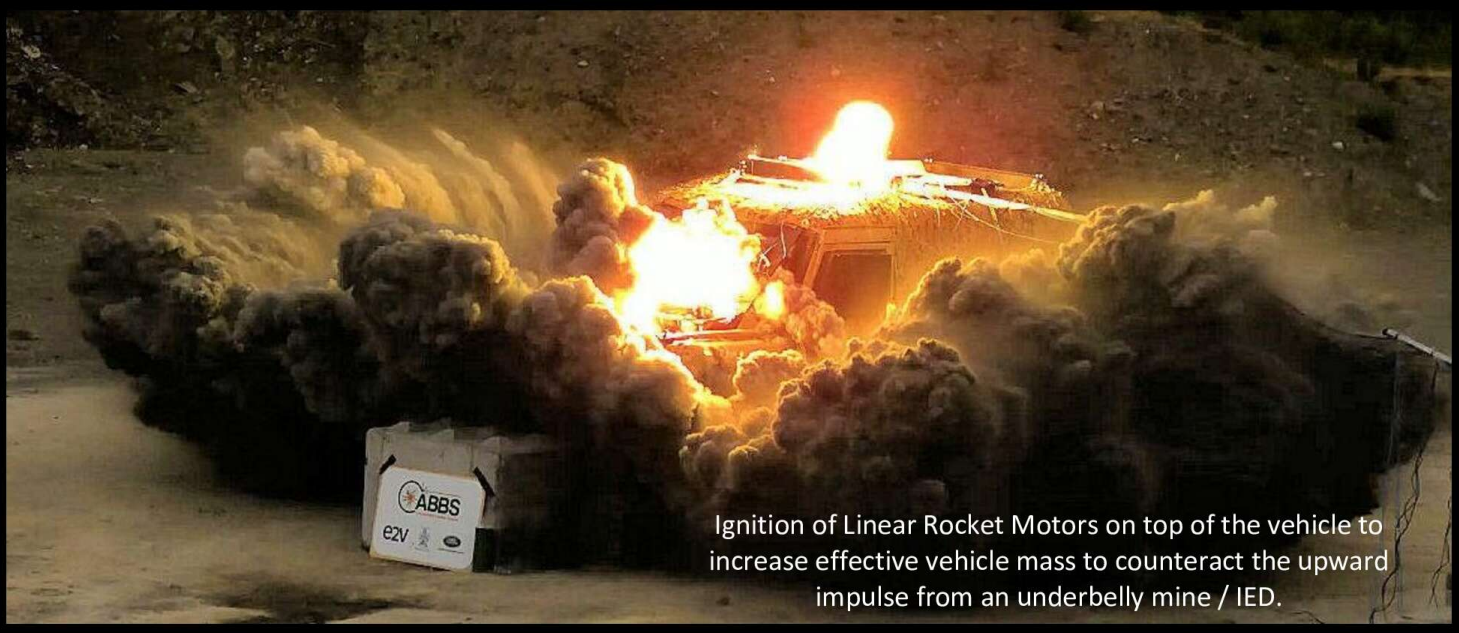
Advanced Blast & Ballistic Systems Ltd

Leading Edge Technologies for Vehicle Protection from Mines and IED's



Ignition of Linear Rocket Motors on top of the vehicle to increase effective vehicle mass to counteract the upward impulse from an underbelly mine / IED.

After investing £7million in R&D over 13 years since 2008 ABBS has become the worlds' leading independent developer of novel technologies designed to provide complete protection for the occupants of armoured vehicles hit by mines and IED's.

ABBS offers a complete suite of active and passive technologies to defeat the specific threats to the vehicle occupants.

The ABBS suite of technologies addresses the following threats:

- **Belly Plate Penetration** – with double steel skins and composite materials in the core the latest ABBS belly plate design provides excellent ballistic penetration resistance.

- **Belly Plate Deformation** – the ABBS sandwich structure design with a unique internal energy absorption mechanism incorporating composite materials and graphene minimises peak deformation – up to 40% reduction compared to an equivalent weight single plate steel design. The energy absorbing elements in the design will also reduce shock transfer into the main vehicle structure.

