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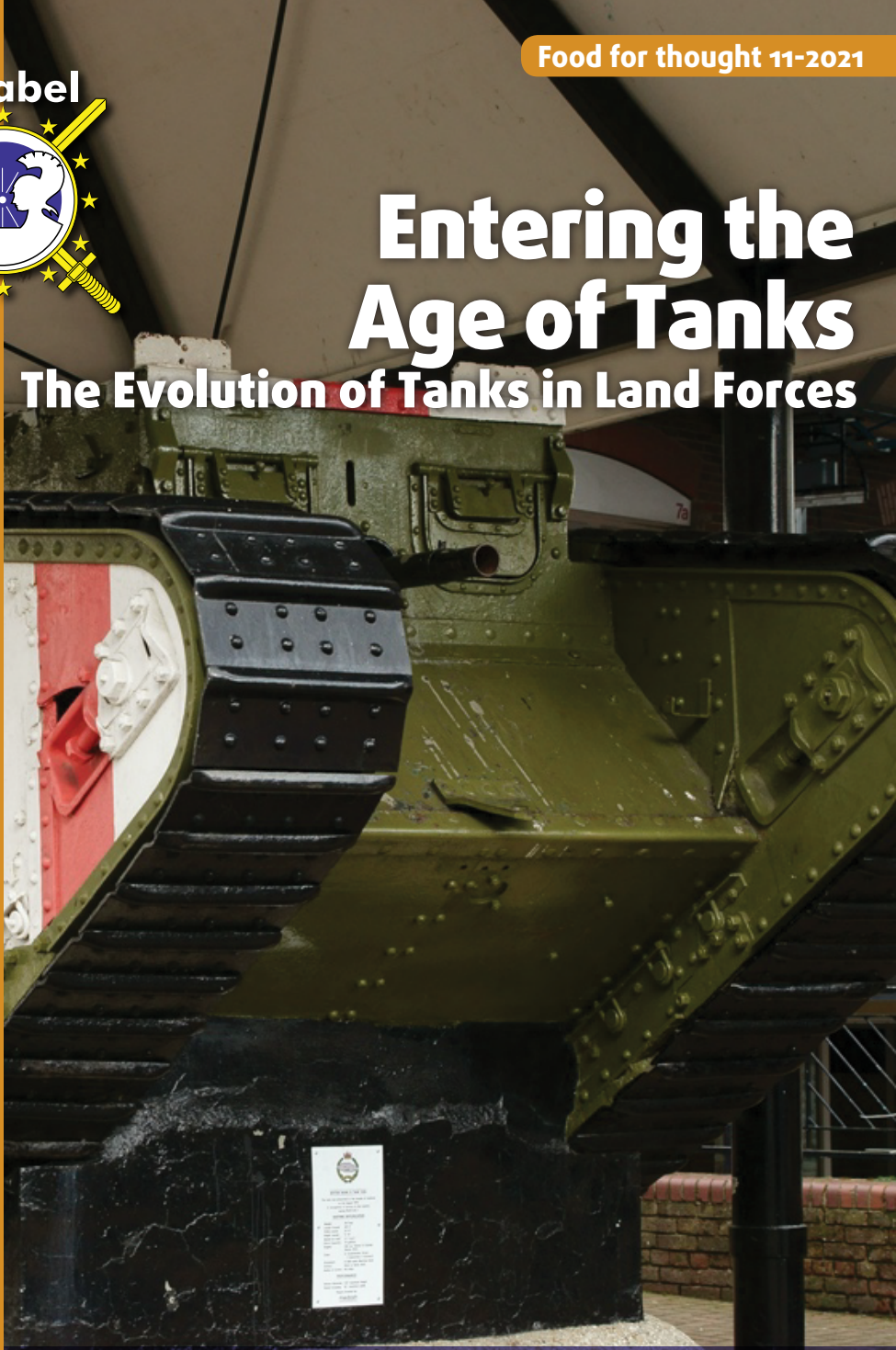
Entering the Age of Tanks

The Evolution of Tanks in Land Forces



AN EXPERTISE FORUM CONTRIBUTING TO EUROPEAN ARMIES INTEROPERABILITY SINCE 1953

FINABEL
European Army Interoperability Centre

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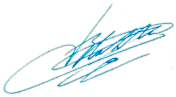
This Food for Thought paper is a document that gives an initial reflection on the theme. The content is not reflecting the positions of the member states but consists of elements that can initiate and feed the discussions and analyses in the domain of the theme. All our studies are available on www.finabel.org

DIRECTOR'S EDITORIAL

With the outbreak of trench warfare in World War I, tanks first emerged as indispensable combat tools. Since then, tanks have continually solidified their role as an embodiment of military capability in the armed forces. First developed in the early 20th century by Western armed forces with the British "Big Willie" and the French Renault FT-17, tanks today are the product of a century of innovation and have spread worldwide. Since their inception, tanks have undergone impressive optimisations through many technological and operational developments as a result of new countermeasures within modern warfare, new operational theatres, and the evolving international threat environment. This complex process led to the development of Main Battle Tanks (MBTs) such as the well-known British Challenger II, French Leclerc, German Leopard 2A7 or US M1A2 Abrams.

Despite widespread appreciation for the progress and current utility of tanks, there is no consensus on the future role of tanks in modern warfare. Some have predicted an imminent end to the "age of tanks". Moreover, recent international developments and shifts in operational needs might mark the potential end to tank production and development as a strategic and industrial blunder.

In this context, the present paper seeks to provide an objective exploration of the historical development of tanks in land forces, an examination of their role and function in modern warfare, and a discussion on their relevance within the security environments of today and tomorrow.



Mario Blokken
Director PSec

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INTRODUCTION

Tanks have figured among world militaries' most vital tools since they first entered the scene in 1915.[1] Although the construction of formal tanks can be traced back to the turn of the 20th century, their strategic importance endures to the present day, given their role as a backbone of warfare. They facilitate tactical movement of armed forces while employing heavy weapons systems for a strong defence, coupled with thick armour for a high degree of protection.[2] Tanks began as excessively heavy, slow-moving vehicles designed to cope with trench warfare of World War I through providing significant offence capabilities and supporting better protection of the infantry. Their types are generally classified as "light", "medium", and "heavy" combat vehicles, depending on their ammunition and weight.

However, today, these combat vehicles have developed higher speed, stronger armour, and a greater defence capacity against diverse threats. Modern warfare has brought new operational theatres and countermeasures, leading to numerous technological improvements embodied by the Main Battle Tank (MBT). MBTs are the dominant model of heavy tanks. They are operated by three to four crew members, achieve high mobility, and incorporate advanced ballistics protection. Acquisitions of MBTs are expected to grow in the coming years, as countries have begun to invest more in tanks and produce them in larger quantities. Countries such as France, Germany, Russia and the US, among others, are modernising their MBTs to be integrated into the 21st-century battlefield, where automation and intelligent technologies are replacing their outdated predecessors.[3] Moscow is also hurrying to develop unmanned battle tanks that provide leverage over other European countries.[4] Overall, we argue that despite some pessimism among military experts regarding the end of the "age of tanks"—which stems partly from an abundance of ageing tank models and their growing costs—the importance of tanks for land forces prevails. It is within this shifting and uncertain context that we embed our close examination of the tank's evolution, past and future.

As tanks gain renewed attention due to the changing security environment that provokes military self-reflection and reorientation, this paper observes the tank's technological evolution through three historical periods: 1915-1920 (World War I), the 1920s-1930s (the interwar period), 1939-1945 (World War II), and 1945-1989 (Cold War Conflicts). After reviewing the historical trajectory of tanks, we explore their current role in warfare, which necessitates a discussion of some contemporary tank models and their general features. Then, we analyse European tank capabilities to compare them to American and Russian

1. Jinkuk Kim, Jungsub Yoon and Jeon-Dong Lee, "Dominant design and evolution of technological trajectories: The case of tank technology, 1915–1998", Journal of Evolutionary Economics, 31, (July 2020): 661-676. [online] Available at: https://doi.org/10.1007/s00191-020-00697-1 [Accessed 10 October 2021].
2. Lemola, Jukka (Product Manager of the Finnish company Patria Land, Military Systems - Vehicle Products), in discussion with the authors, 14 October 2021.
3. Joseph Roger Clark, Innovation under fire: Politics, learning, and US Army Doctrine (Washington D.C.: George Washington University, 2011).
4. Mordor Intelligence (2021), Main Battle Tank Market – Growth, Trends, Covid-19 Impact and Forecasts (2021-2026), [online] Available at: https://www.mordorintelligence.com/industry-reports/main-battle-tank-market

tanks. A subsequent survey of key antitank weapons and corresponding countermeasures gives way to an exploration of perspectives on the future of tanks in terms of both potential technology and their continued relevance.

