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Protection of Light Skinned Vehicles Against Landmines - A Review

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ABSTRACT

The Australian Army currently fields Landrover vehicles, Unimog troop transports and Mack trucks that do not include any form of armour protection, known generically as 'Class B' vehicles. This document is a review and summary of the state-of-the-art in protection of this family of vehicles against the threat from landmines. The approach taken has been to focus on the experience of Rhodesia (now Zimbabwe) and South Africa, primarily during the Rhodesian Bush War of 1972-80. This has the advantages of extensive combat data, it is from a scenario similar to that which the Australian Army could experience during short warning conflict or UN missions, and vehicles common with the Australian fleet (Landrover, Unimog) were employed. Limited data is drawn from other sources where appropriate.

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Executive Summary

There are four approaches to vehicle protection from conventional blast mines;

1. ***Field expedient*** add-on materials such as sand-bags and heavy rubber.
2. ***Retrofitting*** engineered kits including blast deflection shields and blast absorbent materials to existing vehicles. Retrofitting can be inexpensive or expensive depending on the degree of protection pursued.
3. ***Body modification***, whereby a mine-resistant hull is added to the chassis of existing vehicles. Though the cost of this measure is moderate for the level of protection attainable, some investment and planning would be necessary prior to field deployment.
4. ***Monocoque construction***, in which a chassis-less mine resistant body is used to maximise blast dissipation and deflection - high to very high level protection is attainable. High volume production runs are necessary to offset manufacturing equipment costs if the monocoque is based on composite materials.

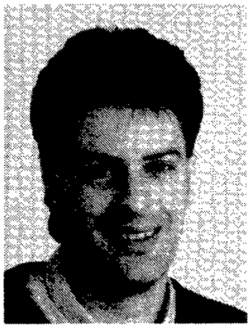
The three methods have been applied to light, mid-range and heavy vehicles with the following casualty levels being attainable, as indicated by Rhodesian casualty statistics [1, pp 84-85]:

Vehicle	Deaths %	Injuries %	Sample no. passengers
Unprotected Landrover	22	44	172
Retrofit Landrover	8 (all rear)	47	573
Vee-hull Landrover (Hyena)	0.3	21	578
Light Monocoque (Leopard)	2.2	15	264
Retrofit Unimog (Rodef 25)	0.9	3.3	317
Vee-hull Unimog (Buffel)**	-	-	-
Unprotected heavy vehicle	10	42	879
Retrofit heavy truck (Bedford)	0.7	25	2594
Vee-hull heavy truck (Puma)	0.3	17	3230
Monocoque heavy truck (Casspir)**	-	-	-

** Note: Both the Buffel and the Casspir are reported to have been involved in many landmine blasts without casualties, but no statistics are available [1].

As a result of this review, it is recommended that DSTO conduct experiments on field expedient mine-protection measures, model and field test blast deflection plates and formulate a database from the information gathered. Further information should be obtained from overseas to supplement the DSTO research.

Authors



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Weapons Systems Division

Craig Lester graduated B Mech Eng (Hons) from Deakin University and joined Explosives Ordnance Division at AMRL now Weapons Systems Division, in 1985, working in explosive/pyrotechnic device development.

Contents

1. Introduction

Australian forces are expected to deal with low-level incursions on Northern Australian soil, with the anticipated threat being from small arms fire, grenades and landmines rather than high technology weaponry. Landmines offer the user the potential to inflict substantial casualties without engaging the enemy, and therefore feature prominently in guerilla warfare. A similar type of threat exists on UN missions, in which Australian troops have been involved with increased frequency in recent years.

The Australian Army currently fields Landrover vehicles, Unimog troop transports and Mack trucks which do not include any form of armour protection, known generically as 'Class B' vehicles. This document is a review and summary of the state-of-the-art in protection of this family of vehicles against the threat from landmines. The approach taken has been to focus on the experience of Rhodesia (now Zimbabwe) and South Africa, primarily during the Rhodesian Bush War of 1972-80. This has the advantages of extensive combat data, it is from a scenario similar to that which the Australian Army could experience during short warning conflict or UN missions, and vehicles common with the Australian fleet (Landrover, Unimog) were employed. Limited data is drawn from other sources where appropriate.

2. . Overview

There are a number of different considerations in protecting vehicle occupants from a mine blast. The primary kill mechanism of anti-vehicle mines is blast overpressure and associated effects such as vehicle deformation, gross vehicle acceleration and impulse. In many cases casualties also result from vehicular accident following a mine blast.

Fragmentation protection of vehicles is important, but for the majority of anti-vehicle mines fragmentation is a secondary effect arising from disintegration of parts of the vehicle, as the mine itself is not designed to produce significant fragments from its casing. It can be assumed, however, that a mine could consist of an improvised device such as a pipe bomb or a hand grenade, or that a conventional anti-vehicle mine could be boosted by the addition of a mortar shell or other fragmenting ammunition. It must be noted at this point that the mine protection systems presented in this report are not effective against Miznay-Shardin 'shaped charge' anti-tank mines, which produce an explosively-formed copper penetrator capable of penetrating heavy armour.

The point of initiation of the mine blast is a highly important consideration in designing mine protected vehicles. Rhodesian statistics [1] show that pressure fuzed mines, which still constitute the majority of the world arsenal, are detonated by front/rear wheels of conventional vehicles in about a 60/40 ratio. This is because many of these types of mines are designed to be activated by heavy vehicles such as tanks, and have triggering mechanisms (fuzing) which require up to 300 kg load to activate. The 'pressure plate' which triggers the fuze may take several passes of vehicle wheels before it is sufficiently depressed to cause mine activation.

Modern anti-tank mines are generally activated by magnetic influence, so the blast site for these mines could be anywhere within the activation envelope of the mine, including directly under the centre of a vehicle. It is generally assumed that threats to Australia will be from a foe with limited capital and technology, so this type of mine is unlikely to be deployed against Australian forces; the increasing availability of cheap Chinese and Warsaw pact munitions on the world market could rapidly change this situation, however. Centreline detonations are also possible from tilt-rod mines and mines which are remotely activated by electrical wiring.

There are several factors affecting the degree of protection which can be provided for vehicle occupants. High ground clearance of the vehicle belly is desirable, as this allows the blast from a landmine to be more readily deflected and dissipated. Good load-carrying capacity is necessary so that the vehicle can support the weight of added counter-mine armour protection without overloading the engine or suspension. Larger vehicles such as the Unimog and Mack trucks in the Australian Army vehicle fleet have both these properties, so they have much better mine-resistance potential than lower, lighter vehicles such as the Landrover.

The other limiting factor is cost. Composite materials have excellent blast absorption and fragment protection properties whilst being relatively low weight, but they are also very expensive.

Shneck [2] recently (1994) summarised the historical development of mine resistant vehicles and he defines the following mine protection levels. The structure of this review is to deal with each type in separate.

