Fighting Vehicle Technology

ABSTRACT

Armoured vehicle technology has evolved ever since the first tanks appeared in World War One. The traditional Armoured Fighting Vehicle (AFV) design focuses on lethality, survivability and mobility. However, with the growing reliance on communications and command (C2) systems, there is an increased need for the AFV design to be integrated with the vehicle electronics, or vetronics. Vetronics has become a key component of the AFV's effectiveness on the battlefield. An overview of the technology advances in these areas will be explored. In addition, the impact on the human aspect as a result of these C2 considerations will be covered.

Tan Chuan-Yean
Mok Shao Hong
Vince Yew

Fighting Vehicle Technology

INTRODUCTION

On the modern battlefield, armies are moving towards Network-Centric Warfare (NCW). Forces no longer fight as individual entities but as part of a larger system. Each entity becomes a node in a network where information can be shared, and firepower can be called upon request.

Key to this network fighting capability is the communications and command (C2) system. By enabling each force to be plugged into the C2 system, information can be shared among entities. Basic information shared includes 'where am I', 'where my friends are' and 'where the enemies are'. C2 capabilities provide fighting forces an edge as they are able to have a common operating picture instantly. A C2 system also allows armies to complete their Observe-Orient-Decide-Act (OODA) cycle significantly faster than those without one. As such, C2 capabilities have become increasingly dominant in Armoured Fighting Vehicle (AFV) designs.

The traditional AFV design considerations of firepower, survivability and mobility are still important as they execute the 'Act' component in the OODA loop – to achieve the mission objective after the situational picture has been assessed by and acted upon by the commander. The incorporation of these C2 systems, and the need for integration of the various sub-systems, would therefore require robust and extensive vehicle electronics (or 'vetronics') architecture. However, the increased flow of battlefield information and the equipping of the AFV with newer and more advanced sub-systems will raise the question of how the modern crew is able to process and use the information effectively.

TECHNOLOGIES IN AN AFV

Firepower

AFVs are usually equipped with weapon stations for self-protection and the engagement of targets. Depending on the threat, some are equipped with pintle mount systems for light weapons (e.g. 40mm Automatic Grenade Launcher, 12.7mm/0.5" Heavy Machine Guns etc.) to defeat troops or soft skin targets. Others are equipped with turreted systems with cannon class weapons (e.g. >25mm cannons) to defeat other AFVs.

In an AFV, there are typically two general types of ammunition projectiles: Kinetic Energy (KE) munitions and High Explosives (HE) munitions.

Kinetic Energy Munitions

Small calibre ammunition ranging from the 7.62mm to the 0.5" heavy machine guns are KE projectiles. Due to the hardness of the material as well as their speed and mass, the projectile will transfer its KE (= $1/2mv^2$) to the target and penetrate the armour. Cannon class ammunition such as the 25mm to 40mm rounds are more sophisticated in that they have fins to stablise the round after they are fired. These are commonly known as the Armour Piercing Fin Stabilised Discarding Sabot-Tracer (APFSDS-T) which has

Figure 1. An APFSDS-T round

a high penetration of up to 150mm Rolled Homogeneous Armour (RHA)[1]. A typical APFSDS-T ammunition is shown in Figure 1. The ammunition is encased in a sabot, and when fired, the energy of the propellant is transferred to the entire round and propels it out of the barrel at high speeds of up to 1,400m/s. Once it leaves the barrel, the sabot is discarded and the projectile, usually made from materials such as tungsten or depleted uranium, will penetrate the target by sheer kinetic energy. Hence, these rounds are used mainly to defeat light to medium-class AFVs.

High Explosives Munitions

HE rounds create damage by the fragmentation from the detonation of the explosive contained within. Usually with a mechanical fuse, they are detonated on impact and inflict damage with the fragments generated. These rounds are used for lightly protected vehicles and troops. However, if the enemy is entrenched or inside a building, the effectiveness of these HE rounds becomes limited. The development of the air-bursting munitions has helped to address the problem. The air-bursting ammunition has a fuse that can be programmed by the gun while the round is in the cannon chamber or as it leaves the barrel. It can be programmed to detonate either on impact, with a delay (e.g. explode after penetrating the wall), or at specific timings (e.g. explode right above or before the target). With this new capability, the AFV is able to engage troops in foxholes and behind walls as well as destroy the sights of enemy AFVs to render their weapon systems ineffective (see Figure 2).

Fire Control System

No matter how good the munitions are, they are useless if they do not land accurately on the intended targets. In World War Two (WWII), firing a tank gun required the tank to come to a complete halt before the gunner could engage the target. Of course, he could still fire on the move, but hitting the target is another matter! Even while stationary, the gunner would have to use his sighting system, gauge the distance and offset his aim to ensure that the round lands on the target. Depending on the gunner's skill, this would normally take more than one round to hit the target and the gunner would have to adjust his aim continually.

AFVs today are equipped with advanced day/night stabilised sighting systems, Laser Range Finders (LRF) and cant/tilt sensors to achieve a high probability of hit, even while moving. These enhancements improve the pace at which an armoured force is able to manoeuvre, as it can now advance speedily towards the enemy with sustained and precise firepower.

