WEAPONIZING ENERGY:

ANTHROPOLOGICAL APPROACH TO FUTURE OF WAR

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YEDITEPE UNIVERSITY

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ABSTRACT

This thesis intends to offer an explanation to the evolution of war along technological developments mainly focusing in laser systems. The anthropological discussion of the study is based on Actor-Network Theory revealing the interaction among human and non-human participants of war network. Laser weapon systems are explained supported by ethnographic fieldwork and literature research. The study seeks to demonstrate an alternative future perception of war with the integration of laser systems.

The redefined character of war can be described as laser-integrated flexible network with human actors and non-human actants on a whole engagement spectrum, across all domains and all phases of conflicts with tactical and strategic implications on battlespace. While human actors are still the main decision-makers in war network, human wisdom is critically important more than ever.

Keywords: War anthropology; actor-network theory; laser weapon systems; future war

ÖZET

Bu tez, lazer sistemler üzerinden savaşın teknolojik gelişmeler etkisinde değişim ve dönüşümüne bir açıklama getirmeyi amaçlamaktadır. Çalışmanın antropolojik tartışması, savaş ağındaki insan ve insandışı öğelerin ilişkilerini açığa çıkaran Aktör-Ağ Teorisi'ne dayanır. Lazer sistemler, etnoğrafik saha çalışması ve literatür araştırması ışığında tanıtılmıştır. Araştırma, lazer sistemlerin entegrasyonuyla geleceğin savaş tanımına farklı bir bakış açısı getirmeye çalışmaktadır.

Lazerin entegre edilmesiyle, yeni karakteriyle savaş, tüm askeri angajman imkanlarına sahip, tüm çatışma alan ve aşamalarında taktik ve stratejik etkiler oluşturabilecek, insan ve insandışı faillerden oluşan esnek bir ağ şeklinde tarif edilebilir. Savaş ağında insan failler halen merkezi karar alıcı konumundayken, insan bilgeliği her zamankinden daha kritik öneme sahiptir.

Anahtar kelimeler: Savaş antropolojisi; aktör-ağ teorisi; lazer silah sistemleri; gelecekte savaş

To Nur, the Light...

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1. INTRODUCTION TO LASER, AND ITS BACKGROUND

1.1. Introduction

In his conspicuous article "Energy and the Evolution of Culture," anthropologist, Leslie A. White (1943), claims cultural evolution has been fostered by the products human beings have produced with the tools they have invented using the energy harnessed from various sources. Along a range of phenomena that defines, and is defined by culture, he refers to wars as well, however in a negative sense, attributing an undermining role to tools of war for the prospect of cultural evolution. War can be considered a multi-faceted socio-technological phenomenon where human quest for progress, and capability of violence manifest themselves as social and cultural aspects of conflict management. Human, tool, and energy interrelation envisioned by White is the dynamic core of warfare. In alignment with cultural evolution and socio-technological developments, character of war has gone through incessant change throughout history. Complexity of war concept has aroused insatiable curiosity which made it subject of inquiry for psychology, anthropology, sociology, war studies, international relations, in addition to various other transdisciplinary areas. White's insight kindled the inspiration for this study which humbly aims to propose an alternative explanation for evolution of war from an anthropological perspective.

Social and technological changes in warfare support war evolution in a correlated way. The way humans fight changes over time with the progress in technological developments. With respect to energy usage, the first violence among humans might have probably started with punching or throwing stones with kinetic energy impetus. Whether it be human physical energy or chemical energy of gunpowder or any type of explosive substance, the input energy is converted into kinetic energy in order to exert lethality upon target. There is another option to warfare which can be considered a breakthrough in weapon technology, and that is directed energy weapons (DEW) based on electromagnetic (EM) energy principles. DEW typically use the electrical energy to produce EM radiation, and deliver it onto target as a beam, thereby having weaponized the energy. Among a variety of directed energy systems, laser is foregrounded with respect to its relative feasibility and effectiveness for military. Laser is an abbreviation for light amplification for stimulated emission of radiation which mainly describes the beam of concentrated

EM radiation. For the purposes of being concise, this study focuses only on lasers, and its prospective influence on the changing character of war.

The main research question of this study is how laser systems may modify the character of war? What advantages would the military expect from laser weapons on the battlefield? How would the soldiers and developers of the technology perceive the weaknesses of laser systems where they cannot respond threats, and thereby inducing vulnerability in conflict? What are the challenges that may affect the efficiency and effectiveness of laser posing a hindrance in their integration into armed forces network? How would engineers and military assess laser weapons' current and future capabilities? What changes can laser weapons bring to the battleground? The answers for these questions are tried to be unveiled throughout this thesis which is far from comprehensive.

In the thesis, in order to reach an in-depth understanding of the subject of lasers, the symbols in distinct cultures evocative of laser beams are explored followed by science-fiction works of art. Subsequently, scientific and engineering quest in developing laser technology is investigated. The evaluation is supported by interpreting the distinction between object and energy as non-human instruments of war in terms of the senses they stimulate on the battlefield. The wielding of laser as weapon is discussed with its advantages and challenges. Consequently, an interpretation for the future of war associated with laser systems is tried to be revealed focusing on the role of weaponized energy.

War is a fortune that has a lot to offer for social science researches from human-focused notions to science and technology oriented social concepts. With the scope of energy utilization in combat, this study aims to understand the evolution of war with respect to human and non-human interaction; human denoting the military personnel who wields weapons which can be referred to as non-human participants of war. This interaction is discussed based on the collaboration of science, technology, and engineering for the purposes of military accomplishments. The research is conducted with an anthropological approach stemming from Science and Technology Studies (STS) groundworks. The objective is to offer an insight to the changing character of war with respect to information from literature, and opinions and comments of experts about laser weapons.

The inquiry into the relation between the social and the technology has enhanced framing of STS with flexible boundaries offering an understanding of socio-

technological phenomena over a wide range of disciplines. This thesis aims to bring an alternative explanation to the evolution of war from an STS point of view scrutinizing the mutual interaction between human and technology constituents of war. Development of certain technologies and artifacts is one of focus areas that STS elaborate. DEW, in particular laser systems, which is the subject matter of this study are products of high-technology materialized by arms industry in recent decades. The study can be considered a contribution to social evaluation of military technology which is a "*terra incognita"* (Meijers, 2009, p. 11) that needs to be investigated in order to reach a comprehension of dynamic coalescence of human, non-human entities of war. In this study, actor-network theory (ANT) is used to inquire into the tensions, and the mutual reinforcements of soldiers, and arms within war network together with engineers who contend with military technology.

Current war waging involves conventional use of kinetic energy weapons with the aim of accomplishing military objectives utilizing the destructive power of projectiles. This thesis is an attempt to propose an insight into the implications of laser systems in the future warfare based on ethnographic methodology where engineers and retired military personnel were sources of information as well as visits to fairs, exhibitions, and seminars in addition to literature search. The aim of this study, given all the restrictions associated with the subject, is to be a thought-provoking example of how contemporary anthropology may offer an explanation for the role of weaponized energy in the changing character of war.

1.2. Methodology

Putting laser weapon and the associated technology's future implications for war at the center of an anthropological study was an audacious task. Significance of social impact of technology made this study compelling, and induced the motivation to confront the challenge of appraising a high-end technology with an anthropological perspective. Literature search and in-depth interviews with experts were fundamental sources of information for the research as well as fieldwork of visiting exhibitions and relevant organizations.

War phenomenon has ever since attracted attention of philosophers and scholars from various fields. Human predisposition to war is an ongoing debate among social scientists, especially anthropologists. Anthropologist R. Brian Ferguson

(1995; 2023) is a contemporary anthropologist who tries to give an explanation to this question with reference to primate behavior, and studying indigenous people. Archaeologist Lawrence H. Keeley (1996) lays out a comparison of violence between prehistoric and modern warfare. Anthropologists' ethnographic accounts from frontlines is revealed in the book edited by Alisse Waterson (2009). The book edited by Koen Stroeken (2012) is a compilation of anthropologists' perceptions of the relationship between technology, war, and people. The works mentioned here are by no means exhaustive.

Throughout history till modern times influential names tried to interpret war, from Thucydides[1] to John Keegan[2] from Niccolo Machiavelli[3] to Kenneth Waltz[4]. Substantial amount of work has been written about war and violence. Theories of war have been conceptualized in order to understand and wage war accordingly. Chinese Sun Tzu's reputed work *The Art of War* (Sun Tzu, trans. Griffith, 1963) from distant past, Prussian Carl von Clausewitz's *On War* (Handel, 1991), and Baron de Jomini's book *The Art of War* (Jomini, trans. Mendell & Craighill, 2008) are pioneering conceptualizations of war strategies, and have been referred in almost all intellectual works on war. Subsequently, many texts and books have been compiled about war theories. It is also possible to reach literature that examines distinctions in warfares, and the evolution of war with respect to social and technological changes. The modern perspective of war evolution is scrutinized by social sciences especially, sociology, political science, and international relations. War studies which can be considered as a subdiscipline of international relations is mainly concerned with war and its related notions. There are conceptualizations and empirical accounts of war technology focusing in weapons, platforms, armaments, and constructions. Detailed discussions are developed about the progress, for example, the transformation of projectiles from bow-and-arrow to assault rifles or larger platforms from catapults to artillery. The evolution of fortifications as an example for military constructions is layed out. Personnel armor and platform armaments are thoroughly examined. Cold war era produced a huge amount of written work on nuclear arsenal. However, being a new technology, directed energy weapons has not been subject of investigation of

[1] Ancient Greek historian Thucydides is well known for his narration of *History of the Peloponnesian War* (Sahlins, 2004).
[2] *The Face of Battle* is one of seminal works of military historian, John Keegan (1983).
[3] *The Prince* is a classical work of Niccolo Machiavelli on political philosophy (Oktay, 2014).
[4] Political scientist, Kenneth Waltz, offered an explanation to war in his major book *Man, the State, and War* (2001).

war technology from social science point of view. This study aims to raise questions about evolution of war with respect to a technology that is considered both emerging and mature enough for battleground. Hopefully, as an intellectual practice it will be a contribution to social sciences literature.

Investigation of laser systems' influence on war evolution from an anthropological perspective required information from both physical sciences and humanities. In order to build the groundwork for the study, scientific, and technological material had to be reviewed due to highly technological aspect of laser. A thorough literature search was conducted in war studies, and science and technology studies along with relevant anthropological material. However, scientific and technological information together with the recent news regarding the development of laser systems could only be obtained from American sources. Laser is a highly advanced technology with American defence industry pioneering in this area. Russia, China, and UK are also active players in this technology (Office of the U.S. Secretary of Defense's Directed Energy Community of Interest, 2021), however, since American institutions are more transparent with their research and development accomplishments, almost all the materials for this study bare American origin.

American institutions not only have proceeded with the science and technology of laser but also introduced pseudo-science and science-fiction works involving energy weapons. Imagination of creative minds in the United States have served for the pop culture with beams, rays, laser depictions, and so forth. The materials of print, audio, and visual media were readily made available to induce further inspiration in the research and development of this then-futuristic technology.

Although many cultures have narratives of light, thunderstruck, and other energy related phenomena in their myths, legends and tales, only English translations of the related materials from American publishers were used in this study due to language barrier.

Literature search was conducted via printed material, in addition to digital written, audio, and visual sources regarding science and technology studies, and defense industry. Anthropology literature was searched in order to find relevant theories for explanation of technology advent and its implications. Additionally, STS sources related to various disciplines were overviewed. However, compared to machine or cyber-based technology, it was not easy to find material about energy. It was observed that electromagnetic energy, which is the source and the driver of

human life, has not been studied sufficiently by social scientists. This was a revelation that the energy imbedded in human life has been probably overlooked by social sciences. However, EM energy has a vital importance for modern life from medical diagnosis techniques to wireless communication and navigation, not to mention microwave ovens and TV remote controls in our houses. Philosophy being relatively more competent in contending with abstract phenomena, literature of philosophy offered the most numerous sources regarding energy relevant to this study. Theories and unstructured approaches to war evolution were seeked in the related literature. News, articles, and advertisements of recent laser weapon systems on online news platforms had to be closely followed in order to trace the recent developments. Due to the dynamic nature of technology developments, local and foreign social media accounts related to arms industry were followed not to miss news and comments regarding recent progress.

