OPEN ACCESS Freely available online

Journal of Defense Management

ISSN: 2167-0374

Review Article

Active and Passive Defence Techniques in Combat Vehicles against Laser Guided Weapons

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ABSTRACT

The history of laser-guided weapons can be traced back to world war-II which augmented the development and use of smart munitions against combat vehicles in various conflicts, globally. Literature highlighted that active and passive defence technique can either be used to neutralize or avoid the incoming laser guided weapons attack. Active defence system uses counter munition to destroy incoming threat while, passive defence system is based on thickening of armor or counter measures like high beam lasers, flares, camouflage or smoke screens. This research examines active and passive defence techniques in combat vehicles against laser-guided weapons under the lens of exploratory research method. It aims to study defence techniques and compare technologies adopted by contemporary armies to explore future prospects of such technologies especially in developing nations. Results have shown that adoption of active and passive defence technique depends upon factors such as technological capabilities, operational environment, operational objectives and cost/resources. Findings and recommendations achieved from this research will be beneficial for stakeholders like defence organizations, defence contractors and academic researchers.

Keywords: Early intervention; Early movement experience; Preterm; Low birth weight

INTRODUCTION

Laser Guided Weapons (LGWs) have transformed the concept of warfare by ensuring precise targeting of enemy when and where required. The history of laser guided weapons originates from world war II, when first guided bomb the "Azon" was developed by British and radio control system was used for guidance purpose. Due to uncertain weather conditions, this system was found inaccurate and unreliable. During 1950's, U.S military made significant developments in laser technology which led to the development of laser-guided weapons. In 1963, "Bullpup" missile was pioneer laser-guided missile and utilized during the Vietnam war (1955-1975). In the 1970's, laser-guided weapons became widespread in military arsenals and became a standard feature. The advent of Laser Rangefinders (LRFs) and target designators enabled laser guided munition to target more precisely and efficiently. In 1980's, semi-active laser guidance system was introduced, further advancing laser-guided weapons.

In recent times, laser-guided weapons have continued to undergo technological advancements with the development of more sophisticated laser seekers and the introduction of new laser sources such as fiber-optic and diode lasers. These advancements have significantly improved the accuracy and reliability of laser-guided weapons, further enhancing their effectiveness in modern day conflict.

Laser guided weapons poses a significant challenge to the existence of armored vehicles in the modern battlefield. In response to the growing and evolving threat, development of active and passive defence techniques in armored vehicles has become an important area of research and development.

Problem statement

With the passage of time, developed nations such as USA, Russia, Israel, China, Sweden, South Africa and Germany etc. have invested much in terms of development of active and passive defence systems. It not only provides protection to defender but also creates alarming scenario for the attacker's foothold in the battlefield. Said technologies are based on two modes that are either to avoid the hit or attack the intruder to

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Received: 29-Sep-2023, Manuscript No. JDFM-23-27257; **Editor assigned:** 02-Oct-2023, PreQC No. JDFM-23-27257 (PQ); **Reviewed:** 16-Oct-2023, QC No. JDFM-23-27257; **Revised:** 10-Jan-2025, Manuscript No. JDFM-23-27257 (R); **Published:** 17-Jan-2025, DOI: 10.35248/2167-0374.25.14.275.

Citation: Muneeb MT (2025) Active and Passive Defence Techniques in Combat Vehicles against Laser Guided Weapons. J Defense Manag. 14:275.

neutralize smart munitions like laser guided missiles, ATGM and RPGs etc.

Contrarily, developing nations like Pakistan are still in effort to develop such modern techniques. In recent times, limited research has been undertaken to ascertain factors due to which hindrance is being faced by developing nations. Moreover, these nations are laying focus on traditional armor protection of combat vehicles leading to increased body weight and mobility of vehicles is traded off subsequently.

Keeping in view the prevailing study gap, this exploratory research is aimed to study/analyze above mentioned systems and identify problems being faced by developing nations towards development of such state-of-the-art technologies. This study intends to highlight the problem areas and devise way forward towards development of modern systems in future.

Research objectives

- To study active and passive defence techniques adopted by combat vehicles against laser guided weapons.
- Comparison of various defence technologies adopted by contemporary armies.
- Identification of problems being faced by developing nations in development of active and passive defence technologies.

Research questions

- What are the current active and passive defence techniques in armored vehicles against smart weaponry?
- Which defensive technique is more effective against smart weaponry?
- What impediments are being encountered by developing nations towards development of active and passive defence technologies?

Significance of the study

This research will contribute to better understanding of the active and passive defence techniques adopted in armored vehicles against laser-guided weapons and will provide a foundation for future research and development in this field. The findings of this research will be of interest to a wide range of stakeholders such as defence organizations, defence contractors and academic researchers.