The capabilities are made possible with the Fire Control System (FCS) on board which is basically a computer that considers factors such as the range of the target, ammunition type, wind information and vehicle cant/tilt angle to ensure a high hit probability. With the highly stabilised sighting system, the gunner can place the crosshair on the target, lase the LRF to get a range and the FCS will adjust the necessary aim-off of the weapon so that the round will hit the target. However,

Figure 2. A demonstration of the 30mm airburst ammunition

even with the stabilisation, some skill is still involved as the gunner still has to manage his controls to ensure that the crosshair is on the target – a challenging task especially while moving in an undulating environment.

Some AFVs have been equipped with auto-target-tracking capability, where the system is able to 'lock-on' to a target and track it continuously. This reduces the workload of the gunner and also allows him to engage even slow-moving air targets such as helicopters.

There is also an increasing trend to equip the weapons system with an independent commander sight (ICS). Traditionally, these are only provided for Main Battle Tanks (MBT). Now, even AFVs such as the German PUMA, Swedish CV9030/35 and South Korean K-21 are equipped with an ICS. The ICS is another sighting system that usually has day/night capabilities and is able to search for targets independently of the gunner. This enables a hunter-killer capability for the AFV crew. The commander can now 'hunt' for other targets while the gunner 'kills' another. Once the gunner completes his task, the commander is able to direct the gunner to the new target position immediately to repeat the hunt-kill cycle. This feature increases the pace at which the vehicle is able to engage multiple targets. Figure 3 shows the CV9035 by BAE Systems

Figure 3. Commander/Gunner's sights of the CV9035 Turret


Figure 4.
Rafael 30mm RWS and its controls

with a commander sight to the left of the turret and the gunner's sight to its right.

Remote Weapon Station

Turret systems have traditionally been the norm for AFVs, with the commander or gunner operating within. However, the asymmetric threats from Improvised Explosive Devices (IED) and Rocket-Propelled Grenades (RPG) are forcing the crew to remain within the vehicles to improve survivability. One trend is the proliferation of Remote Weapon Stations (RWS) which enables the crew to operate the weapon from within the better protected hull. Figure 4 shows a typical RWS and its control station, where all the weapons interfaces are accessible to a crew seated within the hull.

The RWS is equipped with the FCS, sights and advanced munitions. The advantage of the RWS is that the protection levels can be focused more on the hull, where the crew is located. With the weapon mounted above the hull, there is no longer a need for a traditional

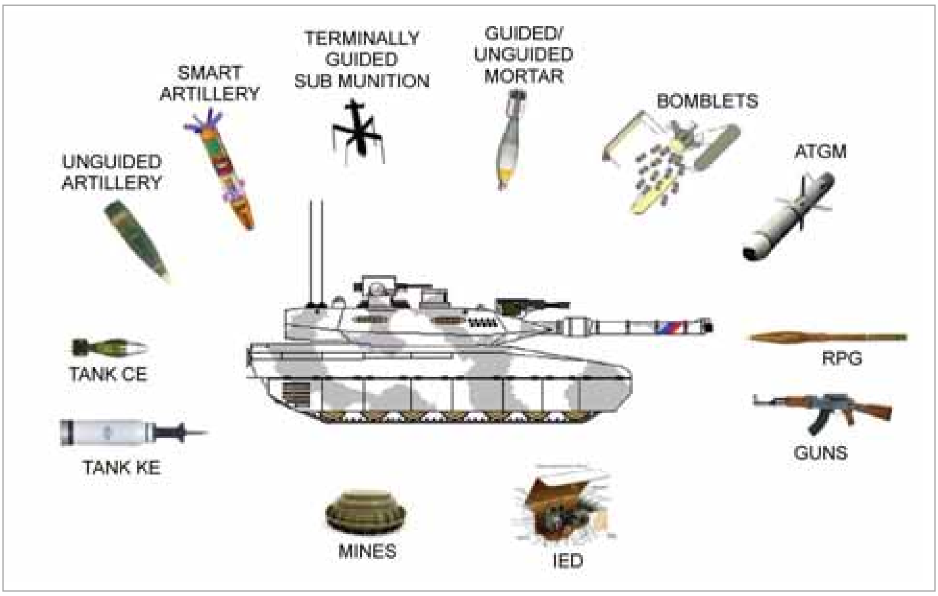

Figure 5. Typical threats AFVs face

turret basket that usually occupies 25% to 30% of the AFV's internal volume. Hence, this allows greater flexibility in crew placement. The disadvantage is that when the weapon jams, the crew is unable to access it to rectify the fault immediately. They will need to do so in a safe and non-hostile environment.

Survivability

Today's AFVs are expected to deal with various threats (see Figure 5) that are multi-directional. To design a vehicle that can withstand these threats will require multiple technologies to enhance its survivability.

Passive Armour

Most traditional armour is designed based on passive armour technology. Generally, all AFVs have a base hull material made from either armoured steel or high strength aluminium. This provides basic armour protection, but it is primarily to provide structural strength to the vehicle. Add-on Armour is usually attached to the basic hull to provide the main armour protection. This usually takes the form of thick armour packages to prevent penetration from various threats. However, with the high penetration capability of today's threats, piling on passive armour will drive the vehicle weight up, affecting its mobility and payload. Furthermore, there are limitations on the extent to which pure passive solutions can meet the survivability requirements.