The topic of the study posed various limitations. The main drawback was restrictions in access to information due to the confidentiality in defense technology. Governments maintain secrecy in research and developments, and in production processes of arms industry, and take necessary measures against technology know-how leak. Therefore, in many countries both state and private sector companies may not cooperate with academic researchers. This approach is most prominent with developing technologies. Laser is no exception for this, and even has further implications based on the tacit concealment of the ongoing projects. Since this research is carried out in Turkey, information was pursued within boundaries of the country. In seeking empirical accounts of experience of the sector, it was challenging to reach local arms industry companies that work on laser technology. However, representatives from two companies accepted to contribute by sharing their experience and comments.

Trade shows, exhibitions, and fairs served as a diverse arena for field research providing opportunities to reach informants, and be able to observe the outputs of laser technology first-hand even though limited number of products were displayed. The first fieldwork was conducted in IDEF '21, 15th International Defense Industry Fair on August 17-20, 2021 at Tuyap Fair Convention and Congress Center in Istanbul where leading Turkish government and private defense companies showcased their products, and offered services, together with various international firms and officials both promoting their products and considering contract options

(IDEF' 23, n. d.). SAHA EXPO 2022 Defense & Aerospace Exhibition was held in Istanbul Expo Center on 25-28 October 2022 (SAHA EXPO,n. d.) serving as an international platform supporting exhibition of especially high-tech products with strategic significance. In both of these exhibitions, visiting the stands, and getting into conversations with the engineers especially the ones knowledgeable about lasers proved to be valuable in gaining an overview regarding the technology and its future. SAVTEK 2022, 10th Defense Technologies Congress, which was held on 13-15 September 2022 at ODTU Kültür Kongre Merkezi in Ankara offered an opportunity to meet representatives and engineers from the defense companies that work on laser technology. This was an organization that brought universities and engineers from the defense industry that offered a platform to discuss the academic papers based on R&D studies in defense technologies (SAVTEK 2022, n. d.). Seminars held in these exhibitions and congress also contributed to the information set of this study.

One of the major caveats of the research was that since laser technology is a recently matured advanced technology with distinct specifications in contrast to conventional military technology, it is unfamiliar to both engineers and military personnel majority except for the specialists of this area particularly. In order to unfold first word of mouth accounts from distinct perspectives in Turkey, knowledgeable informants representing technology and military were contacted as interviewees in the fieldwork. In-depth interviews were conducted with engineers from defense industry. Since these systems have not been actively used in conflict zones, and even in military drills, so far there is no acknowledged experience associated with these weapon systems that the military staff can share. Moreover, there would be constraints in meeting with military personnel at active duty due to armed forces' privacy policy. Hence, retired military personnel with technical backgrounds who are still active followers of military technology were contacted to benefit from their knowledge and perceptions. Similar to military industries of global players in this technology, a few companies work on development of laser weapon systems in Turkey. Three engineers from two leading defense companies were interviewed. Another engineer from a company pioneering in laser technology provided valuable information about the technical details of the technology, and laid out a general evaluation of the role of lasers as war tools. An engineer who works as an advisor in defense sector discussed the prospective effects of laser systems in the changing character of war. An investigative journalist, who follows developments in

arms industry closely, commented on the lasers as substitutes for missiles. A retired officer who had been involved with a laser weapon project at active duty explained his opinions regarding the subject. Two retired officers shared their notes related to the significance of laser systems in armed forces. The identities of informants are kept confidential; their remarks are included in the text with reference to their professions. In addition to these in-depth interviews where insightful information was solicited, additional interviews were conducted at exhibitions and the congress with knowledgeable professionals from the sector.

Due to the technological context of the topic, the narrative of this thesis may sound relatively technical compared to typical works of humanities. Optimum consideration was shown in order to keep the technical and military terminology within tolerable limits of social discourse. For convenience, specific terms are explained in the footnotes.

1.3. Laser Weapon: Product of Science-based Military Technology

Since there is an ongoing refining effort for laser technology to improve capabilities, it is usually discussed in association with its science background. It would be wise to seek the root of Science and Technology Studies in nature because understanding nature and natural processes is key to defining "science" (Montgomery & Kumar, 2018). The resulting accumulated knowledge, that is science, has been processed through "a goal-based effort" in order to improve living conditions of human beings via building dwellings or producing food, clothing, tools including weapons (Montgomery & Kumar, 2018). In fact, military requirements are considered to be significantly effective on the progress of science and technology. While science, can be considered as "knowledge performing special social functions" (Funtowicz & Vetz, 1990, p.2), implementation of knowledge can be defined as "applied science." Applied science with human purposes and social goals (Montgomery & Kumar, 2018) becomes what is called "technology." The origin of the word is the Greek word τέχνη which means art, craft or skill associated with knowledge (Mitcham, 1994). According to accounts of Plato, τέχνη is defined in terms of gauging the amount of physical work being intense as in paintings or sculptures, or minimal as in arithmetic, logic, astronomy (Meijers, 2009, p. 3).

Contemporary definition for technology can be stated as follows:

> "Technology in its broad meaning connotes the practical arts. These arts range from hunting, fishing, gathering, agriculture, animal husbandry, and mining through manufacturing, construction, transportation, provision of food, power, heat, light, etc., to means of communication, medicine, and military technology. Technologies are bodies of skills, knowledge, and procedures for making, using and doing useful things. They are techniques, means for accomplishing recognized purposes." (Merrill, 1968, p. 576-589)

Power, heat, and light elements in the above mentioned definition are relevant to laser technology which is under ongoing exploitation by engineers with the objective of generating a more effective beam in a more efficient method. From another point of view, technology is "a (type of) artifactual, functional system with a certain degree of stability, and reproducibility" (Radder, 2009, p. 887); whereas engineering is "the art of organizing and negotiating the design, production, operation and decommissioning of artifacts, devices, systems and processes that fullfil useful functions by transforming the world to solve recognized problems" (Nightingale, 2009, p. 352). In other words, engineering invents technology, and utilizes it for sustainability. In the late Middle Ages, in Europe military technology was of central consideration in the industrial production, so the word engineering was linked to making and operating military hardware. In the 17th century, "civil engineering" was involved with non-military applications, such as roads, and bridges (Meijers, 2009, p. 3). If the main purpose of engineering is presumed to serve people as mentioned in Webster's Third New International Directory, its task is to utilize science and mathematics in order to make "matter and the sources of energy" (Gove, 2002). Theaters[5] of wars are areas where matter and energy exist concomitantly as products of military technology. As will be mentioned in the subsequent sections, laser technology by itself incorporates both matter and energy by the transmit of energy through medium of matter to be amplified in order to produce a desired coherent beam.

1.4. Earliest Laser Concept in Mythology, and History

Since science is presumably stems from observation of nature, and curiosity about natural processes, it would be worthwhile to look into nature seeking for

[5] "Theater of war" is a military term, defined as "an area in which operations are being carried out" according to Dictionary of Military Terms (Bowyer, 2007, p. 244).

something similar to laser. The natural incident that most resembles laser is lightning.

Lightning must have been one of the most intriguing, and at the same time horrifying weather event for humans with its frightening cosmic flash and cracking noise as if the sky is going to rip apart. As much as it seems catastrophic, its deployed energy inspired some scientists to link it to the initiation of life on earth. A series of experiments are conducted in laboratories trying to imitate primitive conditions of earth, and create an electrical spark, miniature of a ligtning if you will (Miller & Urey, 1959). Hypotheses on beginning of life remaining unresolved, people's interest in lightning can be traced back to the ancient myths and legends. Premordial societies imagined the lightning as the weapon of their major deities. It is no wonder that they weaponize their greatest gods and goddesses with the most fascinating and destructive weather event that demonstrates the omnipotent power. In Greek mythology lightning bolt is the weapon and divine symbol of king of gods, Zeus. In Norse mythology, Thor, the son of god King Odin, tosses his hammer, Mjöllnir, against demonic enemies, flashing lightning bolts around. In Hindu, the lightning was seen as the spear of Indra, king of all the deities. In Japan, Shinto god Raijin is the god of lightning. Similarly, in Slavic, Baltic, and Finnish mythologies lightning was associated with their great gods. For African Bantu tribes, lightning was a sign of the ire of the gods. Navajo Indians used to believe that lightning had a curing effect.

Historical accounts record that lightning was deployed at battlefield like a precedent for lasers. After being weaponized in primitive cultures' imaginations, the lightning in its natural way acted as an unintentional belligerent of wars with no discrimination of enemy. It is said that in Napoleonic Wars more than 150 British ships were damaged by lightning (*The Times*, January 5, 2016). Fatalities from lightnings were noted in diaries and journals of the American Civil War (Sheehan, 2016). Deaths and injuries due to lightnings were also reported in the Second Boer War (BBC, 2010). Metal weapons and equipment such as muskets, swords, bayonets, and helmets are considered to be the main culprit attracting lightning bolts during wars (rodells.uk., March 4, 2019).

In addition to lightning, sun is another generous source of natural energy. As the legend goes, the Greek sage Archimedes is the first person to think of utilizing the sunlight for military purposes during the Siege of Syracuse (c. 214-212 BC) against the Roman naval assault. The Siege of Syracuse was just one of the battles that took place during the Second Punic War (218-202 BC). It is said that a series of hexagonal

mirrors or bronze shields were used to focus sunlight beam onto attacking ships just to burn them down. The socalled "burning mirror" (Simms, 1977) can be denoted as the ancient prototype of laser weapons. Who would have thought to invent such an ingenious set-up but Archimedes, who is known to be a mathematician, physicist, engineer, and an astronomer. His motivation was to defend his hometown Syracuse, then a Greek colony on the island of Sicily. Archimedes' invention triggered a series of debates questioning its basis. There is another account this time from England; an 18th century English cleric theologian John Wesley explained the idea of fire inducing burning glasses (Wesley Center Online, n. d.). Today, Archimedes' set-up has evolved into technology where the "burning mirror" of antiquity is replaced by adaptive optics used in laser weapons. While modern science kept working on developing laser weapons for decades, scientists tried to understand the technique behind Archimedes' invention. Dr. Joannis Sakkas managed to reconstruct a similar model with bronze-coated mirrors in 1973 which was claimed to work (Modiano, 1973). On the other hand, according to A. A. Mills and R. Clift's study (1992), even if the ships had been close enough to focus the sun rays, and even if they had been made up of relatively more flammable material instead of seaworthy wood, it was calculated that it would have taken 440 of 1 m^2 metal mirrors to start a smolder. This does not sound very plausible given the ancient technical know-how and physical capabilities. They concluded that the incident was truly a legend lacking substantial scientific support. Archimedes' invention with sunlight would be a plausible example for White's claim of utilization of energy harnessed "directly or indirectly from the sun" (1943). Whether a legend or a historical fact, this longest surviving account of creating directed energy implied a similar set of challenges that are still faced today. Even though scientists have come along way in achieving a certain quality with emitted beams, engineers still have to work on the technology to produce a more powerful beam for a fieldable weapon.

Despite laser beam propagation resembling lightning depiction, its working principle is more likely to match with Archimedes' sun light focusing model. Further on, laser's cosmic and bizarre characteristics would render it material of science-fiction and pop culture.