1st generation	Improvised protection kits fabricated by soldiers in the field.
2nd generation	Retrofit kits that are developed and provided to the units for installation in the field.
3rd generation	Vehicles equipped with a mine resistant hull mounted above the vehicle frame.
4th generation	Specially built vehicles equipped with a monocoque (frameless) mine resistant hull.

3. Protection options

3.1 1st generation - field improvised protection

☑ Low cost	☒ Low-moderate effectiveness
☑ Rapid deployment	☒ Reduced vehicle capability (for heavy mine protection)

Improvised protection has typically included sandbags, steel plate and conveyor belt rubber. Shneck [2] reports that the effectiveness of these measures has apparently not been quantified in tests, but all are believed to provide only marginal protection against blast mines. This is probably true for low-slung vehicles such as the Landrover, but an examination of Rhodesian casualty statistics illustrated in Figures 7 and 8 shows that substantial protection was achieved in mine-protected heavy vehicles.

The first effective measures to mine-protect vehicles from landmines originated from the Rhodesian bush war (1972-80). The Rhodesian Army mine-protected Bedford trucks by loading the tray with sandbags and lining the wheel wells with double layers of heavy rubber conveyor belting. The most significant modification made was the filling of the tyres of the Bedford with approximately 100 litres of water using a so-called 'Schrader valve', then pumping up the tyres to a pressure of approximately 300 kPa (44 psi). This had the effect of quenching any under-wheel blast to such an extent that it was often possible to place a new tyre on the wheel rim and drive away. Blast pressure was flattened out and dispersed away from the cab so little cab damage occurred [1, pp 53]. The downside of this protective measure is that tyre life is reduced by approximately 50%. To lessen pressure build up in the vehicle cab should an explosion penetrate the floor, a hatch was cut into the cabin roof. Additional protection was provided by 12 mm steel plate on the cabin floor.

Figure 1:
A landmine (*probably a TM-46 containing* 5.3 *kg of explosive - author*) was intentionally detonated under the front left wheel of an unprotected Bedford truck - 'If a person had been sitting above the wheel he would have been killed' [1, pp 50]

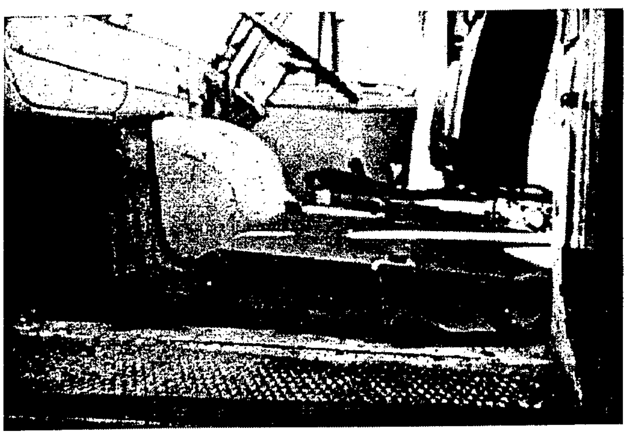

Figure 2:
'Bedford Big Daddy. The cab floor was protected by sandbags covered by a steel plate and the controls were raised. The carrying tray at the rear was protected by sandbags covered with conveyor belting.'
[1, pp 50]

Figure 3: 'A left front wheel blast on a Bedford Big Daddy .. The charge consisted of a Soviet TM-46 landmine boosted by a 60 mm mortar shell. One person in the cab suffered minor injuries and the damage to the vehicle was negligible.' [1, pp 51] *(presumably negligible in comparison to normal effects, however effects are not insubstantial - author)*

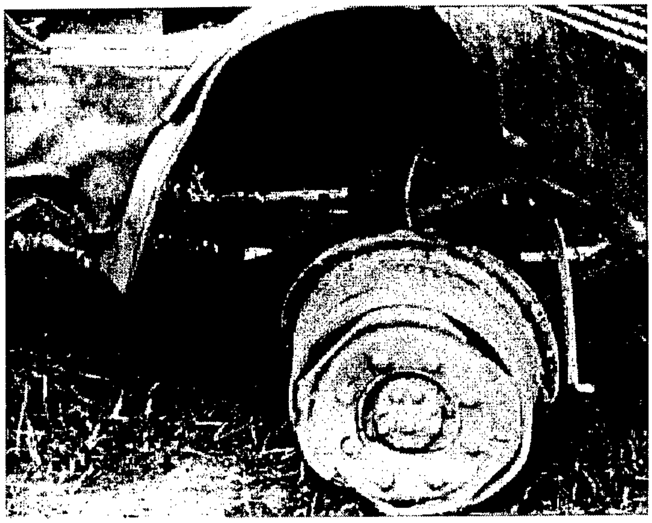

Figure 4: 'Bedford Big Daddy. This close up shows the phenomenon of there being scarcely any damage to the wheel after a landmine blast. Water had been put into the tyre to cool the blast.'
[1, pp 51]

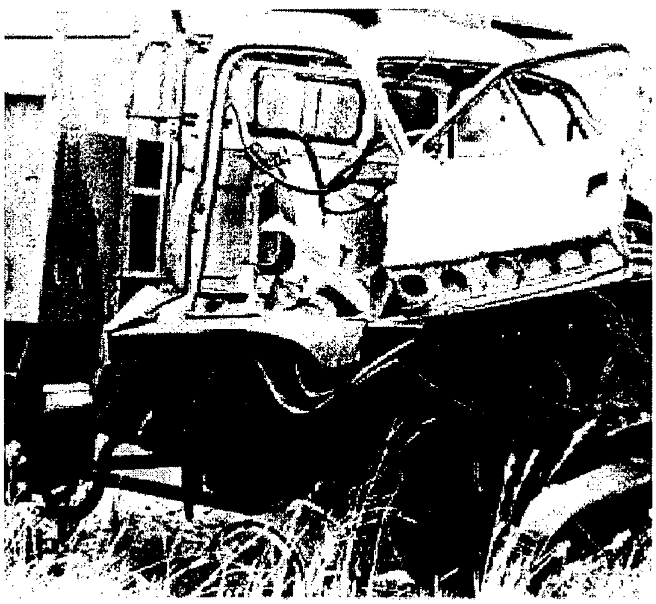

Figure 5:
'Bedford Big Daddy. The wheel arches were reinforced with industrial conveyor belting to provide protection against shrapnel. Water was put in the tyres to cool the intense heat of the blast. All persons in the vehicle cab would have been unharmed.'
[1, pp 50]. *('Unharmed' presumably meaning escaping serious injury - author.)*

Figure 6:
'A right rear wheel blast on a Big Daddy. The tyres were water filled and the damage was negligible.'
[1, pp 51]

Sandbags and other heavy materials provide protection by absorbing blast energy and capturing fragments. In Afghanistan it is common practice for civilians to travel with all their possessions loaded in the back of a truck, with the passengers perched high above the ground on top of the loaded tray. The chassis is reinforced (with pieces of railway track for example) to provide stiffness and dissipate the shock loading from a mine blast across the vehicle. No statistics for the effectiveness of this measure are available, but it is reputed to increase survivability for the passengers, if not for the driver [3].