For KE threats such as APFSDS-T 25-30mm munitions or light calibre weapons (e.g. 14.5mm Armour Piercing), the main defeat mechanism is to break up the projectile. This can be done by having hard and strong armour materials at its surface to break up the projectile, coupled with different layers of materials to erode the projectile during the penetration phase or to reduce its kinetic energy. These surfaces are usually sloped to present a thicker front to the projectile.

However, high strength armour steel alone may have the consequence of a high weight penalty. Armour designers have used different materials in developing armour package. Some have used ceramics to break up the round, with some base armour to absorb

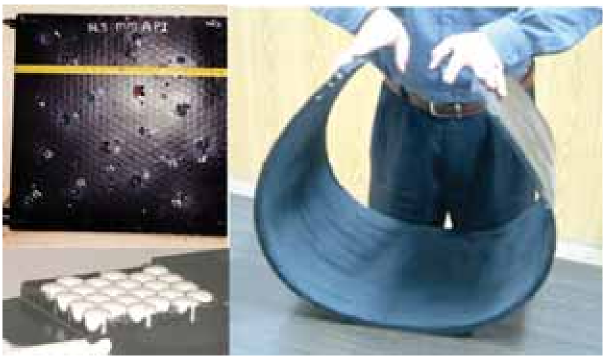

Figure 6. LIBA demonstrating its multi-hit capability and flexibility

the residual penetration while some have introduced spaces between layers of armour to allow the round to tumble. Ceramic armour is an attractive solution primarily because it can be as light as half the weight of steel armour. However, the multi-hit capability is low as a very large area of the ceramic surface is damaged upon impact, rendering the armour ineffective. To address this, some suppliers have embedded numerous smaller cylindrical ceramic elements or ball-shaped pellets into a matrix of elastomeric material or epoxy which is then attached to a composite fibre. Together with the base hull armour, this method enhances the overall protection and improves the multi-hit capability. One such system is the Light Improved Ballistic Armour (LIBA) developed by Mofet Etzion Ltd as shown in Figure 6.

Reactive Armour

Most Chemical Energy (CE) threats are from RPGs and Anti-Tank Guided Missiles (ATGM). These warheads comprise a conical copper liner surrounded by explosives. When detonated, the explosive forces literally invert the conical copper cone to form a thin molten jet that travels at speeds of up to 8km/s to 10km/s. This jet is the main mechanism that penetrates the armour. A RPG-7V can penetrate up to 300mm RHA. For the RPG to perform effectively, it must have an ideal stand-off distance (i.e. distance away from the armour) and this is usually designed in the warhead. Hence, the defeat mechanism for the armour facing such threats is to disrupt this jet formation or to detonate it further from the vehicle. Explosive Reactive Armours (ERA) and Non-Explosive ERA (NERA) have been developed to disrupt the jet formation. Energetic materials are sandwiched between two plates and upon contact with the jet, the energetic material reacts instantaneously and causes the plates to fly apart (for ERA) or bulge (for NERA), disrupting the process of jet formation (see Figure 7).

There has also been some work done in the UK to develop electric armour. The principles are similar to ERA, except that the energetic material is replaced by high

Figure 7. The disruptive mechanism of ERA

Figure 8. Slat armour on a Stryker vehicle

voltage between the two plates. When the copper jet passes through the plates, the high voltage distorts and vapourises the jet to render it ineffective. These systems require a large amount of electrical energy which is a limitation on an AFV. This electric armour is still under development. Other armour such as slat armour (see Figure 8) detonates the shaped charge at a larger distance away from the vehicle or short-circuits the warhead to prevent it from activating. But as the armour protection improves, new and innovative threats are also developed. Tandem CE rounds have been developed to overcome the ERA. The tandem CE round has one small precursor CE round ahead of the main warhead to clear the ERA ahead of the main warhead.

Another significant concern in using ERA is the collateral damage to surrounding personnel when the ERA is activated. The flying plates or fragments formed by the ERA are potentially lethal, and this consequence is not acceptable to some armies. Some companies have developed composite ERAs such as the Composite Lightweight Adaptable Reactive Armour (CLARA) by Dynamit Nobel Defence to minimise this. This solution does away with the metal plates and replaces them with composites so that when the armour detonates, only ejected fibres will be the residue.

Active Defence Suites

Active Defensive Suites or Systems (ADS) have been developed to boost the survivability of AFV crew. ADS comprises soft kill and hard kill systems. Soft kill systems which have been in existence for some time feature Laser Warning Systems that can detect the direction of the threat and launch an appropriate countermeasure. For example, upon detection of an ATGM launched by Semi-Active Command Line-of-sight, the vehicle can activate an Infra-Red jammer to spoof the missile and cause it to crash to the ground. Alternatively, smoke grenades can be launched so that the firer cannot guide the missile accurately onto the target.

On the other hand, hard kill systems comprise a system that detects the incoming threat, and launch a countermeasure to directly destroy it. In the late 1990s, the Russians developed the ARENA system which uses radar to detect a missile, and subsequently launches a module that explodes at a pre-determined time to destroy the threat. Since then, other ADSs have been developed e.g. Deisenroth Engineering's (IBD) Advanced Modular Protection-Active Defence System (AMP-ADS), Saab with Land Electronic Defence System, Israel Military Industries (IMI) with IRON FIST, and Rafael's TROPHY system. Figure 9 shows the IMI IRON FIST concept.