LITERATURE REVIEW

Types of Laser Guided Weapons (LGWs)

Laser-guided bombs: The laser is typically emitted from a targeting pod mounted on an aircraft or from a ground-based laser designator. The laser reflection from the target is detected by bomb guiding system and adjusts its flight path by using control flaps. Paveway series bombs is an example of such kind, extensively used in various conflicts around the world [1].

Laser-guided missiles: Similar to laser-guided bombs, the laser is emitted from a targeting pod or a ground-based laser designator. As a result, missile's guidance system detects the laser reflection from the target and flight path is adjusted accordingly. Hellfire missile is laser guided missile, commonly used by the US military in drone strikes.

Laser-guided artillery shells: In laser guided artillery shells, laser is typically emitted from a ground-based laser designator. The shell's guidance system detects the laser reflection from the target and adjusts its flight path. Examples of laser-guided artillery shells include the Excalibur projectile, used by the US military and several other countries.

Dual-mode seeker weapons: These are weapons that have both laser guidance and another guidance system *i.e.*, GPS and radar. Brimstone II and SDB II are dual-mode seeker weapons.

Classification of guidance systems

Siouris classified Laser Guided Weapons in different categories depending upon the mode of operation/guidance (Figure 1) [2].

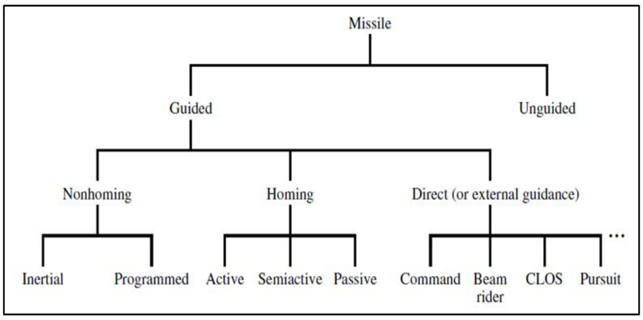

Figure 1: Classification of guidance systems.

Guidance systems in modern weaponry

Semi-active laser guidance: The weapon's seeker receives reflected laser beam from the target which allows the weapon to home in on the laser designated spot. An external laser designator is required to illuminate the target. The AGM-114 Hellfire missile is an example of a laser-guided weapon that uses semi-active laser guidance (Figure 2).

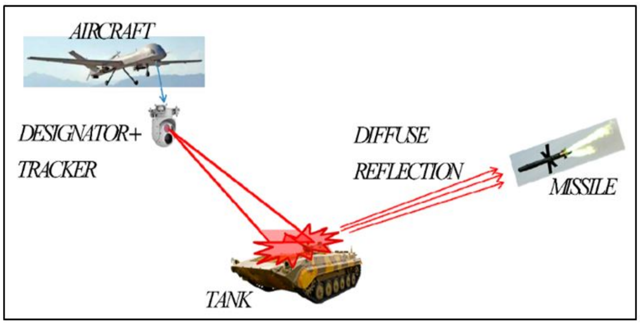

Figure 2: Semi-active laser guidance system.

Inertial guidance: Inertial guidance system relies on two components which are internal accelerometers and gyroscopes to identify the weapon's position and motion relative to the target. This allows the weapon to follow a pre-determined trajectory towards the target. The Joint Direct Attack Munition (JDAM) is based on inertial guidance.

Dual-mode guidance seeker: The weapon's guidance system uses two combinations such as laser and radar or laser and GPS to provide redundancy and improved accuracy. Brimstone missile is an example of a laser-guided weapon that uses dual-mode guidance seeker.

GPS guidance: This system uses signals from GPS satellites to determine the incoming munition position and trajectory. The GBU-54 Laser JDAM is an example of this type.

Comparison of various laser guided weapons

Global security has compared various LGWs being used by contemporary armies in terms of characteristics as Table 1.

Table 1: Comparison of Laser Guided Weapons (LGWs).

Weapon	Type	Guidance system	Max range (km)	Warhead type	Usage	Cost/Unit ($)
GBU 12 Paveway-II	Bomb	Semi-Active Laser	16	Penetrator	Precision Bombing	25,000
SDB II		GPS/Laser	110 (with JDAM)	Various	General Purpose	250,000
GBU-39/B		-do-	110 (with JDAM)	Penetrator	Small Target Strike	250,000
JDAM		Inertial/Laser	28	Various	General Purpose	21,000-40,000
Paveway IV		Dual-Mode	24	Penetrator	Precision Bombing	70,000-100,000
Hellfire	Missile	Semi-Active Laser	8	HEAT	Anti-Armor	110,000
Griffin		-do-	20	HE	Anti-Personnel	200,000-300,000
TOW		-do-	3.75	HEAT	Anti-Armor	30,000
AGM-114R		-do-	8	Thermobaric	Anti-Structure	110,000
Brimstone II		Dual-Mode	20	Penetrator	Anti-Armor	200,000-300,000

Laser guided weapons in conflict setting: Use of laser-guided weapons against combat vehicles in Gulf War 1991 is the earliest example in conflict setting. Afterwards, US military used laser-guided weapons GBU-10 and GBU-12 against Iraqi tanks and other armored vehicles [3]. In 2006, the Israeli military used laser-guided missiles against Hezbollah's armored vehicles during the Lebanon War [4]. Similarly, in 2011, NATO forces used laser-guided bombs to destroy Libyan government tanks during the Libyan Civil War [5].

