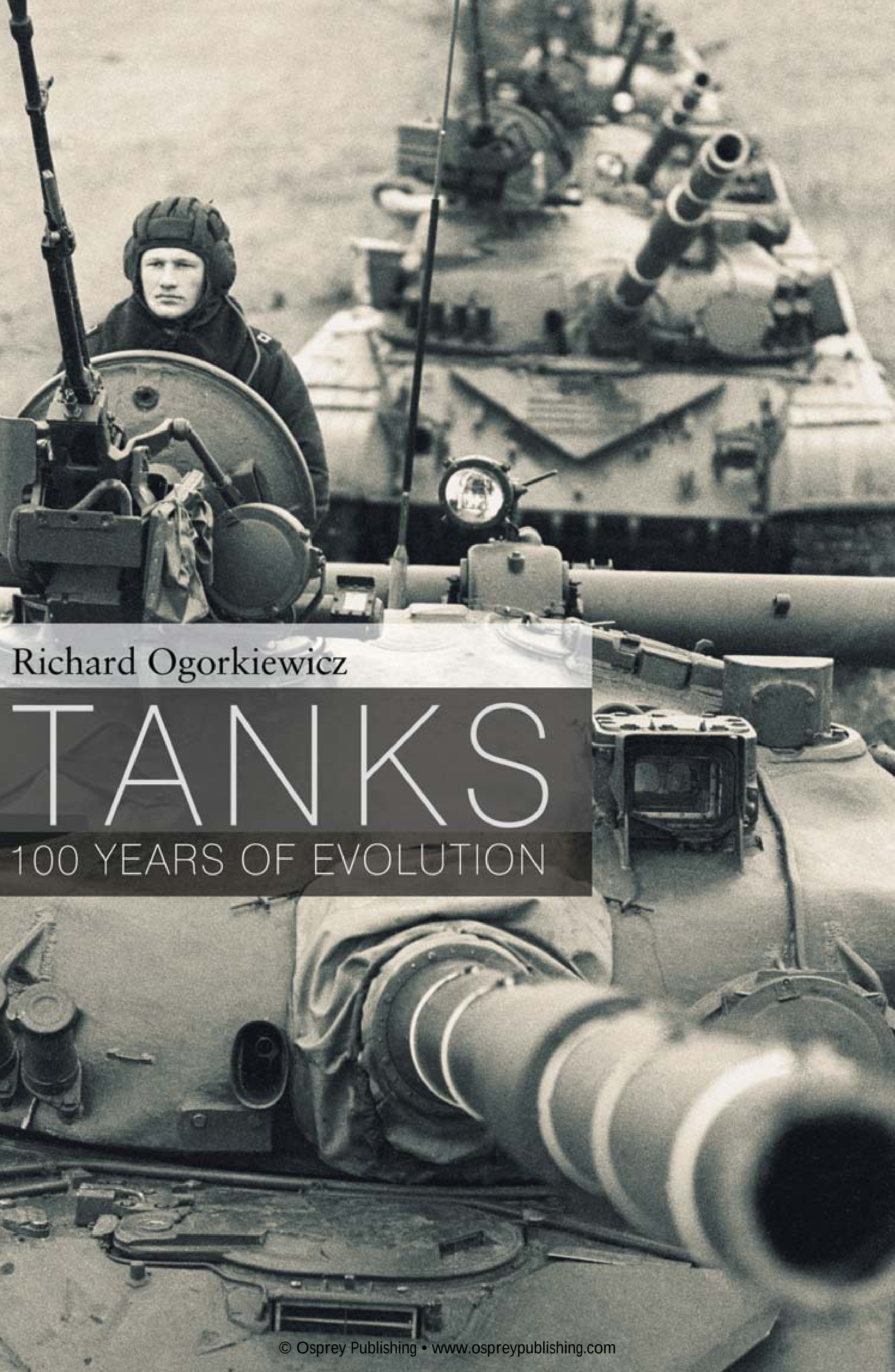

Richard Ogorkiewicz

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100 YEARS OF EVOLUTION

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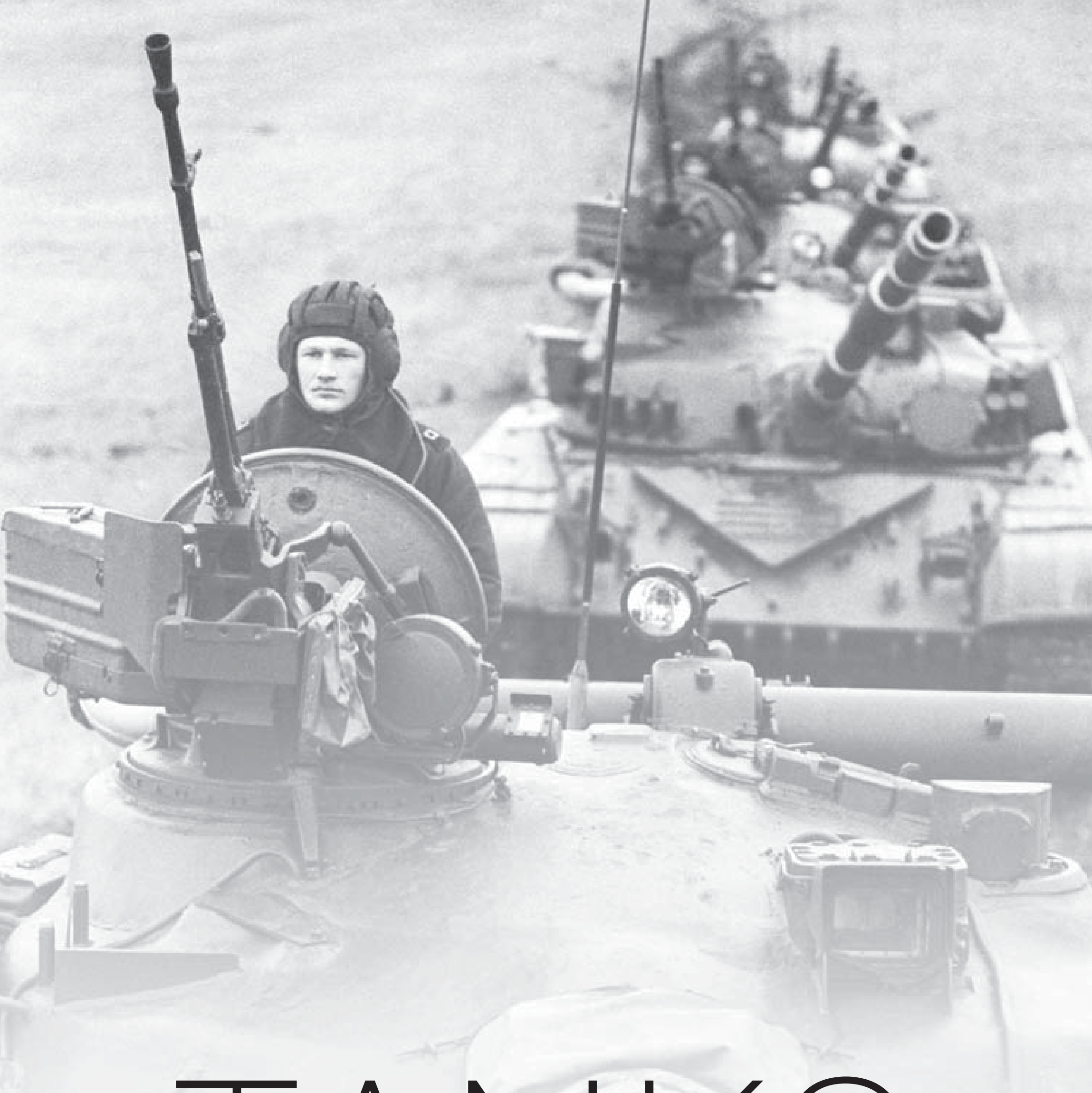


TANKS

100 YEARS OF EVOLUTION

Richard Ogorkiewicz

Contents

Introduction

The aim of this book is to present a comprehensive account of the worldwide evolution and employment of tanks from their inception a century ago to this day.

Because of their military importance and general interest much has been written already about tanks, including three books of which I have been the author.[1, 2, 3] However, there is much more to be said about them, not only because of the more recent developments or because of tanks' worldwide proliferation but also because of the misconceptions about their origins and other developments.

In consequence, the present account starts with a reappraisal of what led to the development of tanks and how they came into being during the First World War. By the end of that conflict tanks had gained considerable importance but this was not sustained in its immediate aftermath, and a revival only began when the British Army started in the 1920s to experiment with a more mobile use of tanks. The subsequent rise in the importance of tanks was accompanied by and was partly due to the advances in their design and performance that were achieved in Europe and America before the Second World War. The enhanced capabilities that tanks consequently acquired enabled them to become the core of combined arms, mechanized formations and these provided the most effective way of employing them, which was demonstrated by the German panzer divisions at the outset of the Second World War.

The successes of the panzer divisions were followed by a widespread expansion of the armoured forces, which came to dominate ground warfare and resulted in the large scale production and employment of tanks during the Second World War by the Soviet Union, the United States and Britain as well as Germany.

The present account goes on to describe the development of tanks during the years of Cold War confrontation between the Western countries and the Soviet Union that followed the Second World War, when large numbers of tanks were deployed in Central Europe by the opposing armies and when further intensive development of them took place in what were at the time the five leading tank producing countries, namely the Soviet Union, the United States, Britain, France and Germany. Significant developments also took place in a number of other countries, in particular in Switzerland, Sweden and Israel, while others acquired tanks produced elsewhere. Important progress has also been made in the Far East, where Japan, South Korea and China have developed in recent years tanks that in some respects have overtaken those built in the United States and Europe, while India and Pakistan have embarked on the production, respectively, of the latest Russian and Chinese designs.

Tanks produced in the various countries may appear to differ, but much of the technology on which they are based is common to them and the principal aspects of it are summarized in three Appendices. The first deals with the general growth in the gun power of tanks and the attempts to improve on it by resorting to guided missiles, liquid propellants and electromagnetic launchers. The second Appendix describes the universal quest for greater protection, which involves not only the use of different armour materials but also explosive reactive armour and computerized active protection systems. The last Appendix concerns the mobility of tanks and includes, among others, the development of various types of engines as well as the interaction of tanks with the terrain on which they operate.

Although the book covers a wide field it does not claim to be exhaustive. It does not, therefore, attempt to deal with more than the most important or the most interesting of the many tanks that have been built. Similarly, it does not attempt to do more than indicate the principal operations in which tanks have taken part, a detailed description of the operations being beyond the scope of one volume.

Richard Ogorkiewicz

Acknowledgements

This book is the outcome of several years of study of the evolution of tanks during which I received much help and encouragement from many individuals that I would like to acknowledge with gratitude.

My early studies benefited from the help given to me by my father, Colonel M. A. Ogorkiewicz, and by Colonel R. J. Icks, in his day the leading American historian of tanks, with whom I corresponded regularly over a period of more than 20 years. I also benefited from discussions with Sir Basil Liddell Hart, whom I had the privilege of assisting when he was writing his history of the Royal Tank Regiment and who encouraged me to write my first book on armoured forces.

During the course of my studies I had the good fortune to meet and subsequently be able to correspond with some of the pioneers of tank development, including Lieutenant Colonel Philip Johnson, whose Medium D tank led the way in the development of more mobile tanks after the First World War, and Leslie F. Little, who, as chief engineer of Vickers Armstrongs, was responsible for the design of the Valentine, the most numerous British tank of the Second World War. I also met and corresponded for several years with Lieutenant General Tomio Hara, who as a young engineer officer designed the first Japanese tank.

I also met some of the leaders of the more recent development of tanks and was able not only to discuss with them tank design but also to examine and to operate the tanks for which they were responsible. In particular they

included Sven Berge, who was responsible for the design of the highly original Swedish S-tank, and Major General Israel Tal, who led the development of Israel's Merkava tanks. They also included Dr Philip W. Lett, who as vice president of Chrysler Defense directed the development of the US Army's M1 tank. All three became close friends and I had the pleasure of serving with them for several years on the Technical Advisory Group of General Dynamics Land Systems.

Others who also became close friends included Dr M. G. Bekker, who introduced me in the early 1960s to his pioneer work in the United States on soil-vehicle mechanics, and Iwao Hayashi, who led the Mitsubishi Heavy Industries' team that developed Japan's Type 74 tank.

More recently I was able to share ideas and information with Professor Manfred Held, the inventor of explosive reactive armour, and Dr Vernon Joynt, the South African mine expert, while lecturing with them on armoured vehicle technology at the Royal Military College of Science over a period of more than ten years.

I have also benefited from sharing information with Rolf Hilmes, who directed studies at the German Defence Academy in Mannhein, with Christopher F. Foss, the editor of *Jane's Armour and Artillery*, with Rickard O. Lindstrom, of the Swedish Defence Materiel Administration, and with David Fletcher, the historian at the Tank Museum in Bovington, who helped to unravel several historical questions.