The use of such improvised protection in UN missions and other military operations has invariably lead to drastically reduced vehicle performance and structural failures. In Somalia, 5 ton cargo trucks were loaded with 4 to 5 tons of sandbags, and HMMWV's (High Mobility Multi-Purpose Wheeled Vehicles) were overloaded such that suspension failures were common [2]. An obvious step forward from these measures is to engineer protection into existing vehicle designs by way of retrofit kits, which may include suspension upgrades and frame strengthening.

3.2 Retrofit kits

- ☑ Moderate to high cost
- ☑ Makes use of existing vehicles (avoids making vehicles obsolete)
- ☑ Moderate effectiveness - protection possible against 1 x 7 kg AT mine
- ☒ Possible substantial development time
- ☒ Reduced vehicle capability

One of the most cost-effective protective measures devised by the Rhodesians was the mine-protected long wheel-base Landrover, described as follows [1, pp 49]:

"The cab of a Landrover was protected from rear wheel blasts by deflector plates mounted forward of the rear wheels. On the long wheel base model this left sufficient distance between the wheels and the cab for a dissipation of the blast. The reduced distance on the shorter model rendered the fuel tank vulnerable and made mine protection impossible. Heavy conveyor belting was positioned at the back of the cab to partially cover the window as protection against shrapnel."

"Protection for the cab of the long wheel base Landrover against a front wheel blast was achieved with surprising simplicity. The front wheel arches, which would be in the seat of an explosion, were shielded from the cab by angled metal boxes welded to the chassis, and filled with sand. This deflected the blast away from the bulkhead across the engine to the other wheel, wrecking everything between, but leaving the people in the cab relatively unscathed."

"Later it was found that the sand could be dispensed with, but the box remained the best deflector as it collapsed progressively. An attempt to replace the box with a single plate of 25 mm mild steel failed, and the blast blew it through the bulkhead and into the cab."

"Heavy roll bars fashioned from 32 mm water pipe were fitted to the vehicle, as well as over-the-shoulder seat belts for the driver and his passenger."

The Rhodesian/South African data of Figure 7 indicate that light vehicle retrofit kits resulted in only a marginal improvement in mine casualty rates, but this does not take into account that the majority of casualties were rear tray passengers. From 162 mine-detonations (68% front wheel, 29% rear wheel, 3% central) involving Rhodesian mine-protected Landrovers, there were 45 deaths and 270 injuries. Of these, all of the deaths and many of the injured were in the rear [1, pp 50]. Over the course of the Rhodesian bush war the carrying of rear passengers in government vehicles was firstly prohibited, then the Landrover was withdrawn from service in mined areas in favour of the Bedford truck, which by virtue of its size affords better passenger protection.

There is limited statistical data available on the effects of a central mine blast.. In the 5 mine-protected Landrovers that received central blasts during the bush war, there were 3 deaths and 4 injured from 13 occupants. This is a higher casualty rate than for either front or rear wheel blasts.

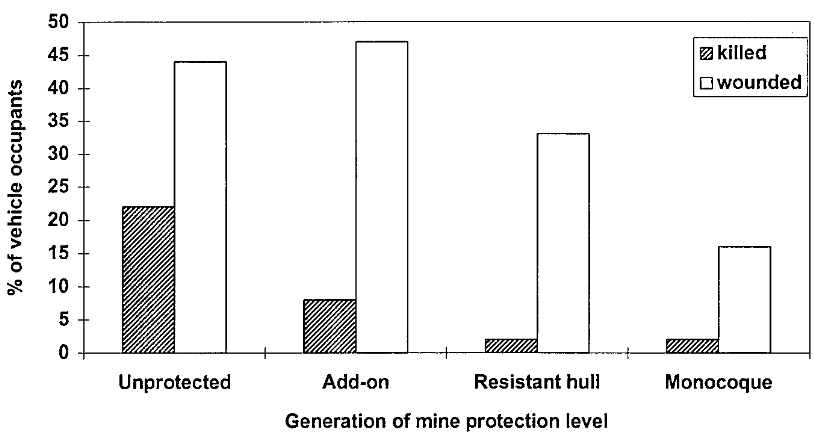

Figure 7: Mine encounter casualty statistics in Rhodesia / South Africa - Light Vehicles [1, pp 84-85]. 'Add on' protection covers both improvised and retro-fitted protective measures.

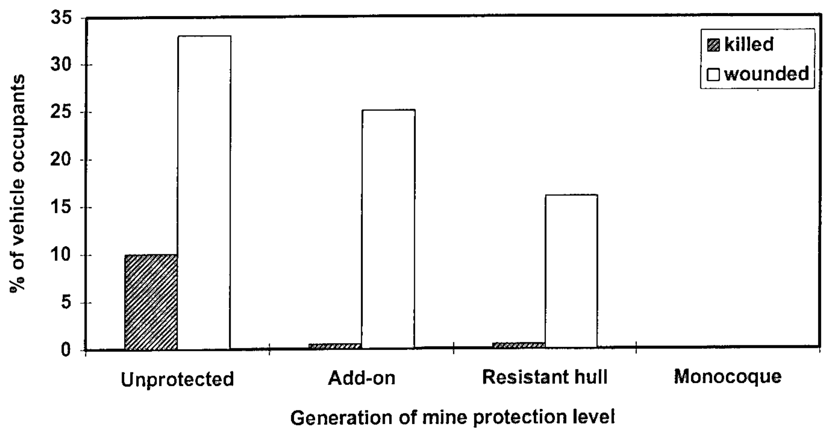

Figure 8: Mine encounter casualty statistics in Rhodesia / South Africa - Heavy Vehicles [1, pp 84-85]. 'Add on' protection covers both improvised and retro-fitted protective measures.