Limitations associated with LGWs

- Need of a laser designator is one of the main limitations for guidance of munition to its defined target. It is difficult to use laser-guided weapons in situations of limited or poor visibility [6].
- Vulnerability of laser-guided weapons to countermeasures like laser beam jammers/dazzlers or decoys. It can disrupt the guidance system of the weapon and ultimately miss its target [7].
- In response to prevailing limitations, various active and passive defence techniques have been developed to protect combat vehicles against laser-guided weapons. These include the use of vehicle armor, active countermeasures such as jammers and flares and passive countermeasures such as camouflage and concealment [8].

Combat vehicles

Studies have shown that the main combat vehicles are categorized as tanks, Infantry Fighting Vehicles (IFVs) and Armored Personnel Carriers (APCs). According to Hausken and Levitin, a defender can defend its object using two approaches: enacting a preventive strike against the attack and shielding from the incoming hit (Figure 3). Bosse highlighted those designers to focus on four crucial areas in this domain [9].

- Detection avoidance.
- Hit avoidance.
- Penetration avoidance.
- Survivability.

Figure 3: Armored vehicle and Infantry Fighting Vehicle (IFV).

Tanks and armored vehicles have been part and parcel of combat since its inception as the army's primary armament. In current times, tanks and armored vehicles have faced three-dimensional dangers due to augmentation of smart anti-armor weaponry on the ground and in the air. In response to this circumstance, nations have created tanks and armored vehicles with protection as their primary function. On the other hand, merely enhancing sandwich-type reactive armors or thickening traditional armors would not suffice the protection of tanks and armored vehicles, but doing so will reduce their mobility because of additional weight and minimize their capabilities. In this context, active protection technology emerges as a center of recent research in the field of tank protection [10]. Global Firepower compared the approximate inventory on arsenals of Maint Battle Tanks (MBTs), Infantry Fighting Vehicle (IFVs) and Armored Personnel Carriers (APCs) of contemporary armies (Table 2).

Table 2: Comparison of MBTs, IFVs and APCs of contemporary armies.

Country	MBT	IFV	APC	Defence techniques
USA	M1 Abrams (6,333)	Bradley (7,000)	Stryker (4,700)	Active Protection System (APS), smoke screen system, armor protection, active IR suppression, jamming systems
Russia	T-72 (20,000)	BMP-2 (12,000)	BTR-80 (10,000)	
China	Type 99 (600)	ZBD-04 (4,000)	ZBL-09 (2,000)	
UK	Challenger 2 (408)	Warrior (789)	Mastiff (400)	Active Protection System (APS), smoke screen system, armor protection, jamming systems
Germany	Leopard 2 (1,200)	Puma (350)	Boxer (700)	Active Protection System (APS), smoke screen system, armor protection
France	Leclerc (406)	VBCI (630)	VAB (5,300)	Smoke screen system, armor protection
Israel	Merkava (400)	Namer (600)	Achzarit (200)	Active Protection System (APS), smoke screen system, armor protection
South Korea	K2 Black Panther (100)	K21 (500)	K200 (1,300)	Active Protection System (APS), smoke screen system, armor protection, jamming systems
India	Arjun (248)	BMP-2 (3,000)	Casspir (1,200)	Smoke screen system, armor protection
Pakistan	Al-Khalid (300)	Al-Zarrar (400)	M113 (2,000)	

Active Defence System (ADS)

An active protection system or active defence system helps to abate enemy weapons from acquiring or taking down a target. It is categorized as "hard kill" measure and deals in to physically counter an approaching threat, destroying or to significantly reduce its intended effect on the target. “TROPHY” system is a good example which actively detects incoming rounds and fire counter rounds to destroy or prematurely explode the incoming munition (Figure 4).

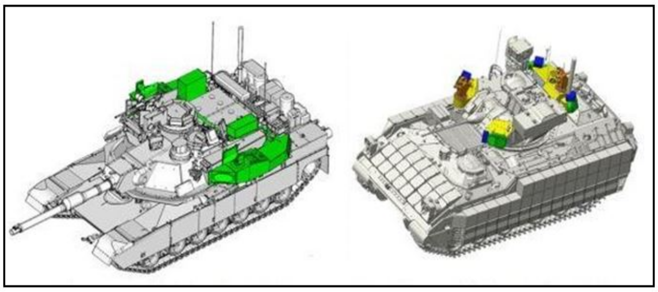

Figure 4: Abram with TROPHY ADS and Bradley (IFV) with Iron Fist ADS.

