# Research Paper for the Future of Main Battle Tank Protection Systems

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*Introduction*

During the Yom Kippur War (1973), Egyptian forces fielded Russian anti-tank missiles, surprising the Israeli forces and forcing the Israelis to think of new tactics to combat the Egyptians. Relating the use of the guided missile which replaced the cannon in naval warfare, it is possible that the guided missile will replace the cannon in ground forces. Comparing a cannon with a guided missile, the cannon has a maximum effective range of 3 kilometers and must be aimed and fired by a human operator and cannot be guided once fired, while a guided missile has an effective range of up to 8 kilometers (and is also light enough to be carried in bulk by a helicopter) and is either a "fire and forget" system (where the missile guides itself to the target on its own) or a manual guidance system (which allows the operator to control the flight manually). Thus, development of an armored vehicle armed with only missiles and self-defense armament seems, especially today, very feasible and practical. By replacing the main gun and turret of a main-battle tank, production would be cheaper and simplified, as well as lighter, allowing for both more efficient engines and transport. There is also the fact that an armored vehicle armed with multiple-launch anti-tank missiles may be able to lock onto multiple targets at once, compared to the slower firing cannon (Crist 1997).

At the end of WW2, the US Military was left with 3 tanks: the M24 "Chaffee" light tank (armed with a low velocity 75mm cannon), the M4 "Sherman" medium tank (originally armed with the same low velocity 75mm cannon as the Chaffee, then upgraded to a high velocity 76mm cannon), and the M26 “Pershing” heavy tank (later reclassified as a medium tank, armed with a 90mm cannon), which was later replaced by the M46 “Patton”. The Cold War caused fear in the Pentagon that the Soviets had better tanks. During the Korean War, the M24 was shown to be ineffective against North Korean T-34-85s (armed with an 85mm cannon). These experiences against T-34-85s led to the development of the M41 “Walker Bulldog”, which was armed with a higher velocity 76mm cannon. The M46 later gained upgrades, such as the M47, M48, and M60 upgrades (the M60 later was upgraded with ERA, creating the M60 RISE). The M60, during the Yom Kippur War, was found to be vulnerable to anti-tank missiles (9M14 “Malyutka” or “Sagger”) and anti-tank rockets. Experiences fighting German heavy tanks and the threat posed by Soviet IS-3 heavy tanks led to the design of the M103 heavy tank, which was never adopted, as studies of captured Soviet heavy tanks found that these vehicles were ultimately overrated. After the emergence of the PT-76 light tanks, the U.S. developed the M551 “Sheridan” light tank, as to both provide armor support to airborne units and have a river fording ability. Due to the shortcomings of both the M60 and the M551, the U.S. and Germany joint-development team created the MBT-70 (known as the KPz-70 in Germany), which provided the basis for the M1 Abrams main battle tank (Cameron 1998). The U.S. Army’s current fleet of main battle tanks, infantry fighting vehicles, and conventional and rocket artillery systems are the center of the armored forces, but were designed and built during the end of the Cold War. Army leadership does not have any new combat vehicle in development and states that the fleet of infantry fighting vehicles and main battle tanks will stay in service for 50-70 years. This has caused concern, as foreign armored vehicle design may surpass existing U.S. systems in this time period (Feikert 2017). Current tank fleets are especially vulnerable to guided missiles. Tank protection is divided up into areas, starting from farthest to closest are: reconnaissance and strategic deception; mobility, stealth, and situational awareness; signal reduction and jamming, deception; soft-kill and hard-kill active protection systems; armor; and finally spall liner (which stops armor on the inside from flying off and injuring crew), crew body armor, insensitive munitions (no ammunition rack detonations), and energy absorbing seats (Rahman, Malik, Kumar, Balaguru & Sivakumar 2017). The weapons of today, such as shaped charge warheads and other guided munitions, have reduced the effectiveness of conventional passive armor on armored vehicles. Vehicles of today must now rely less on passive armor systems and rely more on sensors, computers, and other technologies (Rapanotti, DeMontigny, Cantin & Palmarini 2002). What this means is that the tanks of today need to rely on detection and hit avoidance to increase survivability. By reducing both the size and the background emissions of the armored vehicle, survivability is increased. Hit avoidance is based on missile laser detection, missile detection and tracking, and countermeasures, such as diverting the missile and destroying the missile (Rapanotti, DeMontigny, Cantin & Palmarini 2002).

On the subject of hit avoidance, Active Protection Systems (APS’s) are defined as a defensive system designed to intercept, destroy, or confuse attacking enemy munitions. There are two forms of

APS’s, active (“hard kill”), a system used to damage and destroy incoming projectiles, and countermeasures (“soft kill”), which confuse and divert a projectile, such as a guided missile. The first APS system was Drozd, a Soviet system developed from 1977 to 1982 based on experiences in Afghanistan. Other APS systems are Shtora-1, Arena, POMALS, and MIDAS (Meyer 1998).

Current APS systems also were created to defeat anti-tank guided missiles (ATGMs), not high explosive (HE) or kinetic energy (KE) rounds, such as armor-piercing, fin stabilized, discarding sabot (APFSDS) rounds. ATGMs of today also attack from above, either from ATGM launchers or ground attack aircraft. Current shaped-charge warheads, such as those from man-portable anti-tank systems (MANPADS) (Meyer 1998).