1.5. DEW in Pop Culture

Before modern science and engineering found a way to use energy as a weapon, creative minds busied themselves with producing printed, visual, and audio works of arts on energy weapons. One of the most prominent example of these is the classic novel *The War of the Worlds* written by H.G. Wells in 1898. Here is a delineation in the novel of Martian death ray:

> "It is still a matter of wonder how the Martians are able to slay men so swiftly and so silently. Many think that in some way they are able to generate an intense heat in a chamber of practically absolute non-conductivity. This intense heat they project in a parallel beam against any object they choose, by means of a polished parabolic mirror of unknown composition, much as the parabolic mirror of a lighthouse projects a beam of light. But noone has absolute proved these details. However it is done, it is certain that a beam of heat is the essence of the matter. Heat, and invisible, instead of visible, light. Whatever is combustible flashes into flame at its touch, lead runs like water, it softens iron, cracks and melts glass, and when it falls upon water incontinently that explodes into steam." (Wells, 2001, p. 16)

The resemblance of the Wells' depiction of Martian heat ray to modern laser beam is staggering. Swift slaying of men points out the speed of laser which is merely the speed of light. This "noiseless" "parallel beam" acts "silently" which is like an image of modern laser beam with its flat trajectory propagating silently. "Flaming death an invisible, inevitable sword of heat" is almost an exact illustration of invisible laser beam aiming at target exerting extreme heat as an output of its intensity which is one of the major physical parameters of its energy.

Maybe inspired by the mirrors used by Archimedes, the Martian "polished parabolic mirror" mechanism is like the preliminary version of adaptive optics of modern laser technology. The matter referred in the depiction, "beam of heat is the essence of the matter," is astonishingly comparable to the media of various laser devices into which energy is pumped for radiation of laser, and after which the type of laser technology is named. When the laser beam couples with the target its lethality is similar to the way the heat ray performs, "softens iron, cracks and melts glass." Wells' narrative is an impressive vision into the future, and a successful introduction of death rays to popular interest concurrently an inspiration for science and technology.

A variety of other directed energy weapons have been fantasized in science-fiction novels and printed material, namely, "disintegrator ray" (Serviss, 2012), "blaster" (La Motte, 1925), "needle ray" (Smith, 1934), and "ray gun" (Rousseau, 2021). In 1930s, famous American Buck Rogers and Flash Gordon science-fiction comic strips appearing on newspapers, and other media adaptations promoted the "ray gun". *The War of the Worlds* is the most impressive piece of work among these productions, and it was also on air in 1938 as Orson Welles' radio adaptation. 1951 science-fiction film, *The Day the Earth Stood Still*, was another showcase for ray guns.

Among all fictional directed energy weapons, concurrent with the appearance of engineering applications of laser technology in 1960s, laser became the major weapon of science fiction in the *Lost in Space* television series (1965-1968) (Wakefield, 2009), and the pilot episode of *Star Trek* (1964) (Wakefield, 2009). Following these, *Star Trek: Original Series* (1966-1969) (Wakefield, 2009) television series became very popular, and went on its performance with various imaginary directed energy weapons such as "phasers," "photon torpedoes," and "invisible energy shields." Moreover, "proton beams" of *Ghostbusters* (1984) (Wakefield, 2009) was a fictional example of another type of fantastic directed energy weapon based on beams of particles.

Maybe the most well-known science fiction production is *Star Wars* films and TV series. Generations of people from various age groups have been exposed to the fantastic directed energy weapons of *Star Wars*. There were handheld small-arms blasters in the form of pistols and rifles. Laser swords or rens known as "lightsabers" were sword-like weapons emitting blades of pure energy coming out of their "kyber crystal" cores which grew on various planets of Star Wars galaxy. Vehicle or spaceship based ones were used to be referred as "blaster cannons" and "laser cannons" among which the most powerful type was "turbolasers" mounted on Star Wars capital ships. In addition to these laser-type weapons, there were the "ion cannons" which shot bolts of ionized energy as if early fantastic products of current directed energy systems' ionization technique (Luceno, et al., 2018; Dougherty, et al., 2020; Barr, et al., 2019).

Today's scientists and engineers have probably grew up enjoying these science-fiction works. Once products of imagination and recreation, laser has gone a long way on the route to reality. What is common for the visionary story tellers, and

prudent scientists and engineers is creativity, and expectations from future trajectory. Tales of pseudoscience have probably always inspired science and technology. At the present time, real science assumes the responsibility of laser development with its theoretical background at the maturity stage. Shift to operational utility with hard-core applications will have to wait some more.

1.6. History of Laser Science

When it comes to research in science associated with directed energy, the distinctions between the types are emphatically brought forward; laser and particle bombardments being functionally the two most promising ones. Throughout its history, scientific research into directed energy technology has been conducted concurrently in different countries.

At the beginning of the 20th century the Danish physicist Niels Bohr was the the first scientist to argue by his quantum theory in 1911, electrons[6] around the nuclei of atoms at normal conditions do not exchange energy, however, in case, they move from higher to lower orbits, they are to lose energy to emission (Anderberg & Wolbarsht, 1992). Following this, it was Albert Einstein, in 1917, who first conceptualized a theoretical approach about the possibility of "stimulated emission" (Wheeler & Brehm, 2017, p. 2) suggesting that if a certain type of substance's electrons absorb energy, they are in principle able to give out that energy in the form of light. He explained that this emission would be at the same wavelength of the energy that reached the atom, or molecule. This phenomenon marks the fundamentals of the main process of stimulated emission in laser (Del Monte, 2021; Anderberg & Wolbarsht, 1992).

A series of attempts were carried out, most of them in the U.S., in order to materialize a real directed energy weapon. In 1921, Harry Grindell Matthews claimed that he was about to invent a "death ray" energy weapon which would have damaged a target by putting "magnetos out of action," and been able to operate at a range of four miles. Since his demonstrations for journalists and the military did not go far from stopping small motors and lighting bulbs, the British government showed no interest in the device. Once completed, the weapon that was supposed to bring down

[6] Atoms are considered to consist of nucleus and electrons orbiting around it. The electrons closer to the nucleus, that is in a lower orbit, have lower energy compared to those farther away (Rogers, et al, 2000).

airplanes from sky had never been materialized (Pilkington, 2004). A similar claim was announced by the American inventor Edwin R. Scott. However his "lightning device" as well could not "bring down planes at a distance" (*NYT*, 1924).

Antonio Longoria claimed that his invention would harm a living body by dissolving its red blood corpuscles (*Popular Science*, 1940). At a National Inventors' Congress he demonstrated his device, and to witnesses' bewilderment, managed to kill dogs, cats, pigeons, and rabbits at a distance by exposing them to the ray from the weapon (*Time*, 1936). The government preferred to suppress the existence of the device, and postponed any action related to its development until a requirement would arise for its usage as a defense weapon (Antonio Longoria - Inventor of Violet Ray Machines, Death Rays, and Welding Apparatus, n.d.).

Famous inventor and engineer Nikola Tesla who is best known for his contribution to alternating current principle in electricity also worked on developing an energy weapon, namely "teleforce," which was based on particle beam production rather than ray projection. He claimed that it was not plausible to turn rays into weapon due to difficulty of producing them in satisfactory quantities, and maintaining the intensity over distance. Instead, he argued that minute projectiles of microscopic or relatively bigger particles would exert much higher energy on a designated small area compared to purported "death rays." His theory was based on accelerating particles of matter such as mercury or tungsten within a beam form fed by a high-voltage current power which sounded similar to today's directed energy of particle beam projection. Tesla worked on his "teleforce" weapon for almost four decades during the first half of the 20th century, however, was not able to achieve the results he intended due to lack of funding for his project (Tesla, 1935).

Both World Wars ended without deployment[7] of any weapon that was close to sending out directed energy rays or particle beams. During World War II, the U.S. Navy intelligence suspected that Germans could orbit satellites ‘‘for reconnaissance or for relaying what scare pieces in the press called ‘death rays’’’ which has not been supported with evidence (Green & Lomask, 1997).

[7] "To deploy" means "to organize and send out people or things to be used for a particular purpose" (Merriam-Webster, 2014, p. 446); "deployment" means the movement of forces into and out of an operational area (Dictionary of Military and Associated Terms, 2021, p. 62). Hence deployment may involve movement of weapon systems, including laser weapons.

1.7. History of Laser Technology

In 1952, almost concurrently two physicists from the Soviet Union, Nikolay Basov and Alexander Prokhorov, and one American physicist, Joseph Weber, explained the theoretical principles of maser which is accepted to be the precedent of laser. Maser which stands for molecular amplification by stimulated emission of radiation has been grounded on basically the same principle with laser - light amplification by stimulated emission of radiation. The difference lies in the fact that maser produces lower frequency, lower energy radiation than laser. One year later Charles Townes, James Gordon, and Herbert Zeiger built the first maser. Townes, Basov, and Prokhorov shared the 1964 Nobel Prize in Physics "for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser—laser principle" (*Nobel Prize in Physics 1964*, n. d.).

Townes continued with research of the "optical maser" which would later be called the laser. It was Gordon Gould, a physics graduate student from Columbia University who is accepted to be the name father of laser. When his experiments produced more energetic light compared to maser, he noted in his laboratory notebook the word "laser" along with various concepts related to it (Del Monte, 2021).

Consequently, laser has come all the way from imagination and science-fiction to a point where it attracted military's attention. In 1959, Gordon Gould left university, and joined Technical Research Group (TRG) which has been involved with military projects. Gould suggested that laser be used as weapon which led TRG ask the Department of Defense for funding. "The military was so fascinated by the idea of beam weapons that it gave the company [TRG] almost a million dollars, more than three times the amount that had been requested. . . . Soon, various branches of the military—army, navy, and air force—gave money to several other companies to develop such weapons" (*Military Applications of Lasers*, n. d.). This is how the weaponization of laser commenced.

First working laser was created by Theodore "Ted" Maiman at Hughes Research Laboratory in 1960. The concept of laser was transformed into reality via his ruby laser design. However, despite the lavish funding from the U.S. government, advance of technology slowed down. By 1968, experts believed they came to a stumbling block which they could not proceed forward (Wheeler & Brehm, 2017).

With reemergence of research and development in 1970s, a weapon was produced that would meet military's expectations to some extent; this was a lower-energy, relatively small gun which was considered to be a close combat arm. Development of this weapon has continued for years, and by 1980s it acquired a controversial use. As mentioned in *The New York Times* article, dated to 18 December 1983, this weapon was named C-CLAW which stands for Close Combat Laser Assault Weapon. It was not able to distinguish between human eyes and optical sensors, and was intended to be used for blinding enemy pilots, soldiers, along with optical sensors (Resnick & National Journal, 2014). Since these kinds of weapons were in the category described as causing "superfluous injuries and/or unnecessary suffering for little military purpose," (International Committee of the Red Cross, 1994), the United Nations issued the Protocol on Blinding Laser Weapons in 1995, and prohibited usage of blinding lasers in wars (1995 Protocol on Blinding Laser Weapons, n. d.).

The extensive research on lasers was rekindled during 1980s by the establishment of the U.S. Strategic Defense Initiative (SDI) program inspired by physicist Edward Teller's argument that lasers could be used as defense against nuclear attacks (Atomic Heritage Foundation, 2018). However, the research for utilization of laser technology assuming anti-ballistic missile[8] purposes did not come to fruition due to engineering caveats.

Eventually, instead of hunting down missiles, the laser technology culminated on the battlefield as guiders and range finders wielded by the U.S. military during the First Gulf War. Further, by 2006, low-power lasers were used to dazzle opposing combatants causing temporary blindness to keep them away from checkpoints in the U.S.'s Iraq War (Lasers used on Iraqi drivers who won't stop, 2006, May 18).