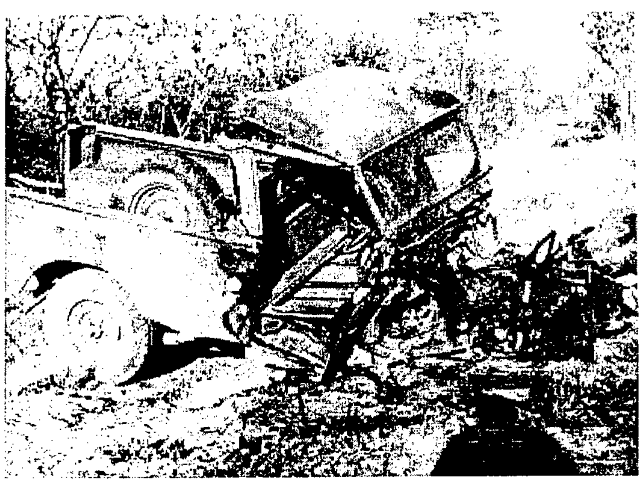

Figure 9:
Results of a front right under-wheel landmine blast against an unprotected Landrover in Rhodesia. The driver died but the front passenger survived with minor injuries. Note that the windscreen stayed intact.
[1, pp 40]

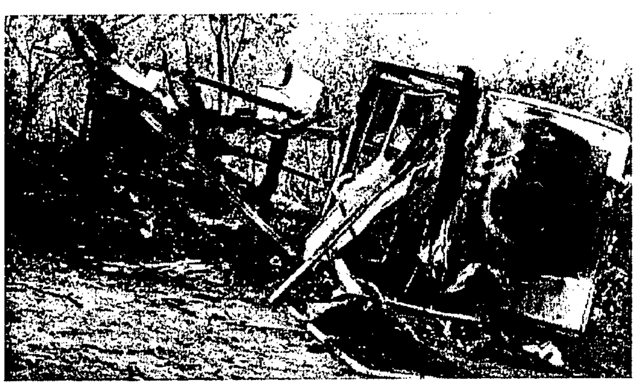

Figure 10:
Rear wheel blast against an unprotected Landrover.

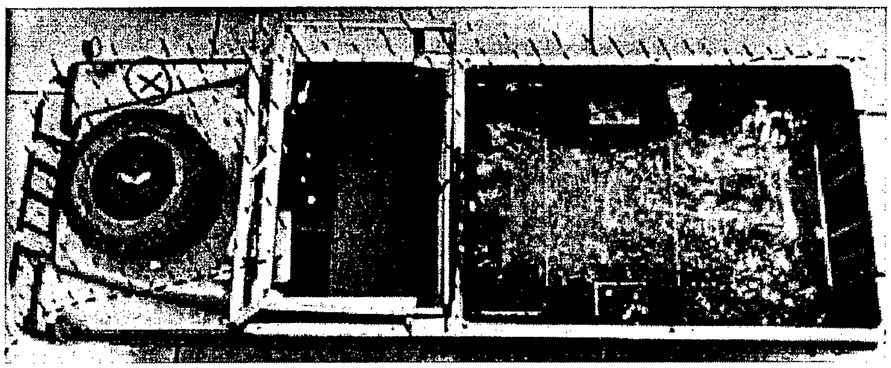

Figure 11: 'The shaded section depicts the high pressure area created by a landmine detonated by an unprotected Landrover's right front wheel. Because the blast will penetrate the cab's floor, the high pressure area reaches far into the vehicle. This would cover the whole vehicle in the case of a steel roofed station wagon.' [1, pp 44].

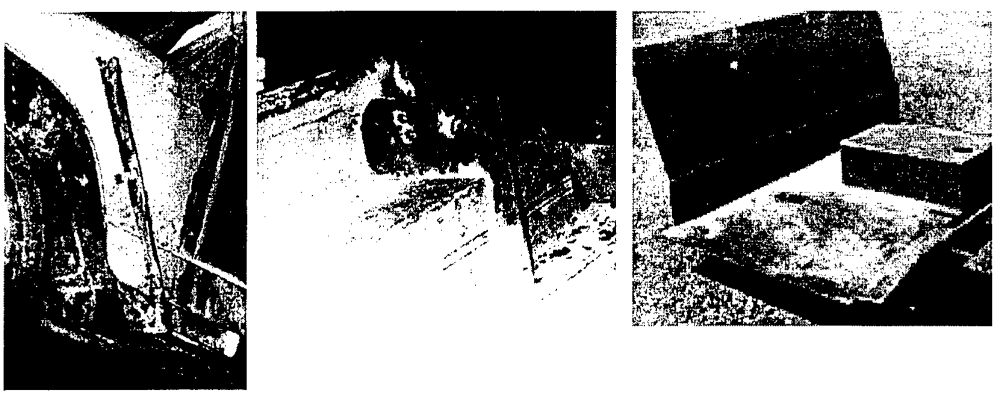

Figure 12: Rhodesian mine protected Landrover - front wheel blast deflector, rear wheel blast deflector and the 6 mm steel plate placed on the cab floor. 'The bent sections on the right hand side served as deflection plates'. [1, pp 44-45].

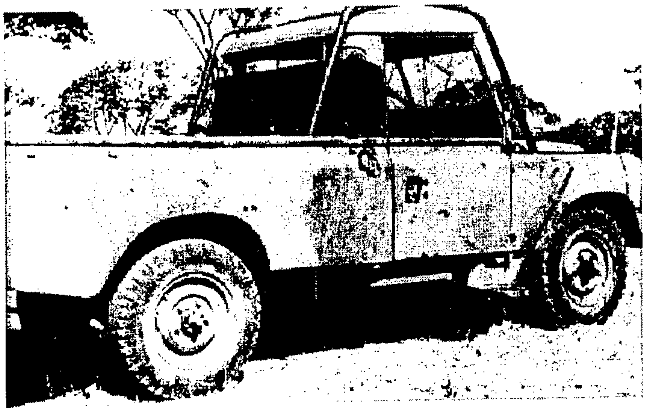

Figure 13:
The Rhodesian mine protected Landrover, showing front and rear deflector plates, heavy duty roll bars and rear-of-cab rubber conveyor belting.
[1, pp 45]

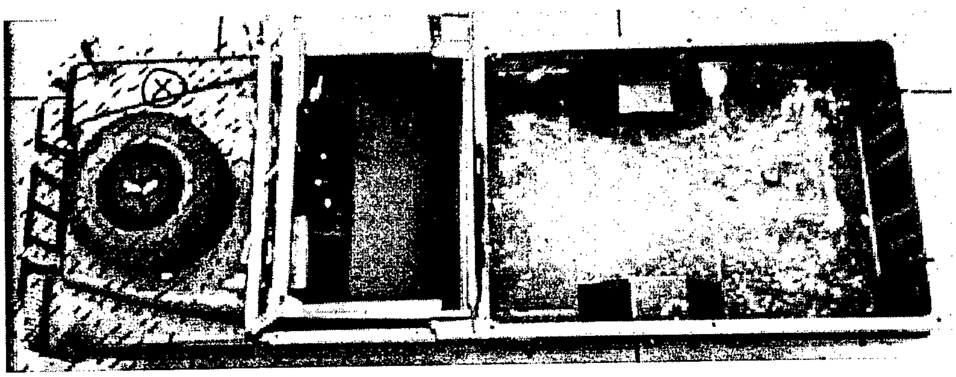

Figure 14: 'This diagram shows how the high pressure area, after a right front wheel landmine detonation by a Landrover, has been dramatically reduced by the addition of deflection plates'. [1, pp 45].

Figure 15 (above left): A Rhodesian landmine protected Landrover after a left rear wheel landmine blast. 'The passengers in the cab were unharmed.' [1, pp 46].

