Hot Seats

Heavily armored boxes can withstand tremendous kinetic energy from mines and IEDs. The real test is in protecting the occupants inside the box. Seats and other ergonomic design features are as important as the steel in the protection equation.

Crew and platform survivability is about protection in depth, providing differing technologies and techniques to cope with a range of threats. Solutions that ensure platform or hull survivability may not necessarily aid crew members. Many, if not most, injuries that occur when an armored or tactical vehicle is hit by vertical or horizontal blasts are not due to armor penetration. Even when the hull remains intact the resulting shock wave causes displacement of organs, broken necks and other fatal trauma. Outside of an explosive event, lives are also being lost when vehicles topple off bridges and road edges. Improved seating is now being procured as a key tool in ensuring crew and passenger survival.

The issue is complex. Off the shelf commercial seats, rather than protect, can actually create dynamic amplification of the sine wave transmitted through the vehicle to the crew by as much as five times. Restraints must also ensure that the individual is kept in the seat despite potential pressures from every axis—and still operate the vehicle. In response, seating is becoming increasingly complex, borrowing techniques and technology from the aviation industry, well versed in protecting crew against high-G impacts.

Mike Smith, vice president, strategy and planning, BAE Systems Land and Armaments outlined the demands for seating from a prime contractor's perspective. "Typically we don't design our own seats. Our organization may provide component parts, for instance armor tiles for helicopter seats. If there is a healthy array of suppliers we will leverage the existing supply chain as long as extant offerings meet or exceed the requirement we seek to meet."

Was seat technology considered part of the integrated survivability systems for ground vehicles before recent operations? "I'd say probably not," stated Smith. "In the current conflict there has been a proliferation of bottom blast threats. You have a pressure wave from the ground and that shock is transferred from the hull of the vehicle to the bracketing of the seats and then to the passengers and crew. We are tirelessly looking for ways to mitigate and dissipate that shock force, whether it is geometry of the hull, the material used in the vehicle and now minimizing shock transfer to the passenger through seating technologies."

New designs and technology are now being sought for inclusion in integrated vehicle protection schemes. "We looked to other industries that have long been confronting analogous physics problems of a similar nature, said Smith. "For instance, a helicopter crash subjects its passengers and crew to enormous forces exerted on the hull upon impact. That is why, in my view, aviation solutions have become so relevant in mine protected seating today. No solution is perfect, particularly in a dynamic threat environment." However, there is widespread recognition that seating technology has become a critical element of a system-of-systems approach to integrated survivability.

By Adam Baddeley
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"There is still work to be done in multi-stage energy attenuation," Smith said in closing.

Smith said that working with the DoD they had not been directed to any one supplier or suppliers by the customer for today's immediate needs. Addressing future requirement for Future Combat Systems (FCS) Smith said that a number of different options were being considered and that they hadn't settled on any one solution.

"Our energy attenuating seat program started approximately seven years ago with a realization that the forces and accelerations that result from mine blast exceeded the injury threshold of the human spine. These events were severe enough that we knew something needed to be done to prevent injuries," said Mark J Phillips ArmorWorks' manager of vehicle armor products, EA/ballistic seating. "We obtained several SBIR [small business innovation research] grants from the Marines and Army for development of mine blast energy attenuating seats for ground vehicles.

Historically, a lot of research had been done on aircraft crash safety and protection from spinal injuries but not for ground vehicles. Interestingly, aircraft and ground vehicles experience similar loading conditions during vertical crashes and mine blasts but at different acceleration levels and durations. Aircraft are subjected a comparatively low-G, long-duration event whereas a mine blast represents a high-G, short duration event. Mitigation mechanisms that worked well in an aircraft needed to be adapted to work in the hyper-acceleration of a mine or IED blast.

Led by Dr. Ken Lu, ArmorWork's chief scientist, the company went back to very basic engineering principles and developed a simple, tailorable, mechanical device with no moving parts. "The beauty of this design is that with our ShockRide seat system we can tailor the amount of load into that seat. If a customer tells us that they want a maximum10-G load into the occupant, we can make it so that occupant will never see more than 10-G's during any event," said Phillips.