HISTORICAL DEVELOPMENTS: FROM EARLY DEVELOPMENT TO COLD WAR CONFLICTS

Earliest Developments

The tank's earliest predecessors can be traced back to horse-drawn war chariots of the 2nd millennium BCE in the Middle East and, later, to the protected vehicles of the Middle Ages in Europe. Both ideas fused in the 14th and 15th centuries when Guido da Vigevano and Leonardo da Vinci developed battle cars. However, more practical forms emerged in early 20th century England with the first self-propelled armoured vehicle—an armoured steam traction engine—and the first motor vehicle mounted with a machine gun. The operational push to develop such vehicles arose from the vulnerability of horse-drawn carriages in the infantry, which were needed to improve the mobility of the heavy machine guns that dominated battlefields.[5]

A shift towards internal combustion engines took place to increase machine gun mobility even further. In 1902, German-born British engineer Frederick Richard Simms developed the first "Motor War Car" constructed by the armament firm *Vickers, Sons & Maxim*. Despite its limited mobility, it was the first self-propelled vehicle to be both armoured and armed. The French *Société Charon, Girardot et Voigt* later produced the first fully armoured car with a turret.[6] Lacking official and military uses, the "Motor Car War" project was abandoned along with the French project of an armoured car and the Austrian project of a four-wheeled, fully armoured body equipped with a hemispherical turret and one or two Maxim guns.[7]

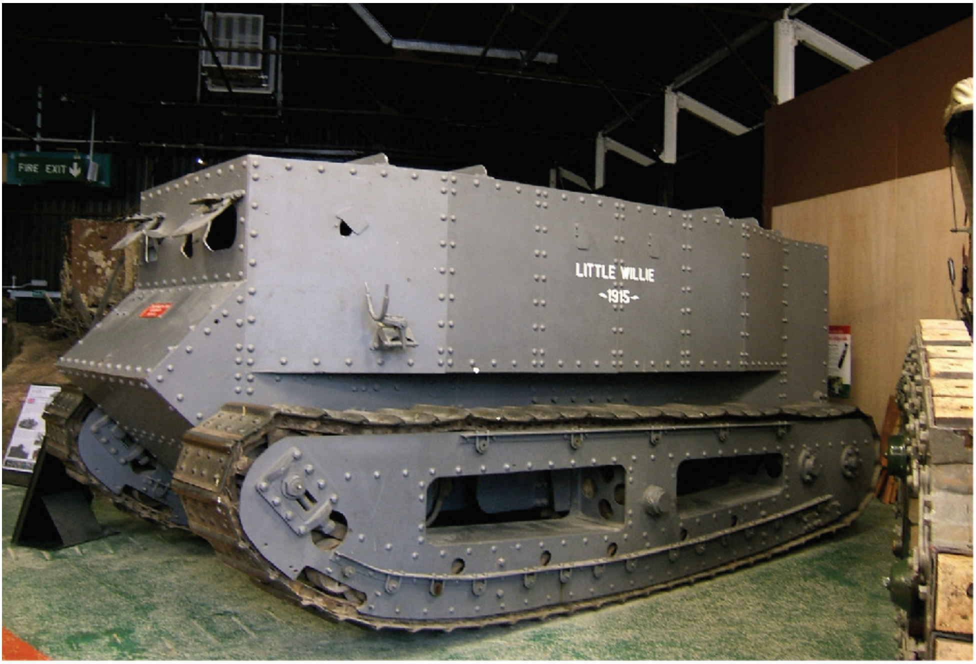
The initial attempts at developing armoured cars were quite disorderly and ruled by complete improvisation. In Belgium, armoured war vehicles were improvised on car chassis to harass German forces. France did the same, followed by the British Royal Naval Air Service for ground reconnaissance and protection in support of flight operations. The British armoured car was based on the Rolls-Royce "Silver Ghost" chassis armed with a machine gun in a revolving turret operated by three men. This peculiar design was the most successful during World War I and the following two decades. Later on, from 1915, armoured cars spread across Europe, the US, and India.[8] Yet, despite the

5. Richard Marian Ogorkiewicz, Tanks: 100 years of evolution (Oxford: Bloomsbury Publishing, 2015): 11-13.
6. Richard Marian Ogorkiewicz, (2020), "Tank.", Encyclopedia Britannica, [online] Available at: https://www.britannica.com/technology/tank-military-vehicle
7. Richard Marian Ogorkiewicz, Tanks: 100 years of evolution, 13- 15.
8. Richard Marian Ogorkiewicz, Tanks: 100 years of evolution, 18- 20.

rising implementation of motor cars, many armies continued to rely on horse-drawn carriages.[9]

World War I

While the armoured cars, moving weapons platforms with increasing mobility and protection, became a reality, they did not permit the participants of WWI to overcome the challenges of trench warfare.[10] The outbreak of WWI was a decisive contributor to the rapid advent and evolution of tanks, given motivational drivers such as the need to drive off-road and tread broken ground and barbed wire.[11] Three key mechanical components also observed increased availability: bulletproof armour, the internal combustion engine, and caterpillar tracks.[12] Indeed, conditions for the concrete adoption of tracks only came with the outbreak of WWI.[13]
Faced with trench warfare, Churchill gave his approval to reflect upon the concept of the "land boat" and created the War Office Com-



Source: Stockvault, https://www.flickr.com/photos/skuds/224525418/in/photolist-jk4buB-21zaxyL-kQKzU-C2kDLF-83rp3Y

Little Willie

Andrew Skudder, August 22, 200

9. Ibid., 16- 18.
10. Ibid., 21.
11. Ibid., 16- 18.
12. Carolina Castaldi, Roberto Fontana, and Alessandro Nuvolari, "'Chariots of fire': the evolution of tank technology, 1915–1945." Journal of Evolutionary Economics 19, no. 4 (2009): 550. [online]. Available at: https://doi.org/10.1007/s00191-009-0141-0 [Accessed 28 September 2021].
13. Richard Marian Ogorkiewicz, (2020), "Tank.", [online].

mittee to work on assault vehicles. The outcome was Tritton's vehicle—an experimental machine with a box hull made of boilerplate and a fixed dummy turret. The development of such landships was subject to high secrecy. Workers were told that they were in charge of producing "water tanks" to carry water on the battlefield[14]. Hence the reason why they began to be called "tanks", and the nickname survived.[15] With some modifications, Tritton's experimental machine resulted in "Little Willie", whose speed improved with the birth of the "Wilson Machine", famously known as "Big Willie". Also called the "Mother", it is considered the progenitor of WWI British heavy tanks. In February 1916, Mark I ("Big Willie" with a few modifications) entered into the final development phase and the production process.[16] Mark Is, however, came with many weak points and drawbacks: the hulls made of armour instead of mild steel plates, lack of universal fitting with machine guns, the need for a crew of four men, difficult communication due to engine noise, heat and noxious fumes, severe jolts due to the absence of suspension, and slower progress than the infantry with which they were supposed to cooperate.[17] The culmination of these factors adversely affected the tank's

British Mark IV Tank

(Ashford, Kent), Peter Trimming, March 19, 2013

Source: Stockvault, https://www.flickr.com/photos/peter-trimming/8574709420/in/photolist-e4HCnA-cVwWpf-dpTWEa-dpU8xb-dpU7d9-2iyjTpw-e4C2QP-cVwWaw-cVwW35-LsEEf7-e4HCv1-2h9YiiB-GujB8n-dpU7Jb-9tfZHk-73xtW9-NhKyMR-X9EiT1-XKpYaY-2ituJ5Q-e4C2Fz-2iRjMuW-XMb6RA-ZFzCAA-XKpXth-XRgboB-bUjGha-9zRGmF-Ws6QbW-7MpAyj-a7eLGz-292YoTp-Q2ryC2-CDSunQ-9UC6KM-9UC66V-RPiYgE-KHxfJZ-29hC8Kq-72msxo-bUjq-Va-asu6J3-astDeN-asqZKX-asrrQZ-asoaVt-asrtBK-asrtp8-asu3HE-asrj4q

