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UNDERSTANDING DIRECTED ENERGY WEAPONS

Aditya Gulati

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About the Author

Aditya Gulati is a postgraduate student at the Jindal School of International Affairs and is a Research Intern at the Centre for Security Studies, JSIA.

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Introduction

Directed Energy Weapons are ranged weapons that use highly concentrated and focused energy, as opposed to a physical projectile, to destroy the targets. Various types of energies can be used like, microwaves, lasers, and beam particles.¹ Unlike conventional weapons that fire missiles or bullets, these weapons can be used to respond to a threat in different ways, like temporarily degrading electronics on a drone or even destroying it.² They can be used for various purposes, like drone defence systems, missile defence, and also to disable enemy electronics.³

The term DEWs is used like an umbrella to encapsulate a number of different technologies. These technologies are currently at different stages of maturity. The three main systems are:⁴

- 1) **Laser-based systems:** Different kinds of lasers exist, such as solid-state, chemical, free electron, and so forth. The primary challenge for laser-based systems is the power requirement. The most developed type of laser currently in use is the chemical laser, although it has several drawbacks, such as the use of dangerous materials. The newest and least advanced technology for use as a weapon is the free electron laser. These weapons' narrow light beams allow them to typically target just one target at a time.
- 2) **Radio-frequency systems:** Both millimeter waves and powerful microwaves are included. Microwaves from powerful weapons have a longer wavelength than millimeter waves and

¹ Yadav, P. (2023, April 3). Explained: What Are Directed Energy Weapons And Hypersonic Weapons. Retrieved from Indiatimes. <https://www.indiatimes.com/explainers/news/explained-what-are-directed-energy-weapons-and-hypersonic-weapons-597340.html>

² Ibid

³ U.S. Government Accountability Office. (2023, May 25). Science & Tech Spotlight: Directed Energy Weapons. Retrieved from GAO. <https://www.gao.gov/products/gao-23-106717>

⁴ Ibid

lasers. These weapons are nearly 150,000 times more powerful than the microwaves used at home.⁵

- 3) **Particle beam systems:** These weapons fire atomic and subatomic particles and emit charged or neutral particles. As a concept, particle beam systems are possible, but their practical use has not been conceptualised yet because achieving the required energy levels and maintaining beam stability over long distances are complex tasks that have not been fully overcome, and also because the equipment needed for particle beam weapons, including power sources and focusing systems, tends to be large and heavy; therefore, shrinking the size and weight of these components without sacrificing performance is a technical challenge that has not been fully addressed.⁶

Historical Use

The earliest use of DEWs as a concept can be traced back to the legend of the destruction of Roman ships using heat waves from the sun by Archimedes.⁷ In 213-212 BC, Syracuse was attacked by the Roman Empire. He made some adjustable-length mirrors and centred them on a single spot to direct solar heatwaves towards the Roman ships, igniting them. In the words of 12th-century Byzantine historian Joannes Zonaras, “At last, in an incredible manner, Archimedes burned up the whole Roman fleet. For by tilting a kind of mirror, he ignited the air from the beam and kindled a great flame, the whole of which he directed at the ships at anchor in the path of fire, until he consumed them all.”⁸

⁵ Ibid.

⁶ Guest, T. (2023, July 27). DEW in the Air. Retrieved from European Security & Defence. <https://euro-sd.com/2023/07/articles/32903/dew-in-the-air/>

⁷ Aviation Week Network. (2015). Directed-Energy Network: No Longer Science Fiction. Retrieved from Aviation Week Network. <https://aviationweek.com/defense-space/directed-energy-weapons-no-longer-science-fiction>

⁸ Aviation Week Network. (2015). Directed-Energy Network: No Longer Science Fiction. Retrieved from Aviation Week Network. <https://aviationweek.com/defense-space/directed-energy-weapons-no-longer-science-fiction>