Figure 16 (above right): 'This front wheel detonation of a landmine by a mine-protected Landrover shows the effectiveness of the deflector plate'. [1, pp 46].

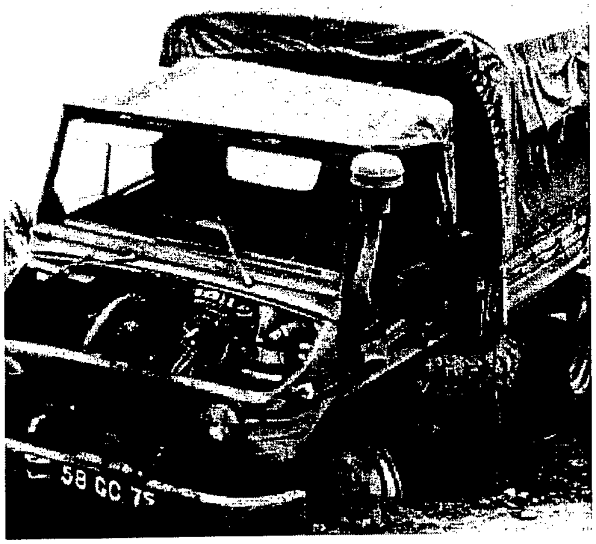

Fig 17: A Rhodesian Army Unimog or Rodef-25 after it had suffered a landmine blast under its front left wheel. The cab was protected by South African 'Barber plates', sandbags had been put in the tray and the tyres filled with water.

In more recent times, designers have had the advantage of using lightweight composite materials** which have the potential to improve the effectiveness of retrofit kits, particularly for light vehicles . In the USA in 1993, retrofit kits were developed for deployment in Somalia for the HMMWV and a 5-ton truck.

The 5-ton truck kit was the result of a detailed design and computer modelling procedure which primarily addressed blast effects [4]. It consists of wheel well armour, cabin and body armour, ballistic windshield and door windows, mesh window screens and most importantly, an under-body wing-shaped blast deflector. The kit has been tested with satisfactory results against up to 7.3 kg of high explosive, which is the average content of an anti-tank mine. This level of protection approaches that of '3rd generation' vee-shaped hull vehicles.

A HMMWV kit was developed at the US Army Belvoir Research Development and Engineering Centre as a 'quick fix' for deployment in Somalia [5], but its protection level was marginal and the project was terminated. In a separate development, O'Gara-Hess and Eisenhardt Armouring Company has produced 55 up-armoured HMMWVs [6]. O'Gara-Hess claims that a 7 kg anti-tank mine blast under the front drivers wheel of its armoured HMMWV would result in only an ankle fracture and a leg laceration for the driver whilst other passengers would suffer no appreciable effects [7]. No information is available on the effects of a centreline blast, as would occur from a command-detonated mine. Because the HMMWV has front wheels well ahead of the cabin (which make it relatively easy to defend against under-wheel blast) and low ground clearance, it is probable that the effects of a centreline blast would be much more deadly.

** S2 Glass (Courtaulds UK), for example, is a glass reinforced composite which in addition to its fragment retarding properties, exhibits some blast adsorption by virtue of internal failures of the glass fibres. Similar proprietary materials have been developed in the USA (developments by Simula Corp.), South Africa and Germany (MEXAS armour).

The O'Gara-Hess design claims to have 'no ballistic gaps' [7], which seems to ignore an important feature of many Rhodesian mine-protected vehicles; an open, canvas or pop-off roof to prevent the build up of blast overpressure in the vehicle (e.g. Hyena, Bedford 'Big Daddy', Leopard, Cougar, Pookie). It is possible that the open roof is unnecessary when blast-absorbing composites such as 'S2' glass are used, but this is unlikely.

Other bidders for HMMWV up-armouring work in 1994 include U.S. companies Simula Corporation and AlliedSignal.

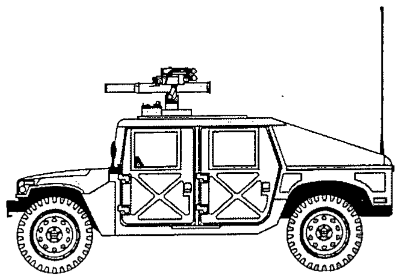

Figure 18:
Schematic of the U.S. High Mobility Multi-Wheeled Vehicle or HMMWV - without armour.

A substantial disadvantage of retrofit kits is that the increase in vehicle weight and reduced ground clearance (especially when an under-belly blast deflector is incorporated) will degrade off-road capability. This will make vehicles more dependent on made roads or tracks which have a higher probability of being mined.

3.3 Vee-shaped hull mounted above vehicle frame

☑ Good cost to benefit ratio
☑ High effectiveness - 22+ kg rating
☒ Reduced vehicle capability

The vee-shaped hull sits high on the vehicle chassis and provides protection by deflecting and dissipating mine blast. The main deployment of vee-shaped hull technology has been in Rhodesia/ Zimbabwe during the Rhodesian Bush War.

The South African produced 'Hyena' light vehicle is a 90° vee-shaped hull mounted on a Landrover chassis; the Rhodesian version is known as the 'Rhino'. In these vehicles, both the passengers and the driver are seated inside this hull. There were 2 deaths and 120 injuries from 578 Hyena passengers involved in landmine encounters during the Bush war, but many of these casualties were reportedly due to excessive speed and failure to wear seat belts [1, pp 54]. Mine incidents included a centre-front detonation of a makeshift charge of 22 kg of HE; neither of the occupants were injured. It is important to note that mild steel was used for the production of hulls not only as armour plate was unavailable because of sanctions, but also because it was thought that armour steel would splinter in a blast creating dangerous secondary fragments [1, pp 48].

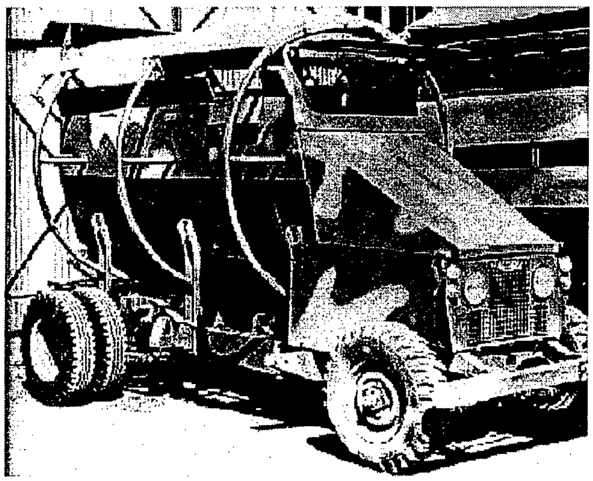

Figure 19:
The Rhodesian 'Rhino', a mild steel vee-shaped hull built onto a Landrover chassis.