Components of ADS

Charles, identified the hardware of the Active Defence System (ADS) as (Figure 5).

- Laser warning receivers
- Missile warning sensors

- Protection processor
- IR Jammer and decoy
- AP tracking radar
- AP launcher
- AP countermeasure
- Signature management

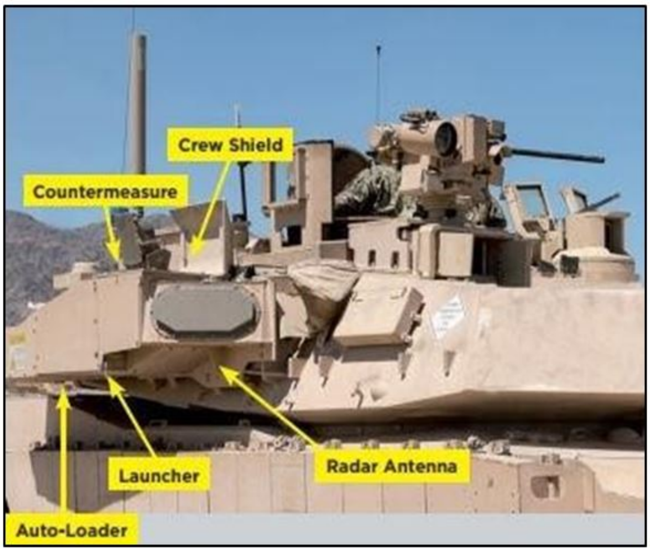

Figure 5: Components of ADS.

Working mechanism

ADS primarily consists of one or more sensors capable of detecting the threat, one computing and data processing device able to identify the threat and initiating countermeasures and one countermeasure device that can eliminate or otherwise incapacitating the threat.

When the incoming munition is detected, it tracks and identify attack direction, speed and other information, which is then transmitted to the control center. Available information is decoded by control center and sends a signal to the transmitter to activate it. If the incoming target is within the interception range, the control center calculates the appropriate launching moment and process it to the launch system, which in return launches the counter ammunition to neutralize the incoming threat. If the counter ammunition hits the incoming target, it explodes and release high-speed fragments which destroys the incoming munition. According to different interception distances, the hard kill system can be divided into close, medium and long-range subsystems (Figure 6).

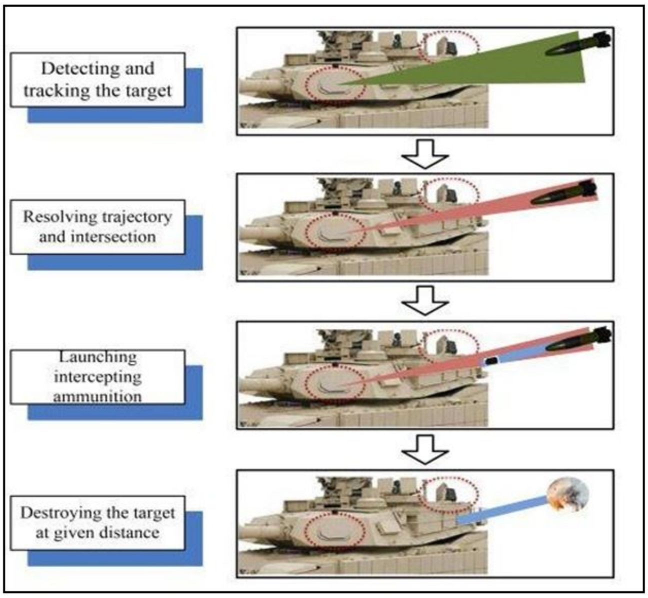

Figure 6: Hard kill mechanism.

Limitations of ADS

Haiping, Ke and Liu Yong, et al., stated multiple threats against active defence system, enumerated as (Figure 7) [11].

- Anti-tank barrel weapons.
- Kinetic energy and shaped charge fired by tank guns.
- Air-to-ground and cruise missiles fired by UAV or armed helicopter.
- Dexterity munitions such as terminal sensitive ammunition.
- High-powered bombs such as mines and IEDs.
- Large-caliber guided or unguided artilleries, including ATGM and RPG.

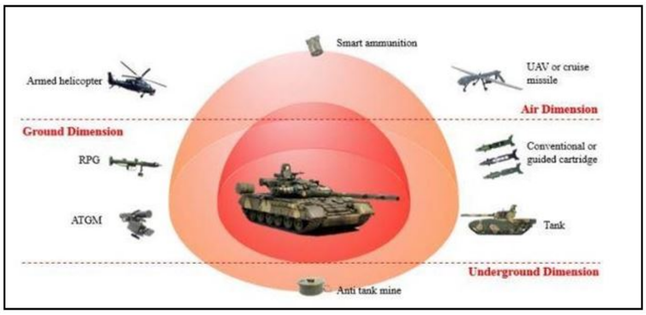

Figure 7: Multidimensional threats faced encountered by ADS.

