusion of full-time, deployable SH&E professionals on all military staffs above the brigade level gives the commander a dedicated, trained resource whose primary focus is preventing accidental losses. The author currently serves in this role.

Some Army organizational and management human error factors remain and many cannot be effectively mitigated. Combat will always be a high-stress environment. Increasing the experience level of deployed soldiers decreases the stress level, but as long as one's personal survival is at risk, stress will always be present. As in nearly every military conflict, resources are often stretched. Unlike a controlled industrial environment, the primary hazard—the enemy—has a vote and the ability to adapt. Lastly, armies are staffed predominantly by young men, a group predisposed to accept increased risk. In the author's opinion, that organizational dynamic will probably never change.

Figure 7

Multinational Corps in Iraq: Vehicle Rollovers

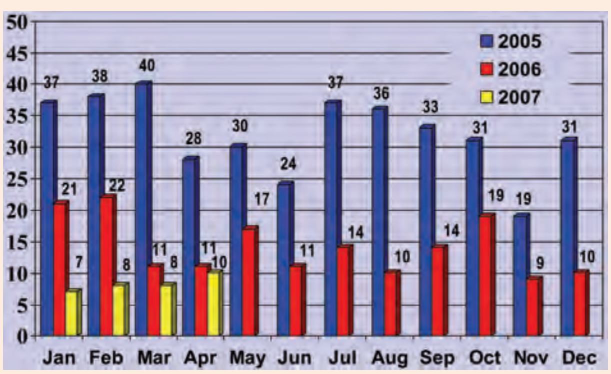


Figure 8

Rollover Fatalities in Iraq: Jan. 2005-April 2007

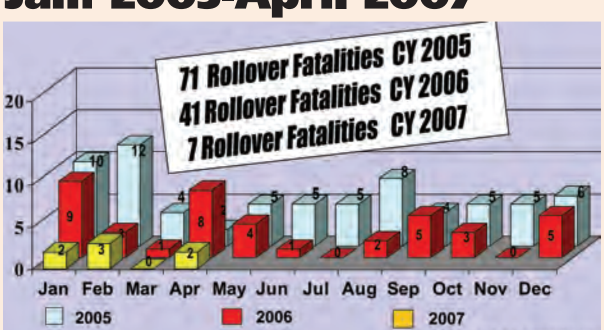
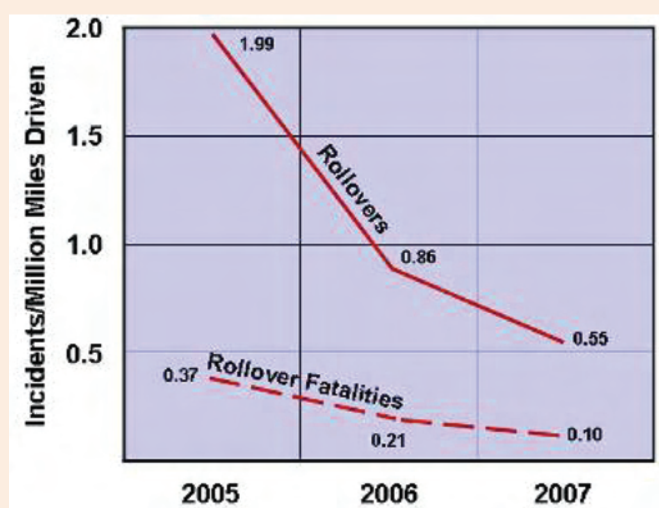


Figure 9

Rollovers & Fatalities: Rate per Million Miles Driven, Calendar Year 2005-07



Note. *Rates adjusted for total mileage changes from year to year. Multiple factors impact mileage driven, notably 2007 troop population surge, increased use of contractors driving long-haul trucks, increased integration of Iraqi security forces into MNC-I and an ever-changing tactical situation.*