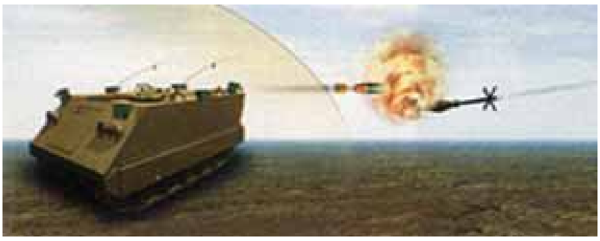

Figure 9. The IMI IRON FIST concept

Although the configurations are different, they all have a radar component and a countermeasure. IBD uses various sensors and radars placed around the vehicle to detect the incoming threat and activate the countermeasures to destroy the threat before impact. Figure 10 shows an IVECO 4x4 truck mounted with the AMP-ADS.

Figure 10. An IVECO 4x4 truck with AMP-ADS on the roof

Similarly, the other systems use radar to detect incoming threats and an explosive grenade will be launched to destroy the threat at further distances away from the vehicle. Most of these systems are still under development, with only the TROPHY being mounted on the Merkava IV MBT as the only operational system. As with ERA, ammunition to counter ADS has been also developed. The Russians are developing the RPG30 which houses the main round and a decoy round. The decoy will deceive the ADS into attacking it, so as to allow the main round to attack the target unhindered. Hence, the success of the attack would really depend on the ADS's capability to differentiate between the actual threat and the decoy, and to launch the countermeasures in quick succession.

Protection Against Mines and Improvised Explosive Devices

Other than KE and CE rounds, mines and IEDs pose other significant threats to AFVs. To counter the mine threat, a mine kit that either deflects the blast wave away from the vehicle or absorbs most of the blast energy is required. For tracked AFVs, the deflection method is a great challenge as the ground clearance between the belly of the AFV to the ground is very small at 400mm to 500mm on average. It is more suited for wheeled vehicles with high ground clearance, and a V-shaped hull so that the blast is deflected away. A typical V-shaped wheeled vehicle is the BAE's RG-35 (see Figure 11).

Mine kits for AFVs are designed to absorb blast energy. However, mine kits alone can only minimise the risk of hull rupture, so as to prevent overpressure from occurring. During a mineblast, the vehicle will experience the first shock wave around the belly which will cause severe leg injuries to the crew, followed by the deformation of the vehicle hull. The crew will also start to experience compressive stress on their spines and necks, followed by the movement of the entire vehicle. If the hull is to perforate, the blast overpressure entering the vehicle will kill the

Figure 11. A RG-35 Vehicle showing a V-shaped hull

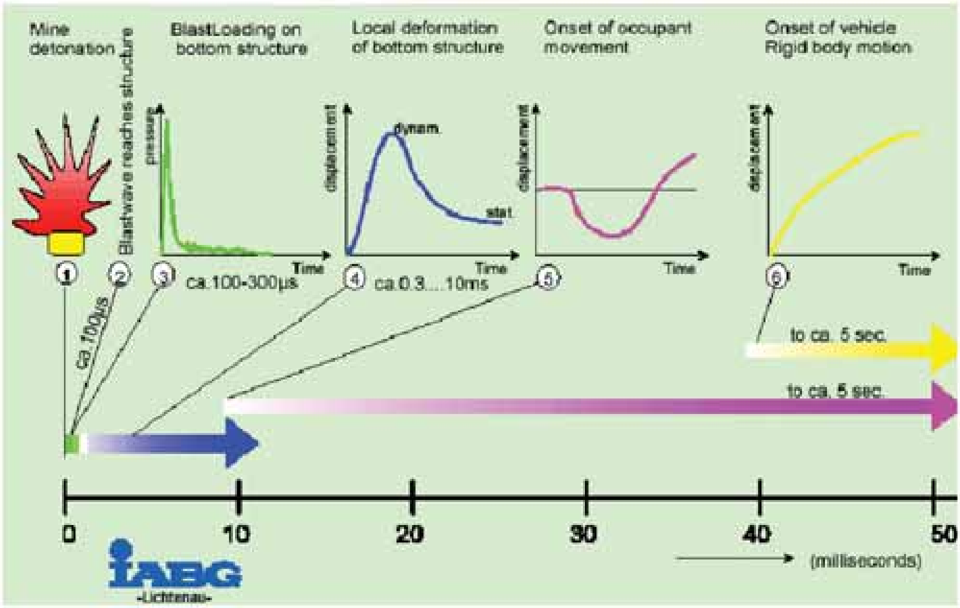

Figure 12. Effects of a mineblast on a vehicle

crew. All these occur within 40ms to 50ms (see Figure 12).

Throughout these phases, injuries can be inflicted on the occupant, and the AFV has to be designed to mitigate the effects. The vehicle's internal design has to ensure that the on-board components are firmly mounted, with foot rests to elevate the crew's feet to avoid direct contact with the belly. The seats and restraint systems have to be designed to mitigate the shock transferred to their bodies and also to protect the crew from being thrown towards the roof and injuring their necks.