Phillips credits the Army and Marine Corps a great deal in the development of workable energy attenuating systems. In particular Dr. Ami Frydman with the Army Research Laboratory and Derek Erdley of the USMC were singled out for their vision and dedication over the long term. Frydman is looking at, testing and evaluating options to find the best protection for the warfighter. The Aberdeen Test Center was also credited for their work in the actual live fire testing of vehicles and seats—the unsung heroes as he refers to them as.

The seats in the USMC's EFV, because it's an amphibious vehicle that operates in salt water, required the use of highly corrosion-resistance materials. "When we looked at the strictly ground vehicle market we realized that we didn't have those same set of materials in the seat itself, said Phillips. "We were able to reduce the cost of the seat and make it affordable for any wheeled or tracked vehicle. We started that development in about mid-2006 and deployed the first set of seats in January 2007. We partnered with BAE Systems in their MRAP vehicle. The results of the first tests were fantastic and we received production orders from BAE Systems for all of their MRAP vehicles."

Brian Kariya at BAE's Santa Clara facility had been looking around the market to find survivability solutions for their vehicles. "They approached us to help them develop an energy attenuating bench seat for tracked vehicles like the Bradley," said Phillips. "We've built several prototypes and are moving forward through two user evaluations with fantastic results. We are excited about the possibility of supplying a unique energy attenuating bench seat and improved restraint system for tracked combat vehicles."

The company is also working on a ShockRide technology retrofit system that can be fitted to floor-mounted seats in ground vehicles. According to Phillips, test have shown excellent results and demonstrated that with a properly designed energy attenuating system existing floor-mounted seats can reduce energy transfer to the occupants. This opens up retrofit opportunities to vehicles like the HMMWV, 915-series trucks, HEMTTs—anything with wheels or tracks and a floor-mounted seat.

ArmorWorks have seats either selected for production or in prototype and evaluation for more than seven MRAP, JLTV and tracked vehicle programs with BAE, Textron Land & Marine Systems, General Dynamics Land Systems, General Dynamics Land Systems Canada, and AM General. Current seat orders between now and October are in excess of 3,000 standard troop seats and by the end of the year hope to have orders for more than 10,000 seats for about four different ground vehicles.

"As you are aware, on the Hill and at DoD the number one priority is to get the MRAPs over into theater as soon as possible," said Bob Codney, ArmorWorks' vice president of business development. "ArmorWorks prides itself in assisting vehicle OEMs in the manufacturing of these seats to coincide with any deliver numbers that are necessary to meet the expeditious requests of both the DoD and the Hill. Even if that means expanding our facilities and production, we are prepared to support the MRAP program."

Today, however, Global Seating Systems (GSS) make the Cobra seat, part of the company's CCOPS (Common Crashworthy Occupant Protection System, "see-cops") family. Christian Hammarskjold, company president explained that CCOPS came out of the Army's Expedited Modernization Initiative Procedure, designed to identify commercially available technologies that can be readily integrated into the Army's vehicles.

"We took a lot of the technology that they had tested, refined it and developed it into the CCOPS family. There are some seats out there addressing the mine blast issue, others that address the crashworthiness, issue but CCOPS is really the only complete system that addresses all the threats in military ground vehicles."

There are four common crashes the Army has identified; frontal impacts, convoy accidents, and lateral accidents both from vehicle-to-vehicle and IEDs. Plus with up-armored vehicles such as the MRAP and HMMWVs, their center of gravity has been raised and during evasive maneuvers there is increased roll over. Hammarskjold said, "We have targeted all our research over the past three years on these areas and the result is CCOPS. We design and own the technology but we have done all the testing through different Army programs with static testing, dynamic testing, sled testing as well a putting

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them in different vehicles and blown them up in mine blasts.

In addition to Cobra, the other members of the CCOPS family are Viper, Sidewinder and Diamondback which are application-specific designs. The Diamondback seat is specifically designed for the guard position in a tactical vehicle where the back flips down and the gunner can stand on top of the seat when he is firing. A modular system, Hammarskjold explained that space not design really dictates what CCOPS components and features are put on the seats.