[8] According to the Encyclopedia Britannica a missile is "a rocket-propelled weapon designed to deliver an explosive warhead with great accuracy at high speed." Strategic missiles are "weapons designed to strike targets far beyond the battle area," and are of two types namely, cruise or ballistic type. "Cruise missiles are jet-propelled at subsonic speeds throughout their flights, while ballistic missiles are rocket-powered only in the initial (boost) phase of flight, after which they follow an arcing trajectory to the target. As gravity pulls the ballistic warhead back to Earth, speeds of several times the speed of sound are reached" (Britannica, n.d.). The thesaurus of Defense Technical Information Center website defines antimissile defense systems as "Techniques and equipment for the interception and destruction of guided and ballistic missiles" including anti-ballistic missile (ABM) systems. (https://discover.dtic.mil/thesaurus/subject-categories/15milsciences/)

1.8. Civilian Application

The first practice of laser technology was in civilian applications. Consistent with the general approach in the world, the interviewees stated that the development of military laser technology in Turkey originated from the civilian industry. There is a wide range of uses of lasers in industrial, commercial, and medical areas. In almost all manufactured items of industrial sectors, it is highly possible that laser is used in the production processes in cutting, drilling, welding, and engraving. High precision and low mechanical stress stand out as their key advantage. Laser technology applications are ubiquitous in optics, laboratory instrumentation, automobile, and manufacture industry, health, and entertainment. For example, optical lasers have been used for cd (compact discs) reading scanning the data on discs. With regards to health and medicine related areas, lasers have widespread applications. They are used in repairing eye retina and vision problems (Case-Lo, 2018; Dunkin, 2023), and are also used as scalpels in surgeries for cutting the tissue with minimal bleeding (Paschotta, n. d.).

1.9. Weaponized Laser Technology

Energy is essence of life and matter. It has a transcendental nature beyond earth. Its existence can be traced everywhere. Humans on earth is immersed in electromagnetic energy, and harness it for life preserving activities. Electromagnetic radiation which bears wavelike movement of photons, and is described in terms of energy, wavelength, and frequency. The figure of electromagnetic spectrum (EMS) below displays the range of electromagnetic radiation (Figure 1.). The variety of energy forms in increasing order of energy can be listed as radio waves, microwave, infrared, visible, ultraviolet, X-rays, and gamma rays. The relevant energy that laser technology works with is within the visible light, and infrared portion (Ellis, 2015).

EM Spectrum

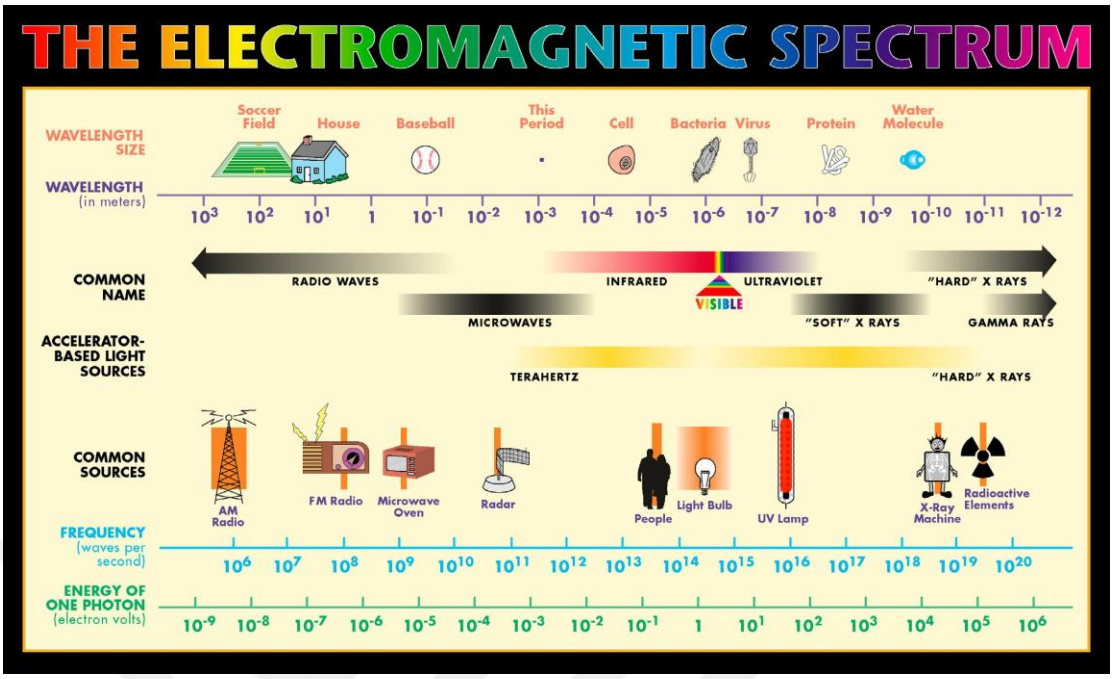

Figure 1. EM Spectrum with respect to associated wavelengths and utilites in life (Ellis, 2015).

Although sounds like an authentic word, it was already mentioned in the preceding sections that “laser” is an abbreviation for light amplification by stimulated emission of radiation, which is associated to the physics and engineering behind the process. The term laser is used to refer to the technology, the electromagnetic beam as the output of the technology, and the device that generates that beam. The essential features of the beam is that it is "coherent," that is of the same frequency and waveform, and "collimated," meaning, going in the same direction (Anderberg & Wolbarsht, 1992).

As described by Del Monte (2021) and Anderberg et al (1992), the design of a laser device is composed of three components: An energy source, a laser medium, and a feedback element. A laser medium is solid, liquid, and gas substance typically confined in a tube that receives energy, and emits light. The energy source supplies energy to the medium through a pumping system by optical, electrical, chemical, or nuclear methods leading to excitation of electrons of the atoms or molecules that make up the medium matter; that is, electrons move from their lower-energy orbit to a higher one. The electrons on the upper orbits are unstable, and they are to return to their original orbits at a cost of giving off their absorbed energy in the form of light as photons, and waves at predominantly the same wavelength rendering the laser beam

coherent. The emitted coherent radiation is confined in the medium tube by the feedback element which is typically comprised of a mirror at each end of the laser medium, with one being partially silvered, that is partially reflecting. The back-and-forth reflection of the trapped coherent radiation in the medium between mirrors enhances stimulation causing a chain reaction for even more electrons in the system producing further emission at the same wavelength. Via amplification, the initial low-energy pulse turns into highly energetic coherent emission which is to pass through the partly silvered mirror as a highly energetic laser beam.

Lasers' lethal effects on targets vary across a range of parameters such as laser intensity, the distance between the laser device and the target, in other words, range, and the characteristics of the target material. The retired officer interviewed explained that the military always "starts planning from the end-point." This is probably consistent with any production planning or development of new products. Likewise, the ultimate objection defined by the range and target damage criteria determines the course of development for laser weapon systems. The preliminary step for damage exertion is to reach, and contact the surface of the target. Low energy lasers can cause temporary blinding of humans, or dazzling effect on electronics of a relevant target. High intensity lasers can drill a hole on the target by melting and evaporation through heating, or can cause buckling by mechanical means (Wheeler & Brehm, 2017).

It is noteworthy that both science-fictional lasers in the novels, TV series and films, and the weaponized laser of contemporary war technology are generally discussed in correspondence to its physics, and technological foundation. The reasoning behind this might be that it is a whole new technology triggering a curiosity that needs to be satisfied, and that there are not plenty of products on the market compared to conventional weapons which leaves only associated science and technology for rhetoric. As a matter of fact scientific discussion of laser technology stands out in the literature compared to other weapon systems which have more mature technologies. By the same token, it is particularly important to hear the engineers' narrative about this weapon system.

RAFAEL[9] executive Michael Lurie asserts, “We don’t have a technology problem or a scientific problem anymore… it’s now an engineering problem. The science is there, we’ve shown that it works,” (Mehta, 2022). All the informants also

[9] RAFAEL Advanced Defense Systems Ltd. is government-owned Israeli defense technology company (Rafael Advanced Defense Systems Ltd., 2023).

agreed that laser phenomena is materialized, and engineers seek its improvement. The current development stage passed from the scientists to engineers. In general once science generates knowledge of the natural physical world, engineering applies this knowledge to design structures, models, processes, and equipment; the cumulative resulting system including the devices, and processes is technology. However, weapon development seems to follow a more distinct path in technology development; it is more committed to the demand specifications. Once the technological product becomes mature enough to be fielded, it is transferred from the production facilities to pass onto the end-user, the military. Work in progress evolves into becoming a deployable weapon system.

Laser technology has been introduced to battlefield where all kinds of threats could have beeen countered or resisted by the existing weapons. Accompanied with this notion, the first working laser weapon was described "as a solution looking for a problem" (Del Monte, 2021, p. 81). Generally technological product is developed as "customer requirements are translated into technical specifications" (Meijers, 2009, p. 11). With regards to laser weapon systems this seems to work in both ways. Though the progress of laser technology can be observed to have its own evolutionary path, interviews confirm that there are certain threats in the conflict zones where laser weapons can presumably address more effective and efficiently than traditional weapons can handle. For example, one of the engineers foregrounded its usage against asymmetric threats in general terms as: "You cannot use kinetic weapons against asymmetric threats. You cannot shoot a drone with gun or a machine gun. Asymmetric... It is not clear, it cannot be modeled, it is a rogue structure. You can counter such a rogue structure only with a swift technique."

The interviewees stated that the aim of engineering is to come up with an optimum design, and manufacture plan supported by scientific feedback to produce a laser device that would generate the best quality beam with the given parameters. Scenario dependent criteria such as range, the specifications of the target, and atmospheric conditions are of utmost importance for the project development. Challenges of the technology requires multi-branch involvement both from physics and engineering branches. As one of the engineers from the sector stated physicists and engineers from various departments (e.g. electricity-electronic, computer, metallurgy-material, mechanical, and chemical engineering) worked in collaboration. Laser technology is a complex multi-linear technology with many attributes seeking

improvement maintained that they work in a coordinated manner. In other words, laser technology demands multi-branch physics and multi-tech engineering comprehension for progress.

1.10. Laser at War

With the introduction of directed energy weapons harnessing electromagnetic energy, it is possible to classify the weapon systems in two groups in terms of the energy they exert, as kinetic energy weapons (KEWs) and directed energy weapons (DEWs) which includes laser weapons. One of the retired officers who was interviewed described the conventional warfare in broad terms as following: "It is the utilization of kinetic energy by material and personnel yielding a negative effect after the initial softening of the region with air force followed by artillery bombing."

Today, defense industries in a number of states are working on developing more effective and efficient directed energy weapons. Being a leading actor in this area, U.S. Department of Defense's Joint Publication 3–13 Electronic Warfare, defines directed energy (DE) as:

> "DE is an umbrella term covering technologies that produce concentrated EM energy and atomic or subatomic particles. A DE weapon is a system using DE primarily as a means to incapacitate, damage, disable, or destroy enemy equipment, facilities, and/or personnel. Directed-energy warfare (DEW) is military action involving the use of DE weapons, devices, and countermeasures to incapacitate, cause direct damage or destruction of adversary equipment, facilities, and/or personnel, or to determine, exploit, reduce, or prevent hostile use of the EMS through damage, destruction, and disruption," (Electronic Warfare, 2012, p. I-16).

Actually laser weapon is so new in military, a specifically evocative term that best describes its employment has not been coined to this day. Let alone its proliferation, no substantial account of powerful laser weapons' field operations is officially announced so far. In simple terms, laser's military engagement is an impact of a beam of radiation from a laser device being delivered toward a target to inflict damage. The term "firing" for kinetic weapons is defined as following in the Department of Defense Dictionary of Military and Associated Terms (p. 82): "Fires: The use of weapon systems or other actions to create specific lethal or nonlethal effects on a

target." However, since there is no propellant[10], explosive, or fire associated with laser, the term "fire" does not sound appropriate for laser weapons. An alternative option "to shoot" is defined as: "Shoot: to fire a gun or other weapon; to fire something from a weapon" (Oxford Learner's Dictionaries), where again firing is an intrinsic part of the meaning. Devoid of descriptive military terminology, based on the working principles or output of the laser device, improvisation may produce terms like "to send a beam or a ray," "to lase," or "to laser" as in "taser." Yet, among the engineers, and military personnel the most common usage is "firing" currently.