14. History.com Editors. (2009), "First Tank Produced", History, [online] Available at: https://www.history.com/this-day-in-history/first-tank-produced
15. Chris Woolf, (2016), "The day tanks changed war forever", The World, [online] Available at: https://www.pri.org/stories/2016-09-15/day-tanks-changed-war-forever
16. Richard Marian Ogorkiewicz, (2020), "Tank.", [online].
17. Richard Marian Ogorkiewicz, Tanks: 100 years of evolution, 34-36.

performance. Still, the first tank unit took shape in February 1916.[18]

France followed the same paths of development and production. Indeed, both countries faced the same military problems and possessed similar technological resources. The French company Renault was in charge of producing both the Schneider tank—a simple box hull—and Saint-Chammonds.[19]Again, for the sake of secrecy, they were dubbed "tractors".[20] However, they were too slow and too short, highlighting the need for a lighter and faster tank: Renault FT-17, the first with a 360-degree turret, successfully fitted for close infantry support.[21] At the end of the war, there had been 24 French tank battalions and numerous deliveries to two US tank battalions.[22]

The Battle of Flers-Courcelette in France on 15 September 1916 marked the dawn of the age of the tank with the breaking of the stalemate of trench warfare by a British Mark I.[23] Mark Is were already on French soil in August to help the Allies at the push of the Battle of the Somme.[24] Tank doctrine relied on making the offence stronger than the defence, with tanks having the mere function of being an auxiliary to infantry.[25] Indeed, tanks had two versions: the "male" one used by the artillery to attack fortified positions, and the "female" one armed with machine guns to target enemy infantry.[26] The element of surprise during battle was a success.[27] However, Mark Is were unreliable, with half of them broken after the battle.[28] Moreover, they were not operably well-fitted, suffering from the engine's heat and toxic fog from exhaust fumes.[29] The lack of doctrine that would enable their efficient use on the ground was an issue compounded by their many design flaws: small, hard to manoeuvre, heavily influenced by commercial tractors, still susceptible to heavy machine gun fire.[30] The British Army lost its advantage of shock and surprise since Germans saw them and began to reflect upon their military response. However, Germany only built 20 A7V Sturmpanzerwagen tanks against the hundreds that belonged to the Allies.[31] Theirs were unstable, prone to overheating and needed a crew of eighteen to operate. Since they could not justify the investment of scarce manpower and industrial material due to the tanks' poor performance, the German Army relied on captured British tanks.[32] "The first tank battle in history took place between three British Mark IVs and two German A7Vs on 24 April 1918 at Villers-Bretonneux, France", while American Expeditionary Force used French and British tanks to help the Allies.[33]

18. Ibid., 42-43.
19. Ibid., 36- 41.
20. Ibid.
21. Michael David Kennedy, (2016), "Tanks and Tank Warfare.", 1914-1918-online. International Encyclopedia of the First World War, ed. by Ute Daniel, Peter Gatrell, Oliver Janz, Heather Jones, Jennifer Keene, Alan Kramer, and Bill Nasson, (May 2016):1. [online]. Available at: https://doi.org/10.15463/ie1418.10905
22. Richard Marian Ogorkiewicz, Tanks: 100 years of evolution, 53.
23. Kyle Mizokami. (2016), "100 Years Ago Today, Tanks Changed Warfare Forever", Popular Mechanics, [online].
24. Chris Woolf, (2016), "The day tanks changed war forever", The World, [online].
25. Kyle Mizokami. (2016), "100 Years Ago Today, Tanks Changed Warfare Forever", [online].
26. Kennedy,"Tanks and Tank Warfare.", 1.
27. Ibid.
28. Kyle Mizokami. (2016), "100 Years Ago Today, Tanks Changed Warfare Forever", [online].
29. Chris Woolf, (2016), "The day tanks changed war forever", The World, [online].
30. Kennedy,"Tanks and Tank Warfare.", 2.
31. Woolf, (2016), "The day tanks changed war forever", The World, [online].
32. Kennedy,"Tanks and Tank Warfare.", 2.
33. Thomas G Mahnken, "Innovation in the Interwar Years." SITC Research Briefs 2018, no. 11 (2018): 2. [online] Available at: https://escholarship.org/uc/item/1hw200dw [Accessed: 27 September, 2021].

Interwar Development:

The 1920s and 1930 witnessed a high degree of overlap between the different models of tanks produced. There were also similar doctrines in France, the UK, and the US concerning the role of tanks in war. They served as accessory infantry support, while in Germany, they were considered as the backbone of new tactics based on speed and mobility.[34] Until the early '30s, France led in tank development and production, with Britain taking over the lead thanks to its highly mobile Vickers Medium tanks.[35] However, not used by the British Army, Vickers Medium served as a model for the Soviets BT-5 tanks.[36] Indeed, after 1929, the Soviet Union became the biggest producer, followed on a smaller scale by Poland, Czechoslovakia, and Japan. Tank development and production then started up again in France and Italy.[37] The USSR engaged in a massive production programme in 1930-1931, producing about 20,000 tanks in 1939—more than the sum total of all other countries.[38]

On the contrary, the power of British tanks had diminished by 1939 due to a threat environment unconducive to the development of armed forces. First, the Treaty of Versailles disarmed Germany. Second, The British government adopted the Ten Year Rule (August 1919 to the 1930s), which assumed that Britain would not engage in war, meaning no Expeditionary Force was needed for the following ten years. Concerning the US, they lacked funding and apparent incentives to develop tanks on their own regarding their operational theatres in the Philippines or the defence of the Panama Canal.[39] However, Germany's covert arms development programmes, in violation of the Treaty of Versailles, designed tanks for export to Sweden and Hungary. For the Allies, the interwar developments were marked by a lack of strategic and operational challenges, poor leadership support, and constrained resources. Germany became progressively a "hot-house for innovation", moving from a second-tier player during WWI to the forefront in WWII.[40]

World War II and Cold War Conflicts

Having internalised the tactical importance of tanks, many of Europe's powers by the late interwar period had either developed their own tanks and antitank guns and rockets or purchased them from others.[41] Propelled by the booming automobile industry, gradual technological advancements made before 1939 can be partially credited with transforming the tank into an indispensable tool of warfare and driving the wide proliferation of tank models across Europe and the United States. General changes in tank design by the outbreak of World War II (WWII) included better performing engines, enhanced lateral vision from the central turret, more efficient crew arrangements, and the use of radios for

34. Castaldi, Fontana, and Nuvolari, "'Chariots of fire': the evolution of tank technology, 1915–1945." 547.
35. Richard Marian Ogorkiewicz, (2020), "Tank.", [online].
36. Castaldi, Fontana, and Nuvolari, "'Chariots of fire': the evolution of tank technology, 1915–1945." 551.
37. Richard Marian Ogorkiewicz, (2020), "Tank.", [online].
38. Ibid.
39. Mahnken, "Innovation in the Interwar Years.", 2.
40. Ibid., 4.
41. Charles River Editors, ed., The Evolution of Tanks in World War II (South Carolina: CreateSpace Independent Publishing Platform, 2018): 2.

communication.[42] Gun calibres of 75mm and 76mm were most prevalent, with some even reaching 88mm to 122mm.[43] Among the most successful tank designs was the Soviet T-34, which embodied the ideal triad of gun calibre, speed capacity, and armour thickness.[44] Also successful enough to be mass-produced were the German Panzer IV and the American M4 Sherman.

A decisive contributor to tank success in WWII was the simple scale-up in vehicle and gun size, which amplified the tank's firepower, protection capacity, and thus its lethality.[45] For example, armour plates of 50mm and 100mm in thickness had replaced those of 15mm to 30mm by the end of the war.[46] The heaviest tanks of the time weighed up to 30 tonnes and provided strong defence, although they often had the fatal flaw of sacrificing agility and mobility for heightened firepower and protection.[47] Moreover, the boom in tank production far eclipsed the figures seen during WWI. This episode in history supported the tank's evolution from a lightly armoured, lightly protected combat vehicle into a profoundly more mobile, massive, and powerful one.[48]

Tanks also led to innovations on a tactical level. Having been barred by the Treaty of Versailles from manufacturing tanks, Germany lagged behind industry leaders such as the Americans, British, and French. At the start of WWII, it possessed only light and medium-weight tanks with relatively weak firepower, such as the PzKpfw I, II, and III. However, The Germans made up for their early deficiencies by quickly producing more powerful tanks and by executing a superior tactical doctrine.[49] The strategy of Blitzkrieg, which assaulted enemy front lines with concentrated fire by tanks and other weapons, devastated the Allies up to 1942. Still, the Allies were able to regain the upper hand in the arena of tank warfare by out-producing the Germans with better armed and better-protected tanks. Soviet T-34's, for example, far outnumbered German Panzer IV's during the war, with the former reaching around 35,000 and the latter around 8,500.[50] Indeed, during WWII, the capacity to mass-produce tanks was considered strategically vital to success as the quality of the tanks themselves.[51] The Allies wielded their advantage in this area to secure their victory.