GSS have CCOPS in the field on a number of vehicles including the HTV and MTV, several MRAP designs including the BAE RG 31 and 33, Force Protection Inc's Cougar and a number of international programs. Moist of platforms have been installed on are wheeled reflecting the current threat.

Hammarskjold believes shock transmission for IED events is the most critical factor in design today. "There were schools of thought that wanted a suspension seat such as in truck seats. That is the worst thing you can do because that increased dynamic amplification four or five times. There is such force in mine blasts that if the seat's suspension bottoms out, it causes dynamic amplification spikes and serious injury or death occur. One of the most common injuries is compression burst fracture of the spine where the spine compresses so hard and fast that vertebrae burst and fragment."

Shock mitigation bases used in helicopters and aircraft are also problematic he believes. "Helicopters have a very predictable dynamic event. The engine stops but the helicopter auto-rotates so you will know when you will hit the ground and what force you have. It is also a single event with a known impact curve and the seat can be designed for a specific force. The same is true of ejection seats. They are one-phase events—they hit the ground once—plus the occupant has to 'dial in' their weight so with energy attenuators (EA) the seat is precisely calibrated to their weight to ensure survival."

Ground vehicles don't have the luxury of being designed for a single known event. A mine blast is not a single event—you have the blast portion where the vehicle is lifted up and a second phase where it slams back down. Second, the size of the munition varies—8 pounds or 100 pounds—so it can't be predicted or modeled. Consequently the system cannot be calibrated. It's also seen as impractical to design a $100,000 dollar seat for everyone in the vehicle where everyone dials their weight in. When aviations seating is used, it is typically designed for a 50 percentile male and nominal blast event, which may mitigate some but not all compression from the blast event.

Hammarskjold explained that they have avoided both approaches by using a proprietary passive EA system that has been tested by the Army and vehicle manufacturers at Aberdeen. "Because we can't predict the inputs, the seat cushion uses rate-dependent foam technology which limits dynamic amplification on the blast and the slam down, regardless of severity, occupant weight and occupant geometry, said Hammaskjod. "That's the secret."

CCOPS keep the soldier in the seat using an all belts to seat (ABTS) design connecting to the seat itself rather than to the vehicle frame, ensuring that the restraints move with the soldier in a crash, no matter the occupant's size. Accordingly CCOPS uses an all-steel seat frame, 5-15 times stronger than a typical automotive seat frame because loads are transferred to the seat rather than the vehicle wall. "If you become uncoupled from the belt as is the case with vehicle-mounted system, when the slam down event occurs your posture is no longer aligned and your injury threshold is even lower than before," said Hammarskjold.

Bosik Technologies Ltd's mine blast protective seat combines shock-absorbing material to attenuate blast forces with a steel blast plate to reduce shrapnel penetration combined with a secure 4-point harness and adjustable angle spine support to hold the users in place. Bosik have also tested a ceiling-mounted seat for use with the M113. The suspension system also combines a shock absorber to reduce G forces.

ACS International's ROPS seating system provides a four or fourteen seat, high tensile steel frame than can be mounted in the rear of tactical vehicles in under 30 minutes and is designed to protect the crew in rollover scenarios protecting the head. The aluminum or polycarbonate seats can be molded to fit specific backpack requirements to enable each soldier to be fully equipped while within the harness. Each seat uses Mouletc multi-density foam to reduce cramp and other injuries during sustaining periods while in the seat.

AmSafe, Phoeniz, AZ, a provider of safety and securement products to the aviation, defense and ground transportation markets, has designed a pre-tensioning system and a unique locking restraint that will protect occupants during a blast event. The new restraint systems are designed with a single hand release for rapid egress and will accommodate occupants of all sizes. The company currently has restraint systems in us on HMMWVs, Strykers, and various other military ground vehicles. The new AmSafe military devices are scheduled to be completed and ready for installation in 2008.

BAE Systems will enter the seating safety restraint systems business through the acquisition of Armor Holding after the latter's acquisition of German firm Schroth.