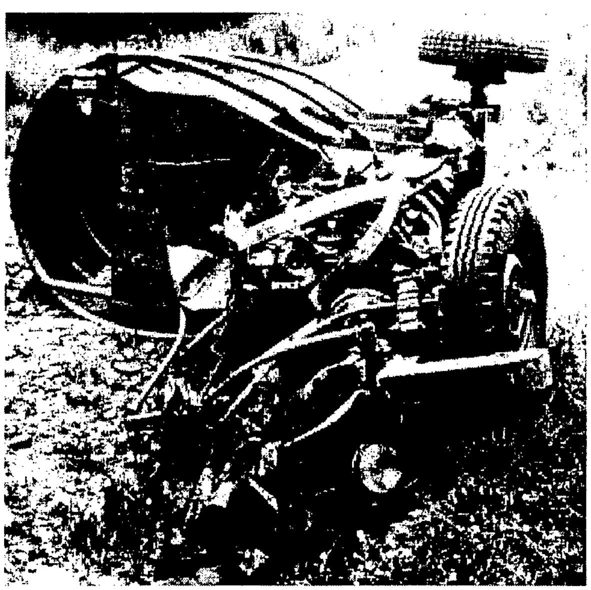

Figure 20:
A Rhino following a right front wheel blast. The crew were unharmed.

The Rhodesian Kudu was a 4 seater vehicle which was adaptable to any 4x4 chassis; it was the only vehicle to be mass produced during the Rhodesian Bush war. The manufacturer, Morewear Engineering, marketed the vehicle to Rhodesian civilians by offering to convert unprotected Landrovers into Kudus. The Kudu provided reasonable protection against the blast of a single anti-vehicle mine and had the additional feature of 'bullet-tumbler' protection plates which could stop projectiles from an AK 47 rifle.

Figure 21:
The Rhodesian built Kudu, built on a Landrover or any other 4x4 chassis. It was mass produced (over 1000 units) and featured bullet tumbler shields. [1, pp 64].

The South African 'Buffel' vehicle is a similar vehicle to the Hyena, but it is built upon a Unimog chassis. Unlike the Hyena and Kudu, the Buffel has a separate, single-seat drivers compartment, which is also vee-shaped. Buffel vehicles have been involved in many landmine incidents without serious injury to occupants, and the vehicle has been successfully proof tested against reportedly 'massive' explosive charges [1, pp 109].

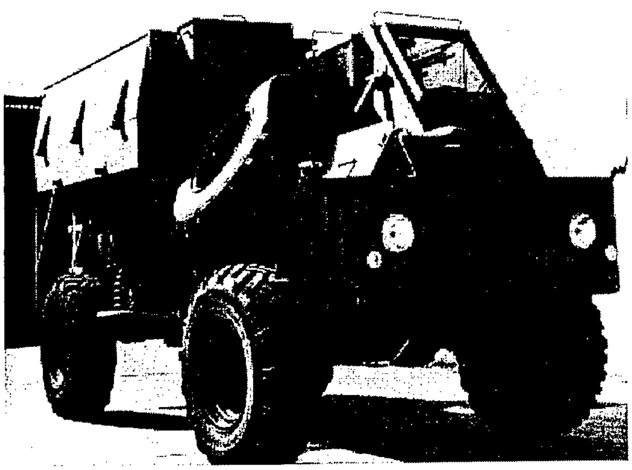

Figure 22:
The South African 'Buffel', a vee-shaped hull built on a Unimog chassis with a separate single-seater vee-shaped driver cab.
[1, pp 107].

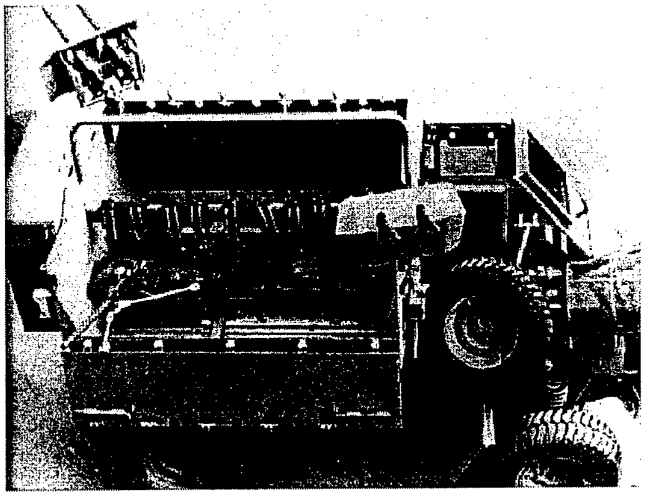

Figure 23:
The Buffel, showing the hardened centreline seating with safety harnesses
[1, pp 107]

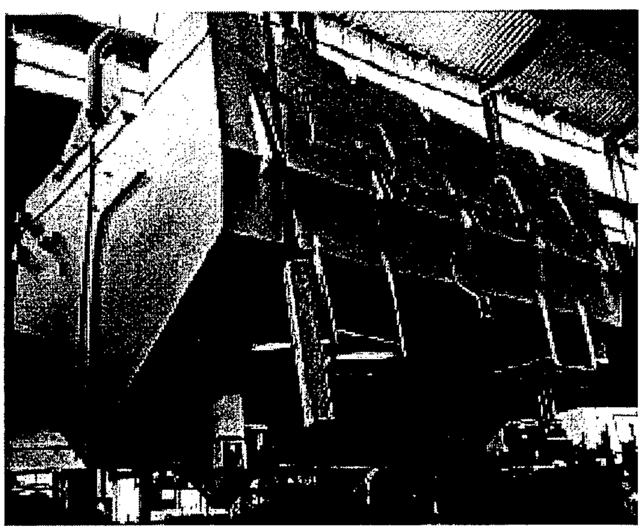

Figure 24:
The vee shaped hull of a Buffel ready for mounting on the chassis.
[1, pp 110]

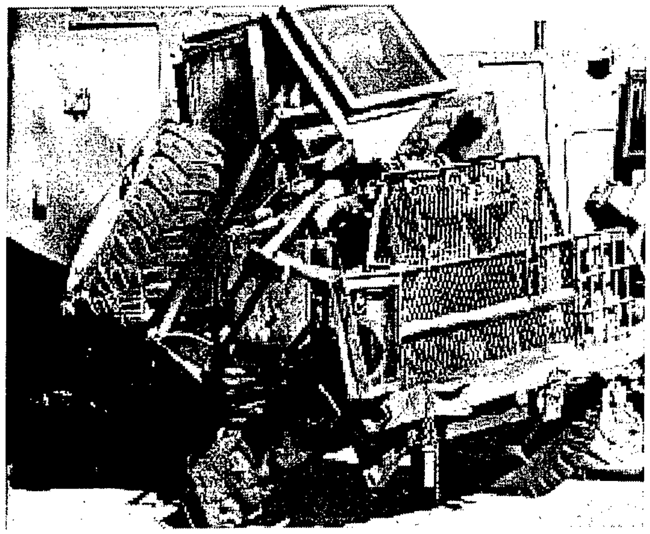

Figure 25:
A Buffel after a right front landmine blast, showing comparatively light damage [1, pp 110]

The Rhodesian 'Puma' heavy vehicle has a vee-shaped hull made of 3/8" mild steel mounted on a 5-ton Isuzu or Nissan chassis, with added features such as roll-over protection, centreline seating and stowage bins to stop loose gear from becoming dangerous projectiles in a mine blast. As shown in Figure 2, the Puma was very successful in reducing passenger casualties, with a fatality rate of under 1%. It is still manufactured in limited quantities by the government of Zimbabwe, and 44 were sent for deployment in Somalia. Other countries using this technology are South Africa, Israel, France and the United Kingdom. The US Army's Tank Automotive Command (TACOM) has developed preliminary plans to mount a modular vee-shaped hull unit on a 5-ton truck as a convoy escort vehicle [2].