Several core lessons had been learnt by the end of the war. Firstly, that favourable terrain, adequate logistics support, and presence in large numbers were requisite conditions for tanks to realise their full potential.[52] Secondly, WWII had demonstrated in general that "while the infantry bore the brunt of the battle and suffered most of the casualties, it was usually the tank that made the pivotal thrust, the decisive manoeuver that decided victory or defeat on the operational level".[53]

During the Cold War (1945-1989), the de-

42. Tucker, Spencer C. Tanks: An Illustrated History of Their Impact. (Santa Barbara: ABC-CLIO, 2004): 138.
43. Castaldi, Fontana, and Nuvolari. "'Chariots of fire': the evolution of tank technology, 1915–1945.", 550.
44. Ibid.
45. Leland S. Ness, Jane's World War II Tanks and Fighting Vehicles (New-York: HarperCollins, 2002):14.
46. Ibid.,10.
47. Tucker, Tanks: An Illustrated History of Their Impact, 41-43.
48. Bishop, Chris. The Encyclopedia of Tanks & Armored Fighting Vehicles (San Diego: Thunder Bay Press, 2006): 10-12.
49. Tucker, Spencer C. Tanks: An Illustrated History of Their Impact, 9.
50. Robert J Bunker, Armed Robotic Systems Emergence (Oxford: The College Press, 2019): 41.
51. Castaldi, Fontana, and Nuvolari. "'Chariots of fire': the evolution of tank technology, 1915–1945.", 550.
52. Tucker, Spencer C. Tanks: An Illustrated History of Their Impact, 11.
53. Bishop, Chris. The Encyclopedia of Tanks & Armored Fighting Vehicles, 14.

sign of tanks evolved along with their applications on the battlefield. Technological breakthroughs rendered the trend toward heavy tanks obsolete, as lighter, less costly, and more manoeuvrable models equipped with more powerful weapons replaced their clunkier predecessors.[54] Indeed, the days of trial-and-error and poorly-planned experimentation with tank design had reached their end by the 1960s, giving way to unprecedented optimisations in the realms of protection, firepower, agility, and preparedness to face enemy forces.[55] Some updates, seen during the era, included the replacement of petrol engines with ever-smaller and more powerful diesel engines, as well as the widespread use of better suspension systems, which allowed for a smoother ride and, therefore, more accurate mobile firing.[56] A notable breakthrough came with the development of explosive reactive armour (ERA), which disrupted incoming antitank warheads by detonating on contact.[57] Additionally, tanks of the era were increasingly equipped with improved sights, night-vision technology, and aiming systems, as well as more powerful guns and projectile systems.[58] The highly advanced Soviet T-64 pioneered many such advancements, including advanced armour and guided projectiles, and had the added design advantage of low weight coupled with strong firepower and protection.[59]

Since WWII, nearly every armed conflict has seen the use of tanks. Early on, most non-Western countries relied on purchasing tanks from European and American producers. By 1962, however, Japan and China had begun developing their own indigenous systems inspired by American and Soviet models, respectively. Tanks proved a key factor in wars in the Middle East—such as the Iraq-Iran wars and Arab-Israeli wars—where the flat landscape provided optimal terrain for tank operation. It was during the wars in the Middle East that the age of antitank missiles came to fruition. Despite the rise of antitank weapons, which, for some, presaged the end of tanks' relevance, tanks persisted throughout the Cold War as a lasting feature of the world's military establishments.[60] Beyond the Middle East, tanks were also in use in certain parts of South and East Asia. In Vietnam, they aided in protecting convoys, defending bases, patrolling secure zones, and conducting sweeps and ambushes.[61] Moreover, many of the Cold War era's repressive regimes instrumentalised tanks to quash popular revolt and reinforce the dominance of the state. Lastly, they served as a tool for the many peacekeeping operations of the era.[62]

As the West met newfound stability in the immediate post-Cold War period, thousands of tanks were either scrapped or sold to third countries seeking to modernise their fleet at a reduced cost.[63] Tanks still experience continued relevance in the Yugoslav Wars, UN peacekeeping missions, and nations outside Europe experiencing security threats.[64]

54. Ibid., 10.
55. Michael E Haskew, The World's Greatest Tanks (London: Amber Books Ltd, 2014): 27.
56. Bishop, Chris. The Encyclopedia of Tanks & Armored Fighting Vehicles, 40.
57. Tucker, Spencer C. Tanks: An Illustrated History of Their Impact, 151.
58. Ibid.
59. Steven J. Zaloga, T-64 Battle Tank (New-York: Bloomsbury USA, 2015): 4.
60. Tucker, Spencer C. Tanks: An Illustrated History of Their Impact, 81.
61. Ibid.
62. Riho Terras (MEP, ex-Chief of Defence of Estonia), in discussion with the authors, 12 October, 2021.
63. David Willey, The Tank Book (London: Dorling Kindersley Limited, 2017): 199.
64. Ibid.

MBTS: GENERAL FEATURES, CAPABILITIES, AND ADAPTATION TO MODERN WARFARE

General Features

Technological evolution has been impressive since WWII. The technological progress of tanks has translated into an increasing variety in models over time. Engineers' attempts to manufacture different tank designs with diverging capabilities have led to the classification of "light," "medium", and "heavy" fighting vehicles.[65]

Namely, tanks are designed to achieve specific performance results, such as cross-country mobility, protection, and firepower with the help of integrated mounted weapons. Protection and firepower refer to the "battlefield performance" of tanks, while mobility is considered crucial not only for the battlefield but also for strategic navigation and operation conduction.[66] Specifically, the battlefield mobility of armoured tanks heavily depends on their weight, mounted weapons, and length. This means that the longer the tanks are, the faster they navigate on battlefronts due to a balanced distribution of weight on their wheels. However, an increased length also leads to an increased weight, thus slowing down their manoeuvres and exposing them to threats.[67]

The operational mobility of these heavy vehicles entails cross-country navigation, which depends on their weight and engine power. For instance, heavy vehicles are less fast-moving than light ones. The battlefield capability of tanks (protection and firepower) relies on thick armour and high armament calibre. Tanks should be capable of resisting firepower from enemy tanks and surviving antitank kinetic energy penetrators as well as artillery, missiles, and mines.[68] Although tanks may differ from country to country, they share a basic technology. The mounted weapons in tanks have undergone technological evolution, ranging from single rifle calibre guns to long-barrelled guns.

Modern tanks provide more advanced terrain and road mobility than in previous generations of vehicles, thanks to higher engine power as well as more capable ammunition. Namely, the weapons systems nowadays are much more efficient and competent as they incorporate 120mm to 130mm guns, with a wide range of different types of ammunition, including missile systems and countermeasure capabilities. Modern tanks are also equipped with advanced armour, which can be passive, active, or reactive, as well as contemporary and advanced sensor/camera systems, thus improving their performance and survivabil-

65. Ibid.
66 Richard Marian Ogorkiewicz, Technology of tanks (Vol 1), (Coulsdon: Jane's Information Group, 1991): 223.
67. Vemuri Madhu and T. Balakrishna Bhat, "Armour Protection and Affordable Protection for Futuristic Combat Vehicles", Defence Science Journal 61, no. 4 (July 2011): 394-402. [online] Available at: https://doi.org/10.14429/dsj.61.365 [Accessed 12 October, 2021].
68. Ibid.

ity on the battlefield.[69] Despite tanks' heavy armour protection, the vehicles' rear, side armour, and the commander's cupola (turret) constitute tanks' most vulnerable parts, making them an easy target.[70]