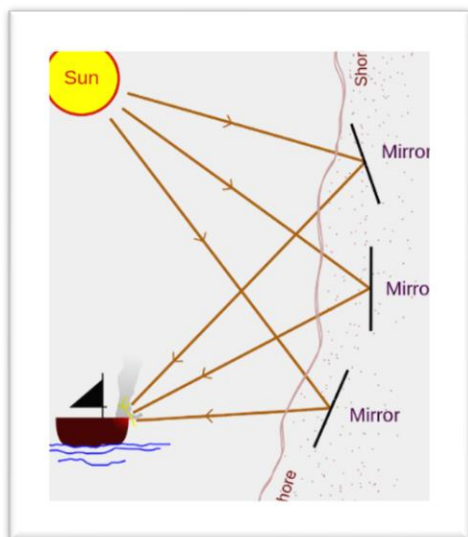


Fig.1⁹

In the 1940s, German engineers created the first known sonic cannon in modern history. This device vibrated the middle ear bones at a distance of 200–400 metres, causing fatal vibrations in the human body that would induce nausea and dizziness. These sound waves have the power to impact organ tissues at distances of 50–200 metres. Later, “Wanderwaffe” (a German term meaning wonder-weapons) was the term assigned to the project of developing superweapons.¹⁰ Nevertheless, the project was not that successful because most of the weapons were never able to be used in combat and only remained as prototypes.

According to CIA reports from the Cold War era, the Soviet Union used laser-based weapons against the Chinese during the Sino-Soviet Conflict of 1969. Henry Kissinger was informed by the CIA that although it has at least 12 reports on the subject, the matter is still up for debate.¹¹ Ronald

⁹ Electronicsforu. (2016, August 12). Directed Energy Weapons : Particle Beam Weapons. Retrieved from Electronicsforu. <https://www.electronicsforu.com/market-verticals/aerospace-defence/directed-energy-weapons-particle-beam>

¹⁰ Imperial War Museums. The Terrifying German ‘Revenge weapons’ of the Second World war. Retrieved from IWM. <https://www.iwm.org.uk/history/the-terrifying-german-revenge-weapons-of-the-second-world-war>

¹¹ Robinson, C. (1970). Soviet Push for Beam Weapons. Retrieved from CIA. <https://www.cia.gov/readingroom/docs/CIA-RDP95B00915R001000510010-7.pdf>

Reagan, the US president at the time, proposed the Strategic Defence Initiative (SDI) in the 1980s. Because a portion of the suggested defence system would be based in space, it was given the moniker Star Wars.¹² ‘The major goal was to stop the USSR's Intercontinental Ballistic Missiles (ICBMs) from attacking the US by intercepting the missiles at different stages before they reached their target. Potentially, the system would consist of laser battle stations stationed in space and on Earth, which would employ various techniques to aim their beams at the missiles as they moved. Radar, infrared, and optical threat detection are the types of sensors that would be used on the ground, in the air, and in space to prevent attacks. Nevertheless, the nature of international politics altered following the fall of the Soviet Union in 1991, and no known weapon utilising this technology was used.’¹³

Advantages and Challenges

Advantages

- 1) DEWs can be added to the military arsenal to complement conventional weapons:** DEWs have the potential to significantly improve the nation's military capabilities and power. They can be fired at the speed of light, i.e., around 300,000 km/s.¹⁴ DEWs, and lasers in particular, have excellent precision and accuracy, low detectability, and low cost per shot.
- 2) Only a power source is required for usage:** Some DEWs can store an endless amount of ammunition and continue to function as long as their power source is present. Logistically,

¹²Augustyn, A. (2023, December 1). Strategic Defense Initiative United States defense system. Retrieved from Britannica. <https://www.britannica.com/topic/Strategic-Defense-Initiative>

¹³ Ibid

¹⁴Yadav, P. (2023, April 3). Explained: What Are Directed Energy Weapons And Hypersonic Weapons. Retrieved from Indiatimes. <https://www.indiatimes.com/explainers/news/explained-what-are-directed-energy-weapons-and-hypersonic-weapons-597340.html>

there would be no need to purchase more weapons because more power would only be needed to operate them.