It is not possible for a single system to effectively defend against the evolving above mentioned threats. Based on the working principle of hard-kill APS and analysis, it has to respond primarily in the ground and semi-air domains, involving Anti-Tank Guided Missile (ATGM), Rocket Propelled Grenade (RPG) or ammunition fired by tank guns and air-to-ground missiles with a specific attack angle, etc. However, the impact of APS on other threats is limited (Figure 8).

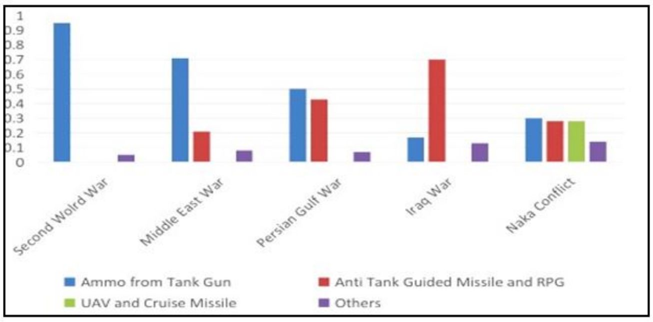

Figure 8: Frequency of anti-tank weapons used in various wars.

Key players of ADS

According to Market Research Future Report (MRFR) "Active protective system market information by platform, type, end-user and region-forecast till 2028," the ADS market is expected to reach USD 4.15 billion between 2020 and 2028. The important key players in this market include:

- Rafael advanced defence systems Ltd-Israel.
- Israel military industries-Israel.
- Raytheon company-USA.
- Artis, LLC-USA.
- KBM-Russia.
- Rheinmetall AG-Germany.
- Safran electronics and defence-France.
- Saab AB-Sweden
- Airbus Group-Netherlands.
- Aselsan A.S-Turkey.

These companies are involved in new product launch, technological and product developments to strengthen their global presence and positions in the active protection system industry. These players are also focusing on entering new markets by introducing innovative and cost-effective infrastructure and platforms. In addition to product launches and innovations, these companies employ agreements and partnership contract strategies.

Passive defence system

Passive defence system is based on adding layers of defence for greater protection e.g., bolt-on armor, attaches to the hull of combat vehicle increases thickness and enhance protection. An opposite charge is fired when bolt-on armor is penetrated. On the other hand, passive armor considerably increases a vehicle's weight, hinder mobility and multiply fuel requirements. Therefore, design engineers are shifting towards hybrid type armor, which can be tailored to provide optimal protection against specific threats. Reactive armor elements can be formed using a variety of materials including steel, composite material combinations with matrices, soft and elastic heat absorbing materials, kinetic energy-absorbing materials such as ceramics as well as depleted-uranium and energetic materials like explosives [12].

Working mechanism

The soft-kill system utilizes tactical means such as interference, camouflage, detection alert and decoy jamming to achieve its own protection. Detection alert is primarily achieved by using laser, infrared or radar detection systems that detect threats and issue alarm signals. The crew deploys plumes of smoke and other measures to deceive the incoming threat. An example of a soft-kill system that uses detection alerts is the Russian "Curtain-I" optoelectronic interference system, which deploys an aerosol smoke screen to protect against semi-active laser-guided missiles and crosshair semi-auto guided missiles (Figure 9).

Figure 9: Shtora-1 system with high beam dazzlers.

Another advancement in battle fighting is Shtora-1 electro-optical jammer system. It comprises four key components: An electro-optical interface station with a jammer, modulator and control panel; forward-firing grenade dischargers capable of deploying an aerosol screen; a laser warning system with precision and coarse heads and a control system with a microprocessor and manual screen-laying panel. Shtora-1 system has a 360-degrees horizontal field of view and an elevation range of -5 to +25 degrees. It contains 12 aerosol screen launchers. The aerosol screen can be formed in less than 3 seconds and lasts for about 20 seconds, with a range of 50-70 m for screen laying.

Types of passive defence armor

Zaloga compared various types of passive defence armors in combat vehicles as (Table 3) [13].

Table 3: Comparison of various passive defence armor.