The Shift towards Main Battle Tanks

In the aftermath of WWII, the notion of Main Battle Tank (MBT) was first presented as a dominant model of tanks, inducing a technological shift that evolved from being obsolete and light to cutting-edge and heavy. According to the Product Manager of Patria, Jukka Lemola, the Main Battle Tanks are tracked vehicles that weigh around 50 to 60 tonnes due to incorporated ballistic protection in them. These combat tanks can gain speed up to 70km on the road and about 50km off the road and hence, are called lighter vehicles.[71] The dominant design relies on "combat doctrine," which assesses risk exposure and source scarcity.[72]

Since WWII, the MBT crew members have been reduced from five (commander, gunner, loader, driver, and co-driver) to four or three members. The third-generation MBTs, as for example, France's Leclerc and Russia's

MBT Leopard 2A7

Katzennase, July 15, 2015

Source: Stockvault, https://www.flickr.com/photos/44560307@N06/19732286031/in/photolist-w4F8b8-ahbeos-JHn77B-JHn5H4-JJYFLe-VW61xM-JLW7Qm-JLW9bY-Jaxzft-J2kYXb-2i4jxyp-JJaUUx-K5Vsez-LsxhpC-JJaVPP-J9CckH-vLDA-MU-vLDFih-BwNocZ-v7fLWb-qAUdUN-2kK5Crn-2kK5CoB-afJjYy-VxsSaY-GGNB9W-HTUqK7-JqgKN1-JESf25-JaxTsa-JF4YWj-J2m26u-Jav8VA-JaxAqK-Jav1ow-JNAi5d-J2kZSC-URhCQW-VW4r3x-W8CUAR-VW67F8-VW64i6-W8C9kM-K5VviF-JRVjvM-J9zqvC-JprDGQ-JE4mu7-Jat8qG-HUHrZ6]

69. Lemola, Jukka (Product Manager of the Finnish company Patria Land, Military Systems - Vehicle Products), in discussion with the authors, 14 October, 2021.
70. Kyle Mizokami (2016), "100 Years Ago Today, Tanks Changed Warfare Forever", Popular Mechanics, [online] Available at: https://www.popularmechanics.com/military/weapons/a22880/100-years-ago-today-tanks-changed-warfare-forever/
71. Ibid.
72. Madhu and Bhat, "Armour Protection and Affordable Protection for Futuristic Combat Vehicles", 394-402.

T-14 Armata, are operated by three crew members: commander, gunner, and driver, and an unmanned loader for the ammunition. In comparison, tanks such as Germany's 2A7+ and the US' M1 Abrams consist of four crew members: commander, gunner, driver, and loader operated by a soldier.[73] The difference between the manned and the unmanned loader is that the latter can slow down the gun-loading as it is automated by a machine.[74] The rapid evolution of intelligent technologies suggests that the new MBTs can now be operated by a two-soldier crew, hence reducing the combats' weight and height. In a two-crew tank, one soldier must act as a driver, and the other must execute command and firing tasks. Russia, for instance, has already raised the question of two-crew members, yet this remains a future goal.[75]

Nonetheless, Main Battle Tanks should not be confused with Infantry Fighting Vehicles (IFV), which tend to be much lighter than the battle tanks. The IFVs are wheeled machines, many of which can also be amphibious. These fighting vehicles operate as modern system carriers for reconnaissance, ambulance, engineering, and antiaircraft vehicles. Moreover, they weigh around 20 to 30 tonnes. They

FV4034 Challenger 2
TankFest 2017, Alan Wilson, June 24, 2017

Source: https://www.flickr.com/photos/ajw1970/31403624768/in/photolist-PR2Mym-PR2Ndh-dHxCmf-Xt5fgs-dPxXPC-C6Buhe-C4fvfw-26NdKdp-dHsdHT-a7gjdo-2j42RGJ-2j44pv2-dHsdFg-2j4fARC-a6XcDF-25pYQY5-26Nz672-27P5w-TU-KKCaQL-L2QAoo-L2PN8C-26Nccoz-KKCxUf-27P6yiW-Jwgo8Z-275pKbb-njAaXu-27P5Yn9-28aNgHD-286oZZq-25pK9JJ-286po7m-27P659E-2j2qi3N-2j2oHvi-VeqQmq-VeqPqY-U4mrTn-24bL5y6-26NefAc-KKD137-y6kEsr-L2Pab1-28aQ16H-275ojYA-28aNmK2-286ncyS-286oHAd-28aJmQF-28aPnDV]

73. Ming Mao, Fang Xie, Jian-Jun Hu and Bo Su, "Analysis of workload of tank crew under the conditions of informatization", Defence Technology 10, no. 1, (March 2014): 17-21. [online] Available at: https://doi.org/10.1016/j.dt.2013.12.008 [Accessed 12 October, 2021].
74. Army Technology, (2021), "Leclerc Main Battle Tank", [online] Available at: https://www.army-technology.com/projects/leclerc/
75. Mao, Xie, Hu and Su, "Analysis of workload of tank crew under the conditions of informatization", 17-21.

are usually armed with automated cannons, collection machine guns, and often with antitank missile weapons systems, providing them with all-encompassing security. These IFVs can reach a speed of up to 60km/h on the road. However, the security importance of MBTs has not retreated in favour of modern IFVs. This suggests that European armed forces are performing again in large-scale or traditional wars as the battle tanks are making their come-back.[76]

EUROPEAN MILITARY CAPABILITIES IN THE GLOBAL CONTEXT

European Tanks Capabilities Facing the World

If we take a closer look at various European MBTs, we can see that all of them have been subject to technical improvements, going from slow and heavy to faster and lighter. This evolution means that MBTs' software and

U.S. Army M1 Abrams

U.S. Army photo by Spc. Andrew McNeil, May 2, 2018

Source: Stockvault, https://www.flickr.com/photos/39955793@N07/41237857564/in/photolist-25Q3Nmd-2cXXpn1-PNwsCf-JMqdTR-22mWAaP-ehLmU8-88bi6G-88bi9f-pqbeB2-am3Fuv-KkYTeH-8887g2-2kSZiTE-pukKbh-GS6sM2-scJnEA-scJNhm-26VqiP1-4bsBqi-CD2JTk-23JnMKK-23FxzUQ-LbdpBi-2482zLB-XSWaHe-UCK1Yg-dnVLhT-ttFEwS-61wufs-61shPt-61shWD-suh4ig-61shTP-aUZjBc-aUZjBk-61wut7-8HVK2Q-28aUrRx-GJq1vf-27Yt4GE-3LxQPt-uJaL-BH-N1i9pm-JoVh46-9wSthr-HmBDJR-puNS2D-hEYoXF-GxcEHM-ugWgMT]

76. Lemola, Jukka (Product Manager of the Finnish company Patria Land, Military Systems - Vehicle Products), in discussion with the authors, 14 October, 2021.

engine control systems have undergone key advancements since their inception. To illustrate, France's tank, Leclerc, is a chained machine first operated in 1992 by French weapons company Nexter Systems.[77] This MBT demonstrates excellent mobility coupled with active protection. It can reach a road speed of over 70km/h and an off-road speed of about 50km/h. The tank weighs about 57 tonnes and involves a crew of three—a gunner, a commander, and a driver—while most tanks require an unmanned loader to serve as a fourth crew member, which can slow down the gun-loading due to the manned loader.[78] The standard Leclerc version has experienced several upgrades, varying from Leclerc Block1 to Leclerc XLR or Scorpion.[79]

Conversely, Germany's defence company Krauss-Maffei (now Krauss-Maffei Wegmann) has produced the Leopard II from the 1970s to the present day, thus making it a successor to the Leopard I.[80] The Leopard II has a number of different models, ranging from Leopard 2A1 to Leopard 2A7+, which is regarded as the next-generation MBT due to its increased mobility and enhanced sustainability.[81] Its maximum road speed is 70km/h, and it weighs 62 tonnes, which is a bit heavier than the French Leclerc.[82] Berlin's combat vehicle combines firing, protection, mobility, and operational preparedness.[83] The tank has also installed an advanced driver night vision for front and back view and advanced optronics for long-range reconnaissance and digitised detonation.[84]

The UK, as the third pillar of European security, has acquired a thickly armoured and fast-moving third-generation MBT for conflict zones and peacekeeping operations, the Challenger II by the BAE Systems. In 1994, this tank succeeded the Challenger I. It consists of four crew members (commander, driver, loader, gunner) and strong armour for maximum survivability. It weighs 65 tonnes and can reach a road speed of 59km/h and a cross-country speed of 40km/h.[85] The British Ministry of Defence has also launched the modernisation of MBT's programme, the future digital Challenger III. The tank will incorporate Active Protection System, heavy lethality, and laser warning system that all together will provide a high level of protection for the crew.[86]