- **Floor Shock Injury** – ABBS offers an automatically re-setting active floor system to suit different vehicle designs, avoiding the need to re-install the floor as necessary with some other systems.

- **Vehicle Global Acceleration Mitigation (VGAM™)** – ABBS's novel patented system with Linear Rocket Motors (LRM™) can eliminate Global Acceleration completely by providing up to 1,000 tonnes of 'artificial mass' for 20-30ms after the mine or IED explodes.

- **Slam-down Injury** – Adopting the ABBS VGAM™ system enables optimisation of the blast seat design with potential for reduction in stroke and weight.

The combined effects of all these systems can radically increase the mine and IED blast resistance of all armoured vehicles from lightweight civilian-based types to MBT's, providing far greater protection for personnel and substantially enhancing tactical capability.

Benefits for Overall Vehicle Design:

The reduction in peak deformation of the belly plate has numerous beneficial effects on the whole vehicle design if it is incorporated as part of the original design process:

- The free space between the belly plate and the floor can be reduced by up to 40% compared to equivalent weight steel belly plate designs. This gain in space can be used to either increase the internal cabin height or reduce the overall vehicle height whilst retaining or increasing ground clearance.

- Reducing the overall vehicle height provides:-
  - ✓ Lower surface area to protect, so less armour weight and cost.
  - ✓ Lower Centre of Mass, so both mobility and stability are increased.
  - ✓ Reduced signature and smaller target.
  - ✓ Easier air transport.

- Alternatively, if weight reduction is the higher priority, a 20-30% reduction in belly plate weight may be possible depending on the specific vehicle design.

- The standard belly plate design is essentially flat, hence lowering the Centre of Mass compared to V-hull designs. A slight V or curvature can be incorporated if preferred.

- Ultimately, a belly plate capable of resisting at least a 50kg ANFO-type IED is possible.

- A potential side-benefit of minimising belly plate deformation is that impulse transfer to the vehicle may be reduced (because the high-pressure gas from the mine is not trapped under the vehicle in a dome-shaped deformed belly plate.)

  The potentially reduced impulse transfer can result in reduced jump height, which would enable the use of lighter blast seats with a shorter stroke.

- Increased energy absorption by the belly plate may result in reduced secondary shock effects on vehicle equipment.

Snatch Land Rover tests using a 6kg TNT-equivalent mine as per AEP55 Level2b demonstrate all the ABBS systems working together:

Snatch Land Rover with 10mm Armox 440 Belly Plate

Belly plate deforms, breaking vehicle in half.

Vehicle jump height approx. 5.5m

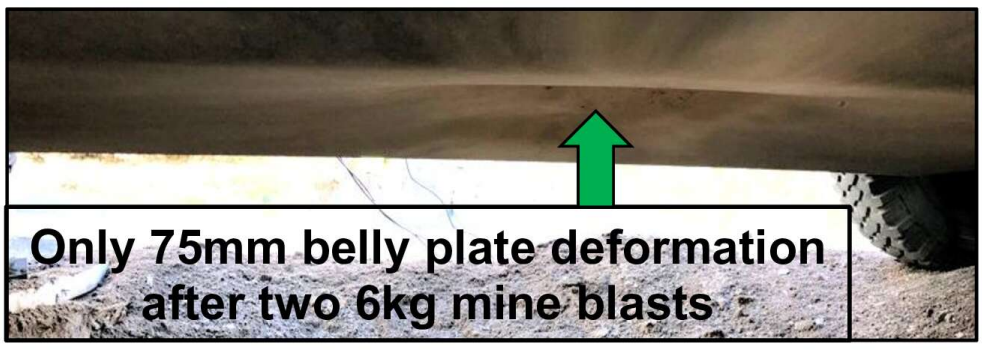
Vehicle badly damaged, crew probably killed.

With Full ABBS Active and Passive Mine Protection Suite

Linear Rocket Motors ignite, belly plate remains flat.

Global Acceleration eliminated.

Vehicle essentially un-damaged, crew un-injured.