Richard Ogorkiewicz, London

CHAPTER 1
The Origin of the Species

For centuries wars were fought almost entirely with individual weapons wielded by hand. But when gunpowder came into use, the relative importance of hand-carried weapons gradually diminished, while that of the heavier weapons increased until they became dominant during the 19th century. None other than Napoleon acknowledged this, reflecting on St Helena that 'artillery decides to-day the destiny of armies and peoples'.

However, siege warfare apart, the effectiveness of guns was constrained by their limited battlefield mobility, which, at best, amounted to being hauled by horses from one firing position to another.

Machine guns became an exception to this when they were developed during the latter part of the 19th century because, unlike other non-portable weapons, they were light enough to be mounted on and fired from horse-drawn carriages. This offered a way of making them more mobile, which was actually adopted during the civil war that followed the Russian Revolution of 1917. Horse-drawn carriages mounting machine guns, or *tachankas*, were then used during the Polish-Russian War of 1920–21 by the Red Cavalry Army of Budyenny, and they were retained as standard equipment by the Polish cavalry until 1939 and by the Soviet cavalry well into the Second World War.

But, whatever mobility they provided, horse-drawn machine gun carriages were very vulnerable to enemy fire and their utility was to a very large extent confined to engagements between formations of cavalry. Moreover, by the time they came into use, far better means of making machine guns, as well as other guns, more mobile already existed in the form of self-propelled vehicles. Guns mounted in them could not only be moved more rapidly and fired more readily, but they could also be fitted with armour protection, which allowed the guns to be deployed more freely under enemy fire.

The first step in the development of self-propelled vehicles was taken by N. J. Cugnot, a French military engineer who in 1769 built a three-wheeled, steam-powered vehicle that can still be seen at the Musée des Arts et Métiers in Paris. Cugnot's venture was supported by General J. B. de Gribeauval, the inspector general of French artillery, who laid the foundations of that arm that Napoleon later used so effectively. A second vehicle was built for further trials but no progress was made beyond this.[1]

The prospect of developing self-propelled vehicles for military purposes revived in the second half of the 19th century with the construction of steam-powered traction engines. It has been widely but wrongly believed that a traction engine fitted with Boydell footed wheels was already used by the British Army for towing guns during the Crimean War of 1854–56, the erroneous belief arising out of the confusion between Boydell's traction engine and some horse-drawn carts with Boydell's footed wheels that were used in the Crimea. In fact, the first steam-powered engine with Boydell's wheels was only demonstrated at an agricultural show in England in 1855 and it was a Garrett-Boydell engine, which appeared a year later, which was first tried for pulling a siege gun at the Woolwich Arsenal. The Burrell-Boydell engine, which is generally believed to have been used in the Crimea, was not completed until 1857 when two were ordered for gun-towing trials, again at the Woolwich Arsenal.[2]

Steam traction engines were also used to tow guns on other occasions during the second half of the 19th century. In the meantime, prompted probably by the Crimean War, J. Cowan proposed another use of steam traction for military purposes in 1855 in Britain by taking out patent No.747 for a 'Locomotive Battery for Field of Battle with a Steam Engine'

– a wheeled vehicle with a turtle-like iron carapace out of which protruded several guns and at the side of which were scythes for mowing down any troops that might attack it.

Cowan's vehicle was never built, but during the South African War of 1899–1902 the British Army used about 50 traction engines for towing supply trucks and guns. In 1900 two of the engines built for use in South Africa by John Fowler and Co. of Leeds were armoured, as were the trucks they towed, to protect them against Boer attacks when they were used for carrying supplies. Eventually the number of the armoured Fowler engines sent to South Africa rose to four.[3] The armour of the Fowler engines and of the trucks was provided with loopholes through which rifles could be fired, and a field gun could be hauled onto a truck instead of being towed. In principle, there was only a small step from this to a steam-powered, gun-armed armoured fighting vehicle. Such a vehicle had in fact already been envisaged by Cowan and was depicted in 1883 by A. Robida in a French journal *La Caricature.*[4]

The ideas of Robida, like those of Cowan, were never implemented, but 20 years later steam-powered armoured vehicles were the subject of a story by H. G. Wells, the science fiction writer, which was published in the *Strand Magazine* in December 1903 under the title 'The Land Ironclads'. This story is often presented as a prophetic vision of future armoured vehicles and as having influenced, albeit indirectly, the development of the first British tanks several years later.[5] In fact, Wells' 'ironclads' did not represent an advance on Fowler's armoured steam engines built three years earlier so far as their means of propulsion were concerned, and this was equally true of their armament, which still consisted of rifles. Nor did they foreshadow future armoured fighting vehicles in other respects, except for being envisaged to operate off the roads over broken ground. However, what was to make this possible was not very practicable, as it was based on the use by the 'ironclads' of Pedrails – another type of footed wheel devised around 1899 by B. J. Diplock. This wheel has been confused with the Pedrail track, which was not brought out by Diplock until 1910, and has led to the erroneous belief that Wells foresaw tracked armoured vehicles.

By the time Wells' story was published a far more effective alternative to steam engines had already emerged in the form of the internal combustion engine, and the motor cars that they powered became a more practical basis of making guns more mobile. The first to recognize this appears to have been

E. J. Pennington, a fraudulent American vehicle designer who came to England in 1895. Within a year of his arrival Pennington produced pictures of four-wheeled motor cars with low, boat-like armoured hulls above which protruded two Maxim machine guns with shields. What is more, he let it be known that such vehicles were being built in Coventry, which was becoming the birthplace of the British motor industry. There is no evidence of what inspired Pennington but, as one of his pictures showed armoured vehicles on a beach attacking a naval landing party, it could well have been the threat of cross-Channel invasion, which was seriously considered in Britain in the 1890s.

Pennington's activities led the *Naval and Military Record* to declare in 1896 that 'there is a great future for the military motor car' and news of them was published in Austrian and French as well as British journals.[6] However, in 1897 a French journal, *La France Automobile*, expressed regret that Pennington's inventions only existed in the form of watercolours.[7] In fact, Pennington never built an armoured vehicle, but the belief he created persisted and more than 60 years later he was still being credited with building one.[8]

While Pennington never put his armoured vehicle ideas into practice, a vehicle very similar, externally at least, to those he depicted was built by F. R. Simms, a German-born British engineer and entrepreneur who was involved with the same motor syndicate as Pennington. After producing the design of a 'motor war car' Simms persuaded the armament firm of Vickers, Sons & Maxim to put up the money for its construction, which they did, and paid him £750 for it, according to the copy of an order dated 20th July 1898 in the writer's possession. A year later Simms exhibited detailed drawings of the vehicle he was building at a motor show in Richmond, Surrey. On the same occasion Simms also demonstrated a powered quadricycle fitted with a Maxim machine gun, which became one of the first self-propelled vehicles ever to be armed.[9]

Simms' 'motor war car' was completed in 1902, when it was exhibited at the Crystal Palace in London. It weighed about 5.5 tonnes with an open-top hull of 6mm Vickers steel and was armed with two Maxim machine guns and a 'pom-pom' automatic cannon. Powered by a 16 horsepower Daimler engine, it was reported to be capable of moving at up to 9 miles per hour, but its steel-tyred wooden wheels restricted it to operating on paved roads. This was accepted as part of its proposed use for coast defence, which formed another link between Simms' vehicle and Pennington's ideas.[10]

The mobility of Simms' vehicle was obviously limited, but it was the first self-propelled vehicle that was both armed and armoured, and even if it was not very practical the potential of vehicles of its kind was recognized by the technical press that reported on it. On the other hand no military officials came to see it, which provoked some very sarcastic comments on the attitude of the War Office in one of the motoring journals reporting on it.[11]

The evident lack of official interest in Simms' 'war car' led to it being abandoned, and further efforts to make heavy weapons more mobile followed the more gradual process of mounting machine guns on motor cars and armouring the latter. The consequences of this process were foreseen by some when only one or two motor cars had been actually fitted with machine guns. One of them was A. G. Hales, a correspondent of *The Times*, who from the basis of his observations of the South African War wrote in May 1901 that armoured motor cars 'were going to revolutionise affairs both in peace and war'. A similar if more measured opinion was expressed by Brigadier J. H. A. Macdonald who wrote in 1902 that 'high speed motor vehicles, with bullet proof sides, would be of great value'.[12]

It was envisaged in both cases that the motor vehicles would be armed with machine guns, and an unarmoured motor car had already been fitted with one in the United States in 1898, a few months ahead of the appearance of Simms' quadricycle. The vehicle was a Duryea three-wheeled passenger car on which Major R. P. Davidson of the Illinois National Guard mounted a Colt machine gun with a small shield.[13] This vehicle was followed by a four-wheeled version, and according to a contemporary report it was being built 'for city use against mobs', which suggests that it may have been inspired by the disorders which afflicted US cities in the 1890s.[14]

A further step forward took place in 1902 when the Charron, Giradot et Voigt company exhibited at the Salon de l'Automobile in Paris a car with a circular shield of armour plate instead of the rear seats and within it a pedestal mounting for a Hotchkiss machine gun. A French Army commission carried out firing trials with it in 1903 but saw no need for such a vehicle.[15]

Nevertheless, Charron, Giradot et Voigt continued to work on the development of an armoured car in collaboration with the Hotchkiss company and Major Guye of the French Artillery, whose patented turret it incorporated. The resulting vehicle was still based on a passenger car chassis but it had a fully armoured body surmounted by a turret with a Hotchkiss machine gun. It came to weigh about 3 tonnes and was capable of a road speed of 45km per hour.

The new vehicle was ready by the beginning of 1906 when it was inspected by the French minister of war. This was followed by tests during the autumn manoeuvres of the French Army, but a commission that reviewed reports on the vehicle as well as other new developments concluded in May 1909 that armoured cars should not be considered further because they could not move over all types of terrain and because of their high production cost. Moreover, the French cavalry preferred unarmoured machine gun cars.[16]

In the meantime the activities of Charron, Giradot et Voigt attracted the attention of the Russian authorities, who are claimed to have considered ordering 36 vehicles but ultimately settled for one, which was delivered in 1906. Subsequently they ordered a series of ten, the last of which was still in France when the First World War broke out in 1914. It was immediately requisitioned by the French authorities and sent into battle but only to be quickly lost.[17]

While Charron, Giradot et Voigt were developing their armoured car in France, another armoured car was built in Austria by the Österreichishen Daimler Motoren company. It was designed by its technical director, P. Daimler, the son of Gottlieb Daimler the motor car pioneer, who started working on it in 1903, and it was completed in 1905. In the following year it took part in the manoeuvres of the Austro-Hungarian Army but the latter showed little further interest in it.[18] By the end of the same year its constructors obtained permission to sell it to France, and at the beginning of 1907 it was tested at the Mont Valerien fort outside Paris. Its performance was described as ‘spectacular’ but this did not alter the negative opinion of armoured cars formed by the 1909 French Army commission.[19]

Like the Charron armoured car, the Austro-Daimler had a fully armoured body that was surmounted by a hemispherical turret with one or two Maxim machine guns. It was somewhat lighter, weighing less than 3 tonnes, and had a lower maximum speed of 24km per hour. But, unlike the other, it had four-wheel drive, which only a few armoured cars were to have until the 1930s. Although they differed in detail, the Charron and the Austro-Daimler cars had a similar general configuration, which foreshadowed the design of most armoured cars built during the next three decades. However, their example was not followed until 1912. The intervening years did not provide any incentives for the further development of armoured cars and armies did not foresee their future potential.

It took the Italo-Turkish War of 1911–12 to prompt the building of two more armoured cars. Both were built at the Arsenal in Turin and were presented to the Italian Army for use in Libya by the Automobile Club of Milan.[20] One of them was based on a Fiat motor car fitted with an armoured body surmounted by a small cylindrical turret with a machine gun. The other, which was generally similar, was based on a Bianchi or Isotta-Fraschini car chassis. The two armoured cars were shipped to Libya in the autumn of 1912, but by then fighting had almost ceased and their use was limited mainly to escorting columns of other motor vehicles.[21] Nevertheless, they became the first armoured cars to be used in military operations.

Two more armoured cars are reputed to have been built in Italy in 1913 and they, together with the two earlier Italian armoured cars and the ten produced in France for Russia, were the only additions to the number of armoured cars constructed before the outbreak of the First World War.

Yet motor cars were already being used in large numbers. In Britain, for instance, their annual production rose from 10,500 in 1908 to 34,000 in 1913 and in the United States the number of cars built in 1914 was no fewer than 573,000. Nevertheless, armies continued to rely on horses. Their approach to motor vehicles was cautious, to say the least, and it was only under the pressure of events that they took up motor vehicles in earnest. For example, before the outbreak of the war in August 1914 the French Army possessed only 220 motor vehicles. The British Army had even fewer of them, its total of mechanical transport vehicles amounting to 100. But by the end of 1914 the French Army acquired 13,000, mainly by requisitioning civilian vehicles, and by the end of the war in 1918 had 95,000 motor vehicles.