In the late 1980s, the US, as most European states, had also integrated its technologically advanced combat tank, the M1 Abrams, through Abrams General Dynamics Land Systems (GDLS). The third-generation tank functions with four crew members as the British Challenger II and the German Leopard 2A7 and is resistant to nuclear, biological, and chemical (NBC) warfare. In fact, the M1 Abrams can reach a road speed of 72km/h

77. Army Recognition, (2020), "Renovated Leclerc Scorpion XLR MBT", [online]. Available at: https://www.armyrecognition.com/main_battle_tank_heavy_armoured_france_french_army/leclerc_scorpion_xlr_mbt_main_battle_tank_technical_data_sheet_specifications_pictures_video_10704171.html
78. Army technology, (2021), "Leclerc Main Battle Tank", [online]. Available at: https://www.army-technology.com/projects/leclerc/
79. Army Recognition, (2020), "Renovated Leclerc Scorpion XLR MBT", [online].
80. Army Technology, (2021), "Leopard 2 Main Battle Tank", [online] Available at: https://www.army-technology.com/projects/leopard/
81. KMV, (2021),"Leopard 2A7: the latest version of the world's leading battle tank" [online] Available at: https://www.kmweg.com/systems-products/tracked-vehicles/main-battle-tank/leopard-2-a7/
82. Army Technology, (2021),"Leopard 2 Main Battle Tank", [online].
83. Rheinmetall, (2021), "Tracked Armoured Vehicles", [online]. Available at: https://www.rheinmetall-defence.com/en/rheinmetall_defence/systems_and_products/vehicle_systems/armoured_tracked_vehicles/index.php
84. KMV, (2021),"Leopard 2A7: the latest version of the world's leading battle tank" [online].
85. Army Technology, (2021), "Challenger 2 Main Battle Tank", [online].
86. Rheinmetall, (2021), "Challenger 2 – Main Battle Tank" [online]. Available at: https://www.rheinmetall-defence.com/en/rheinmetall_defence/systems_and_products/vehicle_systems/armoured_tracked_vehicles/challenger_2/index.php.

and is considered one of the heaviest vehicles, weighing 60 tonnes. American defence has manufactured three primary Abrams operating variants, M1, M1A1, and M1A2, which have undergone advancements in armament, firepower, and optics and are constantly adjusting to the rapid changes in warfare.[87]

Similarly, Moscow has also made headway towards modernising the tanks' industry by displaying the next-generation MBT, the T-14 Armata. It was first unveiled by Russian company Uralvagonzavod (UVZ) in 2015 during the Victory Day Parade. The Russian T-14 Armata is another cutting-edge heavy tank operated by a three-member crew (commander, driver, and gunner) and boasts an automatic loader, just as Leclerc.[88] This combat vehicle is supplied with an unmanned turret, digitalised equipment, and an isolated capsule for the personnel. Furthermore, the tank can travel as fast as 90km/h and weighs 55 tonnes.[89] Finally, the tank is fitted with NBC protection, allowing the crew to stay in an armoured capsule that provides more security.[90]

Accordingly, the manufacture of T-14 Armata is quite expensive for the Russian Armed Forces and thus, not only have cost factors delayed the T-14 Armata's mass production, but also have highlighted the need for modernising older Russian models of battle tanks. Russia's limited financial resources, caused by international sanctions and a stagnant domestic economy, have led the country to hold off on the Armata's mass manufacture.[91] Instead, the

The Franco-German joint venture KNDS displayed its new European Main Battle Tank at the June 2018 Eurosatory exhibit in Paris, 2018

Source: Stockvault, https://www.armytimes.com/resizer/7DnPX2HKsnY5TK18SVIODpmDpA=/1200x0/filters:quality(100)/cloudfront-us-east-1.images.arcpublishing.com/mco/G7QXPXVFVVFHRAAYFULQVZVAWI.jpg

87. Army Technology, (2021), "M1A1/2 Abrams Main Battle Tank", [online]. Available at: https://www.army-technology.com/projects/m1a1-2-abrams-main-battle-tank/
88. Mao, Xie, Hu and Su, "Analysis of workload of tank crew under the conditions of informatization", 17-21.
89. Army Technology, (2021), "T-14 Armata Main Battle Tank", [online]. Available at: https://www.army-technology.com/projects/t-14-armata-main-battle-tank/
90. Inder Singh Bisht, "Russia to start mass producing T-14 Armata tanks in 2022", The Defence Post, 6 July, 2021, [online]. Available at: https://www.thedefensepost.com/2021/07/06/russia-mass-producing-t14-armata-tanks/
91. Hercules Reyes, "Russian Military to use T-14 Armata Tanks to 'Fine Tune' War Tactics", The Defence Post, 20 August, 2021, [online]. Available at: https://www.thedefensepost.com/2021/08/20/russia-t14-armata-war-tactics/

Kremlin has refocused its attention on overhauling its older tank fleets, which are equally efficient and robust in terms of quality. Therefore, Russia's Ministry of Defence, in seeking more affordable alternatives, is upgrading the T-72, the T-80 and the T-90 MBTs.[92] Nevertheless, Moscow still poses a strategic threat to European security, especially Poland and the Baltic states.[93]

Poland and Italy have also developed vital battle tanks since 1995. Polish company Bumar Labedy introduced the PT-91 Twardy tank, which is derived from the T-72M1 modernisation programme and resembles the Russian-made T-72 tank. Nevertheless, the Polish Ministry of Defence decided on upgrading the T-72 MBT with new firepower rather than purchasing a new combat tank from Russia. Warsaw's strained relations with Moscow make their appearance again in the security field. Hence, the PT-91 has embarked on several upgrades, ranging from PT-91A to PT-91P.[94] For instance, the vehicle consists of three crew members, meaning that the tank has incorporated the autoloader and does not need a fourth member for loading fire ammunitions, exactly like the French Leclerc. Regarding its mobility capabilities, the armoured vehicle can run at a maximum road speed of 60km/h and cross waters of 1 meter to 2 meters in depth.[95] In the same vein, another notable MBT developed by Italian company Iveco Fiat Oto Melara is the C1 Ariete tank, made of steel. The C1 Ariete can run at a maximum road speed of 65km/h as it weighs around 54 tonnes. Namely, the combat vehicle is enhanced with armour protection from NBC warfare for four crewmembers and is strengthened with thermal and night vision optics for improved coordination.[96]

Towards a Sole EU MBT? The Franco-German Eurotank

After the end of the Cold War, Western European nations largely neglected tank development.[97] The 2008 financial crisis exacerbated the issue, drastically cutting the production of tanks.[98] Nevertheless, emerging asymmetric and hybrid threats of the past years have constituted a wake-up call for many of Europe's armed forces, particularly since the annexation of Crimea in 2014.[99] The post-Ukraine landscape has led European countries to progressively shift their attention towards common research and development programmes and increase their cooperation in military capabilities.[100] The high production costs and growing technology specialisation complicate the process of modern tanks' manufacturing by a single country.[101]

92. Franz-Stefan Gady, "Russia will not Mass Produce T-14 Armata Main Battle Tank", The Diplomat, 1 August, 2018, [online]. Available at: https://thediplomat.com/2018/08/russia-will-not-mass-produce-t-14-armata-main-battle-tank/
93. Joe Saballa,"Russia to Boost Firepower of Aging T-80 Tank", The Defence Post, 31 August, 2021, [online]. Available at: https://www.thedefensepost.com/2021/08/31/russia-firepower-t-80-tank/
94. Army Recognition, (2021), "PT-91 Twardy MBT Main Battle Tank Poland", [online]. Available at: https://www.armyrecognition.com/poland_polish_tanks_heavy_armoured_vehicles_uk/pt-91_twardy_main_battle_tank_technical_data_sheet_specifications_description_information_pictures.html
95. Ibid.
96. Army Technology, (2021), "C1 Ariete Main Battle Tank", [online]. Available at: https://www.army-technology.com/projects/ariete/
97. Jukka Lemola (Product Manager of the Finnish company Patria Land, Military Systems - Vehicle Products), in discussion with the authors, 14 October, 2021 ; Riho Terras (MEP, ex-Chief of Defence of Estonia), in discussion with the authors, 12 October, 2021.
98. Ben Jones, "CSDP Defence Capabilities Development", European Parliament, DG for external relations, Sub-committe on security and defence, (January 2020): 7. [online]. Available at: DOI: 10.2861/374045. [Accessed 21 October, 2021].
99. Lemola, Jukka (Product Manager of the Finnish company Patria Land, Military Systems - Vehicle Products), in discussion with the authors, 14 October, 2021.
100. European Defence Agency, (2018), "2018 CDP Revision. The EU Capability Development Priorities", [online]. Available at: https://eda.europa.eu/docs/default-source/eda-publications/eda-brochure-cdp
101. Ester Sebatino, "EU Defence: Franco-German Cooperation and Europe's Next Generation Battle Tank", Instituto Affari Internazionali Commentaries 20, no. 58 (August 2020): 2. [online]. Available at: https://www.iai.it/en/pubblicazioni/eu-defence-franco-german-cooperation-and-europes-next-generation-battle-tank. [Accessed 23 Octber, 2021]