- 3) **DEWs can be altered according to needs:** By merely adjusting their intensity and range, DEWs can be used appropriately. It can be used for both lethal and non-lethal objectives. For example, the longer a laser weapon is used against a target, the more damage it will sustain.
- 4) **DEWs can be used for other purposes too:** Research and development on DEW can also help advance benefits for civilians. High-energy lasers, for example, can be helpful in projects that use directed energy to deliver power to remote areas.

Challenges

- 1) **High cost of research and development:** The process of developing DEWs is costly. Some DEWs can be extremely expensive to develop, and a cost-benefit analysis could go awry because most of the technology is still in the early stages of development.
- 2) **Technological limitations:** The ranges of most DEWs are constrained. Their ability to destroy their targets quickly wanes as they approach them.
- 3) **DEWs can be easy to countermeasure:** Comparable technologies can be developed to counteract DEWs and thereby lessen their effectiveness, such as reflective techniques or comparable countermeasures. The atmosphere might also have a countereffect on them. For instance, a laser beam's effectiveness can be diminished by dust particles or water vapour.
- 4) **DEWs can be counterproductive on the battlefield:** DEW use has the potential to be counterproductive and harmful to oneself. For example, powerful microwave weapons can damage all adjacent assets if they are not aimed correctly.
- 5) **Health concerns:** There are serious concerns about the short- and long-term health effects of DEWs because they have not yet undergone adequate and transparent testing. Chemical residues might negatively affect the population in the long run. Also, Article 35 of the Geneva

Convention states that “In any armed conflict, the right of the parties to the conflict to choose methods or means or warfare is not unlimited.”¹⁵

International Market

In 2021, according to the report of International Defense, Security, and Technology (IDST), the global market size of directed energy weapons was around \$8.54 billion. Between the period of 2022 to 2029, it is expected to grow from \$9.2 billion to \$17.43 billion.¹⁶

This development is happening because of the worldwide modernisation of high-energy laser technology and advancements in other technologies over a period of time. But the worldwide expenditure allotted by nations was impacted in 2020 and 2021 due to the pandemic. However, it soon recovered and even touched a high, especially after the Russia-Ukraine war.¹⁷

According to the report, one of the key drivers to accelerate the demand for DEWs over the next decade is the urge to defend against terrorist attacks and CBRN (chemical, biological, radiological, and nuclear) threats to protect civilians and national security.¹⁸ The demand for advanced military combat devices, coupled with an increase in the number of geographical conflicts, is driving the DEW market. For instance, according to the International Institute for Strategic Studies (IISS), in

¹⁵ Chaturvedi, S. (2023, July 25). Bringing Directed Energy Weapons within the purview of The Arms Control Regime. Retrieved from NUALS Law Journal. <https://nualslawjournal.com/2023/07/25/bringing-directed-energy-weapons-within-the-purview-of-the-arms-control-regime/>

¹⁶ Uppal, R. (2023, June 9). Directed Energy Weapons Technology And Market Trends. Retrieved from International Defense, Security & Technology (CA, USA). <https://idstch.com/technology/photonics/directed-energy-weapons-market/>

¹⁷ Badgamia, N. (2023, April 19). Pentagon spends \$1 billion every year to develop 'directed energy' weapons. Retrieved from WION. <https://www.wionews.com/world/pentagon-spends-1-billion-every-year-to-develop-directed-energy-weapons-583865>

¹⁸ Chaturvedi, S. (2023, July 25). Bringing Directed Energy Weapons within the purview of The Arms Control Regime. Retrieved from NUALS Law Journal. <https://nualslawjournal.com/2023/07/25/bringing-directed-energy-weapons-within-the-purview-of-the-arms-control-regime/>

2020, defence spending across the globe was estimated to be around \$1830 billion, which is an increase of 4% as compared to 2019 spending.¹⁹

This might be due to the rising geopolitical conflicts, which ultimately push countries to strengthen their defence forces. Several key players in the DEW market include Battelle, Elbit Systems Ltd., Honeywell International Inc., Kord Technologies, Leonardo S.p.A., Lockheed Martin Corporation, Rafael Advanced Defense Systems Ltd., Raytheon Technologies Corporation, The Boeing Company, Kratos Defense & Security Solutions, and MBDA.²⁰

Various defence manufacturers and tech firms are collaborating on the development of new and advanced DEWs and investing in research and development for ground and naval platforms. For example, General Atomics and Boeing entered into a partnership for the development of a new high-energy laser for air defence. Similarly, Lockheed Martin delivered a 60 plus kW high-energy laser to the US Navy.²¹

Such investments in the development of high-energy laser weapons systems and other DEWs are expected to accelerate the growth of the market share.