Similarly, it was only after the outbreak of the war that armoured cars came into use. This happened almost spontaneously as a result of the use of motor cars for reconnoitring and for harassing enemy forces in the opening stages of the war.

One of the countries in which this happened was Belgium, where within the first month of the outbreak of the war armoured cars began to be improvised on Minerva car chassis and used to harass the invading German forces. Almost simultaneously improvised armoured cars also began to be used in France. Recognizing their potential, the French minister of war ordered 136 armoured cars in August 1914, and a month later the first unit of them was attached to a cavalry corps to provide mobile fire support. The original French armoured cars were based on a variety of motor cars, but their construction was followed by another order to the Renault company for 100, this time all built on the same standard 18 horsepower car chassis, and they became operational before the end of 1914.[22]

At the time Russia had virtually no motor industry but its one car company, the Russo-Baltic located in Riga, Latvia, built an armoured car soon after the war started, and subsequently produced a few more so that a unit could be formed that was sent into action in October 1914.[23] More armoured cars were ordered by the Russian authorities from abroad and especially from Britain. The most numerous of the British cars were produced by the Austin company to a Russian design, which incorporated a very peculiar arrangement of two side-by-side machine gun turrets. Their total, including armoured cars built in Russia on Austin chassis, rose eventually to more than 200. More armoured cars were procured from other companies and some were also built in Russia using imported chassis, bringing the total acquired by the Russian Army to more than 600 in 1917.[24]

Improvised armoured cars also began to be used after the outbreak of the war by the British forces. However, in a bizarre twist of events, their use was taken up not by the Army but by the Royal Naval Air Service (RNAS). It arose out of the forward deployment in France of an air squadron of the RNAS charged with the defence of south-east England against attacks by Zeppelins. As a result of this, armoured cars were improvised to support flying operations by ground reconnaissance and to provide protection. At first there were only two of them, but in September 1914 the First Lord of the Admiralty, Winston Churchill, authorized the procurement of 60 more. These were still of a fairly primitive type, with open-top hulls and based on three different motor cars. But the RNAS formed with them four armoured car squadrons and proceeded to develop better vehicles. The outcome of this was an armoured car of about 4 tonnes based on the Rolls-Royce 'Silver Ghost' car chassis, which was armed with a machine gun in a revolving turret and which was normally operated by three men. Its design proved to be the most successful of those devised during the First World War and became a model for other armoured cars built during the following two decades, while some of the vehicles originally based on it were still being used, albeit with modifications, by the Royal Air Force in Iraq in 1941.

The first three of the turreted Rolls-Royce armoured cars were delivered in December 1914 and soon afterwards RNAS formed a new squadron with 12 of them. The formation of five more such squadrons followed, as did that of others equipped with different types of armoured cars, the total number of which came to about 140, including 78 Rolls-Royce cars.[25]

Italy bypassed the use of improvised armoured cars as a result of not entering the war until March 1915. By then the use of the Belgian armoured cars had attracted the attention of the Italian minister of war, who ordered the armament firm Ansaldo to develop an armoured car for the Italian Army. The outcome of this was a turreted armoured car based on the Lanzia I.Z. car chassis. Deliveries of it began in June 1915, when the first Italian armoured car unit was formed.[26] Eventually about 120 Lanzia I.Z. armoured cars were deployed by the Italian Army, which used them for the rest of the war. They proved as durable as the Rolls-Royce, as some were still in use in Africa in 1941.

In 1915 the use of armoured cars spread outside Europe and in particular to India, where about 60 armoured cars were improvised to bolster the internal security forces depleted by the departure of British and Indian troops for service on the different war fronts. In 1915 the first armoured car was also built in the United States. Interestingly, it was designed by R. P. Davidson, the pioneer of the installation of machine guns on motor cars, and was based on a Cadillac car chassis. A year later the US Army deployed its first two armoured cars during the operations along the Mexican border against Pancho Villa.[27]

Thus armoured cars had come to be used in a number of countries. Most were armed with one or two machine guns, but a proportion of the French cars were armed with 37mm cannon, while some British as well as French vehicles carried 47mm cannon, and a few Russian armoured cars, based on American Garford truck chassis, even mounted short-barrelled 76mm guns.

Armed with these guns, armoured cars were what would later be described as mobile weapon platforms. As such they constituted a revolutionary advance in the employment of some of the heavier weapons by increasing their mobility well above that provided earlier by animal traction. They also provided a degree of protection for their crews, although this was an adjunct to their mobility: it enabled them to operate more freely under fire but was subservient to their basic function of being a mobile source of fire power.

All this meant that armoured cars had the characteristics that have come to be associated with armoured fighting vehicles. But they could only act as such in a very restricted sense because they were generally confined to operating along roads. In fact, for much of the time they were tied to roads almost as much as armoured trains were restricted to operating along railway tracks.

This did not handicap the armoured cars greatly on the Western Front at the beginning of the First World War, when there was no shortage of roads along which they could operate. There was therefore no lack of opportunities for the original Belgian, French and British armoured cars to skirmish along them. But when the opening, mobile phase of the war was followed by trench warfare, roads were cut or blocked and the conditions that allowed armoured cars to operate vanished. It was only three years later, in the final stages of the war when the fronts began to break, that they were used effectively again on the Western Front.

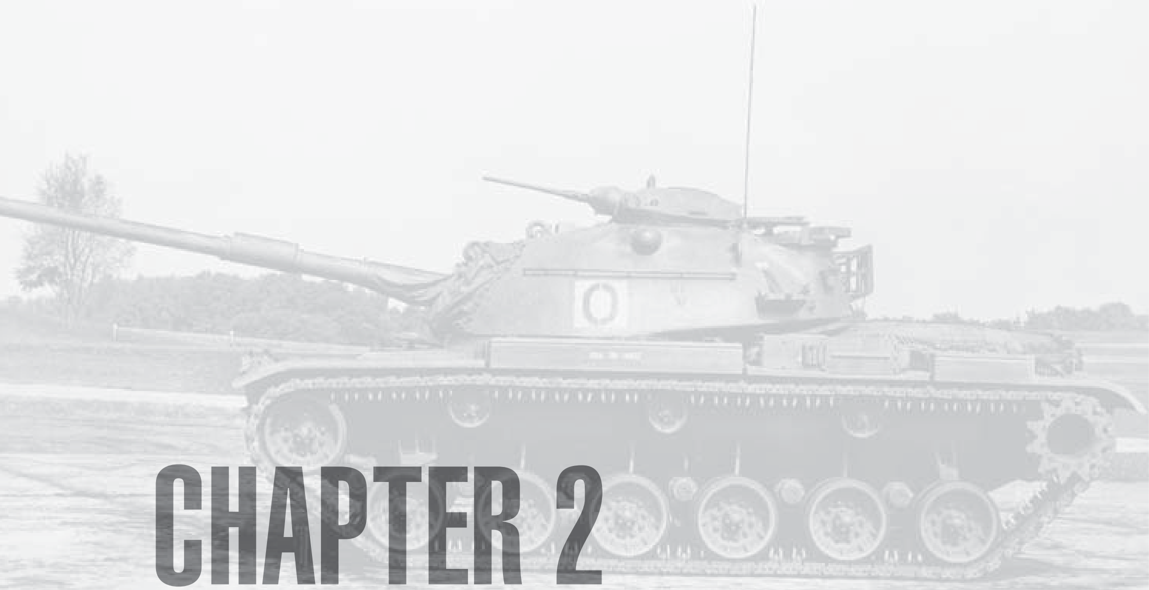
This happened in March 1918 during the final German offensive, when a total of about 130 armoured cars attached in small units to French cavalry divisions fought a series of delaying actions.[28] Another opportunity occurred in August 1918, during the Battle of Amiens, when armoured cars of a British battalion equipped with 16 twin-turret Austins left over from the Russian orders drove through a breach in the enemy lines and wrought havoc behind them.[29]

In the meantime, when the opportunities for their use in France disappeared in 1915, squadrons of what had by then become the Royal Naval Armoured Car Division were sent to other theatres of operations where it was thought there would be greater scope for their employment. This included German South West Africa (present Namibia), German East Africa (now Tanzania) and Gallipoli, but in the event they provided few if any opportunities. There appeared to be greater scope for the employment of armoured cars on the Eastern Front, where there was more room for manoeuvre. In consequence a relatively large Royal Navy unit equipped with 20 or more Lanchester armoured cars, which were similar to the Rolls-Royce, was sent to Russia. It became best known after its commanding officer, Commander Locker-Lampson, and operated in 1916 in the Caucasus and then on the Romanian and Ukrainian fronts. In the course of its far-flung operations the unit overcame some very difficult terrain conditions, which spoke well for the armoured cars at this early stage of their evolution, but the military impact of its small scale actions was very limited. The same applied to the Russian armoured cars, which, although more numerous in total than all the others, were used in small units and could only claim some local successes.[30]

In fact, armoured cars could not have achieved greater results even if they had been concentrated in larger units because they could not spread out on the roads and could, therefore, only fight along them in ones or twos. In consequence, it was only in exceptionally favourable circumstances that they could move off the roads and act more decisively.

A rare example of this was provided by the British armoured cars sent to Egypt in 1915. In March 1916 a unit of nine of the Rolls-Royce armoured cars commanded by the duke of Westminster took advantage of the relatively hard, flat ground to dash at up to 40 miles per hour to surprise a large Arab-Turkish force at Bir Aziz south of Sollum in Cyrenaica, which the armoured cars charged, in line abreast, routing it completely.[31, 32, 33]

To act equally effectively under conditions less favourable than those of the Cyrenaican desert, armoured cars would have required the ability to operate over other, more difficult types of terrain. The need to provide them with this capability was in fact perceived in more than one country by 1915. The consequent pursuit of it led to the use of tracks instead of wheels and hence to the next stage in the evolution of armoured fighting vehicles, which was the development of tanks.



CHAPTER 2

The ‘Invention’ of the Tank

The coming into being of tanks, the first and the most important of the tracked armoured vehicles, is commonly described as a unique event inspired by the ideas of one man, who is usually identified as Lieutenant Colonel E. D. Swinton, an engineer officer of the British Army. Such accounts bear little relation to what actually happened, although Swinton himself professed that it was true. He made this very clear in his memoirs, written several years after the first British tank was built, in which he described himself as its ‘originator’ and included a chart showing how the ideas leading to it, or ‘seeds’ as he called them, sprang from him.[1]

In fact, tanks were the outcome of the ideas and activities of several men, and any contribution that Swinton might have made to their evolution was small and indirect. Moreover, the construction of the first tanks was preceded and based on developments that took place during the previous half century.

The most important of these developments was that of the tracked running gear. Its use in steam traction engines was proposed as early as 1858 or 1859 in patents taken out in the United States. By 1867 at least one steam-powered tractor was actually built there with its two rear wheels as well as the front steering wheel replaced by short tracks.[2] However, the development of tracked tractors did not begin in earnest until 1904, when B. Holt replaced the rear wheels of one of the steam traction engines produced in California by his company by tracks. Because it retained its front steering wheels, Holt's original tracked tractor was what would later be called a 'half-track', as were other tractors produced by him until 1912.

In the meantime, in 1905, a further advance took place when Richard Hornsby built the first fully tracked tractor in Britain. It was shown in 1905 and 1906 to the Mechanical Transport Committee of the War Office, which was sufficiently impressed to conduct official trials in 1907. A year later a Hornsby tractor even took part in a revue at Aldershot before King Edward VII, and in 1909 the War Office ordered a somewhat smaller tractor designed by Hornsby to military requirements, which has been preserved to this day at the Tank Museum at Bovington in Dorset.[3] This tractor was tested at Aldershot, but after about 1911 the British Army lost further interest in tracked tractors, although the tractor built to its requirements was exhibited in London at the beginning of 1914.

Seeing no opportunities for further business in Britain, Hornsby sold his tractor patents to the Holt Manufacturing Company in California, which started to produce tracked tractors on a regular basis in 1908 and subsequently exported a few of them to Europe in addition to those sold to American farmers.

While it lasted, the interest of the War Office in the Hornsby tractors was prompted by their possible use for hauling guns. But in 1908 a member of the Mechanical Transport Committee, Major W. E. Donohue, suggested that instead of being towed a gun be mounted on a tractor and provided with some form of protection. This amounted to a proposal for a tracked self-propelled gun, but Donohue's suggestion was not pursued.[4]

Remarkable as it was, Donohue's proposal was not the first of its kind. Five years earlier a French artillery officer, Captain Levavasseur, put forward a scheme for a self-propelled 75mm gun on an armoured tracked chassis. The scheme was considered by the French Artillery Technical Committee, but the latter came to the conclusion that animal traction was preferable for guns and finally rejected the scheme in 1908.[5]

Other proposals made before the outbreak of the First World War in 1914 did not fare any better. The most interesting of them was made by Captain G. Burstyn, an Austrian officer who apparently saw a Holt tractor in 1911 and this inspired him to design a '*motorgeschutz*', a tracked armoured vehicle with a turret mounting a cannon and with rollers on extended arms to assist the crossing of trenches. Burstyn offered his design to the Austro-Hungarian War Ministry but the latter rejected it.[6]

In Russia, V. Mendeleev, the son of the famous scientist, is reputed to have started working in 1911 on the design of a tracked armoured vehicle armed with a 120mm naval gun, but his work did not advance beyond drawings.[7] Another design originated in Australia, where L. E. de Mole, a civil engineer, produced drawings of a tracked armoured vehicle. He submitted his design to the British War Office in 1912 but the latter showed no interest in it.[8]

The idea of a tracked armoured vehicle had clearly emerged in more than one country before the outbreak of the First World War in 1914, but failed to arouse the interest of the military authorities in any of them. To be fair, few tracked tractors from which tracked armoured vehicles were to be derived had been built and their characteristics or even existence were not widely known. What is more, armies did not fully appreciate the growing importance of heavy weapons and the extent to which their effectiveness was constrained by their limited mobility, based as it generally was on horse traction. In consequence they were less receptive than they might have been to the idea of tracked armoured vehicles, which offered to make heavy weapons more mobile and to a far greater extent than armoured cars had done already.