To this end, Berlin and Paris have created the KNDS joint endeavour between Krauss-Maffei Wegman and Nexter System for the Main Ground Combat System (MGCS) programme—also known as the next generation "Eurotank." The Eurotank represents the Franco-German effort to upgrade heavy land platforms within the European context by establishing the next generation MBT as part of the MGCS that may entail both manned and unmanned ground vehicles along with Unmanned Aerial Vehicles (UAVs).[102] Therefore, in 2012, the Franco-German coalition decided to launch a bilateral initiative to establish a land warfare system to replace the German Leopard 2 and the French Leclerc by 2035, which have been in service since the 1970s and 1980s, respectively.[103] The future Eurotank is expected to conduct military operations by 2040 and to give an impetus for further defence integration within the EU.[104] However, the question of who will be in charge of the design of the Eurotank still has to be settled between Paris and Berlin. Modularity will make it easier to follow the further evolution of the armed conflict.[105]

Nevertheless, deploying the Eurotank implies some potential challenges, as the two sides of the Rhine have not historically shared the same tank industry culture. Berlin, on the one hand, prioritises mobility over armour, thus facilitating rapid counteroffensives. On the other hand, Paris focuses its attention on mobility and firepower and armour protection.[106] Furthermore, Europe has 14 different models of MBTs, thus posing substantial interoperability difficulties in the bilateral endeavour by France and Germany to co-construct a new combat tank. Although the Franco-German project is bringing new members on board, such as the UK, Italy, Poland, and Spain, to develop the European land warfare system, France and Germany still have to decide on the accession requirements of third countries.[107] A comparative advantage that stems from this bilateral project would reduce the fragmentation that characterises different models of land forces, diminish interoperability roadblocks, and improve the deterrence capacity of Europe's armies.[108] While the MGCS is still at its initial stage of development, Russia's T-14 Armata—with which the Eurotank will be capable of competing—is expected to be delivered in 2022.[109]

Adapting to New Antitank Weapons

The Threat from The Air

A variety of weapons have threatened tanks' existence since WWII. Growing ineffectiveness, these mines, grenades, guns, artillery, rockets, and missiles continue to pose challenges to existing tank technology, thereby backing the need for fast, innovative countermeasures in tank design. Due to space constraints, this section focuses solely on the

102. Kyle, Mizokami, (2021), "Britain, France and Germany might build a super 'Eurotank'", Popular Mechanics, [online]. Available at: https://www.popularmechanics.com/military/weapons/a35194111/britain-france-germany-could-build-eurotank/
103. Ibid.
104. Joakim Kasper Oestergaard, (2021), "Main Ground Combat Systems (MGCS) – Status and Path Forward", Defence and Security Monitor, [online]. Available at: https://dsm.forecastinternational.com/wordpress/2021/05/18/main-ground-combat-system-mgcs-status-and-path-forward/
105. Michel, Y. (2018, July 11) France and Germany: on the right tank track? International Institute for Strategic Studies. Available at: https://www.iiss.org/blogs/military-balance/2018/07/france-and-germany-tank-tracks. Accessed at: 25/10/2021.
106. Kyle, Mizokami, (2021), "Britain, France and Germany might build a super 'Eurotank'", Popular Mechanics, [online].
107. Ibid.
108. Sebatino, "EU Defence: Franco-German Cooperation and Europe's Next Generation Battle Tank", 3.
109. Joakim Kasper Oestergaard, (2021), "Main Ground Combat Systems (MGCS) – Status and Path Forward", Defence and Security Monitor, [online].

threats posed by missiles, kinetic energy penetrators, and drones. Today, a major vulnerability of modern tanks remains the threat from the air, which comes chiefly via antitank guided missiles (ATGM).[110] Capable of mid-flight course correction, ATGM's can strike tanks and other targets from great distances with a level of accuracy unseen in previous, unguided generations of antitank missiles.[111] They come equipped with a wide range of warheads depending on the nature of damage an actor seeks to inflict on the enemy tank. The highly successful Javelin, used worldwide since its genesis in 1996, is an archetype of modern ATGM's. This man-portable, fire-and-forget missile can hit targets both directly and from the top, attacking them with an onslaught of metal particles.[112]

Additionally, France's Medium Range Missile (MMP: *Missile Moyenne Portée*) represents a new generation of ATGM's. It has been in operation since 2018 and employed in Mali and Iraq.[113] The MMP can hit both stationary and moving targets either fully autonomously—without in-flight input from the shooter—or under command guidance, which allows the shooter to abort the mission post-launch or to set a different target entirely.[114] The MMP is also designed for maximum success on all terrains and boasts a range of 4km.

Antitank ammunition in the form of kinetic energy projectiles—high density, non-explosive ammunition designed to perforate the thick armour of tanks—also pose a formidable threat. As armour-piercing discarding sabot (APDS) ammunition of WWII has given way to armour-piercing fin-stabilised discarding sabot (APFSDS), a struggle for supremacy between armour and antitank ammunition has played out.[115] The thin, elongated metal body of APFSDS projectiles can impact targets at a hypersonic speed of over 1500 m/s.[116] Their efficiency and level of destruction depend on their impact velocity, length, diameter, and density.[117]

A new and quickly growing threat faced by modern tanks originates from drones. The changing nature of warfare in the information age sees more and more state and non-state actors actively researching and developing means of robotic warfare.[118] Russia, for instance, pours resources into creating drones, humanoid military robots, and robotic military vehicles.[119] China, too, has been successful in cheaply producing armed drones for export all over the Middle East and the Sahel.[120] Low-cost combat drones such as those used with devastating effects in the Nagorno-Karabakh conflict confer tactical advantages due to their small size and quietness, which enable them to go unnoticed by enemy personnel on the ground.[121] Another factor giving drones

110. Riho Terras (MEP, ex-Chief of Defence of Estiona), in discussion with the authors, 12 October 2021.
111. E. G. Berman, "Anti-tank Guided Weapons", Small Arms Survey Research Notes, no. 16 (April 2012): 1. [online] Available at: https://www.files.ethz.ch/isn/142363/SAS-Research-Note-16.pdf
112. Duncan Long, John Lyons, and Richard Chait, Critical Technology Events in the Development of the Stinger and Javelin Missile Systems (South Carolina: CreateSpace Independent Publishing Platform, 2012): 16.
113. Ministère français des forces armées, (2021), "MMP- Missile Moyenne Portée", [online] Available at: https://www.defense.gouv.fr/content/download/604523/10167089/S%20-%20Fiche%20LPM%20-%20MMP.pdf
114. Ibid.
115. NS Venkatesan, "Recent Developments in Anti-Tank Ammunition", Defence Science Journal 35, no. 2, (April 1985): 225.
116. K Motyl, M. Magier, J. Borkowski and B. Zygmunt,"Theoretical and experimental research of anti-tank kinetic penetrator ballistics", Bulletin of the Polish Academy of Sciences, Technical Sciences 65, no. 3, (2017): 400 [online] Available at: DOI: 10.1515/bpasts-2017-0045
117. Tolga Dursun, "Effects of Projectile and Gun Parameters on the Dispersion", Defence Science Journal 70, no. 2 (March 2020): 167.
118. Bunker, Armed Robotic Systems Emergence, 54.
119. Ibid.
120. Ibid.
121. Jacob Parakilas, "Tanks vs. Drones Isn't Rock, Paper, Scissors", The Diplomat, 07 October, 2020, [online]. Available at: https://thediplomat.com/2020/10/tanks-vs-drones-isnt-rock-paper-scissors/

an unprecedented advantage is the nature of tanks' defence systems. With their weapons largely intended for engagements with *ground* targets, tanks faced with threats from drones find themselves greatly limited in terms of defence options.[122]

Countermeasure Capabilities

Efforts to decrease vulnerability have existed since the inception of tanks, starting with simple plates encasing the vehicle. As threats intensified, armour fortification grew progressively thicker, heavier, and less sustainable.[123] Out of this challenge emerged active protection systems, which are highly varied in their capabilities and provide a lighter, more effective alternative to the simple addition of extra armour.[124] So-called "soft kill" measures defend against antitank projectiles by electronically interfering with enemy guidance systems and thereby effectively "hiding" the tank. Jammers, spoofers, and magnetic signal duplicators all serve to neutralise the threat without deploying the tank's costly and finite defence weapons.[125] "Hard kill" measures, on the other hand, rely on a tank's network of sensors and computers to detect incoming enemy projectiles and quickly intercept and destroy them.[126] For example, Russia's Arena active protection system, developed in 1993 and still in use today, tracks incoming ATGM's and antitank grenades and automatically sends small projectiles into their path, detonating anywhere from 1.3 to 3.9 metres away from the target and effectively destroying them.[127] Arena's 300° protection, however, leaves the rear of the turret at risk.