KEWs are mainly grouped into two major categories as shock weapons and missiles (Dupuy, 1980) with regards to the characteristics of the impact they exert. Kinetic weapons are effective on a broad range of kill-spectrum, but they have some drawbacks in response to novel asymmetric[11] threats such as swarm attacks of unmanned systems[12]. Moreover, kinetic weapon solutions are considered to be too expensive for countering cheap threats. Whether single or in the form of swarms, drones and UAVs can be countered by lasers in a relatively more feasible way incurring less cost. As forthcoming technologies render overwhelming swarms of unmanned systems possible, the demand for laser weapons is expected to increase. However, it should be noted that the common perception of cost-benefit advantage seems to miss the major point of the target value under adversary threat, which will probably induce deliberate assessment during procurement and deployment decision of laser systems.

Laser weapons are meant to be a whole spectrum engagement[13] systems from detection to damage exertion across soft-to-hard kill[14] lethality range. They are

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[10] Propellant for military purposes is defined in *Dictionary.com* as "the charge of explosive used to propel the projectile from a gun," or "a substance, usually a mixture of fuel and oxidizer, for propelling a rocket" (*Dictionary.com*).

[11] According to the definition in the Encyclopedia Britannica (Sexton, 2016) asymmetrical warfare involves "unconventional strategies and tactics adopted by a force when the military capabilities of belligerent powers are not simply unequal but are so significantly different that they cannot make the same sorts of attacks on each other.

[12] Unmanned systems, which are guided with remote control or by autonomous means such as unmanned aerial vehicles and unmanned surface vehicles (Roblin, 2019, September 30), can be major elements within asymmetric warfare. These unmanned systems can be organized to pose swarm attacks which is defined as "high-risk, coordinated assaults sometimes directed against multiple targets or building complexes, using mobile groups to circumvent security measures" (Collins, 2012).

[13] Engagement is defined as "attack against an air or missile threat" or "tactical conflict, usually between opposing lower echelons maneuver forces" (DOD Dictionary of Military and Associated Terms, 2021).

[14] Soft kill denotes "impairment of combat effectiveness" usually by electronic means, and hard kill refers to physical destruction of the target (Seigel, 1994).

currently used in military applications in range finding, remote sensing for detecting a threat or a target, ordnance guiding toward its target, as well as warding off threats from adversary electronics by electronic means, in addition to supporting satellite communications systems, laser radar-based navigational aids, and also for law enforcement by blinding, or disorienting target temporarily (Wheeler & Brehm, 2017).

Justin Martin from Raytheon[15] suggests "the laser weapon must be an integrated system that prosecutes the entire kill chain[16] from acquiring and tracking a target to controlling and directing the beam," (Breaking Defense, 2022, September 12). Technology advent will help determine whether laser systems will address a whole range of functions or distinct usages in defense, offense, and for ISTAR[17] purposes. In general terms, some weapon systems are denoted as either offensive or defensive, and is inscribed in the development purpose of the weapon; however, for some, the functional purpose is not predetermined, and attain their task designations based on their roles in the operating environment. Currently, and for the near future, laser systems can be considered an optimum choice for counter-measures against asymmetric threats in the form of swarm of unmanned systems. Subsequent technological improvements will enable them counter-act against robust military platforms and ammunitions such as rockets, artillery, and mortars (RAM)[18].

[15] Raytheon Technologies and Raytheon Missiles & Defense are American multinational companies involving with high-technology research and production in aerospace and defense technologies (Raytheon Technologies Corporation, 2023).

[16] Kill chain can be described as the process on the battlefield for gaining understanding about what is happening, making a decision about it, and taking an action that creates an effect to achieve an objective via lethal or non-lethal actions (Brose, 2020), also referred to as engagement spectrum.

[17] "Intelligence, surveillance, target acquisition, and reconnaissance (ISTAR) is the activity of equipping armed forces' with information and intelligence to assist in combat roles and other operational duties. This often derives from linked information networks which improve upon situational awareness" (Defense IQ Glossary, 2023).

[18] RAM stands for rocket, artillery, and mortar, each with the following descriptions:
Rocket and missile system, "any of a variety of weapons systems that deliver explosive warheads to their targets by means of rocket propulsion." "Rocket is a general term used broadly to describe a variety of jet-propelled missiles in which forward motion results from reaction to the rearward ejection of matter (usually hot gases) at high velocity," (Durant, et al, 2023).
Artillery refers to "crew-served big guns, howitzers, or mortars having a calibre greater than that of small arms, or infantry weapons. Rocket launchers are also commonly categorized as artillery, since rockets perform much the same function as artillery projectiles, but the term artillery is more properly limited to large gun-type weapons using an exploding propellant charge to shoot a projectile along an unpowered trajectory," (Vernon, 2023).
Mortar is "portable, short-barreled, muzzle-loading artillery piece that fires explosive projectiles at low velocities, short ranges, and high, arcing trajectories," (Britannica, 2023).

Ultimately, future prospective use is expected to be against hypersonic missiles[19], intercontinental ballistic missiles (ICBM), and anti-satellite (ASAT) missiles[20] which pose threat to satellites. So far these functions address the defensive portion of the engagement spectrum. Engineers from the sector argued that lasers are in general defense weapon systems, particularly to be wielded in air defense, which was a key attribute pointed out by the retired officer who had served for air defense at active duty. One of the engineers suggested that lasers' defensive utility is naturally foregrounded due to the fact that it was a recent technology devoid of operational first strike capability. He went on to say that energy, power electronics, or the efficiency of energy, and also the operational requirements were some factors that positioned the laser systems as defensive. However, ongoing improvements aimed to mount lasers on 6th generation fighters, he added; these are war planes of immediate future which are more advanced in many aspects than the ones at current service. Hence, although based on present technological capabilities, and operational needs lasers are promoted as defensive, this designation seeks further research, and elaboration; "In the near-to-medium future, we may witness their offensive use," according to the engineer.

This trajectory is in alignment with the comment in the Diplomat article stating, "When the technical limitations ... are solved – which, admittedly, may not happen for a decade or more – lasers could make the jump from being a defensive to an offensive weapon. Such lasers could, in theory, be suitable for targeting aircraft, armored vehicles, or ships at long range, rather than defending them at short range" (Parakilas, September 9, 2021).

Many aspects of the laser systems can be understood over a timeline in alignment with technological developments. In addition to operational military requirements, the performance of technological progress will seem to determine the role of laser systems on the theater of war. Today, laser systems which are perceived as defensive, can be wielded as attack instruments in the future contingent on the improvements of the key parameters defining the beam quality and effectiveness. Therefore, similar to all technology-based projects, a sound future trajectory and positioning of the weapon can be done with respect to timeline.

[19] In NATO 2020-2040 Science & Technology Trends report, hypersonic weapons are described as missiles, vehicles, etc. that can operate at speeds greater than Mach 5 (6125 kph) (Reding, & Eaton, 2020). (Mach number is the ratio of speed of an object to speed of sound which is 343 km/s or 1,235 km/h.)

[20] Anti-satellite (ASAT) missile is "a missile that can destroy or jam an enemy country's satellite in space," (Verma, 2019, March 27).

Classification of weapons helps determining their roles during integration into the existing military doctrine[21], and relevant operational concept[22]. Due to on-going technology development and limited deployment, there is no clear cut categorization of laser weapons. Based on classification of existing weapon systems and specific features of lasers, alternative classifications of which some were suggested by the retired officer can be listed as:

- by power - high power, medium power, low power;
- by range or altitute (in proportion to power) - short range, medium range, long range or low, medium, high altitute;
- by source of power such as electrical, chemical, or nuclear;
- by types of laser media e.g. solid-state, optical fiber;
- by deployed domain or platforms - ground-based, air-borne, sea-borne, space-borne.

Above mentioned attributes with various configurations of the feedback element can yield a diverge set of laser beams with respect to power, wavelength, and pulse[23] characteristics.

Not to digress from the topic with the technical details it will probably suffice to mention that the most preferred types of lasers for military purposes have become solid-state lasers, including fiber lasers, that are powered by electricity (Wheeler & Brehm, 2017). This is actually no surprise since fiber-optics and other solid-state laser technology have become the forerunner of industrial development and commercialization (Directed Energy Community of Interest, n. d.).

Based on military technology conception, the changing character of war, depends on a number of criteria which determine the specifications and capabilities of weapons. Numerous advantages in terms of these criteria put laser weapons forefront over kinetic weapons.

[21] In www.rand.org, military doctrine is explained as the fundamental set of principles that guides military forces as they pursue national security objectives (RAND Corporation, n. d.).
[22] Concept of operations can be defined as "verbal or graphic statement that clearly and concisely expresses what the commander intends to accomplish and how it will be done using available resources," (U.S. Department of Defense, November 2021).
[23] Pulse is the burst of electromagnetic radiation (Ellis, 2015) created when the laser is activated.

1.11. Laser in Space

Devoid of atmosphere, space is the ideal medium for laser performance. In alignment with the ongoing research and development for ground-based laser weapons, the exploitation of space capabilities is also being pursued. The existence of space-based laser systems are not confirmed by governments. However, the countries that have domineering presence in space with their comparably high number of satellites are considered to contend with developing space laser systems if have not still materialized. The space assets orbiting around the earth are military and commercial satellites that execute various utilities such as communication and navigation. Despite the fact that space is intended to be weapon-proof governed by UN treaties (Del Monte, 2021), this is hard to confirm. For instance, laser systems mounted on satellites are used for both commercial and military purposes including communications, environmental monitoring, position location, intelligence, surveillance and reconnaissance, warning, weapons guidance, etc. The destructive energy of high intensity lasers are meant to be used both in terrestrial conflicts and future space conflicts. Military operations from space may involve engagement against ballistic and cruise missiles, aircraft threats, as well as fuel transporters of belligerents on the ground (Preston et al, 2002).

Space-to-space response may target adversary satellites or other space-based entities. Laser beams can be used as an element of electronic warfare by exerting military effect on electronics of hostile assets. Some of the key strengths of laser engagement can be stated as prompt attack at the speed of light concurrently posing a challenge for the adversary in detection of the culprit. However, since consistent emittance is required for damage, the stealth of the system can be compromised during an employment that takes long. Loss in the effectiveness of the beam along a distant range, and through penetration into atmosphere may be other constraints for space-based lasers (Egeli, 2021).

1.12. Advantages

All the advantages attributed to laser weapons should be considered across a timeframe because current advantages may become even more substantial strengths in the future, and additional benefits of lasers may be developed via technology

progress. Hence, in this study it would be reasonable to disclose the most prominent advantages of laser weapons according to general consensus irrespective of time.

Speed is of central consideration in the changing character of war. From arrows to modern projectiles[24] including bullets and missiles, attacks are intended to cover longer distances with a higher pace at a shorter time. Fast maneuver with speed is a crucial initiative to surprise the enemy. Higher speeds shorten the distances. New technological capabilities extend wars beyond traditional distances. Faster and more convenient transportation systems enhance the mobility of armed forces including personnel and armament. Due to advances in communication and information technologies, armed forces act at a faster rate than previously. In line with these developments, advance engineering techniques provide faster projectiles as kinetic weapons. The fastest of these weapons are hypersonic missiles with speeds at least Mach 5 (1.715 km/s) or greater (Obering III, 2020). However, these very fast objects are considered hardly moving compared to lasers delivered at speed of light (300,000 km/s). However, it should be noted that although the laser beam propagates to the target at the speed of light, damage exertion takes a little longer expressed in seconds by holding the beam on the target till destructive effect is obtained. Damage time depends on the power of the laser and specifications of the target. Ultimately, with respect to their prompt delivery, laser weapons are to be considered the fastest weapons of engagement.