IEDs are a more recent threat and can come in all forms and sizes. The passive, reactive armour and mine kit described earlier would be able to withstand most IEDs, and are easier to implement for heavier AFVs. For light trucks, it is more challenging to do so as the armour payload is limited. However, despite the various designs, designing protective measures for AFVs against such threats is very challenging as the enemy is very innovative in designing IEDs. In 2002, a Merkava III MBT, one of the best protected tanks in the world, was destroyed by an IED equivalent to 100kg TNT. Technologies such as electronic jamming to prevent the remote detonation of IEDs, and chemical detection systems to sniff out explosives have been explored. Non-conventional methods such as capturing digital images of the route and evaluating changes in the scenes to assess if the environment has been tampered with are also being evaluated. In general, technologies to overcome IEDs are closely guarded and understandably so as the information can be used by insurgents to overcome them.

Mobility

Mobility is the ability of the AFV to traverse from one area of operations to another. It is generally divided into strategic/operational mobility and tactical mobility. Strategic/operational mobility is the capability to project the force over long distances via air, sea or land. Strategic/operational mobility needs dictate the size and weight of the

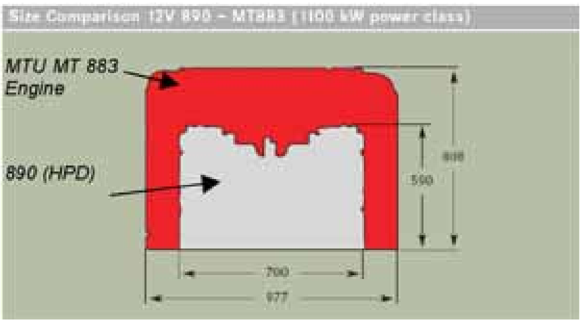

Figure 13. Comparison of MTU MT 883 and the 890 (HPD) engine sizes

vehicle. Tactical mobility depends more on the performance of the platform i.e. the power train system which comprises the engine transmission and cooling system. This forms the main power source that drives the AFV. The wheels or tracks affect the AFV's manoeuvrability. It supports the weight of the vehicle and distributes it over the ground. The suspension system supports the vehicle, but also affects the ride comfort of the vehicle. The maximum speed at which the vehicle can travel is indirectly affected – a poor suspension design causes the driver to drive slower as higher speeds will make the ride too uncomfortable for him, even if additional power is available.

Powerpack

The internal combustion engine is used as the main propulsion system. AFVs generally use diesel engines since diesel is less flammable than petrol. Most of the development of diesel engines is driven commercially to improve the fuel efficiency. Military engines do need to be fuel efficient, but more importantly, they must have a very good power-to-volume ratio or power density so as to maximise the space they occupy. One of the most recent engines developed is the MTU High Power Density (HPD) engine. It is a very compact engine with up to 60% savings in weight and volume (see Figure 13).

While the HPD engine was designed primarily for hybrid electric systems, it is able to couple to mechanical transmissions too. The proposed Manned Ground Vehicle under the US Future Combat System programme adopted the hybrid electric system. It comprises the HPD engine, generators, generator dissipater controller, traction drive system, energy storage system and cooling system. The hybrid electrical system serves as a power generator and provides electrical power to

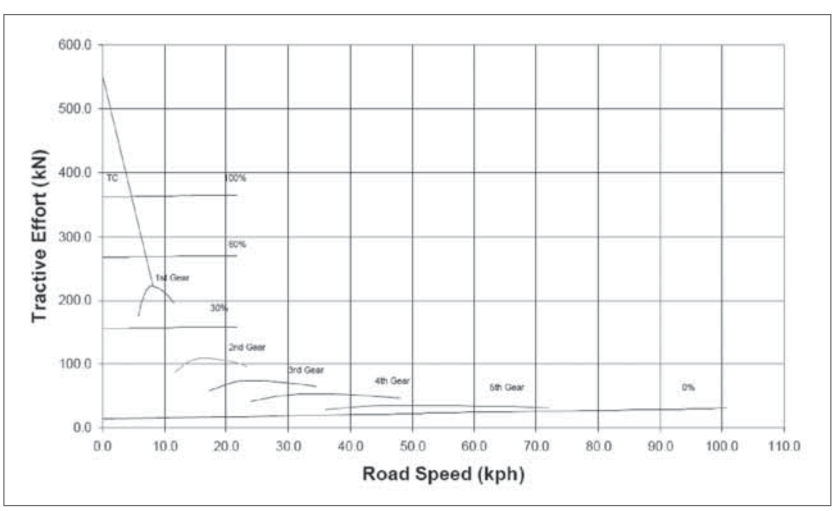

Figure 14. A comparison between tractive effort and road speed

all vehicle systems, including the propulsion, which is via the traction motor. This system allows the vehicles to operate in silent watch, silent running (i.e. from batteries for short distances), burst acceleration, and enhances their low speed manoeuvrability. The system is de-coupled from the drive train, and this allows its components to be positioned in the vehicle with greater flexibility.