We can segregate the different types of markets for DEWs based on the following criteria:²²

- 1) By Product:** The market can be divided into two categories: weapons that are lethal and weapons that are not. Among these two, the non-lethal weapons are in greater demand than the

¹⁹ Ibid.

²⁰ Uppal, R. (2023, June 9). Directed Energy Weapons Technology And Market Trends. Retrieved from International Defense, Security & Technology (CA, USA). <https://dstch.com/technology/photonics/directed-energy-weapons-market/>

²¹ Lockheed Martin. (2022, August 11). Inside the Lockheed Martin Laser Technology. Retrieved from Lockheed Martin. <https://www.lockheedmartin.com/en-us/news/features/2022/inside-the-lockheed-martin-laser-technology-that-defeated-a-surrogate-cruise-missile.html>

²² Global Market Estimates. (2021). Directed Energy Weapons Market Size. Retrieved from Global Market Estimates. <https://www.globalmarketestimates.com/market-report/directed-energy-weapons-market-3472>

others.²³ The increased need for non-lethal weapons stems from their capacity to manage tumultuous situations, such as riots, without inflicting substantial casualties. The increase in the demand for and market share of non-lethal weapons has resulted in a rise in military spending in national budgets as well as significant investments in the R&D of DEWs.

- 2) **By Technology:** Based on the different types of technology used in the DEWs, the market can be segmented into high-energy laser, electromagnetic weapons, high-power microwave, and high-particle beam weapons.²⁴ The market for high-energy laser weapons is expanding at the fastest rate among these categories. This is mostly happening because of how easy it is to install and how little power it uses.
- 3) **By Application:** Based on the type of application of DEWs, the market can be divided into military and homeland security.²⁵ When contrasted with homeland security, the military sector is expanding at the fastest rate. This has happened as a result of the introduction of various military-based unmanned aerial vehicles (UAVs) and drones equipped with various DEWs that can target a longer range and facilitate remote operations.
- 4) **By Platform:** According to different types of platforms, the market can be divided into space, land, naval, and airborne.²⁶ The naval platform market is expanding at the fastest rate of all of these. Weapons used in naval applications, such as warships and submarines, are known as naval DEWs.

²³ Ibid

²⁴ Ibid

²⁵ Allied Market Research. (2023, October 20). Directed Energy Weapons Market to Reach \$22.2 Billion, Globally, by 2032 at 16.4% CAGR. Retrieved from CISION PR Newswire. <https://www.prnewswire.com/news-releases/directed-energy-weapons-market-to-reach-22-2-billion-globally-by-2032-at-16-4-cagr-allied-market-research-301962512.html>

²⁶ Ibid

Over the past year, there have been many conflicts worldwide in which it is speculated that there was the deployment of DEWs in the combat forces, like the Syrian War, the conflict between Saudi Arabia and Yemen, the U.S.-Iran conflict, and the Indo-China conflict.²⁷ The Pentagon had suspected DEWs to be used on American soldiers by Russia.²⁸ The increased interest in the use of DEWs in conflicts, lethally or non-lethally, has led to a global surge in their demand and eventually huge investments in their research and development. Similarly, the conflict between Russia and Ukraine had a significant impact on the defence spending of countries worldwide.²⁹

The Russia-Ukraine conflict has led to an increase in global investments and defence spending on directed energy weapons as countries look to defend themselves against various perceived threats. Due to the growing threats posed by missiles, unmanned aerial vehicles, rockets, etc., the deployment of directed energy weapons—which are used to defend against attacks from threats like ballistic missiles, nuclear weapons, etc.—is accelerating. Currently, the majority of countries are trying to integrate counter-UAV laser systems into their armed forces, like Germany, France, and Russia.³⁰