Type of Armor	Composition	Function	Pros	Cons
Rolled Homogeneous Armor (RHA)	Single and solid piece of steel	Provides all-around protection to vehicle	Simple and reliable	Heavy and less effective against modern anti-tank weaponry

Explosive Reactive Armor (ERA)	Tiles/plates with explosive charges	Detonates when in contact with a projectile	Highly effective against shaped charges and HEAT rounds	Adds weight to the vehicle
		Disrupts penetration		Limited number of activations
Composite Armor	Comprised of layers of different materials (ceramics, metals and plastics)	Absorbs and dissipates the energy of an incoming projectile	Highly effective against kinetic energy penetrators	Can be expensive and heavy
Spaced Armor	Two or more layers of armor separated by a gap	Disrupts and deflects incoming projectiles	Simple and effective	Can be heavy and bulky
Slatted Armor	Series of metal bars or slats	Disrupts and deflects incoming projectiles	Simple and light weight	Lesseffective against modern anti-tank weapons

Research methodology

In consideration of the classified nature of the information, data for this study was sourced from secondary, yet credible, sources including extensive literature review of academic journals, books, conference proceedings as well as reputable defence reports. The design used in this study is exploratory research, suitable for exploring the research questions and providing a detailed description of the techniques used for defence against laser-guided weapons. Said research design was chosen as it allows an in-depth analysis of the existing literature on the subject [14-17].

Data collection

For data collection, an extensive and meticulous search of academic databases was conducted, along with a thorough review of relevant government reports and conference proceedings. The search was conducted using carefully chosen keywords and search terms to ensure relevancy. The inclusion criteria for article selection were limited to peer-reviewed articles and articles published in the English language. Conversely, articles that were deemed irrelevant to the research topic, not peer-reviewed, or not published in English language were excluded from consideration, in order to maintain the integrity and quality of the data collection process [18].

Data analysis

The data collected for this research was analyzed using a thematic analysis approach, which entails a systematic process of identifying, analyzing and reporting patterns within the data. The analysis was conducted in multiple stages to ensure robustness. Initially, the data was screened and filtered based on the pre-defined inclusion and exclusion criteria. Subsequently, the relevant articles were thoroughly read and succinctly summarized. Then, the data was systematically categorized and coded according to the main themes and sub-themes that emerged from the comprehensive literature review. Finally, the data was analyzed and synthesized to discern the key findings and draw well-supported conclusions [19].

Ethical considerations

As this research relied solely on secondary sources for data acquisition, there were no human participants involved and therefore, ethical considerations pertaining to informed consent and participant confidentiality were not applicable in this study.

Limitations

The limitations of this research include the fact that the data was acquired from secondary sources, which may have limitations and biases. In addition, the focus of this research was limited to active and passive defence techniques in combat vehicles against laser-guided weapons and therefore other related topics have not been fully explored.

Validity and reliability

The validity and reliability of the research findings were ensured by using reputable sources of secondary data and by following a systematic approach to data analysis. The use of a thematic analysis approach also helped to ensure the validity and reliability of the research findings by providing a transparent and reproducible method for analyzing the data.

RESULTS AND DISCUSSION

Detailed literature review of articles pertaining to the subject resulted into the comparison of both technologies as follows (Table 4).

Table 4: Comparison of active and passive defence system.

Feature	Active defence system	Passive defence system

Definition	System use countermeasures to actively intercept incoming threats	System use physical barriers or armor to protect against incoming threats.
Examples	Iron Dome	Armor plating.
	TROPHY	Composite materials.
	Strike Shield	Reactive armor.
	THAAD	Camouflage and concealment.
Response Time	Quick response time since it engages the incoming munition proactively	Based on the strength of protective barrier/ armor, which may not be as quick to respond.
Effectiveness	More efficient	Less efficient as compared to ADS.
Vulnerability	Active defence systems can be overwhelmed by large numbers of incoming threats and may not be effective against unexpected threats	Passive defence systems can be defeated by more powerful weapons or clever tactics.
Flexibility	ADS can be programmed to respond specific threats, making it more adaptable to changing environments	Less flexible and cannot be reprogrammed in response to changing threats.
Cost	More expensive due to requirement of advanced technology and the high maintenance cost	Generally, less expensive as it does not require complex technology.

Factors affecting adoption of defence technique

The effectiveness of active and passive defence techniques against laser-guided weapons in combat vehicles depends on various factors and there is no one-size-fits-all answer. Study patterns have revealed that the choice between active and passive defence techniques in this context depends on several factors such as:

Technology and capabilities of the laser-guided weapons

The type, sophistication and capabilities of the laser-guided weapons being used by adversaries can impact the effectiveness of active and passive defence techniques. Active defence techniques may involve the use of countermeasures such as directed energy weapons to disrupt or disable the laser guidance systems of incoming missiles or projectiles. Passive defence techniques may involve the use of physical or technological countermeasures such as armor, shielding or decoys to minimize the impact of laser-guided weapons. The technology and capabilities of the laser-guided weapons being used including their range, accuracy and ability to overcome countermeasures can influence the effectiveness of active and passive defence techniques.