However, the Future Combat System programme has come to a halt as it did not adequately reflect lessons learnt during operations about protection against roadside bombs and it remains to be seen how this technology will be applied to other systems. The PUMA IFV also uses this HPD engine but is coupled to a Renk HSWL 256 hydrostatic/hydrodynamic transmission. It has a large flywheel generator that doubles up as a starter motor.

Transmission

An engine provides the power and the transmission converts this power to torque which propels the vehicle forward. A transmission will give the necessary gear ratios to transfer the power to the final drives, providing the necessary torque to overcome the road resistance. Figure 14 shows a typical tractive effort/road speed curve of a transmission. The curves, as indicated by the % lines, show the road resistance increasing with speed at its respective gradients. The curves indicated by the *nth* Gear show the tractive effort of the transmissions at its respective gears. The intersection of the two curves will thus indicate the expected vehicle speed. This analysis indicates the projected vehicle speed performance of a chosen transmission.

Another purpose of the transmission of a tracked vehicle is to provide steering. This is unlike wheeled vehicles which steer by the front wheels. In older transmissions, the inner track needs to be mechanically braked so that the outer track propels forward to turn the vehicle. It is an inefficient system as the power transmitted to the inner track is completely lost and converted to heat energy. Modern transmissions provide regenerative steering where the power that is usually lost in the inner track is re-directed or 're-generated' to the outside track via a steer or zero shaft, allowing the power to be efficiently used in a steer.

Transmissions on AFVs are being developed to allow for Drive-by-Wire (DbW). Normally, transmissions have mechanical linkages to the vehicle driving controls such as braking, steering, throttling and gear selection. Transmissions with DbW capability have intelligent controllers that will receive the driving control inputs electronically, and dictate the corresponding transmission response. DbW enables increased flexibility in positioning the driver within an AFV, and also allows another crew member to take over driving if the driver is unable to. This creates more flexibility in crew configuration. DbW technology also facilitates unmanned operations. Instead of using remote actuators to access the drive controls, a remote system can directly interface with the transmission controller. This will provide the added flexibility for a crew to take over the vehicle quickly when the unmanned roles are completed.

Vetronics

To integrate the C2 system or a Battlefield Management System (BMS) on an AFV, a vetronics system would be required to enhance its effectiveness. An AFV without vetronics can be equipped with a BMS but this allows it to have only inter-vehicular information exchange. Vetronics enables both inter- and intra-vehicular information exchange which enhances the overall effectiveness of the AFV. For example, when the BMS is integrated to the FCS, specific targets can be assigned to each AFV. The weapons of each AFV can be slewed towards their assigned targets, thus minimising the overlapping of fire on the same target.

After engaging or obtaining the range of a newly detected target, the information can be disseminated via the BMS to friendly forces to update on the combat situation. The logistic status of the vehicle such as fuel and ammunition can also be disseminated to the logisticians so they are able to plan a more timely replenishment schedule. All these features would not be viable without a vetronics system that links the vehicle systems to the BMS. A Common Crew Station concept can also be attainable with the introduction of the vetronics system. The roles of the crew can be duplicated, over multiple stations within the vehicle – this means that the commander can take over other roles such that of a gunner or driver and vice versa.

Systems Architecture

An integrated vetronics suite requires the use of a systems architecture to define the overall structure of the system, its internal protocol as well as its internal and external interfaces. The vetronics architecture design concept should be adaptable, flexible, sustainable, scalable, responsive and robust. In most cases, the vetronics architecture is also based on an open system which promotes cross-fleet commonality as well as the ease of upgrading and system enhancements. One key attribute of vetronics architecture design is adaptability i.e. the ability to adapt to changing operational environments or requirements, handle new technology insertion, and manage legacy systems while incorporating new systems. This is an important parameter as computing technology changes rapidly, and the architecture must be able to adapt to new inputs without rewiring the entire vehicle.

The vetronics architecture also links all the various sub-systems on board the platform. This is achieved through the use of Internet Protocol, serial communication and Controller Area Network bus to ensure intra-vehicular information flow. Video data buses are also incorporated as more cameras are used on