Precision is another feature that engineers work on incessantly which is one of the most essential specifications determining the performance of a weapon. High precision minimizes collateral damage[25], that is unwanted civilian casualties and loss from own or allied forces. Lasers theoretically have high precision capabilities that enable them probably as being the best choice for surgical[26] engagement. Unlike projectiles and explosives with blasting effects, lasers are capable of eliminating the threat with a higher probability of hitting with almost no or causing limited explosion. One of the engineers gave an example of a scenario where a building of critical importance in an urban region being aimed by the adversary. There would presumably be some caveats in countering with traditional kinetic weapons. In addition to risk of

[24] Projectiles are simply articles such as a shell or bullet which are projected from a cannon or any other artillery, gun, rifle or other small arm (Military Analysis Network, n.d.).
[25] Collateral damage is "unintended damage during military operations, usually referring to the deaths of civilians or the destruction of their property" (Wither, 2008, p. 2421).
[26] Cambridge Dictionary defines surgical strike as "a type of military attack that is made in an exact way on a particular place" (Cambridge Dictionary, n. d.).

missing the incoming target, there would be unwanted consequences of hitting the projectile which might have resulted in even more fierce destruction leading to collateral damage including civilian deaths, as well as unintended psychological effects. Depending on the location, and the timing of the contact, if the threat was to be detonated by laser, the explosion would be less severe than the case of two projectiles clashing.

Lasers have a unique weapon characteristic which is scalibility; that is, their effect can be adjusted to cause the required harm from non-lethal to lethal over the kill-chain. Laser weapons can engage within soft-kill range by denying or degrading the adversary to disable or else they can cause further damage or destroy the enemy across the hard-kill spectrum (Obering III, 2020). Del Monte describes this feature as "dial-in capability" giving the example of a U.S. Navy laser weapon which is supposed to disable an adversary’s drone or boat by dazzling or which can destroy that drone or boat when set to full-power (2021). In any case, it was already mentioned that with relatively low power, lasers are currently used in range finding, remote sensing, ordnance guiding, and blinding, jamming, dazzling the target, as well as law enforcement by blinding, and disorienting target temporarily. Higher energy lasers are to be able to respond more effectively to asymmetric threats mainly swarm of unmanned systems. On the far-end spectrum with increased power and beam quality, the prospective game-changing technology aims to counter-act against rockets, artillery, mortars (RAM), and further against hypersonic missiles, anti-ballistic missiles (ABM), and anti-satellite (ASAT) missiles.

In countering asymmetric threats laser weapons' forthcoming performance will distinctly show itself in a dynamic shooting fashion. As one of the engineers from the sector narrated, especially in urban areas, shooting could be done with varying intensities, typically from low-to-high, simultaneously gauging the effectiveness, and checking any potential harm upon civilian population. He suggested, it was possible to use lasers with this kind of check&balance practice in order to inhibit collateral damage. A further advantage that this feature offered was, once shot, in case of contingency the shooting can be stopped. He pointed out that the beam propagation was at the speed of light, whereas damage exertion on the target would take a couple of seconds. Within this short time, the shooting could be ceased if required. On the other hand, with kinetic weapons, once fired, the projectile cannot be "called back" expressed the interviewee. Kinetic weapons shoot in discrete fashion one-shot-at-a-

time; while laser shooting is continuous, and consistent with optional pulses set at very short intervals.

One unaccustomed feature of laser weapons is that they can shoot as long as the power source feeds the system; that is, the depth of magazine is unlimited. This is the most essential advantage of laser weapons according to one of the engineers. While conventional weapons' engagement capacity is contingent on their ammunition arsenal, laser weapons have unlimited capacity as long as they are connected to power.

Cost effectiveness is an important criteria in weapon systems' assessments for procurement. It is critical that the cost of the weapon is acceptable with regards to its lethality of execution. Almost all the informants pointed out that laser weapons have an incredible low cost per shot. Currently, relatively cheap drones are to be countered with much more expensive conventional ordnance. One of the informants expressed the underlying infeasibility as, "You cannot send a 10-20,000 dollar missile against a 2,000 dollar threat." The cost per shot ratio for laser engagement is comprised of merely the electrical power required to fire the shot (Congressional Research Service, 2022, September 13) in addition to, if relevant for the particular operation, the cost of the fuel for deployment. It can be inferred that the cost to kill advantage stands out as a central consideration for the developers of the technology and the armed forces.

Since laser systems do not use projectiles, the traditional ammunition supply-chain on battlefield is irrelevant for these systems. Exemption from projectile supply will entail less logistics burden as well as less complicated military planning in the future. Moreover, replacement of conventional weapons with laser systems on battleships would reduce the vulnerability of the vessels eliminating the risks of ammunition storage (Del Monte, 2020).

One of the distinguishing advantages of laser weapon systems is its stealth feature. The Encyclopedia Britannica defines stealth technology as any military technology intended to make vehicles or missiles nearly invisible to enemy electronic detection (Britannica, n.d.). Since there is no strike or explosion involved, the operational usage of laser weapons is almost undetectable giving off neither sound nor light or flashing. As the retired officer pointed out, they would not lift dust by explosive or blasting effects that are characteristic depictions of traditional war zones. No auditory, smell, or visibility aspect can be attributed to laser weapon systems. This almost perfect stealth attribute is termed as "without signature" in military jargon

which is a desirable feature from the offensive point of view. Furthermore, without causing any debris this leads to deniability (Egeli, 2021) advantage where the attacker cannot be designated.

1.13. Challenges and Disadvantages

Similar to the strengths and advantages of laser weapons, apparently it is reasonable to assess the challenges of deployment of laser technology across a timeframe. The ongoing engineering effort is aimed to overcome or minimize the hurdles. Military operation scenarios require that the technology is to be improved and refined in order to to produce the best combination of various parameters for an optimum beam quality with the purpose of creating the desired effect on the target surface despite the radiation medium's negative circumstances. In addition to drawbacks posed by aerosols, charged particles, or magnetic fields, weather conditions such as winds, haze, fog, rain, snow, etc., and atmospheric effects such as turbulence are difficulties that need to be surpassed by engineering solutions (Nielsen, 1994). The engineer from the sector elaborated on how the laser beam would behave under influence of its surroundings including the winds. He indicated that the beam would change shape during propagation through atmosphere acting like a hose trying to hit the target, or more like a construction iron rod that was held from one end, moving up and down making it difficult to aim. Consistent with this depiction, precision becomes a concern as explained in Rand Corporation's report *Space Weapons Earth Wars*, "a need for a steadier 'hand'" is required "minimizing jitter to keep the smaller spot concentrated on the intended target area," (Preston et al, 2002).

Laser technology performs like a network where energy intensity, environmental effects, range between the weapon and the target, and the specifications of the target are interlinked. The engineer's description confirms this interrelationship between distinct elements. He briefly explained the aim of the engineers: To produce a beam at the right wavelength that would minimize the effects from the atmospheric conditions, and to send it with the maximum possible intensity that would focus at a certain spot as small as possible at the farthest range. This implies that without the atmospheric medium it would be easier to utilize the laser technology. As one of the engineers with the military background pointed out "the ideal medium for laser operation is space," devoid of atmosphere.

A predominant challenge standing in the way to materializing laser weapons on the battlefield is concerned with size, weight, and power shortly called SWap of the system (Obering III, 2020). One of the reasons that a laser system is bulky is the size of the power sources that deliver power to the system. Engineers stressed the aim of reducing the size, weight of the weapon in order to facilitate its adaptibility to the dynamics of conflict environments increasing the beam power concurrently.

There are a number of additional challenges that need to be addressed. Thermal management (Ellis, 2015) is concerned with the cooling of the system during operation which needs to be improved. One of the engineers mentioned the pace of shooting can be a problem. He argued, "Time inbetween shootings can be long because the system needs to recharge itself, it needs to refresh itself. For instance, it cannot fire hundreds of bullets per minute like a machine gun. This is a disadvantage." That is to say, the shooting intervals of laser systems can delay the prompt response during engagement when compared to kinetic weapons.

In addition to focusing the beam on the spot, cumulative heating for damage exertion may take some time (Preston et al, 2002). This lag of time may pose a problem especially when the laser has to deal with multiple targets as in swarm attacks. Addressing swarm attacks is a strength for lasers as long as the technology minimizes the dwelling time. Since deliberate tracing of and aiming at target is key point of engagement, laser's stabilization should be maintained during operation lest it poses a drawback as mentioned by the retired officers. Once mission applicability is achieved to a sufficient level for fielding, another issue that needs to be addressed is to ensure the system's ruggedness. The delicate set-up of the optical elements of the system may pose a stumbling block on the way to ruggedness (Wakefield, 2009). If these shortfalls are eliminated, the system would be ready for combat area. Mission adaptibility of the laser system along the conventional weapons is to be governed by the military. In other words, the system should be integrated into the relevant operational concept of the armed forces to be able to accomplish current and future tasks.

In addition to the above mentioned challenges and shortfalls, the informants confirmed that there were threats that could not be countered by laser systems at the present time which would render laser systems as complementary to existing conventional systems rather than as alternative. Since laser beams are not powerful enough to penetrate thick materials, they cannot be utilized in exerting damage upon

buildings. It can be inferred from engineers' accounts that it would be irrelevant to question the laser impact upon critical buildings or constructions with reinforced walls, major installations, or underground targets such as missile silos.

Laser beam's flat trajectory might be considered a weakness in some cases which deems it unable to respond all types of threats. As one of the engineers pointed out, lasers did not have ballistic courses therefore they could not engage with threats behind hills or barricades. They require line-of-sight to the target (Ellis, 2015) for engagement. Laser operation from the ground over-the-satellite onto the target is yet a futuristic objective to be accomplished.

The retired officer indicated at the time of the interview (December 15, 2022) that the existing laser systems "do not meet range requirements, [and are] costly [that is] not cost-effective, not mission effective. However, this is the concept of the future, and its development should be taken seriously."

Therefore, given the current capabilities, laser weapons can be tasked with limited applications of maintaining security of critical settings such as railways, logistics channels, airports, air bases, bridges, dams, power plants, and nuclear reactors, as suggested by the retired officer. In addition to this, according to one of the engineers with military background, the initial placement of laser weapons for hard-kill purposes will be navy. The invesgative journalist suggested an additional laser function as active protection for tanks. From the interviews it can be inferred that regarding the future of laser weapons, the general consensus is that their current and near future utilization will be as complementary to conventional concept of operations rather than being deployed in all-laser networks.

As with all weapons, counter-measures are being considered against laser weapons as well. For negating the effect of laser beam, in addition to shape, and orientation that can minimize the exposure, materials that do not absorb the radiated beam can be preferred (Preston et al, 2002). Insulation, including anti-laser coatings, can be an effective measure against laser (Preston et al, 2002). Apart from the shielding of the weapon to be protected, rotation or higher acceleration can help dissipate heat to mitigate lasers' thermal effect (Del Monte, 2020). In addition to target-oriented counter-measures, attacks can be arranged in a way to pose saturation effect with multiple targets in order to circumvent laser defense (Preston et al, 2002). Some exotic techniques such as spraying of aerosol clouds containing nanoparticles

(Hendricks, 2018, as cited in Egeli, 2021, p. 120) are also under consideration that would exploit lasers' intrinsic characteristics.

In short, the aim of laser engineering for weaponizing the laser is to generate a collimated beam using the power efficiently that would propagate against the opposing effects of the medium with sufficient intensity to be able to exert the damage on the military target at a predetected range.

2. LASER AS ACTANT IN WAR NETWORK

2.1. Sensous War

People live in a "sensous world" (Porteous, 1990) where they observe and perceive their environments through their senses. Sight, sound, smell, touch, and taste are intelligible input received through senses. These stimulations nurture human awareness searching for the vital dynamics of life situations. Body senses collect the input from the surroundings for people to conceive the reality. The environment of existence is a hub of sensory stimuli forming sensory scapes that are unique within themselves. The "sensuous world" is composed of sightscape, soundscape, smellscape in addition to the other two sense domains, touchscape and tastescape which have not been explored deliberately compared to the rest (Porteous, 1990). The "multisensory," "allscape" world is a combination of domains of various sensory experiences (Porteous, 1990) just like wars which stem from conflict of interests, and thrive as "sensescapes."