Once the war began, heavy weapons and in particular machine guns and field guns, until then regarded as only an adjunct to the rifle armed infantry that constituted the bulk of the armies, proved dominant. At the same time horse traction failed to provide them with the mobility necessary for offensive action. All this favoured static defence in which heavy weapons needed little, if any, mobility and in which they could be used to full effect. The effectiveness of static defence was further increased by the use of entrenchments and barbed wire.

The outcome was deadlock, particularly on the Western Front in France, with neither side being able to break through the other's defences by the traditional massed infantry attacks. The immediate problem became that of finding a way that would enable the infantry to continue to attack in the face of machine guns and barbed wire. In response to this came proposals for armoured assault vehicles that would pave the way for the infantry by attacking enemy machine guns and by crushing the barbed wire.

The first in Britain to think of using tracked vehicles to solve the problems created by the onset of trench warfare appears to have been Swinton, and to this extent he deserves credit for originality. But what his thoughts were is not very clear and, whatever they were, any influence they might have had on the development of the first British tanks was indirect and limited.

According to his own account written several years after the event, the idea of a tracked armoured vehicle came to Swinton suddenly in October 1914 when he recalled the description of a Holt tractor sent to him four months earlier. This occurred while he was travelling to England from France where he was acting as the sole official correspondent with the British Expeditionary Force (BEF). On arrival in London he discussed his views with Lieutenant Colonel M. Hankey, the secretary of the influential Committee of Imperial Defence.[9] There is no record of what was actually discussed but it seems to have included the possibility of converting tracked tractors into some kind of assault vehicle, and such a vehicle is alluded to in a letter written a month later by Swinton to Hankey.[10]

A clearer outcome of the contacts is a device described in a memorandum written by Hankey in December 1914 and this, according to Swinton, embodied what he had put to Hankey.[11] But what Hankey proposed was only a large heavy roller pushed by a single, engine-driven track and provided with an armoured cab for a driver and a machine gun. As Hankey explained, the object of this device would be 'to roll down the barbed wire by sheer weight'.[12] What he was proposing was therefore a specialized wire crusher and not an armoured fighting vehicle.

A copy of Hankey's memorandum was sent, among others, to the First Lord of the Admiralty, Winston Churchill, who after receiving it wrote to the Prime Minister, H. H. Asquith, saying that he agreed with Hankey about the use of 'special mechanical devices for taking trenches'. However, he saw them in a different form from that envisaged by Hankey, namely that of steam tractors that were armoured and fitted with machine guns as well as tracks. The prime minister then took the matter up with the Secretary of State for War, Lord Kitchener, and this led to the formation of a War Office committee that was to consider the possible adaptation of tracked tractors to the role of assault vehicles. As part of its activities the Committee arranged tests of a Holt tractor over an obstacle course made up of trenches and barbed wire entanglements in February 1915. The tractor, handicapped by being made to pull a heavy trailer, failed to cross some of the trenches, which led the Committee to conclude that what was proposed was impracticable and to abandon further consideration of it.

Prior to the test the Committee received a memorandum written by Captain T. G. Tulloch, an artillery officer recommended by Swinton, which more clearly than hitherto envisaged armoured vehicles armed with machine guns that could move across country and over barbed wire to attack enemy trenches. The vehicles were to be based on Holt tractors but coupled in pairs to form articulated vehicles – which Tulloch appears to have been the first to propose in 1911 in sketches of a large articulated armoured vehicle.[13] However, the ideas contained in Tulloch's memorandum were not taken up. But its title, which was 'Land Ship', became the designation of the first British tracked armoured vehicles and also reflected the influence of naval ideas on contemporary thinking.

In the meantime Churchill had Hankey's idea of using large rollers to crush barbed wire put to test by the Royal Naval Air Service, which he controlled. The test was carried out using steam rollers, which proved incapable of climbing the slightest slope, and the whole idea was abandoned. As a result Churchill turned his attention to other ideas. These were put to him by officers of the RNAS who were seeking vehicles more capable than their armoured cars, which were becoming ineffective with the onset of trench warfare.

The earliest of these ideas came from Flight Lieutenant T. G. Hetherington, who in November 1914 proposed to Commodore M. Sueter, the director of the Admiralty Air Department who was in charge of the RNAS, the construction of a giant three-wheel armoured vehicle armed with 12in. (309.8mm) naval guns. Sueter realized that this was not a practical proposition but was prepared to pursue the idea of a scaled down version, which he submitted to Churchill in January 1915.

The vehicle that was now being proposed was still very large, the front two of its three wheels having a diameter of 40 feet (12m). Moreover, it was to have three turrets, each with two 4in. guns, while its weight was estimated to be 300 tonnes. In its proposal it was described as 'a cross-country armoured car of high offensive power', which showed that the aspirations of the RNAS officers were sound. But their judgement of what was practicable was not. It is not surprising therefore that when Churchill referred the proposal to the Admiralty it was turned down by one of its experts, Admiral Sir Percy Scott.[14]

However, Hetherington's idea of a large three-wheeled vehicle was not entirely irrational. Such a vehicle with two driving wheels with a diameter of 10m, or almost as large as those of Hetherington's proposed vehicle, was actually being built in Russia in 1915. Its construction was promoted by M. Lebdenko, the head of the experimental laboratory of the Russian War Ministry, and was allegedly supported by the tsar. But it was abandoned as impracticable without being completed.[15]

Although it was not practicable and in spite of its rejection by Admiral Scott, Hetherington did not abandon his idea of a large-wheeled vehicle and got a chance to put it directly to Churchill at a dinner on 14 February 1915. This time Churchill showed greater interest in it and referred it to the Director of Naval Construction, E. H. T. d'Eyncourt. The latter concluded that the proposed vehicle would weigh 1,000 tonnes and was not therefore practicable. But he did not reject the concept of a large-wheeled armoured vehicle, and suggested that Hetherington's vehicle be replaced by a smaller one.[16] Churchill agreed and ordered the formation of a committee chaired by d'Eyncourt to pursue the ideas put to him. This came into being on 20 February 1915 under the title of 'Landships Committee'.[17]

While these events were taking place, Sueter was pursuing his interest in the use of tracks, originally for mobile armoured shields to be pushed by infantrymen in front of them like wheelbarrows. Then, having apparently turned against big wheel vehicles, he began in February 1915 to consider the design of a tracked 25-tonne armoured vehicle armed with a turret-mounted 12-pounder gun. The design was produced in collaboration with B. J. Diplock and incorporated the latter's Pedrails, which were the only tracks made at the time in Britain.[18]

By the time the Sueter-Diplock design was drawn, the Landships Committee had come into existence and shortly afterwards was informed about it. In consequence, the committee had two different designs to consider, one being that of a wheeled vehicle derived from Hetherington's proposals but with wheels having a diameter of 16 feet (4.9m) instead of 40 feet, and the other being a tracked vehicle with Pedrails. The committee reported on them to Churchill, who, relying on the advice of d'Eyncourt that the two proposed designs were viable, took it upon himself to authorize on 26 March 1915 the construction of six-wheeled and 12-tracked vehicles.[19]

The order for the wheeled vehicles went to the William Foster Company in Lincoln. Their work suffered a series of false starts and the order issued to them was cancelled in June 1915 without a vehicle being built.[20] Work on the tracked vehicles produced more tangible results. It was directed initially by Colonel R. E. Crompton, an experienced engineer who pioneered the use of steam traction engines in India in the 1870s and was then involved with their use in the South African War, who was appointed a consultant to the Landships Committee.

Working with another engineer, L. A. Legros, Crompton produced a design similar to that conceived by Sueter and Diplock. But, instead of having a turret with a 12-pounder gun, Crompton's vehicle was to be an armoured carrier capable of carrying as many as 50 or even 70 men, which came to be considered at that stage the tactical purpose of what were beginning to be called 'landships'. Otherwise it was to have the same peculiar configuration as that adopted by Sueter and Diplock, which consisted of a long rigid chassis resting on two wide Pedrail tracks arranged in tandem, each driven by a separate engine. The vehicle was to be steered by turning the track assemblies in relation to the chassis, which meant that its turning circle was impractically large. Crompton realized this even before the vehicle was built, which it eventually was in a reduced form by the Stothert and Pitt company in Bath, and proved unsatisfactory.[21]

The failings of the original design became clear to Crompton after a visit to France on 21 April 1915 when he concluded that the vehicle he was designing would not be able to negotiate the bends in roads and village streets. In consequence, he decided to abandon the original design in favour of an articulated vehicle that would have a smaller turning circle and therefore be more manoeuvrable. The idea of an articulated tracked vehicle was not entirely new, as one had already been proposed by Tulloch, and it was actually implemented by Diplock who exhibited an articulated tracked truck in London in 1913.[22] But no other articulated tracked vehicle had been built and it was going to take more than 40 years before one was successfully developed.[23]

Each section of Crompton's second articulated vehicle was still to have only one Pedrail track. But by May 1915 he recognized the shortcomings of the complicated and heavy Pedrail tracks, which had not been used successfully in any vehicle, and recommended the purchase of American tractors with lighter and proven tracks. As all the available Holt tractors had been earmarked already for the British Army for gun towing, the Landships Committee ordered two similar 'Creeping Grip' tractors from the Bullock Tractor Company of Chicago.[24] Following this Crompton started working on his third design, which was similar to the second design but with each section of the articulated carrier having two Bullock tracks.

In addition to recommending the purchase of the two Bullock tractors, Crompton also arranged the purchase of a lighter American tractor produced by the Killen Strait company. This tractor was almost unique in having a short track instead of the steering wheel that almost all contemporary tractors still had. This was not of any mechanical merit, but the two main tracks of the Killen Strait tractor were very effective for their day. As a result the Killen Strait tractor was used very successfully in June 1915 to demonstrate for the first time the ability of tracked vehicles to negotiate barbed wire entanglements and other obstacles in front of the Minister of Munitions, Lloyd George, Churchill and others whose support was essential for the development of landships.[25] The Killen Strait tractor was subsequently fitted with the hull of an RNAS Delaunay-Belleville armoured car, and this combination became in July 1915 the first, albeit only experimental, tracked armoured vehicle.

When the two Bullock tractors arrived in England they were coupled to test Crompton's concept of an articulated vehicle. Tests of the coupled tractors were carried out in July 1915 and showed that an articulated vehicle would be difficult to develop.[26] In consequence, the Landships Committee decided to abandon further work on it and at the same time terminated the appointment of Crompton as its consulting engineer. Instead of the large articulated troop carrier that was aimed at until then, the Landships Committee decided to develop a smaller vehicle with a rigid, one-piece hull and a turret-mounted cannon. An order for such a vehicle was issued on 29 July to the William Foster Company, which had worked previously on the wheeled landships. It proceeded with remarkable speed and had the vehicle built and running by 6 September 1915.

The vehicle built by Fosters, which came to be known after its managing director W. A. Tritton, corresponded to one half of Crompton's third design, that is the articulated carrier with lengthened Bullock tracks. In the interest of speed Tritton used the engine, gearbox and differential of a heavy wheeled artillery tractor that his company was producing. He also copied the method of steering used by the Bullock as well as other contemporary tractors, which involved a pair of steering wheels but mounted behind instead of in front of the vehicle. However, the vehicle could also be steered by braking one of the output shafts of the differential – a method first used by Hornsby 10 years earlier.

Tritton's vehicle was only an experimental machine with a box hull of boiler plate and a fixed dummy turret. But it provided, at last, a sound basis for the mechanical development of landships. When it began to be tested its Bullock tracks proved unsatisfactory and it was rebuilt with a longer and stronger type of track. The new type of track was designed by Tritton, whose prior experience of track development was confined to a single half-track tractor called 'Centipede' built by his company in 1913. Nevertheless, the track proved successful and its performance was crucial to the further development of landships.