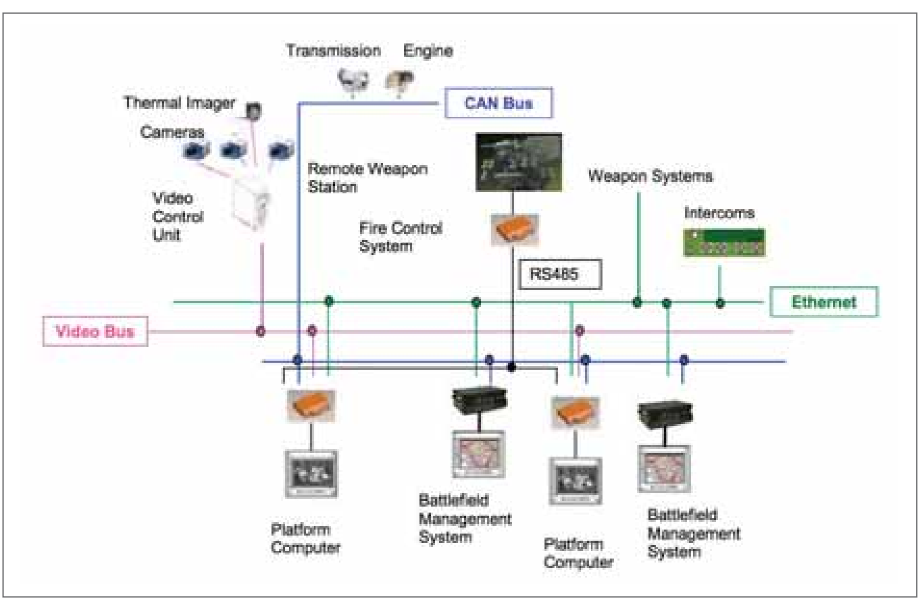

Figure 15. Generic vetronics systems architecture

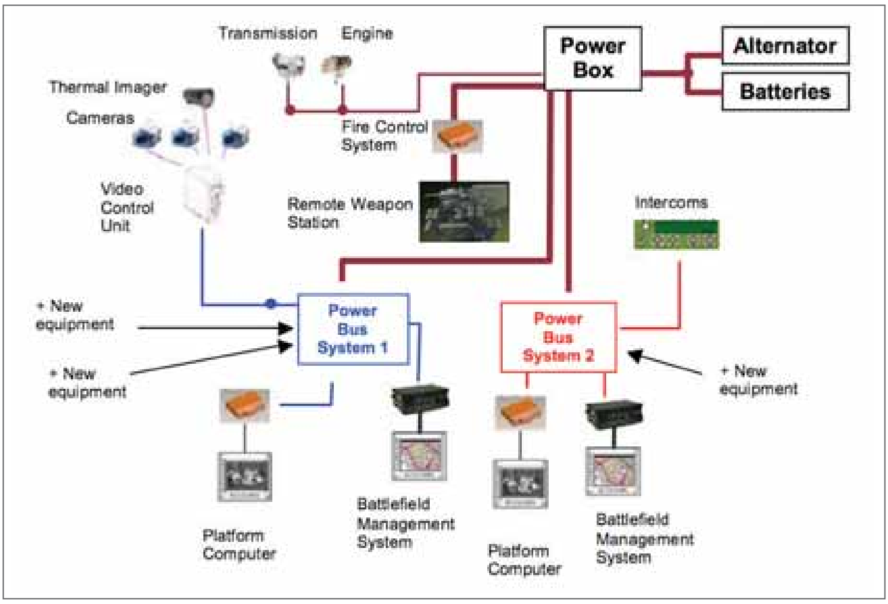

Figure 16. Intelligent power management systems architecture

AFVs to improve their situational awareness in closed hatch fighting. These camera views can be made available to all on board by ensuring that the video data bus distributes the picture to all the crew and troops. A generic vetronics systems architecture is shown in Figure 15.

From this architecture, it can be seen that the various systems are interconnected and information from the BMS can be transmitted to the weapon systems if required. In addition, if the enemy is spotted by the crew in the AFV via the camera systems, they can click on the display and the system is able to slew the weapon to the direction of the threat to allow a rapid response. This would enhance the overall operational effectiveness of the AFV.

Power Generation and Management

Power management is crucial to the performance of vetronics. With more computers and electronics on board, there is a greater challenge on how to generate power to sustain the operations, especially during silent watch operations. Batteries and auxiliary power units (APU) are generally used to meet these increased power requirements. However, the number of batteries used is three to four times more than a conventional AFV. Technologies such as hydrogen fuel cells and solid oxide fuel cells generate greater power with better electrical efficiency than the common APUs, and can be explored to meet the growing power demand. However, these electrical components also generate considerable heat energy. The components can be designed to withstand the heat, but the crew will be subjected to high temperatures. Hence, air cooling systems have to be installed to ensure that the crew is protected from the heat to sustain operations.

Another approach to manage power demands may be to explore an intelligent platform power management system to provide distributed power such that only essential key electrical and electronics systems will be powered during different modes of operation. Intelligent power management system architecture is shown in Figure 16. Based on the different power requirements in operations, the system allows the crew to quickly configure the vehicle to provide only what is necessary to support the operation, hence conserving power. For example, during silent watch operations, the system will provide power to the necessary platform computers and systems to ensure that sufficient power is left to start the engine. The power distribution is also easily configurable as the system resides on a bus network. Hence, new equipment can be added without major re-modification of the power harnesses.

PUTTING IT ALL TOGETHER

The challenge now is to integrate these various technologies onto a common platform. All of these systems capabilities – Firepower, Survivability, Mobility and Vetronics – are competing for space and weight. An AFV has size and weight limits as it needs to manoeuvre in certain terrain or to meet certain transport requirements. Thus, trade-off studies are required to integrate these various technologies. An AFV will not be able to move if it carries too much protective armour. If more firepower is required, more ammunition will be required on board and this will affect the payload it carries e.g. less troops. More vetronics will require more batteries, hence reducing available space. Thus, a fine balance among these aspects need to be deliberated before an agreement can be reached by all stakeholders.

The Human Aspect

NCW presents obvious advantages in the battlefield but also inadvertently poses fresh challenges to the design of the AFV crew station. In a networked environment, an escalating amount of information is being compiled, processed, analysed, and shared among the crew. If not properly managed, the sheer complexity and volume of available data may actually reduce crew performance due to information overload. New methods must be explored to present battlefield information and provide the commander with continual high quality situational awareness without significant cognitive overhead. For example, should the commander view all the available information made to him or only selected information? If the latter, which information is relevant?