Operational environment and threat scenarios

The operational environment and threat scenarios in which combat vehicles are deployed can also impact the choice between active and passive defence techniques. Factors such as terrain, weather conditions and proximity to hostile areas can influence the feasibility and effectiveness of active and passive defence techniques. For example, in a high-threat environment with multiple laser-guided weapons being employed simultaneously, active defence techniques that involve countermeasures may be more effective in disrupting or disabling incoming threats in real-time. On the other hand, in a lower-threat environment with limited laser-guided weapon threats, passive defence techniques that rely on armor or shielding may be sufficient to minimize the impact of such threats.

Cost and resources

The cost and availability of resources including budget, personnel and technological capabilities can also impact the choice between active and passive defence techniques. Active defence techniques that involve the use of advanced technologies such as directed energy weapons may require higher investments in research, development and operational capabilities. On the other hand, passive defence techniques that rely on armor or shielding may require lower upfront costs but may require ongoing maintenance and upgrades. The availability of resources and the affordability of active or passive defence techniques can influence the decision-making process.

Training and personnel expertise

The training and expertise of personnel operating combat vehicles can also play a role in the effectiveness of active and passive defence techniques. Active defence techniques may require specialized training and skills to operate and manage advanced technologies, while passive defence techniques may require expertise in using armor, shielding or other physical countermeasures effectively. The level of training and expertise of personnel, as well as the availability of skilled operators, can impact the effectiveness of active and passive defence.

Operational objectives and risk tolerance techniques

The operational objectives and risk tolerance of the defending entity or nation can also influence the choice between active and passive defence techniques. Active defence techniques that involve countermeasures may carry risks, such as potential escalation or retaliation from adversaries, while passive defence techniques may focus on minimizing risks by relying on physical or technological countermeasures. The operational objectives, policy preferences and risk tolerance of the defending entity can shape the decision-making process.

It's important to note that the most effective approach may be a combination of active and passive defence techniques, tailored to the specific context and requirements, as part of a comprehensive defence strategy against laser-guided weapons in combat vehicles.

Problems faced by developing nations

The development of active and passive defence systems in developing nations may face various challenges that can result in lagging behind in their development. Some of the key reasons include:

Limited resources: Developing nations often face resource constraints, including financial, technological and human resources, which can hinder the development of active and passive defence systems. Defence technologies can be expensive to develop, procure and maintain. Moreover, it may require specialized knowledge and expertise. Limited funding, technology infrastructure and skilled personnel can impact the pace and scale of defence technology development.

Prioritization of development needs: Developing nations may face pressing needs in areas such as education, healthcare, infrastructure and poverty alleviation taking precedence. This can result in limited investment in defence technologies, as governments may prioritize other areas that are perceived to have more immediate socio-economic impact.

Technology dependence: Technological dependence can pose challenges in terms of access to cutting-edge technologies, technology transfer and in-house development capabilities. Dependence on foreign suppliers may also raise concerns related to national security, export control regulations and geopolitical factors which can impact the development of domestic defence capabilities.

Policy and regulatory constraints: Regulatory challenges related to defence technology development including export controls, intellectual property rights and technology transfer regulations may be crucial for under developing states. These constraints can limit the acquisition and development of defence technologies, as well as collaboration with foreign partners and can pose hurdles in building domestic defence capabilities.

Security and conflict challenges: Conflicts, including regional tensions and geopolitical dynamics can divert resources and attention away from defence technology development. Security threats can also pose risks to defence infrastructure, disrupt research and development activities and impede technology acquisition and knowledge transfer.

Lack of local industrial base: Developing nations may lack a strong local industrial base for defence manufacturing, research and development, which can hamper the development of active and passive defence systems. Building a robust domestic defence industry requires significant investments in infrastructure, technology, and skilled workforce, which may take time to develop.

Ethical and moral concerns: Some developing nations may have ethical and moral concerns related to the development and use of defence technologies, including issues such as the impact on human rights and international humanitarian law. These concerns can influence the pace and scale of defence technology development in these nations.

It's important to note that the challenges faced by developing nations in the development of active and passive defence systems can be complex and multifaceted and may vary depending on the specific context and circumstances of each country. Addressing these challenges often requires a comprehensive approach that takes into account technological, financial policy, regulatory, security and ethical factors. Collaborative efforts, including partnerships with advanced nations and international organizations can also play a role in supporting the development of defence capabilities in developing nations.

Technological backwardness in developing nations

There are several reasons of technological backwardness in the development of active and passive protection systems for combat vehicles in developing countries. It may vary depending on the specific context and circumstances of each country but, some common factors include:

Lack of research and development capabilities: Developing countries may face challenges in establishing robust R and D capabilities in defence technology. Limited funding, inadequate infrastructure and lack of skilled personnel can hinder the ability to conduct cutting-edge research and develop advanced defence technologies.