When it was modified and fitted with the new type of track, Tritton's vehicle became known as 'Little Willie' and in that form has been preserved at the Tank Museum at Bovington. It was successfully demonstrated in December 1915, and because of its longer tracks could cross wider trenches than in its original version, whose 4ft trench crossing capabilities proved inadequate when it was first tested in September 1915.[27]

In the meantime the Landships Committee had established contact with the War Office and on 26 August 1915 received from it a set of requirements to be met by landships. These requirements were derived from three memoranda submitted by Swinton to the General Headquarters of the British Forces in France between 1 and 15 June and sent on to the War Office on 22 June.[28] In the memoranda Swinton set out his ideas concerning 'machine gun destroyers built on the caterpillar principle that would lead infantry assaults on enemy trenches' and suggested, among others, that they should be able to cross trenches 5ft wide. This was subsequently incorporated in the War Office requirements which the Landships Committee received on 26 August.[29]

However, on 29 June Swinton wrote again to the General Headquarters tentatively suggesting that the trench crossing requirement be increased from 5 to 8ft.[30] This suggestion obviously arrived too late to be included in what was sent to the War Office seven days earlier and was not part of the requirements received by the Landships Committee.

Whether Swinton's 8ft trench crossing requirement was ever made known to the designers of the landships is an open question. If it was it could only have been after they received the War Office requirement for a 5ft trench crossing capability on 26 August, by which time they were bound to have started thinking of improving on the design of the first landship since a full size wooden mock-up of the second landship was already built by 19 September, when Swinton first saw it.[31]

Nevertheless, after seeing the mock-up of the second landship Swinton declared that it was 'the actual embodiment of my ideas and the fulfilment of my specification'. In fact, the only feature of the second landship that might have provided some justification for such a claim was its ability to cross wide trenches. But, although this was similar to what Swinton had belatedly suggested to the General Headquarters, the second landship was designed without reference to him and the general ideas it represented were already embodied in the first landship, which, as Swinton himself acknowledged, was not built to his specification.[32]

As to Swinton's more general claim, quoted earlier, to have been the 'originator' of the tank, Churchill, who was closely connected with its development, rightly observed 'there was never a person about whom it could be said "this man invented the tank"' and added, with some justification, that the tank was a child of the RNAS.[33] But when Sueter quoted this in a book in which he tried to put on record the achievements of the RNAS, Swinton wrote on the margin of his copy of the book now in the possession of the present writer 'It was not. EDS', refusing to let go of the claim that he assiduously fostered for many years.[34, 35]

The second landship was actually designed by Tritton and Lieutenant W. G. Wilson, an engineer seconded from RNAS to Fosters who was to become well known for his designs of epicyclic transmissions. Its salient feature was the novel layout of the tracks, devised by Wilson.[36] This provided the tracks with a high, upturned nose and a high return run so that they went around the body of the vehicle instead of being below it. The upturned nose was inspired by the high parapets of enemy trenches, and together with the long length of the tracks provided the second landship an exceptional trench crossing capability that greatly exceeded the War Office requirements. It also gave the second landship its characteristic rhomboidal silhouette.

The configuration of the vehicle did not lend itself to the installation of a turret and the original idea of arming it with a turret-mounted gun was therefore discarded. Instead the vehicle was armed with two guns mounted in sponsons projecting out of its sides – a contemporary mode of mounting the secondary armament of the larger warships. As the Army was short of suitable guns, the vehicle was armed with 57mm 6-pounder naval guns that the Director of Naval Ordnance promised to supply in sufficient quantity. In addition to the two 57mm guns the vehicle was also armed with three machine guns.

In other respects the second landship followed Tritton's machine. In particular, it was powered by the same 105 horsepower Daimler engine and had the same Foster wheeled tractor transmission as well as a pair of steering wheels at the rear. It also ran on the same type of unsprung plate track as its forerunner. The thickness of its armour, which was simulated by soft steel plates, varied from 6 to 12mm and fully laden it weighed 28 tonnes.

Development of the vehicle proceeded with remarkable speed: a mock-up of it was built in September 1915, its design was completed in October and the vehicle itself was completed by 26 January 1916. It was at first referred to as the 'Wilson machine' but later as 'Big Willie' and 'Her Majesty's Land Ship Centipede', and eventually as 'Mother' as it became the progenitor of the British heavy tanks of the First World War.

By February 1916 the Army finally decided that it wanted what by then had began to be called tanks rather than landships for reasons of secrecy. However, its decision was only taken after trials of Mother at Hatfield in January and February 1916 during which it successfully negotiated all obstacles. This included trenches 9 feet wide, while the official requirement was still that it should cross trenches 5ft wide and not what Swinton ultimately suggested.[37] Its performance convinced most of the military and civilian officials who attended the trials of its potential value, although Lord Kitchener dubbed the tank 'a pretty mechanical toy'.

However, the decision to go ahead with the production of tanks similar to Mother was, curiously, left to the General Headquarters of the British Forces in France. Its representatives attended the trials at Hatfield and recommended the acquisition of tanks, although only 40 were subsequently asked for. On hearing of this ridiculously small number Swinton, who had returned to an influential government post in England in August, persuaded the War Office to raise the number of tanks to be produced to 100 and on 12 February 1916 the Ministry of Munitions authorized their production.

Thus the evolution of tanks in Britain reached the end of its experimental phase and entered that of production and use in the field.

Concurrent with the development of the tank in Britain and with no knowledge of it, the tank was also developed in France. That this should have happened is not entirely surprising since the two countries faced the same military problems and possessed or had access to similar technological resources. Nevertheless, it is remarkable that some of the steps in the development were taken in the two countries at almost the same time. This applied, among others, to the decisions to produce tanks, which were taken in Britain and in France within days of each other.

The French decision was bolder as it called for the production of 400 tanks. However, no prototype of the French tank had yet been built and the French production order took several more months to implement than the British.

As in Britain, the development of the tank in France was preceded by proposals for the use of special devices to overcome the problems created in 1914 by the onset of trench warfare and in particular that of attacking trenches protected by barbed wire. The first of them appears to have been a proposal made in November 1914 to convert a road roller into an armoured vehicle that would crush barbed wire. The proposal was actually implemented and the resulting Flot-Laffly roller was tested, but only to be rejected as being impractical, like the rollers considered in Britain by Hankey and by Churchill. Another proposed barbed wire crusher consisted of the Boirault apparatus – a bizarre device consisting of six large, 4 metre by 3 metre linked skeleton panels engine-driven by chains to move forward as if it were a hexagonal wheel or six-link track. On the advice of the French commander-in-chief a ministerial commission rejected this device outright, but it took a demonstration carried out 5 months later to make another commission, representing the technical services of the Army, reach the inevitable negative conclusion.

A different method of breaching barbed wire entanglements, which amounted to the use of a large wire cutter mounted on a wheeled agricultural tractor, was proposed in November 1914 by J. L. Breton, an influential deputy to the National Assembly. This method was tested in July 1915 and, in spite of the inadequate performance of the tractor over broken ground, the Ministry of War ordered the construction of ten Breton-Prétot wire cutters.[38]

Much more practical results followed the development of an armoured car on which the Schneider armament company of Le Creusot embarked towards the end of 1914. By mid-January 1915 its design had been drawn, and later that month a Schneider engineer involved with the project, E. Brillié, travelled to Aldershot in England to see the 75hp Holt tractors that had just been acquired by the British artillery for hauling heavy guns. During his visit Brillié also learnt of the existence of a new, smaller 45hp 'Baby Holt' which, unlike the heavier 75hp model and other contemporary tractors, dispensed with the steering wheels. As a result of the visit Schneider ordered one tractor of each type, receiving both from the United States by the beginning of May 1915.

Trials of the tractors at Le Creusot showed that the Baby Holt was the more manoeuvrable of the two and that it could form the basis of a tracked armoured car superior to the wheeled cars. Its ability to move over rough ground and to negotiate obstacles was demonstrated in the presence of the President of the Republic, and in July Schneider started to design an 'armed and armoured tractor' based on a slightly lengthened Baby Holt chassis. However, work on it was stopped in September because of the intervention of Breton and the technical branch of the Ministry of War, which made Schneider redirect its work to the design of a vehicle that would carry modified Breton-Prétot barbed wire cutters more effectively than they were originally. Trials of a cutter mounted on a Baby Holt tractor carried out in December 1915 raised doubts about its effectiveness but, even before they took place, an order was given to Schneider by the minister of war for ten tracked armoured vehicles to carry the cutters.

Further tests were carried out in January 1916 and showed that the Breton-Prétot cutters were not needed for opening passages through barbed wire because a tracked vehicle could crush it down by its weight.[39] Nevertheless, more time and effort might have been wasted on the wire cutters because of the political influence of Breton, who continued to promote them. However, this was prevented by the arrival on the scene of Colonel J. E. Estienne, who managed to bring the work at Schneider back on to a more fruitful path and provided a new drive for the development of tracked armoured vehicles.

Estienne was a technologically minded artillery officer who, among other things, was a pioneer in the use of aircraft for directing artillery fire. When the war broke out, he was given the command of an artillery regiment and was allowed by the minister of war to take with him a section of two aircraft that he had organized and that made his regiment the only one during the first two months of the war to have its own spotter aircraft.[40]

Once the war began, Estienne turned his attention to the mobility of the artillery and after only a few days of operations is reputed to have told the officers of his regiment that victory would belong to whoever of the belligerents was the first to mount a 75mm gun on a vehicle capable of moving over all types of terrain – the 75mm field gun being the basis of the French artillery and probably the most successful gun of its time.[41] This was a remarkable recognition of the need to make heavy weapons more mobile, but Estienne did not see how this could be done until October 1915 when on the Somme front he visited a neighbouring British division and saw Holt tractors being used for towing guns.[42] This led him to the idea of an armed and armoured assault vehicle and to write, on 1 December 1915, to the French Commander-in-Chief, General Joffre, asking for an audience to present his ideas.

On the strength of his reputation for novel ideas, Estienne was summoned to the General Headquarters on 12 December 1915, when he explained in some detail the vehicle that he had in mind to General Janin, who was in charge of army materiel. The vehicle that he envisaged was to be tracked and weigh 14 tonnes, with armour 15 to 20mm thick and an armament of a 37mm cannon and two machine guns, and it was to be manned by a crew of four.[43] It was called a '*cuirassé terrestre*' or 'land ironclad', which was virtually the same as the 'landships' designation applied to the first British tanks and reflected, once again, the contemporary influence of naval ideas.

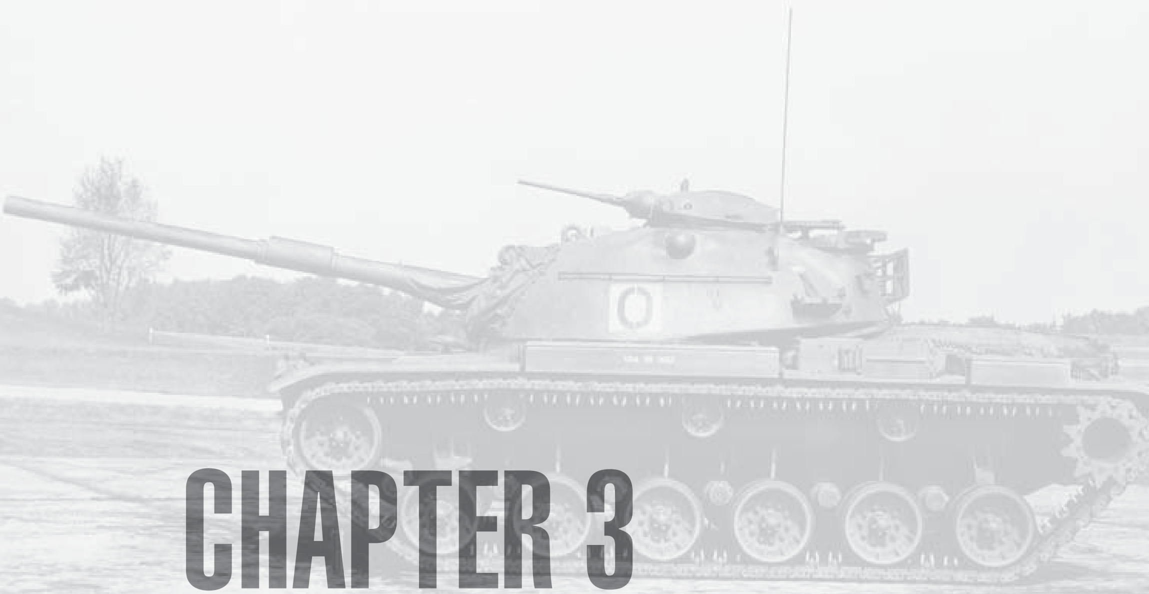
Eight days later, with the approval of General Joffre, Estienne began to investigate who could produce the vehicle he proposed. He first called on Louis Renault, the head of the car company that still bears his name, but the latter already had as much war work as he could deal with. Estienne then met Brillié, who was working on the vehicles ordered to carry the Breton-Prétot wire cutters instead of the tracked armoured car he had originally conceived, and found much similarity between their ideas. In consequence Brillié agreed to study Estienne's proposal. Having secured industrial collaboration, Estienne wrote again, on 28 December 1915, to General Joffre suggesting that Schneider be given an order for 300 to 400 vehicles. Joffre responded favourably, recommending further study and, when Estienne reported to him on the situation, decided on 31 January 1916 to order 400 *cuirassés terrestres*, which by then were to be armed with a short-barrelled 75mm gun instead of the 37mm cannon originally proposed.[44]