Mitigating or averting the disastrous impacts of kinetic energy projectiles is more complex and poses significant technological hurdles. Historically, Europeans and Americans have overlooked protection systems against APFSDS penetrators, focusing instead on countering ATGM's and rocket-propelled grenades, which were commonplace in Iraq and Afghanistan.[128] Modern tanks with composite, reactive, and spaced armour also tend to offer better protection against high-explosive antitank (HEAT) chemical penetrators, than against APFSDS kinetic penetrators.[129] Currently, passive armour offers the greatest protection against kinetic energy projectiles, although future technology may see kinetic threats mitigated through non-explosive reactive armour, intelligent dynamic armour, and electromagnetic armour.[130]

Defence against hobbyist drones is an equally complicated issue, made more difficult by the quickly evolving nature of drone attacks. In 2017, the state-of-the-art attack drones were highly amateur and equipped to drop hand grenades or mortar rounds on the enemy.[131] However, by 2020, some groups had developed autonomous drones capable of chasing

122. Parakilas, The Diplomat, 07 October, 2020.
123. Kyle Mizokami, (2017), "How Tanks Defend Themselves from Rockets and Missiles", Popular Mechanics, [online] Available at: https://www.popularmechanics.com/military/weapons/a26768/tanks-defend-themselves-rockets-and-missiles/ [Accessed: 15 October, 2021].
124. Ibid.
125. A H. Rahman, S. A. Malik, J. R. Kumar, V. Balaguru and P. Sivakumar, "A Design of Experiments Methodology for Evaluating Configuration for a Generation Next Main Battle Tank", Defence Science Journal 68, no. 1, (January 2018): 22.
126. DK, The Tank Book. The Definitive Visual History of Armoured Vehicles (London: DK Publishing, 2017), 82.
127. Tom Meyer, "Active Protective Sytems: Impregnable Armor or Simply Enhanced Survivability", Armour, (May-June 1998): 9.
128. Jon Hawkes (2021), "IAV 2021: Rafael details challenges of defeating APFSDS long rod penetrators with APS", Janes, [online] Available at: https://www.janes.com/defence-news/news-detail/iav-2021-rafael-details-challenges-of-defeating-apfsds-long-rod-penetrators-with-aps
129. Per Olsson, "Measuring Quality of Military Equipment", Defence and Peace Economics, (2020): 4. [online]. Available at: https://doi.org/10.1080/10242694.2020.1851474
130 Madhu and Bhat, "Armour Protection and Affordable Protection for Futuristic Combat Vehicles", 400.
131. Kyle Mizokami, (2021), "Why Tanks Are Vulnerable Against Drones", Popular Mechanics, [online] Available at: https://www.popularmechanics.com/military/weapons/a37171074/army-tanks-vulnerable-against-drones-congress/ [Accessed: 16 October, 2021].

down human targets.[132]

What Might be Next for tanks?

Emerging developments and new strategic realities call for quick adaptations in tank technology so as to avoid falling into obsolescence. Looking toward the future of tanks, many have predicted the rise of "stealth" capabilities, which conceal the detectable infrared signature of a vehicle and consequently provide enhanced defence. Defence manufacturers have also forecasted lighter machines that incorporate active protection weaponry capable of neutralising the adversary's rockets and missiles. Tanks might also develop their own microdrones designed to detect enemy forces and annihilate them using lasers or missiles.[133] In general, the fighting machines are likely to become more lethal. Nonetheless, engineers first address the issue of how to generate and store the large amounts of energy that new state-of-the-art technology could require.

The changing nature of warfare and the proliferation of new antitank weapons have sparked debate on the relevance of tanks to the modern battlefield, characterised by asymmetrical battles and counterinsurgencies. Technological advances in tank technology, which far outpace advancements in tanks themselves, have also called into question the viability of tanks. John Hawkes, an associate director of the defence intelligence company Janes, has stated that "the tank is more vulnerable now than it has ever been. We're reaching the apex of the armour versus gun race—and armour has lost that race." However, others view tanks as indispensable due to the lack of suitable substitutes: "It is not enough for there to be a weapon capable of defeating a tank in order to make it obsolete; there must also be a means of accomplishing the same missions."[134] Indeed, global militaries rely on tanks to penetrate and encircle the enemy and possess few tools other than tanks that combine high mobility, firepower, and survivability.[135] To ensure their continued survival as assets on the battlefield, tanks of the future must embrace new technologies that would enable them to use concealment, cover, darkness, and dispersal.[136]

CONCLUSION

While the "age of tanks" emerged in practical terms with the outbreak of WWI, the dawn of WWII and the Cold War conflicts solidified the tank's position as a backbone of warfare. Huge technological developments throughout the past century have made tanks more reliable, more efficient, mobile, lethal, faster, and lighter. Yet, given economic constraints and other political and strategic factors, today, tanks do not tend to receive the same

132. Ibid.
133. Kyle Mizokami. (2016), "100 Years Ago Today, Tanks Changed Warfare Forever", [online].
134. Parakilas, The Diplomat, 07 October, 2020.
135. Imran Shamsunahar, "Could Tanks Become Obsolete Like the Battleship", The National Interest, 28 August, 2020, [online]. Available at: https://nationalinterest.org/blog/reboot/could-tanks-become-obsolete-battleship-167878
136. The Economist, "Tanks have rarely been vulnerable", 10 September, 2020, [online]. Available at: https://www.economist.com/science-and-technology/2020/09/10/tanks-have-rarely-been-more-vulnerable

attention as throughout the 20th century. Though some argue that the era of tanks has now come to an end, this paper supports the opposite conclusion. Tanks will likely remain a battlefield institution for the foreseeable future, as they have been in the past. A lack of suitable alternatives to tanks, coupled with their tendency to adapt to changing demands through technological and doctrinal optimisations, point to their sustained relevance in the future.

Nevertheless, only a few European countries can produce modern MBTs based on their individual financial and industrial resources. Europe's ability to build effective, innovative tanks is also hindered by a weak commitment to interoperability, which gives rise to redundant weapons systems: while the US military has one main type of MBT, the EU has 17.[137] The fragmentation among European states regarding defence architecture and industry is not new. Instead of cooperating on shared battle tanks, industrial companies have been competing with each other, thus complicating the process of European defence integration and leading the European self-defence to a standstill. However, the Franco-German project of the Eurotank might usher in a new era for Brussels, where Europe presents a more united front in security affairs.

The changing security environment has continually forced tanks and antitank technology to adjust in response. Looking toward the future, some trends might be observed: the implementation of stealth technology and a novel shift toward a "quality over quantity" approach to tank production, which will see militaries race to modernise. Still, competing with the rapid, technologically advanced, and sometimes cheaper-to-produce systems made in China and Russia continues to present an uphill battle for European defence. Whether or not the age of tanks meets its demise depends on Europe's commitment to both interoperability and to prioritising tanks and antitank weapons in the conflicts of the future.

137. Robert Palmer, "Opinion - Europe is Still Able to Build Tanks", e-International Relations, (September 2020): 2 [online]. Available at: https://www.e-ir.info/2020/09/23/opinion-europe-is-still-able-to-build-tanks/ [Accessed: 26 October, 2021].

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