Hybrid lll ATD Data from Snatch Land Rover Test Using Linear Rocket Motors, Energy Absorbing Sandwich Belly Plate, and Active Floor System:

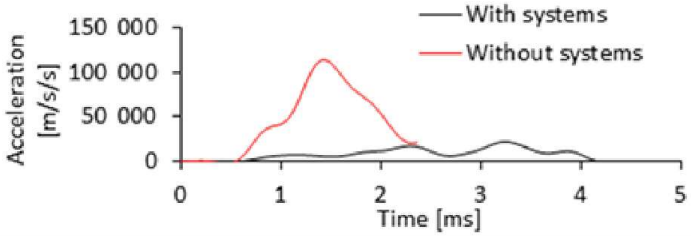
The ATD was sitting in a Jankel blast seat mounted on the centreline of the rear of the vehicle, very close to the location of the mine under the vehicle. Importantly, the feet in standard UK Army boots were resting on the floor in order to test the ABBS Active Floor system designed to prevent Floor Shock injuries.

Body Region	Limit	Value	Units
Head Injury Criteria (HIC15)	250	5.25	
Neck Axial compression (FZ-)	4.0	0.75	kN
Neck axial tension (Fz+)	3.3	0.45	kN
Neck shear force (FX+)	3.1	0.23	kN
Neck shear force (Fx-)	3.1	0.33	kN
Neck shear force (Fy+)	3.1	0.05	kN
Neck shear force (Fy-)	3.1	0.06	kN
Neck Flexion moment (MOCy+)	190	33.41	Nm
Neck extension moment (MOCy-)	77	24.84	Nm
Thoracic Compression (TCC frontal)	30	0.22	mm
Viscous Criteria (VC frontal)	0.7	0.004	m/s
Dynamic Response Index (DRIz)	17.7	6.27	
Femur (L) Compression force (Fz-)	6.9	0.54	kN
Femur (R) Compression force (Fz-)	6.9	0.43	kN
Tibia (L) Compression force (Fz-)	5.4 (HIII)	2.91	kN
Tibia (R) Compression force (Fz-)	5.4 (HIII)	3.06	kN
Chest wall velocity (CVW)	3.6	0.61	m/s

Note that all the ATD loads measured are far below the threshold for injury, including the tibia loads. Considering the ATD feet were resting on the floor this confirms the success of the ABBS Active Floor system concept, which removes the floor from below the ATD feet within 1-2ms of the mine exploding. The floor than automatically re-sets to its original position so does not require any repair, with just the energetics in the active elements requiring replacement. A multi-shot system is also possible allowing for multiple hits without refurbishment.

Floor accelerometer data from the 2017 Snatch Land Rover test is presented below:

	With counteracting systems	Without counteracting systems
Peak acceleration (Accelerometer 1 – next to the feet of the ATD) [m/s²]	18 438	103 600
Time of peak acceleration (Accelerometer 1 – next to the feet of the ATD) [ms]	3.3	1.98



The ABBS Suite of Mine Blast Protection Systems

Individual elements of the full suite, or the full suite itself can be fitted to any form of armoured vehicle. We recommend the following:

1) ABBS Passive Composite Reinforced Belly Plate Design

The design can be fitted economically to light civilian vehicles such as the Toyota Hilux to provide a large increase in mine blast performance. Two 4kg TNT equivalent under-belly tests have been carried out confirming this level of capability for the Hilux with a belly plate design weighing about 380kg. Further design evolution is continuing to reduce this weight to about 325kg with the same deformation level.

Equally, the design can be retrofitted to all weights of military armoured vehicle to provide either a reduction in weight with an increase in performance, or a significant increase in mine blast performance with low belly plate deformation.

Being completely passive (i.e. there are no energetic elements) the design can be certified for service very quickly and at low cost.

2) ABBS Active Floor Systems

These options need to be designed for each specific vehicle. They contain a small energetic element in the actuators so need both sensors and a safe/arm/control/initiation system, albeit relatively simple.

3) ABBS Linear Rocket Motor Global Acceleration Mitigation System

The full LRM™ system is highly energetic and has a very sophisticated sensor/control and initiation system. The design makes it impossible for the motors to be initiated without a mine exploding under the vehicle. It effectively measures the strength of the mine blast within 2-3ms and will only activate the motors when they are required, not for such as anti-personnel mines that are not a threat to the vehicle or its occupants.