The actual issue of the order to Schneider was the responsibility of the technical branch of the army, which resented Estienne by-passing its bureaucratic procedures and demanded further trials. These were successfully carried out, but had it been left to the technical branch there would have been further delays. However, Estienne appealed once again to Joffre and as a result on 25 February 1916 the minister of war approved the issue of an order to Schneider for 400 vehicles that, for the sake of secrecy, were called 'tractors'.[45]

The first Schneider tank to be built as a result of the order was completed by the beginning of September 1916. Like that of the British 'Little Willie', its simple box hull was still of mild steel. The supply of armour plate caused delays in the production of more tanks, but even before the first Schneider tank was built the technical branch of the army, smarting from being left out of its development, decided to promote the construction of another tank. In pursuing this objective it found a willing partner in the company of Forges et Aciéries de la Marine et d'Homecourt, commonly known as Saint Chamond, which was a bitter commercial rival of the Schneider company, and it won the approval of Breton, who had become the head of an inventions committee in the Ministry of Armament. In consequence Saint Chamond proposed a tank designed by Colonel Rimailho that was quickly accepted by the minister of war, who issued an order to Saint Chamond on 8 April 1916 for 400 vehicles. All this was done without reference to Estienne or even Joffre, who was not informed by the minister of the order until 27 April 1916.[46]

Like Schneider's, the Saint Chamond tank was based on the Baby Holt tractor but had a lengthened track. It had a more powerful armament in the form of a full-size 75mm gun and thicker armour, which contributed to it weighing 23 tonnes instead of the 13 tonnes of the Schneider. It also incorporated a novelty in the form of an electric transmission, but its design was seriously flawed because the front of its hull overhung the tracks to such an extent that it dug in whenever it tried to cross a trench of any width.

The prototype of the Saint Chamond tank was completed at the beginning of September 1916 at approximately the same time as the Schneider tank. In consequence, the development of tanks in France started not with a single model, as in Britain, but with two different vehicles built almost simultaneously.



CHAPTER 3
First World War Battlefield Debut

Tanks began to appear on the world scene with the delivery at the beginning of June 1916 of the first British tanks, produced as the result of the order placed for them only four months earlier by the Ministry of Munitions. The tanks were simply designated Mark I and were virtually identical with ‘Mother’, except that their hulls were made of armour instead of mild steel plates and that half of them were armed only with machine guns. Like their progenitor they relied for sharp turns on a crude system adopted not on its merit but for the sake of using existing transmission components and thereby saving time and development effort.[1] It involved putting the secondary gearbox on one side of the differential into neutral and applying a brake to the undriven track while the other track continued to be driven. This meant that four men were required to manoeuvre a tank: commander and driver at the front, who controlled the engine and applied the brakes, and two gearsmen, one on each side of the rear of the tank. There were also two gunners at each of the two sponsons, which brought the crew to a total of eight men.

The problem of steering the Mark I tanks and hence of manoeuvring them was aggravated by the difficulty the commander had of communicating with the gearsmen, as well as the gunners, because of the noise of the engine, which was located in the middle of the hull. The engine also generated heat and emitted noxious fumes, which could make the interior of tanks extremely uncomfortable for their crews. The crews also had to endure severe jolts caused by the absence of a sprung suspension when tanks operated over broken ground. Under some conditions the tanks were slower than the infantry with which they were co-operating, although on flat, hard ground they were capable of a maximum speed of 3.7 miles per hour and had an operating range of 24 miles.

These and their other shortcomings were bound to have an adverse effect on the performance of the first tanks. However, this did not hinder their adoption and was not allowed to delay the sending of the first tanks into battle only seven months after they were ordered.

The remarkably rapid production of the first tanks was accompanied by a decision taken by the War Office on 16 February 1916 to form the first tank unit and by an increase in April of the production order from 100 to 150 tanks.[2] In consequence, by the end of June two of the six companies into which the tank units were to be organized, and each of which was to have 25 tanks, began to train.[3] Moreover, having endorsed the production of tanks, the General Headquarters of the British Forces in France was keen to employ them as soon as possible.

The speed with which the British Army accepted tanks and set about employing them must be credited to some extent to Swinton, who returned to England at the end of July 1916 to become assistant secretary of what was called the Dardanelles Committee of the Cabinet. On his return he discovered the existence of the Landships Committee and its work on tanks.[4] He then took advantage of his influential position to instigate in August an interdepartmental conference to co-ordinate the activities of the Landships Committee, the War Office and the Ministry of Munitions, and he went on to promote tanks wherever an opportunity arose. For his efforts he was rewarded in February 1916 by being made commander of the tank units that were being raised in England. As such he was responsible, among others, for the somewhat peculiar decision to arm one half of the 150 tanks that were being produced only with machine guns, on the grounds that such 'female' tanks would be needed to protect the 'male' tanks, although the latter were already armed with four machine guns as well as 57mm guns, against an onrush of enemy infantrymen![5]

Swinton was also the first in the British Army to write about how tanks might be employed. He did so originally in a memorandum entitled 'The need for machine gun destroyers' that he submitted on 1 June 1915 to the General Headquarters in France.[6] In this he suggested that 'armoured machine gun destroyers' should be used in a surprise assault on enemy positions with the object of destroying hostile machine guns and thus paving the way for the attacking infantry. He subsequently elaborated his ideas in a paper entitled 'Notes on the employment of tanks' written in February 1916.[7] In this he again defined the principal role of tanks as clearing the way for infantry assaults by destroying hostile machine guns. He envisaged therefore a somewhat specialized, limited role for tanks and did not contemplate their employment beyond the confines of trench warfare.

In both cases Swinton warned against the premature employment of a few tanks and advocated 100 being used in a surprise assault.[8] But even before the first tanks were built the commander-in-chief, Sir Douglas Haig, became keen to use some in the forthcoming offensive on the Somme. As it was, the earliest that any tanks could be made available was August 1916, when two companies were sent to France. Once they were there the General Headquarters decided to use them to bolster an attempt to revive the offensive on the Somme, which had by then stalled. In consequence the two companies were moved to the front and on 15 September 1916 took part in a large scale attack on German positions in what became known as the Battle of Flers-Courcelette.

The tanks were distributed over the front of ten infantry divisions and were used in twos or threes to attack enemy strong points in support of the assaulting infantry. Forty-nine tanks were available but only 32 reached the starting line; nine then led the attacking infantry, engaging the enemy with their guns and machine guns, while nine others assisted in a similar way in clearing up pockets of resistance. Of the remaining 14, nine broke down and five became ditched.[9]

Overall, the performance of tanks in their first battle was not a great success and the contribution they made to the progress of the Somme offensive, which was limited to an advance of about one mile, was very modest. However, bearing in mind the primitive nature of the first tanks and their attendant shortcomings, the fact that they were, at best, only three months old, and the inadequate training of their crews, the participation of tanks in the Somme offensive was a very considerable achievement.

Nevertheless, the use of the tanks on the Somme has been widely criticized as premature, mainly on the grounds that more might have been achieved had their debut been delayed until more were available. On the other hand it has been argued in its defence that tanks had to be put to test in battle at an early stage to gain experience with them.[10] However, it is not evident that some of the lessons that were brought out by the early employment of tanks, such as the need for adequate training of the crews, could not have been foreseen in advance of Flers-Courcelette.

Although tanks had not achieved what had been hoped of them, their first action was considered to have justified their existence in the eyes of Haig. In consequence, a meeting was held at the War Office only four days after the first tank action at which it was agreed that an order be placed for 1,000 more tanks.[11] However, because of some confusion, the order was not confirmed until 14 October and it did not begin to bear fruit until March 1917, when the first of the new Mark IV tanks was completed. Eventually 1,015 tanks of this type were produced.[12] In the meantime, to keep the factories going, an order was placed for 100 Mark II and Mark III tanks, which were very similar to the original Mark I type.

Following their debut on the Somme, the use of tanks was confined to a few small scale actions until the Battle of Arras in April 1917, for which 60 tanks became available. These were dispersed among the attacking infantry formations, and although they were successful in a few local actions many became bogged down in a terrain made impassable by heavy rains. Even worse conditions were encountered in the next major engagement of tanks, in the Third Battle of Ypres, or Passchendaele, in July to October 1917. This was fought in an area of reclaimed swampland turned into a sea of mud by a combination of artillery bombardment and heavy rains. The number of tanks available had risen to 216 and included some new Mark IVs, which incorporated a number of improvements on the Mark Is, including better armour.[13] However, they were again dispersed among a number of infantry divisions and the terrain severely restricted their movement, which helped enemy artillery to knock many of them out while others became bogged in the swampy ground.

By the third day of the Ypres offensive the commander of the Tank Corps, Brigadier General H. J. Elles, recognized the futility of the further use of tanks in it and suggested that the remaining tanks be withdrawn for use *en masse* in suitable terrain.[14] At the same time his chief of staff, Lieutenant

Colonel J. F. C. Fuller, came up with the idea of a 'one-day tank raid' – a surprise spoiling attack carried out over suitable ground without the customary preliminary artillery bombardment. Fuller's memoirs imply that this led to the Battle of Cambrai, which became the first successful large scale tank attack.[15] In fact, the Battle of Cambrai came to be a much bigger operation than Fuller had originally envisaged and others were involved in its conception, including the commander of the Third Army, General Byng, in whose sector of the front the battle took place.[16]

All available tanks were assembled for the battle, the total being made up of 378 fighting tanks, 54 older tanks carrying supplies, 10 radio and cable communication tanks and 34 other tanks for clearing the ground of barbed wire for the planned follow-up by the cavalry and carrying bridging for it.[17] The assembly of the 476 tanks and of the supplies of fuel and ammunition required by them was carried out in great secrecy, and for the attack on 20 November 1917 the tanks were drawn up in a single line in front of seven miles of British trenches. As they moved forward, tanks crushed the barbed wire covering enemy positions and subdued enemy machine guns by fire, clearing the way for the infantry that followed them. The supporting artillery, which totalled 1,000 guns, did not open fire until the tanks began to move so as not to alert the enemy and the attack thereby achieved complete surprise.

Led by tanks, the attacking forces broke through the defences of what was known as the Hindenburg Line and advanced up to 7 miles, which was more than the total advance made in the three months of the Ypres offensive and which was achieved at the cost of far fewer casualties. The attack demonstrated clearly how effective tanks could be as assault vehicles when used in numbers over suitable ground, even though 112 of them were destroyed by the end of the battle by enemy artillery fire.[18]

However, the success of the initial attack was not exploited, the tanks being too slow to do so and the cavalry too vulnerable to machine guns. Moreover, when the German forces counter-attacked ten days later they recovered most of the ground. The Battle of Cambrai ended therefore in deadlock and its outcome made the German General Staff consider tanks less of a threat than it might have done.[19] But it did not prevent a further expansion of the Tank Corps from three to five brigades.

In the winter of 1917–18 the five brigades were spread out to form a defensive cordon some 60 miles behind the British lines in anticipation of a major German offensive. When that came in March 1918, the tanks were used piecemeal and in the ensuing retreat many were lost, having to be abandoned when they broke down or ran out of fuel. In consequence they proved relatively ineffective.

Most of the tanks used were Mark IVs, which, like the Mark I, were designed for assaults on enemy trenches and were too slow as well as having too short an operating range for effective employment under the fluid conditions created by the German offensive. However, there was a new British tank more suited to them, the Medium A or Whippet, which made its battle debut on 26 March 1918. It was lighter than the earlier tanks, weighing 14 tonnes instead of the 27 or 28 tonnes of the Mark IVs, and it had a maximum speed of 8.3 miles per hour compared with 3.7 miles per hour, as well as an operating range of 80 miles compared with 35 miles of the Mark IV. It was also more manoeuvrable as it was driven by one man who could steer it by changing the speed of its two 45hp engines that separately drove its two tracks – ostensibly a simple method of steering a tracked vehicle, but one which required very considerable dexterity on the part of the driver as the engines were easy to stall.

The Medium A also departed from the rhomboidal configuration of the earlier tanks, its tracks being surmounted by a fixed turret that contained a crew of four and mounted four Hotchkiss machine guns. Because of its greater mobility Medium A scored some local successes, but shared with the others the consequences of the ineffective, dispersed employment.