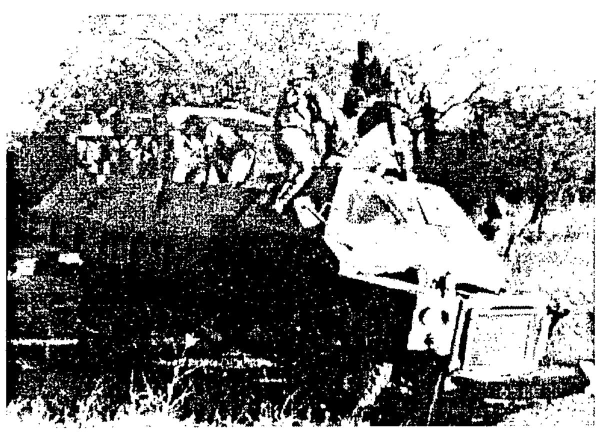

Figure 26:
A Rhodesian Army Puma shortly after detonating a landmine with its left front wheel. The driver is being lifted from the cab.
[1, pp 63]

The disadvantages of this family of vehicles is that they are inherently top-heavy, degrading handling characteristics and producing an uncomfortable rolling motion for the passengers. Because the vehicle chassis and suspension components are external to the hull, the vehicle itself will suffer substantial damage in a mine blast.

3.4 Monocoque (Frameless) Hull

☑ Very high effectiveness Light vehicle - 7+ kg HE rating Heavy vehicle - 30+ kg rating	☒ Very high cost

The monocoque vehicle uses the vehicle body as the main structural element rather than using a frame. By this means, components external to the vehicle that normally inhibit the dissipation of blast are eliminated. This technology has been successfully applied to both heavy and light vehicles.

The first monocoque vehicles were light passenger vehicles produced in Rhodesia. The 'Leopard' and 'Cougar' vehicles had vee-shaped hulls, roll bar protection, and front and rear wheels extended well away from the vehicle body.

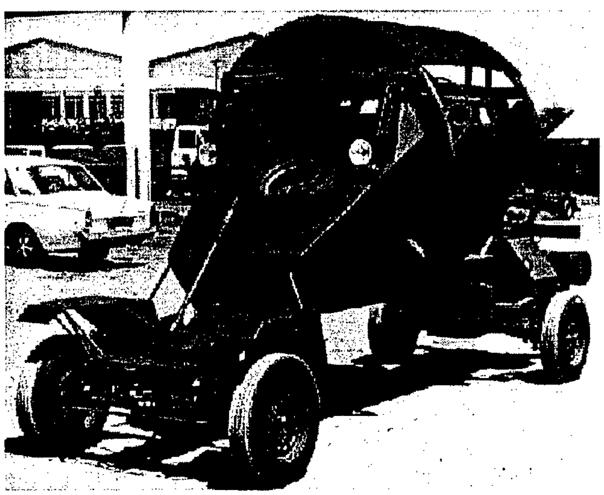

Figure 27: The Rhodesian 'Leopard' fully monocoque vehicle

The South African 'Casspir' family of heavy vehicles are able to withstand a blast from 30 kg of explosive under-wheel or a centreline blast from 23 kg without harm to passengers [1 pp 116]. Just as importantly, the Casspir (and other vehicles of this type) are field repairable after a mine blast, as vital components of the vehicle are also protected by the monocoque hull. Casspir vehicles also incorporate special seats and restraints to protect personnel from both gross vehicle accelerations, which can crush an individual's spine, and from vehicle crashes after a mine blast.

Monocoque vehicles are still heavier and more top-heavy than conventional vehicles, but they compare favourably to other mine-protected vehicles on these two counts. In South Africa the Casspir was nick-named the 'Kalahari Ferrari' because of its exceptional off-road capabilities and ruggedness [1 pp 115]. Successors to this vehicle include the 'Ingwe', the 'Albatross', the 'Wolf', the 'AC200' and the 'Soetdoring' [1 pp 122-124].

Figure 28:
The monocoque design 'Casspir' fully mine-protected APC.
[1, pp 114]

Figure 29:
The 'Soetdoring', a monocoque design APC which followed the Casspir.
[1, pp 114]

Courtaulds Aerospace of the UK have produced over 1000 mine protected vehicles; the 'Snatch' armoured patrol vehicle and its sister commercial variant, the 'CAV 100' (Composite Armour Vehicle). The Courtaulds design consists of a monocoque shell on a Landrover Defender 110 (4x4) chassis. It does not appear much different to a conventional Landrover in appearance, and does not have any vee-shape to its body. A large production run is necessary to offset the costs of the special tooling required, the 1000 vehicles produced by Courtaulds being a good example.

The shell is constructed from a lightweight composite armour designated 'CAMAC', which is sheets of 'S2' glass bonded with a phenolic resin to form a laminate. The resultant material is claimed to be 20% more weight-efficient than the equivalent steel armour against a range of threats considered [8, 9]. The Composite armour is readily repairable by cutting out and replacing damaged sections, its insulation properties reduce infrared signature and the ability to mould panels offers the potential of adopting rounded 'stealth' designs with reduced radar signature. Most importantly, the vibration damping properties of the material absorb and dissipate blast shock, and it is free from secondary effects such as spalling that occur with steel armour. Steel armour is lighter and much cheaper than equivalent composite armour if the threat is solely ballistic (light ammunition and fragments).

The CAV 100 has been fielded in Bosnia in 1994, and one vehicle suffered a front wheel mine blast thought to contain in the vicinity of 5 kg of explosive. The vehicle occupants were uninjured.

Immediately upon the lifting of the trade embargo with South Africa, South African company Mechem Consultants exclusively licensed Alvis Vehicles of the UK to supply its ballistic and mine-protected vehicles to the UK, UN and other customers. The 3 vehicles in question are all based on Mercedes-Benz Unimog components; the Alvis 8 and Alvis 11 4x4 vehicles seat 8 and 11 people respectively, whilst the 'Iron Eagle' fully-armoured liaison vehicle has a 3 man crew. The Alvis 8 is designed to withstand the simultaneous blast of 2 conventional landmines under any wheel and also provides protection against 7.62 mm ball ammunition. Although figures are not mentioned, Alvis Vehicles claim that the 'Iron Eagle' is, as of the end of 1993, the only vehicle in the 4-8 tonne weight class to be 'fully mine protected' and to be qualified for air-dropping [10].