War zones have been arenas of sensory elements since soldiers of ancient history are expected to be attentive to stimuli in order to develop a perception of combat dynamics. Sight, smell, and sound are significant identifying elements of warfare. All the sensory perceptions embodied as a sensescape is an important aspect of war taken into consideration in operational planning in military actions. For example, it is for the advantage of the defensive side to spot any attack beforehand or as soon as possible by tracing the sensory clues. The assaulting party, on the contrary, tries to suppress or eliminate all sensory marks to execute surprise offensive or to keep the size and capabilities of its armed power secret. Sensual marks of seeing, hearing, smelling, touching or even tasting can be both advantageous or disadvantageous with respect to the mission of the belligerent sides. Sometimes intimidating scenes accompanied with loud noise are performed in order to scare the enemy; whereas, other times surprise raids are prepared under secrecy not to stimulate senses on the adversary side. Whistling arrows, war horns, and war cries are audible elements of war. Galloping cavalry set the background for sight and sound of attack. Burning animal and human bodies, bloodshed arouse the olfaction of war. Tactile contact used to be prominent such as punching, spurring, or using the weapon with the hand. For the purposes to be exhaustive, if an example needs to be provided for taste

sense at battles, anthropological accounts reveal the practice of ritual, and culinary cannibalism (Keeley, 1996, p. 103).

Science and technology moved the address of violence from deadly physical contact between humans to inflict harm from a distance. Missiles and explosives need to cross an area in order to exert their lethal blow on the target. In modern warfare the sensory alertness of soldiers are undertaken by electronic sensors. Among many other utilizations, remote sensors are used for target or threat detection, and overviewing the war theater. From electromagnetic spectrum, microwave and laser devices can carry out remote sensing task in addition to radar. In order to circumvent the sensor signals of remote detection, stealth attribute is introduced to military vehicles and ammunition thereby rendering the battlezones undetected. One of the most prominent advantages of laser weapons is that the emitted beam has inherent stealth characteristics. It can be described as a beam of invisible electromagnetic radiation emitting no sound or smell with no sensory traces, almost totally concealed from remote sensing technology.

Vision is considered to be the dominating sense convincing humans about the worldly existence indicating a notion of certainty. The first perception of any object is usually derived from our visual impression. Visionscape of armed confrontation has a lot to offer to combatants about the terrain, other physical conditions of the war theater, and valuable information about the adversary. In premodern battles, any activity taking place within reasonable distance could have been detected through visionary sense. Vision brings with it the knowledge of the environment. As anthropologist David Le Breton puts "Distance is abolished through seeing" (Le Breton, 2017, p. 35), as long as there is no obstacle between the subject and the object. This reminds of the elevations and other view blocking obstacles that were mentioned in the interviews with relation to laser utilization. Distance is an important aspect at war. It is a dimension that needs to be covered in order to attack or escape from the threat. Distance between the weapon and the target, that is range, is one of the determining factors in weapon specifications. Visibility weakens with distance. For example, in South American Quechua language two similar verbs *ricuni* and *riccuni* mean "to see" and "to go," respectively, pointing out the relation between sight, movement, and distance (Howes & Classen, 1991, p. 264). Here there is a connotation to laser, which is amplification of the EM radiation around visible light, and near-infrared wavelengths that traverses a distance aimed at its target; that is,

laser "sees" and it "goes." It itself has nothing to offer to spectators, it is invisible, unseen by eyes, but harmful on them. Lasers' initial introduction to combat was as a threat to eyes. When aimed at eyes, and held there long enough it would cause blindness, which is deemed a war crime by UN subsequently. Laser due to its nature has intrinsic stealth; it is not light nor it has a color as commonly thought. In *The Waste Land*, T.S. Eliot says "I will show you fear in a handful of dust" (as cited in Porteous, 1990, p. 127). On the battleground, laser will create fear without any dust and smoke. Its intimidation is concealed under its transparency.

Wars are, as they appear to be, quite noisy endeavours. As technology offers more powerful explosives, war fighting gets more challenging for the ears. Soundscape of war environment helps explain the evolution of war with respect to the variety of sounds changing over a timeline. Once the sound horseshoes, charging catapults, and war cries are now replaced by frightening noises of rifle shootings, terrifying sounds of blasting bombs or descending missiles. These are technological sounds with their ups and downs, sometimes sharp sometimes suppressed due to the weapons used, and giving an idea about the intensity of the fight with valuable hints regarding the belligerent forces on the field. It is also possible to disclose the characteristics of war, and gauge its scale in terms of the sounds produced. For example, a state-to-state war would create a sonic environment of intensive explosives such as rockets, artillery, mortar, and even more destructive missiles. On the other hand, rifle shootings, angry noises of Toyota pick-ups[27], or combatants' distinct yellings would connote urban warfare. The audibility of these sounds from a range of distances contributes another dimension to this perception. Premodern wars were restricted to relatively smaller regions with noises nearby in contrast to high-tech wars with loud chargings and bombings audible from far distances. As a matter of fact, sound also is a defining factor for the battle with its commensurable attribute. In particular, speeds of some aerial vehicles, and a variety of missiles are quantified with reference to speed of sound to define their rate of engagement.

Sound can be assessed differently from two opposing perspectives in a conflict. Associated to psychological war practices, from the offensive side's perspective, sound is utilized as a tool to magnify the attacker's power by performing a loud intimidation with war cries, or consistent noises of automatic shootings,

[27]Many features of Toyota Hilux pick-up trucks appeal to insurgent groups in various regions of the world thereby becoming an iconic symbol of marginal fighting groups (Somaiya, October 14, 2010).

blasting sounds of explosives, or deafening noise of low flying fighter jets. On the other hand, for successful attacks, stealth must be secured by eliminating all sensory stimuli including sound. Therefore, on the individual level, for example, special suppressors are provided for guns, or tactics can be planned in consideration of noise element within operating environments. As one of the informant engineers pointed out, in general weapons have acoustic signatures which indicate their position, and range once fired. Lasers, in contrast to other weapon systems, do not have acoustic signature that can be linked to them marking their involvement in an engagement. Once fully deployed, lasers will be the most silent attack element of the war.

Unpleasant scents can be associated with wars; human scents like sweat and blood; smell of animals, such as horses and mules; odor of gunpowder. The heavy smell of death would surely rise from the deadly battleground. Like other sensuous triggers, smells can stimulate emotions (Porteous, 1996) which may influence soldier behavior at combat. Smells associated with particular elements of wars can help identify the situations to understand the combat environment. In contemporary wars where humans and animals are largely replaced by technology, olfactory is almost rendered ineffective. Similarly a laser system does not dissipate any smell during operation nor does its beam give out any scent that would make it discernible which is an advantageous aspect in terms of its stealth.

2.2. Laser *thing*

Tactile and tasting modalities are probably the least relevant senses in respect to modern warfare. In medieval wars, castle gates have been broken open with battering rams or javelins have been plunged into bodies evoking a pure sense of deadly touch. As the technology extends the geographical limits of war, two items coming together close enough to touch would be rarely observed during modern warfares. However, touching is still a major notion in conception of existence. "Touch is the true test of reality" suggests philosopher Hans Jonas (as cited in Breton, 2017, p. 100). In contrast to the other sensory impressions, touching creates an awareness of concrete materiality of presence. Contact is a direct connection between the subject and the object which has a physical form with tactile aspect. However, some entities surrounding humans that are in physical contact with human subjects cannot be classified as objects because they do not have apparent physical boundaries and are

beyond touching. For example, gaseous air that people live in; it is known to be made up of molecules that are in contact with people. Individuals know they are immersed in air, but they cannot perceive it readily by senses. Air is intangible, invisible, not audible as long as it does not blow as wind.

Further in the conceptualization, untouchable unseen energy is neither material nor can its existence always be sensed. Given the presumption that humans call what they see and touch as objects, entities that are not concrete, irrespective of being intelligible through senses can all be defined as *things* including the material objects. Hence, gas, liquid, solid, all forms of matter, and energy can be considered thing. Consequently, non-human elements of life network are not only plants, animals, and inanimate objects, but also air, atmosphere, and energy within. Non-humans' interactions with human life foster their *thing*ness even more.

Consistent with the above mentioned definition, accounts from Socrates emphasize the thingness of light energy suggesting mutually reinforcing relation between object, vision, and light. He refers to light's centrality with respect to seeing:

> "Surely sight may be present in the eyes and its possessor may try to use it, and colors may be present in things; but unless a third kind of thing is present, which is naturally adapted for this specific purpose, sight will see nothing and the colors will remain unseen," (as cited in Brown, 2015, p. 298).

Seeing takes place under light via sensory reception of eyes aiming at the object observing the revelation of colors associated with the object. The visible light which entails seeing corresponds to the electromagnetic wavelength range used in producing the laser beam. Light's thingness is even more substantialized in the form of laser which turns out to be a very effective thing of war.

From another point of view, vision can be considered as an extention of touch. The concreteness of the object in proximity to us is revealed by touching; whereas, the physical form of the object that is far away is perceived through seeing. Le Breton's description of focused vision is evocative of laser:

> "Vision is sometimes imagined as a projection cast onto the world and sweeping across it like a beam of light. However, unless focused on a particular sight, it does not stretch out along a single line but, rather, encompasses a multitude of elements in a diffuse manner, from one moment to the next..." (Le Breton, 2017, p. 33)

Laser is a type of a directed energy delivered in the form of coherent beam aiming at a target similar to the way vision seeks its object. In the case where vision cannot literally touch the object, laser can because laser has the capability to get into contact; it couples with its target. Laser is made of light particles, photons, acting in the form of waves, and thereby, it can be considered as a thing if not object. It is capable of melting or buckling metal through heating. Though it is untouchable by humans, the response by other things to its performance shows that it is tangible. Just as Breton puts "Where the fog renders vision powerless," the same fog weakens the laser too. When encountered by the particles in the atmosphere, photons scatter, and the beam diverges which is one of the major challenges that scientists and engineers try to overcome in the development of the technology. Evon Vogt, in his book, Tortillas for the Gods narrates that according to Zinacanteco culture, light represents sight, and with its thermal attribute it has the "thermo-tactile" (as cited in Howes, 199, p. 236) effect just like the laser in contact with its target. A laser beam reaches out, and couples with its target, and directs its heating effect on the target in order to melt a spot and disturb the target's material integrity or buckle it by mechanical means. This is how energy manifests its power in war. Current laser technology enables laser's influence with "soft-skin" aerial vehicles, as one of the informants put, which are relatively thinner, and not resistant to laser beam's effect. The aim is to advance the technology to make the laser's "touching" more lethal, if you will.

Arjun Appadurai argues that "things-in-motion" pose significance for humans (Appadurai, 2013, p. 5). Motion is an intrinsic feature of laser with its very fast moving photons forming a texture of energy. The thingness of the laser beam is veiled under this invisible motion. This motion is the essence of laser's impact. The electromagnetic energy in its natural dormant way may have an undetected effect on its surroundings. However, when it is amplified and put into motion, then it manifests its thingness and becomes effective.

2.3. War Network

Actor-Network Theory was first introduced by Bruno Latour and Michel Callon (1981) as a valuable contribution to Science and Technology Studies (as cited in Williams, 2020, p. 4). It proposes an explanation to the relations between human and non-human entities forming a network. Many scholars designate human and non-

human elements of a network as actor and actant, respectively, equipped with agency imposing effect on one other within an interrelationship. Armed forces satisfy the definition of such a network with personnel as human actors, and lethal and non-lethal systems as non-human actants[28]. Since war is conceptualized as organized violence among armed forces, war itself is even a more comprehensive network where ANT may present a insightful perspective to understand it. ANT is a flexible approach that can offer an explanation to the transformations of networks fostered by the dynamics of relations. It can shed light onto the dynamism associated with war. This dynamism is seen both in vigorous activity of military bodies at war theaters and in the changing character of war over time. ANT can provide an alternative perception to the evolution of war, and unveil the human-weapon interconnection.