The fortunes of the Tank Corps did not revive until the Battle of Amiens, fought on 8 August 1918. This was the second major British tank battle and it was larger and more decisive than Cambrai. The whole of the Tank Corps was assembled for it, except for one brigade that was still equipped with Mark IV tanks. The other brigades had by then been re-equipped with the new Mark V tanks. These were basically similar to the Mark IVs but they had somewhat more powerful engines and could be driven by one man, as they had an epicyclic gear steering system instead of the crude method involving four men by which the earlier tanks were steered. In consequence they were much more manoeuvrable. In addition to the 324 heavy tanks there were 96 Medium A tanks, and with supply tanks and spare vehicles the total assembled for the battle amounted to 580 tanks.[20]

As at Cambrai, the tanks were assembled secretly and attacked *en masse* along a 13 mile front without a preliminary artillery bombardment. The surprise tank assault overwhelmed the German defences and led to a major breakthrough, during the course of which the German Army suffered heavy losses. General von Ludendorff, who was effectively the German commander-in-chief, described 8 August 1918 as 'the black day of the German Army'.[21]

However, the breakthrough at Amiens was achieved at the cost of many tanks destroyed by the German artillery. As a result of the losses, by the second day of the battle the number of tanks available for further action was down to 145. Moreover, the success of the initial attack was again not exploited because the Mark V tanks were still too slow, being only marginally faster than the Mark IVs. The Medium A were faster but they were tied to the cavalry, which was expected to exploit the breakthrough but proved incapable of operating in the face of machine guns, as it did at Cambrai.

Nevertheless, the Battle of Amiens led to the beginning of a slow retreat of the German Army that went on until the end of the war three months later. During this period tanks attacked successfully on a number of occasions but their attacks were generally on a relatively small scale, involving at most 40 to 50 tanks, because of their shortage after Amiens. This was aggravated by further losses inflicted by German artillery and by the increasingly mobile nature of the operations, to which the available tanks were not suited. About 175 were assembled at the end of September for the assault on the Hindenburg Line, but only 37 could be scraped together for the final tank attack on 4 November 1918.[22]

Three weeks before the Battle of Amiens, the French Army also carried out a large scale tank attack at Soissons, which became another major success for tanks. This was preceded by a series of smaller scale actions by French tanks, the first of which took place on 16 April 1917 as part of an offensive on the Aisne. By then 208 Schneider and 48 Saint Chamond tanks had been produced of the total of 800 ordered a year earlier, and 160 of the Schneiders were considered ready for action, although not all of them had been fitted with the additional armour found to be necessary because of the introduction by the German Army of armour-piercing machine gun ammunition in response to the use of tanks by the British Army.[23]

When French tanks began to be developed, it was thought that they would be used to break through enemy fronts by surprise assaults carried out without preliminary artillery bombardments. But by the time they were built the British Army had began to use tanks and the German Army responded to them by digging wider trenches that the Schneiders, let alone the Saint Chamonds, could not negotiate. In consequence it was decided that they should not be used to lead infantry assaults but to support the infantry beyond the effective range of the supporting artillery.[24] In other words, they came to be regarded as mobile close support guns, which was in keeping with the designation given to the French tank units of '*artillerie d'assaut*'.

A total of 132 tanks was assembled for the attack on the Aisne, which failed, with tanks contributing little to the limited penetration of enemy positions. The tanks, almost all of which were Schneiders, had difficulty negotiating trenches and the shell-cratered ground, and 57 were destroyed by enemy artillery.[25]

The inauspicious debut of the French tanks was not followed by another tank action until October 1917, when 64 tanks took part in the Battle of Malmaison. This time they successfully supported the infantry, although they still operated in small groups, and only eight were knocked out by enemy artillery.[26] No further action took place until after the German offensive in March 1918, in anticipation of which French tanks were held behind the front line for counter-attacks, the total of operable tanks amounting by then to 245 Schneiders and 222 Saint Chamonds.[27] They were at first employed piecemeal in a number of local counter-attacks under conditions of mobile warfare for which they were no better suited than the contemporary British tanks, although they were more manoeuvrable than the Mark IVs, being driven by one man and having sprung suspensions. But the most significant of the counter-attacks, which was carried out on 11 June 1918 by a force of 144 Schneiders and Saint Chamonds and infantry in the Matz valley, was successful in halting an enemy advance, albeit at the cost of 69 tanks.[28]

In the meantime, in June 1916, the French High Command was informed of the British development of tanks and Colonel Estienne, who was about to be given the task of organizing the first French tank units, was sent to England to investigate. After being shown British Mark I tanks Estienne came back with the idea that there should also be a much lighter tank, which he saw as an armoured, machine gun armed infantryman who could operate over all types of terrain. During the following month Estienne put his idea to Louis Renault, who took it up with enthusiasm and proceeded to design a two-man light tank to meet it. By November 1916 Estienne was sufficiently confident of Renault's design to write to the Commander-in-Chief, General Joffre, as he did at the inception of the development of the Schneider tank, recommending that as soon as a prototype of the light tank was approved 1,000 be ordered.[29] Joffre was in favour of it, but the technical branches of the Army and the Ministry of Armament again raised various technical and bureaucratic objections and although in February 1917 Renault received an initial order for 150 tanks the follow-on order for 1,000 tanks was cancelled in April, albeit temporarily. To make matters worse, Joffre was then replaced by General Nivelle, who was less favourably disposed towards tanks, and it was only in October 1917 when he, in turn, was replaced by General Pétain that 2,380 tanks were added to the earlier orders for 1,150.[30]

Fortunately, Renault and his company continued to work on the tank, in spite of problems including that of the supply of armour plates, which had to be imported from England for lack of sufficient industrial capacity in France. As a result, a prototype was built in April 1917 but the first production tank was not completed until September.[31]

The light tank became known as the Renault FT, or simply as the Renault. It was very different from the French and British tanks that preceded it and in several respects represented a major advance on them. In particular, it was the first tank to have its armament mounted in a rotating turret. Moreover, its general configuration became and remains to this day the norm for most tanks. Its features included the location of the driver in the front of the hull, a weapon compartment surmounted by the turret in the centre and the engine compartment in the rear of the hull, separated from the crew by a bulkhead. As in most modern tanks, the track driving sprockets were also at the rear.

In battle order, the Renault weighed 6.5 tonnes but, in spite of its light weight, it had hull armour 16mm thick and even 18 or 22mm thick turret armour, which was thicker than that of the much heavier British tanks and sufficient to defeat the armour-piercing bullets of the German machine guns. It was also marginally faster than the British Mark V, having a maximum speed of 4.8 miles per hour, but it was not as fast as the Medium A.

Although the Renault was conceived as a machine gun tank, in April 1917 Estienne decided that some should be armed with a short-barrelled 37mm cannon instead of the Hotchkiss machine gun.[32] Such a cannon was being used by the French infantry as a close support weapon and after modifications it was successfully mounted in the Renault, a proportion of which were subsequently armed with it. The cannon fired a full range of ammunition, including armour piercing and canister as well as high explosive rounds, and the tank could carry up to 240 of them.

The rather odd calibre of the cannon mounted in the Renault and later adopted for tank and anti-tank guns produced in several countries originated with the 1868 St Petersburg Convention that, on humanitarian grounds, defined the minimum permissible weight of high explosive shells. This led Benjamin Hotchkiss in France to design a cannon that fired shells of the prescribed weight whose calibre came to be 37mm.[33] The cannon was adopted by the French and several other navies for the defence of large ships against the contemporary threat of high speed torpedo boats, and although after a time the naval use of 37mm Hotchkiss cannon declined, other cannon of this calibre came to be used on land.

Originally the intention was not to use the Renaults until they could be employed in some number. However, a German offensive against the French front in May 1918 called for the deployment of all available resources. In consequence two battalions of Renaults were rushed to the front at the end of May, although the formation of the first was only completed earlier in the month. As soon as they reached the front in the region of the Retz forest, 21 tanks charged the advancing enemy to gain time locally for the defence. Following this hasty debut Renaults were confined to assisting the defence of the Retz forest by a series of small scale counter-attacks, which were carried out at the cost of 70 tanks destroyed or severely damaged out of the total of 210 initially held by the three Renault battalions involved in these counter-attacks.[34]

The Renaults did not come into their own until the counter-offensive launched by the French Army in the region of Soissons on 18 July 1918. All the available French tank units were assembled for it, their strength amounting to about 225 Schneiders and Saint Chamonds and six battalions of Renaults with a nominal strength of 432 tanks, or a total of more than 600 tanks. This was even more than the total number of tanks assembled four weeks later by the British Army for the attack at Amiens, but the French tanks were generally lighter.

As at Cambrai, the attack was carried out by surprise, without a preliminary artillery bombardment, and succeeded in disrupting the enemy front. It took place over the fronts of two French armies, over one of which it was led by almost all the available Schneiders and Saint Chamonds, while the three Renault battalions allotted to it were held in reserve for the exploitation of a breakthrough. On the front of the other army, the attack was led almost entirely by the three other battalions of Renaults with about 200 tanks.[35]

From then on Renaults were used increasingly to lead or to support infantry attacks by a series of small scale actions rather than in massed assaults. In spite of tanks lost in battle, the number of Renaults in use grew rapidly as a result of the large scale orders placed for them, which had risen to 4,000 tanks and resulted in the actual delivery of 3,177 tanks by the Armistice of 11 November 1918.[36] The numbers of tanks that were being produced made possible the formation of an increasing number of tank units, which were being created in the last four months of the war at the astonishing rate of almost one new Renault tank battalion per week. As a result, by the end of the war the French Army had as many as 24 battalions of Renaults in addition to equipping two US tank battalions with them.

The large number of tanks that the French Army came to use during the war contrasted sharply with the few the German Army deployed. The difference resulted in part from the late start of the development of tanks in Germany, which was only taken up after the appearance of the first British tanks in 1916.

Yet a Holt tractor similar to those that later became the basis of the development of tanks in Britain and in France was demonstrated to Austro-Hungarian and German military authorities in 1912 and 1913 respectively. The demonstrations were arranged by L. Steiner, a Hungarian engineer and land owner, who in 1910 ordered a Holt tractor for use in farming but then demonstrated its ability to haul heavy guns as well as becoming a Holt dealer. The gun-hauling demonstrations were successful and the Austro-Hungarian authorities acquired some Holt tractors before the outbreak of the war in 1914, but the German authorities dismissed the tractor Steiner demonstrated as of 'no importance for military purposes'.[37]

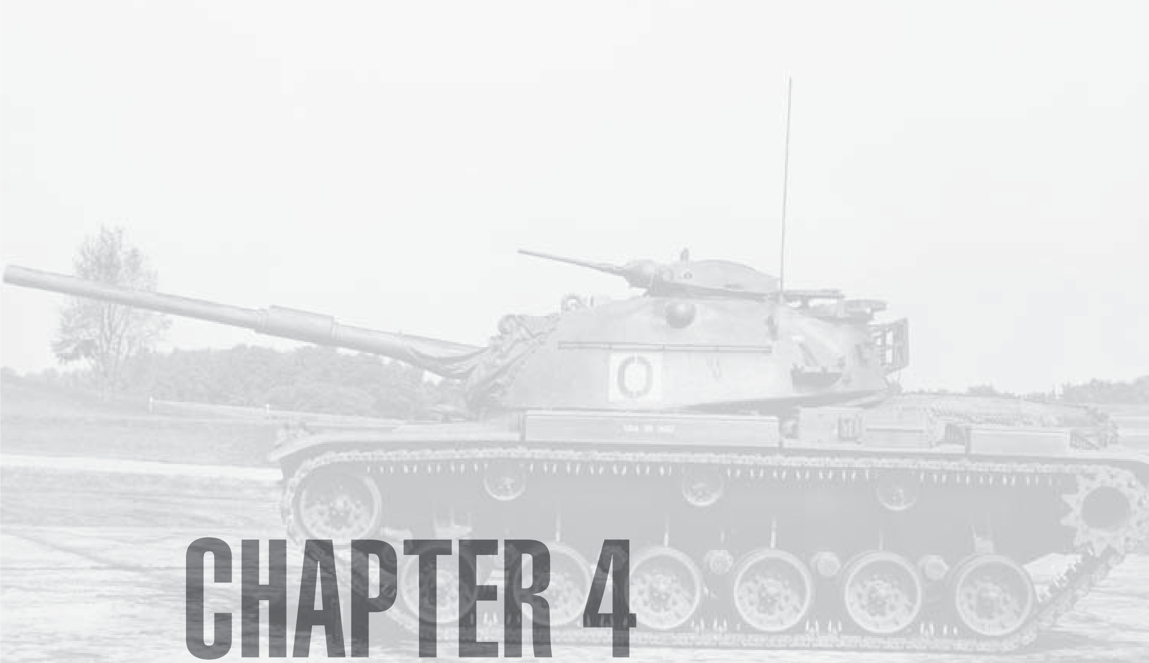
It was only in November 1916, two months after the debut of the British tanks on the Somme, that the German War Ministry purchased a Holt tractor from the Austro-Hungarian War Ministry and invited Steiner to Berlin for discussions with J. Vollmer, who was to become the designer of the first German tank.[38] By then, in October 1916, the German War Ministry had set up a committee to draw up the specification of a tank, which was then designed with remarkable speed by the end of December. Earlier that month an order was also placed for the production of 100 tanks, the first of which was ready for use by October 1917.