The system is relatively lightweight and low profile (only 130mm deep) – hence, it can be fitted to any top-facing surface of the vehicle without raising the height significantly. The current motor design is 130 x 130 x 1100mm, weighs about 45kg, and delivers almost 10kNs impulse in 20-30ms. Peak thrust (to be confirmed with the very latest design iteration tested recently in the USA) is expected to be about 100 tonnes, results currently awaited.

A wider and slightly deeper LRM™ design which would deliver 15 to 20kNS per motor could be developed to minimise the required motor locations on the vehicle and increase the peak thrust to 150 to 200 tonnes per motor so that only four or five are required to achieve an 'artificial mass' total in the 600 to 1000 tonnes range which would be required to counteract very large IED's.

Given the ability to optimise the belly plate design for such large IED's, ABBS believes there is no practical limit to how big an ANFO-type threat can be dealt with, whilst the global acceleration can be held within tolerable limits by the use of the LRM's and blast seats.

Due to the highly energetic nature of the VGAM system and the complexity of the safe/arm/sensor/control and initiation system, certification for service will require a substantial and prolonged test programme.

New European Joint Blast Survivability Development Programmes

It is now clear that the suite of protection systems that ABBS has developed can provide a step-change in mine/IED blast capability for vehicles of every type from light commercial to the biggest APC's and MBT's.

Elements of the ABBS systems are currently being evaluated and further developed by the US Army Ground Vehicle Survivability Centre (GVSC) and by the UK MOD DSTL at Porton Down, and we would now welcome discussion re similar development programmes with NATO and European Defence Forces and armoured vehicle manufacturers.

The ability of the purely passive belly plate design concept to provide substantial, game-changing under-belly mine blast performance for very light commercial and military vehicles will also be of great interest for users such as the UN and other Aid Agencies, Mine Clearance operations, Foreign Embassies, and Special Forces.

At the other end of the blast threat scale, the ability of the full Linear Rocket Motor system to instantly provide a massive amount of downforce to eliminate Global Acceleration gives the potential to counteract practically any level of IED threat.

Other Protection Products in the ABBS Range

ABBS has partnered with other companies to supply a range of products aimed at providing enhanced protection and safety.

AVCP
Active VTOL Crash Prevention

Active VTOL Crash Prevention Ltd
Emergency Descent Arrest System (EDAS) for VTOL Aircraft Protection

AVCP (part of the ABBS Group) offers an enhanced Ballistic Parachute Recovery System can provide a controlled landing in essentially all circumstances. Depending on the descent velocity the retro-rockets are activated within 5-15m of the ground to provide a safe controlled landing.

AVCP, working with Aviation Safety Resources LLC, are developing a system which combines multiple ballistically-extracted recovery parachutes with a retro-rocket effector to slow the VTOL aircraft descent in its Xtreme Rapid Deployment (XRD) vehicle recovery system. Having been deployed on a tether from the airframe with the parachutes, the XRD retrorocket continues to produce thrust and deliver lift to the aircraft to prevent it acquiring a high descent rate whilst the parachutes inflate thereby reducing the minimum deployment altitude to c.100ft/33m

Cymat Technologies Ltd

SmartMetal™ Aluminium Foam

Stabilized aluminium foam products for absorbing large amounts of energy in an efficient, lightweight, and recyclable package. The density can be tuned to deliver effective blast attenuation from an assortment of present and future threats. In combination with composite systems, SmartMetal™ can be configured to neutralize multi-threat events.

As a blast front hits SmartMetal™, the bubbles collapse, absorbing energy and attenuating the transfer of this destructive force to targeted vehicles or building structures and its occupants.

Mobius Protection Systems

Energy Absorbing Seats

A range of energy absorbing seats for use in both land vehicles and eVTOL aircraft. Designed to meet all occupant sizes – from light 5th percentile female up to heavy 95th percentile male, Mobius seats are already in use in a wide range of logistic trucks, personnel carriers and mine-protected armoured vehicles.

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