For the purposes of simplicity, and framing the subject matter of the study, war and military will be considered as closed circuits functioning and evolving within themselves, detached from the political, economic, and social dynamics. War and military bodies are so enmeshed that change in one transforms the other. This study tries to provide a discussion for only the technological advancements as the key dimension in the evolution of war phenomena. Technology's role in dehumanization of social life as well as wars is evident in advent of artificial intelligence, robotics, and automation.

Being a complex system crowded with many parameters and players, war contains networks within networks. The statement "complexly inscribed Actor Network which consists of many unstable, and constantly evolving Actor Networks" (Williams, 2020) is compatible with wars and armed forces which present distinct, interrelated, and evolving networks within a broader network. The outer network which frames the modern war enterprise is generally composed of two or more armed forces, and various groups of non-state combatants. The interaction of these organizations either show antagonism if they are enemies, or support in case they are allies. Each force is yet another network which is a military body simply composed of personnel and technological systems. In modern armed forces, the human element, personnel, may include soldiers, technicians, engineers, while the non-human element, that is technological products are mainly composed of weapon systems

[28] Although non-human actants present in war would imply not only lethal instruments but also elements such as non-lethal remote sensors, etc., in this study for the purposes of appraising laser's role in war, non-human actants refer to weapons and ammunition, that is lethal elements of war.

including platforms, arms, and ammunitions, along with various detection systems and auxiliary units.

Since the scope of the study focuses at war with its human and non-human elements, the interactions of soldiers and weapons irrespective of their sides within war will be foregrounded. Weapons and all the other instruments of war carry a potential impact that can change the course of war. Despite the common conception that it is the human beings who establish an architecture of soldiers and weapons, ANT underlines the indispensible significance of non-humans along humans, and attributes agency to both. According to ANT, non-human is ascribed agency as long as it acts within network.

Human and non-human participants of military are complementary figures that are assembled around a common purpose of victory. Consequently, this requires an organized collaboration of soldiers and weaponry. Human and non-human nodes of armed forces are mutually-interactive irrespective of duration of war extending beyond time and location of war. During peace, a soldier has to receive certain training to be able to use a gun. During fire exchange, the soldier who is in charge of his weapon needs to gauge the response of the weapon in order to determine their next step. They are in a vital cooperation of "shaping each other in and through their encounters," (Clark, 2020, p. 158). Without activation of the bonds inbetween the nodes of a military unit, the soldier-weapon assembly cannot accomplish enough. On the other hand human and non-human elements knit together in a network paves the way for military success. This would provide a typical example for "heterogeneous elements" assembled in "some given state of affairs," as Latour (2005) describes. In addition to reflexive mutual-response of the actor and the actant, there is also mutual-benefit involved in soldier-arms relationship. They engage in a very strong "synergic activity" (Williams, 2020, p. vii) with each other due to the fact that accomplishment of their goal depends on the survival of their network. Their collaborative mission of maintaining security, also is diverted to each other for mutual-protection as participants of a common endeavor. In other words, they are in a symbiosis induced by their joint defense of themselves and of their bonds in a military engagement. This can be denoted as a "combined effort of the collaborative and cooperative activities... of human and nonhuman actants" (Williams, 2020, p. vii).

This agent-to-agent reinforcement has a compatible counter-symmetric network on the enemy side. The inevitable contact between opposing parties is

executed by human actors indirectly, and non-human actants directly in contemporary warfare. A particular weapon, friendly to one side, poses danger to the hostile side. Actants of war, impose their power of essence through military response at contentious situations as deny, degrade, destruct, damage, etc. by exerting their influence on both the actors and actants of the adversary network. This countering relationship is hidden in John Law's expression, "*Contra* appearances, nature is always entangled with culture and society," (2004, p. 121). If his referral is extrapolated to war paradigm, the constructed products, weapons, which can be represented by "culture" seem to pose a "contra appearance" against soldiers which is a sample of the "society." These so-called countering identities are enmeshed within their natural environment, war.

2.4. Laser as Non-human Actant of War Network

ANT also can explain the context of contemporary innovations which are products of culmination of special technologies (Latour, 2003). In general, weapons are high-tech products which are manifestation of technology forming an interconnected bond with human actor during a military confrontation. Conventional weapons are inanimate objects made of concrete material. On the other hand, laser technology brings a novel instrument to the war arena. While a laser weapon system can be depicted as a concrete object, the electromagnetic beam it produces is far from being concrete, furthermore highly undetected by senses; it is a kind of concentrated energy that propagates on a linear straight path. Direct utilization of energy as a weapon introduces a new type of non-human actant; instead of a concrete object of ammunition, the agent, in this case, is a thing in the form of energy. It is not only non-human but also non-object. As Latour points out, "Things are everywhere mixed with people, they always have been," (2003, p. 37).

Being a thing, electromagnetic energy goes beyond getting mixed with people, it envelopes them. People getting inspired by its presence, did not tacitly enjoy it as source of natural energy but transformed it into a powerful lethal beam. Human intentions about the energy is pointed out in a catchy way by one of the engineers: "Power out of control is no power at all," as in once the memorable advertisement slogan on Turkish TV channels. The human actor, engineers, harness the energy out there just to turn it into something more effective with amplification. The introduction

of lethal energy to the battlefield by laser technology would be a groundbreaking change that threatens the centrality of object weapon as non-human element of war. Future will show to what extent laser will replace material weapon systems and ammunitions. However, this new technology may instigate transformation of the battlefield. Non-human object actants can be replaced by non-human non-object energy actants. Laser may lead to *reification* of energy embodied in a beam which is to become the new candidate for non-human actants of military network.

Latour points out that "non-human things-in-themselves 'lack nothing,'" (1988, p. 193), and do not need humans' help for existence. The energy surrounding the humans on earth is consistent with this claim. Electromagnetic energy exists, and manifests itself as being part of human life irrespective of human existence. However, it needs human craft to be turned into a tool, and be ascribed the responsibility of a node in a network. As elaborated in the interviews, engineers work on the technology to turn EM energy into laser to be utilized by military. Laser needs human intent and control to exist, and function as a non-human actant of the war network.

It is hard to fit laser into Latour's conceptualization that "the objects of science and technology had become ... social-compatible" (2005, p. 10) since war is a unique phenomena distinct from the daily routine of social life, however, in a confrontation, human and non-human participants deem war a dynamic social network. Being an effective node within military body, laser may be regarded as indispensable member of military concept in association with human members. Since laser is to be tasked in correlation with other non-human and human entities' duties, it will be compatible to the overall dynamics of the social war network. Latour's description of actor and actant relations is evocative of relations in war network. There is human-to-human connections, and object-object connections, but the nature of war will require "zigzag from one to the other" (Latour, 2005).

3. CONCLUDING THOUGHTS: FUTURE WARFARE WITH WEAPONIZED ENERGY - LASER

Direct energy usage as weapon was a concept of science-fiction about to be adopted by real science during the first half of 20th century when White wrote "Energy and the Evolution of Culture," (1943). Today, scientific research yielded the working principle for energy weapons, which in turn led to technology maturation with products ready for integration into war structure. At the present time, laser technology is under incessant development to enhance efficiency and effectiveness. Energy that has been used for sustenance of human life so far is materialized as a weapon.

The stunning change that laser brings to war is directed use of concentrated energy. The collimated, coherent beam of electromagnetic radiation is a new candidate for being a major combatant actant of the battlefield. It threatens to replace the object actants of war fight. Once fielded on the battleground, it is to become an agent of the conflict zone interacting with human actors and other non-human actants influencing the course of the combat. As tried to be explained in this study under contextualization of Actor Network Theory, laser is a potential non-human non-object actant connected to the other agents of war network. Despite the ceaseless debate of violence whether intrinsic human attribute or not, the humane act of war is on the cusp of becoming less and less human and non-concrete rendering the war domains to the domination of energy. Together with already existing sensing, detection, and guiding systems using radiofrequency, infrared, or laser radiation, in the future, laser weapons may contribute to the dehumanization of war also supported by artificial intelligence, automation, and robotics.

Due to the political, social, and economic parameters, and the contingencies unforeseen for the world, it is not easy to draw a trajectory for laser weapons' technological development, and the role they will assume in the future warfare. Given the presumption that war and all of its constituents are under influence of various interconnected dynamics, the assessments drawn in this study is based on conservative anticipation, and may be considered as mere speculation for purposes of intellectual practice. Under uncertainty, almost all the informants agree on the partial inclusion of lasers on war zones as complementary force in the near future. The retired officer's comment was a well-known expression stressing the predominance of

human actor at war; "Without boots on the ground you cannot seize an area." Though this is a referral to decisive significance of infantry branch as tacitly understood in the military, it underlines the indispensible agency of military personnel at combat. This perspective infers that only under considerable control of human actor, objects and things of war share the responsibility in victory or defeat.

The change that laser will exert on the character of war will be in line with the overall advent of war technology. Laser technology is considered to be an alternative to missile technology. It is presumed that projectiles will be replaced by lasers to some extent; that is to say, non-human actants of war will be diversified as objects and directed energy such as laser. This will entail dematerialization of military engagement on a route from concrete to abstract. The explanation of the engineer with military background supports this argument. He suggested that based on the current assumption of one percent laser usage to ninetynine percent kinetic engagement against drones, in the future, might turn to sixty to forty percent usages respectively, laser increasing its share. The new character of war may be defined with respect to the new energy-based war instrument in addition to matter-based weaponry.

A projectile is an object that can stimulate all humane senses in war environment. From bullets to missiles all projectiles have sensual attributes marking their agency. The modern conventional war region is like a theater of senses in action. Vehicle hit by a mortar would draw a picturesque blast with fire and flash of light lifting a cloud of dust and smoke. The accompanying sound is deafening for the nearby individuals, and murderous for the victims. The sense of heat and pressure from the explosion triggers humane instinct of escape, leading people run away till the smell of death and destruction is left behind. Whizzing bullets, exploding mines, and rockets fired from fighter jets even add more to the commotion and debris. This audacious sensescape is war theater made up of visionscape, soundscape, smellscape, and touchscape. Everything about war appeals to senses. That is why combatants are expected to be alert, and open to detect every change on the battleground.

If and when the physical presence of ordnance is replaced by laser beams, almost all the sensual elements would be eliminated from the theater of war. Laser is invisible, silent, does not smell, does not arouse sense of pressure or heat as long as a person is not directly targeted; furthermore, it does not cause dust and smoke across the battleground. From retired officer's point of view, silence attribute would be an advantage, and he appreciated that laser would not raise any dust. Additionally, he

mentioned his expectation of future capabilities such as hitting a plane as an element of air defence. Laser is a non-object thing numb to human senses, only to be detected by remote sensing technology to some extent. For the far future it has the potential to obliterate projectiles, and all the sensual stimuli associated with them. Lasers may create silent, unseen wars undetected by senses; thereby leaving the detection task solely to military remote sensing equipment. Character of war may be redefined as devoid of sense and stimuli.

Laser weapon capabilities such as precision, speed, range, scalability of effects, deep magazine, and stealth will meet distinct requirements of military missions. Among these especially speed, and range are properties that may transgress the boundaries of war theater. Adaptability to all kinds of platforms, its speed of light, and performance over unaccustomed long ranges may expand military operations across all domains of land, see, and air leaping into space. The traditional term of battleground or battlefield may be replaced by battlespace as seen in recent literature. Such a vision may require substantial changes not only in military doctrines but essentially for national security policies of states due to probable future space wars.

Future will show if warfare will ever evolve into senseless, and dehumanized energyware with energy-based engagement instead of object-base. The redefined character of war can be described as laser-integrated flexible network with human actors and non-human actants on a whole engagement spectrum, across all domains, and all phases of conflicts with tactical and strategic implications on battlespace. Ambiguity in changing character of war due to military relevance of lasers cannot be resolved at the present time. Anthropology may encounter with more material to process as science and technology experts and military personnel get more familiar with this possibly new type of warfare. While human actors are still the main decision-makers in war network, human wisdom is critically important more than ever. Otherwise, lasers, as one of the informants expressed, "might be a product of a pessimistic future" for humanity...

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