Limited access to advanced technologies: Restrictions or limitations in accessing advanced technologies due to export controls, sanctions act as barriers. This can result in a lack of access to state-of-the-art components, materials and systems which can impact the development of active and passive protection systems for combat vehicles.

Budget constraints: It can affect the funding available for R and D, procurement and maintenance of active and passive protection systems for combat vehicles, leading to delays or limitations in technological advancement.

Technology transfer restrictions: Technology transfer restrictions imposed by developed countries or Original Equipment Manufacturers (OEMs) can limit the transfer of advanced defence technologies to developing countries. This can hinder the ability to acquire and develop active and passive protection systems for combat vehicles, leading to technological backwardness.

Lack of local defence industry: Limited or nascent defence industries can result in dependence on foreign suppliers for defence technologies, including active and passive protection systems for combat vehicles. This can lead to challenges in technology transfer, customization and adaptation to local needs and operational requirements.

Human capital challenges: Developing nations may face challenges in developing and retaining a skilled workforce in the field of defence technology. Lack of specialized expertise, brain drain and limited opportunities for training and skill development can impact the development of modern systems for combat vehicles.

Operational priorities and strategic focus: Developing countries may face competing priorities in allocating resources for defence, with a focus on other areas such as personnel, equipment or infrastructure. This can result in limited investments in RandD and procurement of advance defence technologies, including active and passive protection systems for combat vehicles.

Geopolitical considerations: Geopolitical factors, including regional tensions, security threats and diplomatic relations can impact the development of active and passive protection systems for combat vehicles in developing countries. Embargoes, sanctions or restrictions imposed by other countries or international organizations can affect the acquisition and development of advanced defence technologies.

Indicators of technological maturity

Comparison table of some common indicators of technological maturity for selected countries in the South Asian subcontinent (Table 5):

Table 5: Comparison of technological maturity.

Indicator	India	Pakistan	Bangladesh	Sri Lanka	Nepal
Defence budget–FY 22/23	$72.6 Bn	$6.24 Bn	$3.85 Bn	$1.58 Bn	$1.34 Bn
R and D expenditure (% of GDP)	0.88	0.74	0.23	0.16	0.52
Patents granted-2022	23,100	1,099	371	244	15
Internet penetration (Population-Mn) in 2023	692	87.35	66.94	21.54	36.9
Gross enrollment ratio in tertiary education (%)–2021	31	14	25	24	15.4
Global innovation index ranking-2023	40	124	116	98	119
Ease of doing business ranking (2020)	63	108	168	99	94

CONCLUSION

In conclusion, the effectiveness of defence techniques may vary depending on various factors such as the type of laser-guided weapon, the sophistication of the enemy's targeting system and the operational environment. The research underscores the need for continuous research and development in this field, as laser-guided weapons continue to evolve.

RECOMMENDATIONS

The development of active and passive protection technologies in developing countries can be improved through various ways:

Research and Development (R and D): Investing in R and D to develop indigenous active and passive protection technologies can be a key way forward for developing countries. This can involve funding research institutions, universities and private companies to conduct research and development in areas such as armor materials, electronic countermeasures and other relevant technologies.

Technology transfer and partnerships: Developing countries can seek technology transfer agreements or partnerships with developed countries or other countries with advanced defence technology capabilities. This can involve collaborations in joint R and D projects, procurement of advanced defence technologies or knowledge sharing to help build indigenous capabilities in active and passive protection systems domain.

Training and skill development: Developing a skilled workforce is crucial for the successful development of active and passive protection technologies. Providing training and skill development opportunities to local engineers, scientists and technicians can enhance their expertise and contribute to the advancement of defence technologies in the country.

Policy and regulatory support: Developing countries can implement favorable policies and regulations to promote the growth of their defence industry and facilitate the development of active and passive protection technologies. This can include measures such as tax incentives, import/export regulations, intellectual property protection and defence procurement policies that prioritize indigenous development.

International co-operation: Engaging in international forums, partnerships and collaborations related to defence technology can provide access to global expertise, knowledge, and resources. This can include participation in international defence exhibitions, forums and collaborations with other countries, international organizations or regional defence alliances to leverage collective capabilities and knowledge.

Capacity building: Developing the capacity of local defence industry and defence research institutions can help foster innovation and technology development. This can involve building infrastructure, labs, testing facilities and other necessary capabilities to support research, development, testing and evaluation of active and passive protection technologies.

Strategic planning: Developing a strategic roadmap and plan for the development of active and passive protection technologies can provide a clear direction and focus for the country's defence industry. This can involve setting specific goals, timelines and resource allocations to drive the development of these technologies in a systematic and organized manner.

Collaboration with industry: Collaborating with the private sector both domestic and foreign can be a valuable way forward. Partnering with defence contractors, technology companies and other stakeholders can help leverage their expertise, resources and capabilities to accelerate the development of active and passive protection technologies.

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