In DEW developments, the US is at the forefront of industry research and development. Additionally, it awarded contracts to firms like Lockheed Martin for the advancement of the

²⁷ Clement, S. (2022, May 12). Directed Energy Weapons: a new look at an ‘old’ technology. Retrieved from UNIDIR. <https://unidir.org/directed-energy-weapons-a-new-look-at-an-old-technology/>

²⁸ Swan, B & Banco, E. (2021, April 22). Pentagon investigated suspected Russian directed-energy attacks on U.S. troops. Retrieved from Politico. <https://www.politico.com/news/2021/04/22/pentagon-russia-attacks-us-troops-484150>

²⁹ Verma, S. (2023, August 28). Russia develops lethal Laser Gun to take on Ukraine’s drone barrage. Retrieved from Firstpost. <https://www.firstpost.com/world/russia-develops-lethal-laser-gun-to-take-on-ukraines-drone-barrage-13046742.html>

³⁰ Office of Naval Research. (2022). Directed Energy Weapons: High Power Microwaves. Office of Naval Research. <https://www.nre.navy.mil/organization/departments/aviation-force-projection-and-integrated-defense/aerospace-science-research-351/directed-energy-weapons-high-power-microwaves>

technology and its integration into the US Navy. Some reports indicate that Iran and Turkey already have DEWs.³¹

Turkey even claimed that it shot down a UAV with its laser weapon, ALKA.³² There is also an arms race in South Asia, in which the leading countries include India, Pakistan, and China.³³

The Need for Trade Regulations

As the international market demand for directed energy weapons is increasing exponentially, a strong case is building up to regulate their movement. Many international companies, like Lockheed Martin, have launched their products, which are currently being used in the U.S. Navy³⁴. The events advance a clear call to nation-states to develop mechanisms to control and regulate the grade of DEWs. The Arms Trade Treaty of 2014 prohibits the transfer of some conventional weapons like certain battle tanks, combat aircraft, warships, etc., but it fails to mention anything about the so-called unconventional weapons like UAVs and DEWs, etc.³⁵ Therefore, to fit the DEWs within the purview, a significant number of changes are required within the treaty.

Similarly, there exist several treaties and agreements that aim to control the usage of highly destructive weapons, like nuclear weapons. The Non-Proliferation Treaty (NPT) prohibits the development of nuclear weapons, though it gives exclusive rights to the permanent members of

³¹ Congressional Research Service. (2023, August 2023) . Department of Defense Directed Energy Weapons: Background and Issues for Congress. Retrieved from Congressional Research Service Report. <https://sgp.fas.org/crs/weapons/R46925.pdf>

³² Office of Naval Research. (2022). Directed Energy Weapons: High Power Microwaves. Office of Naval Research. <https://www.nre.navy.mil/organization/departments/aviation-force-projection-and-integrated-defense/aerospace-science-research-351/directed-energy-weapons-high-power-microwaves>

³³ Ibid

³⁴ Ibid

³⁵ Chaturvedi, S. (2023, July 25). Bringing Directed Energy Weapons within the purview of The Arms Control Regime. Retrieved from NUALS Law Journal. <https://nualslawjournal.com/2023/07/25/bringing-directed-energy-weapons-within-the-purview-of-the-arms-control-regime/>

the Security Council.³⁶ Similarly, the Intermediate-Range Nuclear Forces Treaty aims at the reduction of different kinds of weapons, like ballistic missiles, cruise missiles, intermediate missiles, etc., but these treaties don't leave any scope to bring DEWs within their ambit.³⁷

There exists a possibility to include DEWs within the Missile Technology Control Regime (MTCR).³⁸ This is because MTCR includes a wide range of weapons, like nuclear weapons, chemical weapons, and biological weapons.³⁹ It also grew to encompass unmanned aerial vehicles (UAVs) equipped with cruise missile systems. The contentious issue, however, is that for anything to fall under the purview of the MTCR, it must be demonstrated that the weapon has the capacity to cause mass destruction. This requirement does not apply to DEWs, as it has not yet been demonstrated that they are capable of causing such massive amounts of destruction.