Cognitive Task Analysis techniques can be employed to uncover the specific cognitive challenges experienced by the crew, and to elicit the relevant information requirements of the users. Information that is not required for the task would be filtered out, and key information required for sense-making and decision making highlighted and made readily accessible in the system design. Such efforts to reduce crew workload are prevalent especially on complex and sophisticated platforms.

Even if specific information is required, is the information presented easy to process and intuitive? Customised Man-Machine Interface (MMI) and Graphical User Interface (GUI) allow the crew to process the information better and faster and so specifically improve the Observe-Orient-Decide portion of the OODA loop.

Modelling and Simulation – A Developmental Tool

Modelling and Simulation (M&S) tools are increasingly used to design the AFV crew station MMI and GUI at the early stage of the system development cycle. Through rapid prototyping of the conceptual and detailed designs of the crew stations, M&S systems provide the benefit of conducting man-in-the-loop experimentation to uncover work-flow issues and cognitive requirements very early in the development cycle. Subsequent design iterations can be quickly implemented on M&S systems, and results can be verified much earlier – often before any fabrication or procurement is done. Thus, M&S offers a mechanism for shortening developmental time, increasing systems effectiveness of the final system, mitigating developmental risk, and controlling overall cost.

CONCLUSION

AFVs have evolved through the years. Since the beginning of World War One, AFVs have been deployed on the battlefield to achieve a tactical advantage. They were further exploited by the Germans in WWII, where technology provided them with improved radio communications and allowed them to move faster with greater firepower and protection. Thus, they were able to adopt the concept of 'Blitzkrieg' or 'lightning war'. As we enter the NCW age, the AFV still has a strong role to play as seen in the Iraq and Afghanistan conflicts in the 2000s. As technology advances, the AFV must also keep up with the changes and be ready to adapt and evolve to face these new challenges.

REFERENCES

Bochenek, Grace M. and Jennifer Hitchcock, 2007. Army Transitions Hybrid Electric Technology to FCS Manned Ground Vehicles. Army Magazine (October–December): 37.

Cropley, D.H. and P. Campbell. 2004. The Role of Modelling and Simulation in Military and Systems Engineering. Paper presented at the Systems Engineering/Test and Evaluation Conference 2004, 8–10 November, in Adelaide, Australia.

Defence Update. Light Improved Ballistic Armor (LIBA). http://defense-update.com/products/l/liba.htm (accessed 27 August 2009)

Defence Update. Slat Armor for Stryker APC. http://defense-update.com/products/s/slat-stryker.htm (accessed 27 August 2009)

Israel Military Industry Ltd. http://www.imi-israel.com/news.aspx?FolderID=13&docID=681 (accessed 27 August 2009)

Jane's Defence Weekly. 2009. US Army outlines how it will 'devolve' FCS. Volume 46, Issue 21 (27 May): 8.

Mine effects on Vehicle Structures and Occupant Protection in Military Land Vehicles, Mining. 2002. Mannheim, 27–29 May.

MTU Friedrichshafen Gmbh. Diesel-Electric Drive Systems for Future Armored Vehicles: High Power Density Diesel Engine Series 890.

Reynolds, Paul. 2005. 30mm Air Burst Development, Translating Lessons Learned into System Requirements. Paper presented at the 40th Annual Guns and Ammunition Conference, 25–28 April, in New Orleans, Louisiana, USA.

Richardson, Doug. 2001. Vetronics for Fighting Vehicles. Armada International, (1 February): 20-28.

ENDNOTES

[1] RHA or Rolled Homogeneous Armour is a common reference term used to describe the penetration capability of ammunition.

BIOGRAPHY

Tan Chuan-Yean is a Principal Engineer (Land Systems) and develops crew and vetronics systems for fighting platforms. He has been involved in the development of the Bionix I and II Infantry Fighting Vehicles, as well as the Bionix Recovery Vehicle variant. As the Project Manager, Chuan-Yean led the Trailblazer Countermine Vehicle project from conceptualisation to prototype stage. He was part of the Trailblazer Team that won the Defence Technology Prize Team (Engineering) Award in 2009. Chuan-Yean graduated with a Bachelor degree in Mechanical and Production Engineering (Honours) from Nanyang Technological University in 1996 and obtained a Master of Science (MSc) degree in Weapon and Vehicle Systems from the Royal Military College of Science, Cranfield University, UK in 2001. He was also awarded the Vicker's Trophy for the best MSc thesis.

Mok Shao Hong is an Engineer (Land Systems). He is currently involved in experimental studies on the development of the fighting platform crew station Man-Machine Interface. Shao Hong also works on other variants of the fighting platforms. He graduated with a Bachelor degree in Mechanical Engineering (Honours) with specialisation in Design from Nanyang Technological University in 2007.

Vince Yew is an Engineer (Land Systems) and is currently assisting in the management of vetronics for fighting vehicle projects. She was also involved in the planning of the Systems Architecture and other electronics systems. Vince graduated with a Bachelor degree in Electrical Engineering (Honours) from the National University of Singapore in 2006.