4. Discussion

4.1 Light Vehicles

Both vee-shaped hull (the 'Hyena') and monocoque body designs (CAV 100) have been successfully applied to light vehicles. The vee-shaped hull offers high levels of protection, but this is offset by reduced off-road capability. Australian Army requirements probably dictate that a larger vehicle be used for troop transport, as troops in a hostile environment will generally travel as a section of 10 men.

For the reconnaissance role, the Rhodesian design for mine protecting the long wheel-base Landrover is the most cost effective design available; it could be enhanced by using S2 glass for added blast suppression. The Rhodesian concept of using box-structure blast deflectors has been overlooked in the U.S. and U.K. in favour of single-plate deflectors but, as discussed in section 3.2, the Rhodesians reported that the box-structure deflector was much more effective because it progressively collapses.

The limitations of the basic mine-protected Landrover are that it has little protection against centreline blasts and provides poor protection for passengers travelling in the rear of the vehicle. Consequently, in any mine-threat area, heavy vehicles should be used in preference to light vehicles, and if light vehicles must be used, rear passengers should be prohibited.

The use of water-filled tyres could be investigated as an additional protective measure, but it is probable that the operational requirements of the Landrover vehicle such as good handling and speed would overrule this option.

Monocoque designs such as the Courtaulds Aerospace 'Snatch' Patrol vehicle claim to offer more complete protection for both front and rear occupants. Certainly, as discussed by Shneck [2], the concept of 'acceptable losses' is not viable for UN missions, so expensive composite armour vehicles may be an appropriate investment in these circumstances.

Australia has a longer term project ('Bushranger') to locally build a light infantry vehicle, and there are obviously many contenders for the final design - it is not the aim of this review to include them all. As most mine-resistant vehicle developments in the US/UK/SA have been by commercial companies, it is very difficult to obtain data upon which a scientific judgement can be made. In evaluating designs, little emphasis should be placed on the success of single mine/vehicle encounters, as there is great variability in the results of a mine explosion; many people have walked away uninjured from a mine blast against an unprotected Landrover. For Army to fully validate a design, data for acceleration, blast overpressure and fragment penetration into the cabin are required.

In the immediate future, the Australian Army may be best off negotiating a short term/ short notice supply arrangement from a foreign company specifically for UN missions.

4.2 Heavy Vehicles

In mine threat areas, both the Unimog and Mack trucks should use water-filled tyres for blast suppression of under-wheel detonations; this measure could be rapidly developed and deployed. Even though tyre life is halved, this procedure is very cost effective, as it requires virtually no capital investment during peace time. By taking additional retrofit measures such as armouring wheel wells, providing blast deflector plates and sand-bagging, it is possible to achieve reasonable protection levels for both types of vehicle against under-wheel blasts.

The only means of retrofitting a Unimog vehicle to provide high level mine protection (centreline and multi-mine blast) is through a vee-shaped-hull design (e.g. the South African 'Buffel'). The advantage of this type of design is that it utilises the chassis of existing vehicles, so given that plans were prepared in advance, mine-protected vehicles could be hastily assembled by modifying existing Unimogs - it may also be feasible to keep a strategic reserve of vee-shaped hull units which were ready for fitting should a conflict eventuate. It must be recognised that this design constitutes a major vehicle modification which would involve considerable expense, so this type of project should only be entered into if a long-term commitment to the Unimog fleet is envisaged. The most expeditious course of action for the Australian Army to pursue this concept would be to procure design details from the countries of origin.

Sand-bagging and similar measures have been used to protect heavy trucks in many conflicts, allegedly with success, but as reported in reference 2, the effectiveness of these measures has not be quantified in scientific tests. Given the low cost of deploying this type of protection, it would be cost effective overall to conduct field experiments in this area. It is certainly feasible that an Australian Mack truck could be loaded with sufficient weight of sandbags to protect rear tray passengers without overly degrading vehicle performance. It is worth noting, however, that the comparable Rhodesian vehicle, the Bedford RL/RM series, had a solid steel tray which would enhance blast dissipation over the whole vehicle structure by virtue of its rigidity. It may be necessary to structurally reinforce a Mack truck to achieve a similar effect.

Protection of large trucks against the blast of a single anti-vehicle mine has been achieved in the U.S. by means of retro-fitted blast protection kits. As the Mack truck is generally not a cross-country vehicle in the same sense as the Unimog truck, there is more latitude to fit under-body blast deflectors which decrease the ground clearance of the vehicle. As with the concept of retrofitting a Unimog, a Mack truck protection kit represents a substantial investment which should not be entered into lightly. Much of the groundwork in this area has been covered by U.S. research however, so the development costs would not be excessive.

To achieve full mine protection in a large troop transport, it is necessary to look at foreign made monocoque vehicles. The latest generation South African personnel carriers protect all passengers against very substantial blast mine threats (for example the large command detonated mines which caused substantial US losses in Somalia [2]) whilst maintaining excellent mobility. These vehicles are the end product of 20 years of mine-protection research, and it would not be economical to duplicate this work in Australia. If landmines are considered a significant threat to envisaged troop deployments, the Australian Army could consider the direct procurement or timely supply of South African vehicles.

5. Recommendations

The following DSTO research is proposed in light of development time constraints and the need for cost effectiveness.

1. Develop a methodology for assessing the survivability of 'B class' vehicle mounted personnel in landmine detonations, in conjunction with US, UK and Canadian laboratories if possible.
2. Conduct baseline testing of unmodified selected vehicles to assess the validity of these models in predicting survivability of occupants following the wheel initiation of simulated blast mines of varying explosive content.
3. Assess the effectiveness of field expedient measures such as water-filled tyres, rubber matting and sand-bags, and cost effective retrofitting techniques such as blast deflectors.
4. Develop or acquire a computational modelling capability to assist in the design and placement of blast deflection plates and other retrofit devices.

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Protection of light skinned vehicles against landmines

Craig Lester

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19. ABSTRACT

The Australian Army currently fields Landrover vehicles, Unimog troop transports and Mack trucks that do not include any form of armour protection, known generically as 'Class B' vehicles. This document is a review and summary of the state-of-the-art in protection of this family of vehicles against the threat from landmines. The approach taken has been to focus on the experience of Rhodesia (now Zimbabwe) and South Africa, primarily during the Rhodesian Bush War of 1972-80. This has the advantages of extensive combat data, it is from a scenario similar to that which the Australian Army could experience during short warning conflict or UN missions, and vehicles common with the Australian fleet (Landrover, Unimog) were employed. Limited data is drawn from other sources where appropriate.