India and DEWs

In April 2023, India's Chief Air Marshall emphasised the need to develop Directed Energy and Hypersonic Weapons and to integrate them into airborne platforms to achieve the desired range⁴⁰. The technology could enhance India's military and defence capabilities and act as a deterrent against regional hostilities like China and Pakistan. Several other countries, like the USA, France, Russia, China, Germany, the UK, and Israel, are also developing DEWs, and some countries already claim to have them in their military arsenal.⁴¹

³⁶ Freedman, L. (2023, November 16). Treaty on the Non-Proliferation of Nuclear Weapons. Retrieved from Britannica. <https://www.britannica.com/event/Treaty-on-the-Non-proliferation-of-Nuclear-Weapons>

³⁷ Thompson, K. (2023, December 3). Arms Control. Retrieved from Britannica. <https://www.britannica.com/topic/arms-control>

³⁸ Ibid

³⁹ Ibid

⁴⁰ Yadav, P. (2023, April 3). Explained: What Are Directed Energy Weapons And Hypersonic Weapons. Retrieved from Indiatimes. <https://www.indiatimes.com/explainers/news/explained-what-are-directed-energy-weapons-and-hypersonic-weapons-597340.html>

⁴¹ Banerjee, A. (2022, July 7). India's DURGA II In A Growing Directed Energy Weapons Market. Retrieved from Indian Aerospace and Defence Bulletin. <https://www.iadb.in/2022/07/07/indias-durga-ii-in-a-growing-directed-energy-weapons-market/>

The primary players in the research and development of DEWs in India are the Defence Research and Development Organisation (DRDO) and the Centre for High Energy Systems and Sciences (CHESS). Other entities, like the Bhabha Atomic Research Centre (BARC), the Army Design Bureau (ADB), and the National Security Council Secretariat (NSCS), are also involved in various DEWs programmes⁴².

The DRDO oversees the defence laboratory known as the Centre for High Energy Systems and Sciences (CHESS). It is situated in Telangana's Hyderabad. Its goal is to carry out high-energy laser systems research. India has been utilising the DEWs for experimentation in an effort to update its defence technology. The nation's defence system already uses the innovations made possible by CHESS. According to some reports, DRDO has a tie-up with the Bengaluru-based Bharat Electronics Limited (BEL) for the mass production of these systems, as it is only a research and development organisation.⁴³ Scientists at CHESS claim that it is necessary for India to work on the development of these weapons due to our increasing adversaries.⁴⁴ Hence, in order to give India strategic and operational superiority, CHESS is working on both the hard kill and the soft kill of these systems.

For the development of DEWs in India, there are various classified programmes like Kilo Ampere Linear Injector (KALI) and Directionally Unrestricted Ray-Gun Array (DURGA).⁴⁵ India began working on DEW development in 1996, first with the Laser Science and Technology Centre (LASTEC) in Delhi. The Doklam standoff with China in 2018 gave the ongoing research into DURGA II more impetus. While much of the information is classified, there are some sources that

⁴² Baruah, S. (2023, July 23). What are India's top-secret Directed Energy Weapons?. Retrieved from THE WEEK. <https://www.theweek.in/theweek/current/2023/07/21/what-are-indias-top-secret-directed-energy-weapons.html>

⁴³ Ibid

⁴⁴ IANS. (2022, September 11). DRDO's Centre for High Energy Laser Systems on a mission to modernize defence technology of the nation. Retrieved from ETGovernment.com.

⁴⁵ Baruah, S. (2023, July 23). What are India's top-secret Directed Energy Weapons?. Retrieved from THE WEEK. <https://www.theweek.in/theweek/current/2023/07/21/what-are-indias-top-secret-directed-energy-weapons.html>

indicate that it would be a 100-kilowatt lightweight DEW. The Indian Defence Ministry has also claimed that the Indian Army will soon receive the DURGA II.⁴⁶

Also, the technology will be integrated with sea, air, and land platforms. The project goes as far back as the early 2000s; however, minimal progress was made in the initial time frame.⁴⁷ There wasn't much work done on the project in the 2000s. It gained momentum in 2017 when DRDO tested a 1Kw truck-mounted laser weapon,⁴⁸ Following that, the work of LASTEC was progressively split between CHESS and Chandigarh's Terminal Ballistics Research Laboratory (TBRL).