The German firm Autoflug has an innovative design that takes parachute and aviation technology and applies it to military vehicles.

Holger Hansen, creative director at Autoflug and inventor of its seating systems explained how they became interested in the solution after they learned that the magnitude and duration of shock forces from mine/IED blast transmitted to vehicle ceilings were comparable to those of a high speed parachute deployment such as with ejection seats. The company has a nearly 90 year heritage of supplying military parachutes and harnesses and presently is providing the seating on the A400M military transport aircraft.

"Many other traditional seat manufacturers are adapting their conventional solutions by incorporating shock absorption or other mitigation systems," Hansen commented. "We are supplying the one and only specially designed concept for the new demands."

Hansen states the problem bluntly. "When a conventional seat is floor mounted, the shock forces are transmitted directly to the occupant into his spinal column and inner organs. The occupant has no chance of survival. Instead, we isolate the occupant from any rigid structure in the vehicle. This doesn't mean the absence of connections to the vehicle but just the absence of a rigid metallic connection to the ceiling. The crew hang from the vehicle ceiling like parachutists in their safety harness as they would when they experience the deployment shock force of the parachute. The principle is that you can't transmit compression force via textile fabric. You can't push a rope."

Autoflug's dynamic seat system consists of a harness seat system connected to the hull via six restraints and a single zero-G restraint to hold the user in place if inverted. The position of the wearer is controlled with mechanical springs and Bowden cables via a control unit, with the weight of the wearer becoming the actuating force. No electronics or hydraulics are involved. The system can be adjusted by the user and then be locked in position and held in all three axes. There are no restrictions in terms of installation apart from having suitable suspension points for the seat harness. For passengers, Autoflug have developed a further solution which appears as a bench seat with harnesses but uses the same approach. "We are mitigating shock forces and the vehicle's own vibrations, everything is done through textile materials, via the belt," Hansen explained.

This radical approach has caused some scratching of head by approving authorities. "We have had long discussions with them and we have agreed that we are not in the true sense, supplying seats," explained Hansen. "Instead we are supplying restraining safety harnesses with integrated seating accommodation."

Autoflug seats are now in 30 programs worldwide with 16 nations in applications ranging from testing to series production. A major program is the Leopard 2 MBT in six nations across Europe and Canada, as the harness-based seat was developed in response to a request from the Bundeswehr's Leopard 2 program office in 2001. Other platforms include the new Puma IFV, M113, CV90 and the Wiesel. In the U.S. Autoflug systems are now being installed in the M1A1 and M1A2 SEP Abrams tank. To meet the U.S. demands Autoflug has recently established a production and design facility at El Paso TX, next door to Fort Bliss with a further site in Troy MI, close to TARDEC and TACOM and associated program executive offices in Warren MI.

Hansen noted that feedback from the user community is developing fast. "When we began our work we had a lot of discussion with high ranking officers but they were careful in disclosing information," said Hansen. "Now they know we have a solution and they are now openly discussing with us what has happened in the past and what they need for the future."

The seats also have other benefits such as reducing fatigue in passengers. This is because the seat is isolated from the vehicle vibrations and the passenger is effectively in a gimbaled mount.

Autoflug is exploring a number of innovations based on user feedback. Instead of getting in the way as can be the case with the current seating system the seat design becomes part of the solution, replacing the extemporized options available today. Each of the mountings has a single point of release.

The low volume approach coupled with replacing padding and shock absorbers with restraints has also had an indirect benefit to designers—namely weight reduction. The dynamic seat systems weighs just 15 kilograms which is many times less than conventional seating thus providing tens of kilograms of weight savings for each seat. This weight reduction is helpful in designing new lightweight vehicles and for legacy platforms that are already close to their payload limits.

Survivability

Today seating is being retrofitted to meet immediate operational requirements. Nevertheless, new demand and awareness is bringing change where seating has ceased to become a component or afterthought and evolved to become an integral element to the integrated survivability package. That said, seating can only enhance chances of survival. The combination of a safe vehicle hull and restraint can enhance the survivability of the occupants. But blast resistant seating can only go so far. If the vehicle doesn't survive the impact then all bets are off.