*Literature Review*

Current nature of modern wars is determined by military-political goals, the means of achieving those goals, and the scale of the operation(s). The military-political goals are defined either as just (a war waged in self-defense as the subject of aggression) or unjust (a war waged in aggression, an armed attack), the means of achieving those goals can be conventional or use nuclear weapons and other weapons of mass destruction, and scale can be local, regional, or large-scale (global). Modern war has an extensive use of indirect means of operation and engagement (such as aerial and artillery bombardment) and the use of state-of-the-art systems of arms and military hardware, as well as the use of highly mobile troops (motorized infantry, airborne troops, and other special forces) and the use of military force against the opposing force, means of communication, and other important infrastructure. Armed conflict, on the other hand, has a high amount of involvement by the local population and uses mostly irregular forces, which use an extensive amount of sabotage and other "terrorist methods" [sic], and more forces are required to protect important infrastructure (Arbatov 2000).

In possible modern warfare, beside the usual kinetic and chemical shells, there are also Penetrators with Enhanced Lateral Efficiency (PELE), also known as Frangible Armor Piercing Discarding Sabot (FAPDS), which use hydrodynamic pressure to convert axial velocity to radial velocity. The PELE round is a made up of a low density filling surrounded by a higher density jacket. When the projectile penetrates the target, the projectile, due to pressure, fractures into multiple high velocity fragments, similar to a frangible bullet (Paulus & Schirm 2006). Ceramics, due to their properties of high compressive strength and lower density compared to metals, are a good fit for lightweight armor. Observations of kinetic penetrators against ceramics have shown that ballistic resistance against kinetic penetrators is based on ceramic confinement and configuration (such as multiple layers of ceramics). The ballistic resistance diminishes the further the kinetic projectile penetrates the ceramics (Espinosa, Brar, Yuan, Xu & Arrieta 2000).

On the other hand, current local wars show that armored vehicles, such as tank, are still the main combat systems on the battlefield.

Shaped charge warheads are some of the strongest counters to armored vehicles; however, in 1969, researchers found that a sandwich structure (metal panel-explosive-metal panel) can reduce the penetration value of shaped charge warheads and kinetic energy penetrators, which became explosive, reactive armor (ERA) and is found on the majority of armored vehicles today. ERA increases the vehicle's survivability and sustained combat ability in a combat area. Thus, two new shaped charge warheads have been developed: armor piercing and multi-stage shaped charge. Both comprise of two parts: a pre-warhead and a post-warhead. The former uses an armor piercing pre-warhead and a shaped charge post-warhead, as to pierce ERA without detonating it and detonate through the hole created by the pre-warhead. The latter uses two different shaped charges, one to detonate the ERA and the other to pierce the armor (Ding, Tang & Ran 2018).

Armored vehicles have two main measures to counter enemy projectiles: active protection systems and armor. Rolled homogeneous steel has remained the standard all over the world for use in tank production. This steel armor continues to be used because of its ability to increase its own penetration resistance. This can be achieved through cycles of tempering. Increasing hardness while maintaining toughness has been the key to success for this armor type (Singh, et. al. 2017). Active Protection Systems (APS's), on the other hand, are defined as a defensive system designed to intercept, destroy, or confuse attacking enemy munitions. There are two forms of APS's, active ("hard kill"), a system used to damage and destroy incoming projectiles, and countermeasures (“soft kill”), which confuse and divert a projectile, such as a guided missile (Meyer 1998).

The United States Military’s current fleet of motorized combat vehicles were designed to counter the Soviet Union’s numerically superior ground forces and current maneuver warfare. They were not designed with the threat of insurgents in mind. Today, fighters using man-portable anti-tank weapons (MANPATs), such as RPG-7s, are able to surprise combat vehicles with high penetration shaped charge rounds that can knock out even the most heavily armoured main battle tanks. Situational awareness of the battlefield is the key to combat survival and superiority (Ramesh 2017).

*Analysis*

The anti-tank guided missile (ATGM) is a weapon that allows a group of infantry or a light, armored vehicle to combat and destroy a tank or other heavily armored vehicles. Development of composite armor, explosive reactive armor, and active protection systems followed soon after, using experiences from fighting other militaries, insurgencies, and other forms of asymmetrical warfare. Experiences with fighting insurgencies in Afghanistan and experiences fighting enemies armed with ATGMs caused multiple nations, which include Israel and Russia, to develop active protection systems and explosive reactive armor, while the need to innovate to gain an edge over possible opponents caused the development of composite armor.

The design and development of the passive infrared sensor-Raspberry Pi 3 circuit was problematic, as we didn’t get our parts until the second to third week of the 4th Quarter. Among other things, we had troubles getting the sensor to work (eventually, we found out that I had the ground and power wires swapped), and later on had problems with the time delay. In fact, the time delay had a minimum delay of 3 seconds, which we couldn’t make smaller. The schematic development also had problems, as we waited too long to complete it. The PIR Sensor, however, was a good introduction to Raspberry Pi sensor systems, and is ultimately a good start for other systems, such as radar.

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