The work on the DEWs further gained momentum after the Sino-Indian border standoff of 2020, when China made claims that it had used microwave weapons to force Indian soldiers off the contested peak in eastern Ladakh.⁴⁹ Despite India's denial of the claim as part of China's propaganda campaign, scientists continued to work on the laser-based DEWs. Later, the Indian Defence Ministry announced that the Navy was procuring the first indigenously developed anti-drone system that can detect, jam microdrones and use laser-based technology to attack targets.⁵⁰

The decision to select 18 key platforms for industry-led design and development was then made public in 2022. DEWs, powerful electromagnetic devices, and powerful laser devices were among them.

⁴⁶ Indian Defence News. (2020, October 26). Aditya Project: DRDO's Directed Energy Weapon (DEW) Program. Retrieved from Indian Defence News. [https://www.indiandefensenews.in/2020/10/aditya-project-drdo-directed-energy.html#:~:text=Weapon%20\(DEW\)%20Program-.Aditya%20Project%3A%20DRDO's%20Directed%20Energy%20Weapon%20\(DEW\)%20Program.of%20Star%20Wars%2Dlike%20weapons.](https://www.indiandefensenews.in/2020/10/aditya-project-drdo-directed-energy.html#:~:text=Weapon%20(DEW)%20Program-.Aditya%20Project%3A%20DRDO's%20Directed%20Energy%20Weapon%20(DEW)%20Program.of%20Star%20Wars%2Dlike%20weapons.)

⁴⁷ Malik, A. (2012). High Power Lasers-Directed Energy Weapons. Retrieved from DRDO. <https://www.drdo.gov.in/sites/default/files/monographs-documents/28-highpower-lasers.pdf>

⁴⁸ Baruah, S. (2023, July 23). What are India's top-secret Directed Energy Weapons?. Retrieved from THE WEEK. <https://www.theweek.in/theweek/current/2023/07/21/what-are-indias-top-secret-directed-energy-weapons.html>

⁴⁹ Ibid

⁵⁰ Ibid

Conclusion

To sum up, this study has examined the various aspects of Directed Energy Weapons (DEWs), including their creation, use, and possible influence on contemporary warfare. The analysis has elucidated the advantages of DEWs, such as their speed of light delivery, precision targeting, and potential for cost-effectiveness in comparison to traditional kinetic weaponry. However, it is crucial to acknowledge the ethical and legal considerations surrounding the use of DEWs, particularly in terms of collateral damage, unintended consequences, and adherence to international laws governing armed conflict.

Furthermore, the evolving nature of DEWs raises concerns about arms races, strategic stability, and the need for robust governance frameworks to prevent misuse. International cooperation and diplomatic efforts are essential to establishing norms and regulations that govern the development and deployment of these advanced technologies.

Looking ahead, it is imperative to continue research into the potential long-term effects of DEWs, both from a technical and strategic perspective. This includes exploring countermeasures, assessing vulnerabilities, and understanding the broader geopolitical implications of widespread DEW deployment.

India's entry into the world of directed energy weapons marks an important step in strengthening its defence capabilities and keeping up with cutting-edge military technology. The nation is committed to using directed energy for both offensive and defensive objectives, as evidenced by its concentration on creating anti-drone laser systems, high-intensity lasers, electromagnetic railguns, and space-based capabilities.

Due to their accuracy and affordability, directed energy weapons have promise, but their successful development and deployment require difficult technological obstacles and extensive testing. India's efforts in this area show its dedication to updating its defence systems and adjusting to changing security challenges.

In conclusion, while Directed Energy Weapons offer unprecedented capabilities, their integration into military arsenals requires careful consideration of ethical, legal, and strategic implications. As the global security landscape continues to evolve, ongoing research and international collaboration are crucial to ensuring the responsible and effective use of Directed Energy Weapons in the pursuit of peace and security.

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