The tank was called A7V after the designation of the committee that initiated its development. It consisted in essence of a large box hull mounted on a tracked chassis based on that of the Holt tractor acquired from Austria. The hull was riveted from plates 30mm thick at the front and 15mm at the sides, which was considerably more than the thickness of the plates of British tanks, but also made it heavier, its weight in battle order being 33 tonnes. In spite of this, A7V had a relatively high maximum road speed of 8 miles per hour, but, like that of the French Saint Chamond, its obstacle crossing ability was very limited. It was armed with a captured Russian 57mm gun mounted in the front of the hull and two machine guns in each side and the rear of it. Otherwise the most noteworthy feature of A7V was its large crew of 18 men, which set up a record not surpassed since by any other tank.

As tanks were produced, three detachments of five A7Vs each were formed, and they took part in the German offensive that broke through the British lines in March 1918. One of the detachments went into action for the first time at St Quentin on 21 March and all three were engaged three days later at Villers-Bretonneux, where they spearheaded infantry assaults with considerable success.

At Villers-Bretonneux, the A7Vs were also involved on 24 April in the first ever tank versus tank battle when they ran into some British tanks. The latter were initially two Mark IV 'female' tanks armed only with machine guns that were forced to withdraw, damaged and unable to fight back, when an A7V fired its 57mm gun at them. Then a Mark IV 'male' arrived on the scene firing its 57mm guns, causing the A7V to run onto a side slope and overturn.[39] This historic incident provided an early illustration of the need to arm tanks so that they could fight other tanks, as well as an indication of the indifferent performance of the A7V over uneven ground.

The three A7V detachments continued to be employed right up to the end of the war, but their impact was very limited because of the small number of tanks they could deploy. Although they absorbed the whole of the production of A7Vs, this only amounted to 20 tanks of the 100 originally ordered. The shortage of indigenous tanks made the German Army use captured British Mark IV tanks, with which it formed six detachments of five tanks each by the end of the war and was planning to form six more.[40] However, even if these plans had been implemented the number of tanks the German Army had would only have been increased to about 75.



CHAPTER 4
Post-War Anticlimax

The initial use of tanks by the British and French armies was followed during the latter part of the First World War by considerable further development of them and ambitious plans for their large scale production and employment. But all these activities and plans were drastically scaled down or abandoned when the hostilities on the Western Front ended in November 1918.

In Britain the downturn was made very evident by what happened to the medium tanks that followed the original Medium A. The first was Medium B, which had already been designed in 1917 and 550 of which were ordered by November 1918. However, the orders were then cut down and only 80 were built. Even more drastic reductions were made in the case of Medium C, orders for which had risen by September 1918 to as many as 3,230 tanks only to be cancelled when the war ended. Not more than 36 or 48 were eventually completed.[1]

Both tanks combined in a lighter form the rhomboidal track layout of the British heavy tanks with a fixed superstructure, or turret similar to that of the Medium A, in which were mounted four machine guns. They were heavier than the Medium A, weighing 18 and 19.5 tonnes respectively, and neither was faster, but they were easier to drive by one man, having a single engine.

Medium C was considered to be the best of the British tanks produced during the war and the only one to remain in service for some time after the war – until 1925 in fact. However, like all earlier British tanks it still had unsprung track rollers that resulted in a very harsh ride over broken, hard ground and limited its maximum speed.

This shortcoming was only rectified in the last British tank to be conceived during the war, the Medium D.

Medium D stemmed from experiments carried out by an engineering unit of the Tank Corps commanded by Major P. Johnson, which was charged with making improvements to tanks. Its principal objective was a major increase in their speed, and by installing a much more powerful Rolls-Royce aero engine in an existing heavy tank the unit demonstrated that on suitable ground it could attain 15mph, or almost four times its normal speed, in spite of its unsprung tracks.[2] This as well as other experiments led to a conference on 28 April 1918 at the headquarters of the Tank Corps attended by Colonel F. Searle and Colonel J. F. C. Fuller, who were its chief engineer and chief of staff respectively, at which plans were made for the design of a new medium tank capable of a speed of 20mph. The task of developing such a tank was entrusted to Johnson and it was designated Medium D.

A month later Fuller produced a paper entitled 'The Tactics of the Attack as Affected by the Speed and Circuit of the Medium D Tank'.[3] In it Fuller proposed that the speed and range that the Medium D tanks were expected to have be exploited by making them burst through enemy lines and advance well beyond to attack enemy headquarters to bring about a collapse of the enemy's command system. This would create confusion and the disorganized enemy forces would then be crushed by an assault by heavy tanks and infantry.

Fuller's proposal was accepted in a modified form by the War Office and in July 1918 led to a 'Memorandum on the Requirements for an Armoured Striking Force for an Offensive in 1919', which was endorsed by the chief of the Imperial General Staff and which was approved by the Allied Commander-in-Chief, General Foch. The memorandum called for no fewer than 10,500 British, French and American tanks, or almost four times the total wartime British production, which amounted to 2,636 tanks.[4]

However, the grandiose plans for the large scale production and use of tanks were abandoned when the war ended. In consequence, Plan 1919 was never put to test. In fact, it could not have been put into effect in 1919 as its key element, the Medium D tank, was nowhere near being ready for use, and it could not have been even if its design had been entirely satisfactory, given the time required to develop and to produce it. The much lauded Plan 1919 was not therefore entirely realistic.

In fact, by the time the war ended development of the Medium D had only reached the stage of a wooden mock-up. Subsequently the construction of ten was ordered, although only seven appear to have been completed, the first in mid-1919 and the last in 1920. On trials they exceeded the required speed of 20mph and they could be made to float, but they also incorporated some questionable and troublesome design features. These included an unusual suspension with a steel cable connecting all the track rollers on one side to a single spring and a very odd type of track with wood-faced track plates that could swivel to conform to the ground. Originally the designers also expected the functions of the tank commander and of the driver to be performed by one man, which was hardly practicable, and they were only armed with machine guns, although the installation of a 57mm gun was considered.[5]

Nevertheless, in January 1920, Fuller, who was by then dealing with tank affairs at the War Office, recommended the adoption of the Medium D and also of a Light Infantry Tank, which still had to be built. The latter was a lighter version of the Medium D that weighed 7.5 instead of 13.5 to 14.5 tonnes and had laterally flexible 'snake tracks' with lubricated ball joints between the track plates. When tested in 1922, the Light Infantry Tank attained what was then a record speed for tracked armoured vehicles of 30mph.[6] Whether an infantry tank needed to be so fast may be doubted, but Fuller produced a curious argument that it had to be fast to be able to protect the infantry as a destroyer protects a convoy at sea.

In addition to the Light Infantry Tank Johnson also designed an even lighter tank, the 5.5-tonne Tropical Tank, which was intended for use in India and had a peculiar configuration with two slightly staggered side-by-side machine gun turrets, like the Austin armoured cars produced earlier to Russian requirements.

However, development of the Medium D and its offshoots came to an end in March 1923 when the government-run Department of Tank Design and Experiment that Johnson headed was closed and work on tanks was passed on to industry. Whatever the reasons for this change of policy, the decision to abandon Medium D was not very surprising as after five years of development it had still not reached the stage of being ready for use, as even Fuller who was its chief protagonist admitted.[7]

As a result of it all, the number of tanks built in Britain during the five years that followed the end of the First World War was reduced to a mere handful once the leftovers of the wartime Medium B and C programmes were completed. During the same period the number of tank units was also reduced drastically, from 26 tank battalions in November 1918 to five battalions in March 1920.[8]

In contrast, the French Army retained a relatively large tank force. In fact, for several years it was the world's largest, although equipped almost entirely with the Renault FT light tanks. Having already ordered 4,000 of them, in 1918 the French Army was planning to acquire more, which would have brought the total number of Renault FTs ordered since production began to 7,800.[9] The number actually ordered by the Armistice of 1918 reached 4,635.[10] As a result of this and production not ceasing immediately, in 1921 the French Army had no fewer than 3,737 Renault FTs, in spite of losing a number in battle and supplying or selling some to other armies.[11]

But as soon as the hostilities ceased, the French Army relinquished the claim to its share of the Anglo-American-French heavy tank programme that it had originally hoped would provide it with 1,285 tanks.[12] It also stopped the production of 2C heavy tanks, 300 of which were on order. Only ten of these 68-tonne tanks were eventually completed in 1921, to become the heaviest tanks in use for almost two decades. During this period there were claims, repeated in more recent years, that the French Army developed even heavier 74-tonne 3C tanks armed with a 155mm gun.[13] But all that actually happened was an experimental installation in 1923 of a 155mm howitzer in place of the 75mm gun in one of the ten 2C tanks.

The German Army's plans for a large scale production of tanks were brought to an abrupt end in 1918 by its defeat. One of the tanks affected by this was the A7V-U, which was based on the components of the original German tank but had a rhomboidal track layout similar to that of the British heavy tanks to remedy the poor cross-country performance of the A7V. A prototype of it was built by June 1918 and 240 were subsequently ordered for delivery by June 1919, but none of them was built.[14]

Similarly, none of the light tanks that the German Army was planning to use advanced beyond the construction of prototypes. The first was LK-I, a≈7-tonne vehicle based on a large passenger car chassis that was fitted with tracks, an armoured body and a small machine gun turret. Its development started in September 1917 and although it did not proceed beyond the construction of a prototype, the latter served as the basis of the next light tank, the LK-II, which was similar but had a fixed turret with a 57mm gun. An order for 580 LK-IIs was issued in June 1918 but only two prototypes were built before the war ended. LK-II was to be followed in 1919 by LK-III, which was a further development of the previous model, but none was ever built.

As early as June 1917 the German High Command also issued an order for 10 super-heavy breakthrough tanks, which were designated K-Wagen. They came to weigh no less than 148 tonnes and were armed with four sponson-mounted 77mm guns. Two were nearing completion in a Berlin factory when the war ended and were destroyed by the Allied Control Commission.

While the war was still going on the German High Command expected, somewhat optimistically, that production of tanks would rise in 1919 to 4,000 light and 400 heavy tanks.[15] However, the end of the war not only brought all the plans and expectations to an end, but Article 171 of the Versailles Treaty imposed in 1919 on Germany by the victorious Allies prohibited it having any tanks. As a result, all that came out of the German wartime tank programmes were the components of the LK-II, which were incorporated in the ten Strv/21 tanks built in Sweden in 1921. Several writers have claimed that some of the surviving A7Vs were given after the war to the Polish Army but there has been no evidence that would support these claims.

The United States started to build tanks later than Germany but had the advantage of being allied to Britain and France, which were already producing them when it entered the war in the spring of 1917. It could therefore draw on their experience and even obtain some tanks from them. Thus, when the US Tank Corps was formed in 1917 its first two battalions were equipped with Renault FTs supplied by the French Army and the third battalion was equipped with British Mark V tanks.

Ambitious plans were drawn for the expansion of the US Tank Corps to 45 battalions, which were to be equipped with Renault FT light and Mark VIII heavy tanks.[16] The latter were the last and at 37 tonnes the heaviest of the British rhomboidal tanks and they were to be produced in France at a factory specially built for the purpose following an agreement between the British and US governments. A total of 1,500 Mark VIII was to be produced there during 1918.[17] Of these the first 600 were to go to the US Army while the French government, which had joined the agreement, claimed the remaining 900.[18] In addition 1,500 Mark VIII tanks were to be produced in the United States.[19] But the Armistice caused all these production plans to be abandoned and eventually only 100 Mark VIII tanks were assembled in 1920 in the United States. Similarly, plans to produce 1,375 Mark VIII tanks in Britain were abandoned and only 11 were completed there.[20]

To meet the requirements of its light tank battalions, the US Army awarded contracts to three American companies for the production of 4,440 of a US version of the Renault FT.[21] Some were completed by the Armistice but none arrived in France before it occurred, and the contracts were subsequently cut down with the result that only 952 tanks were completed as the Six Ton M1917 light tanks. Still more light tanks were to have been produced as the result of an order for 1,000 Ford Mark I tanks, which were similar to the Renault FT, but only one of these was completed.[22]

The only other country to embark on the production of tanks during the≈war was Italy, which was no exception to the drastic cuts in the orders for tanks that were made when the war ended. The tank Italy produced was another version of the Renault FT, which was designated Fiat 3000 and 1,400 of which were ordered in 1918 from Fiat and Ansaldo. But after the Armistice the order was reduced to 100 tanks, which were built between 1919 and 1921.[23]

The large numbers of tanks that the major belligerents were planning to produce in the latter part of the war attested to the importance attached to them at the time. By the same token, the drastic reductions in the number of tanks after the war reflected a contemporary decline in their standing as well as the state of the post-war economies and the changes in the political situation. Once this happened it would be several years before tanks recovered their importance.

In the meantime tanks aroused considerable interest around the world, although without gaining commensurate military recognition. During the war their use was confined to Western Europe, except for a few British Mark I and Mark II tanks used in the Second and Third Battles of Gaza in 1917.[24] However, after the war their use spread worldwide as they were acquired by different countries, but invariably in small numbers.

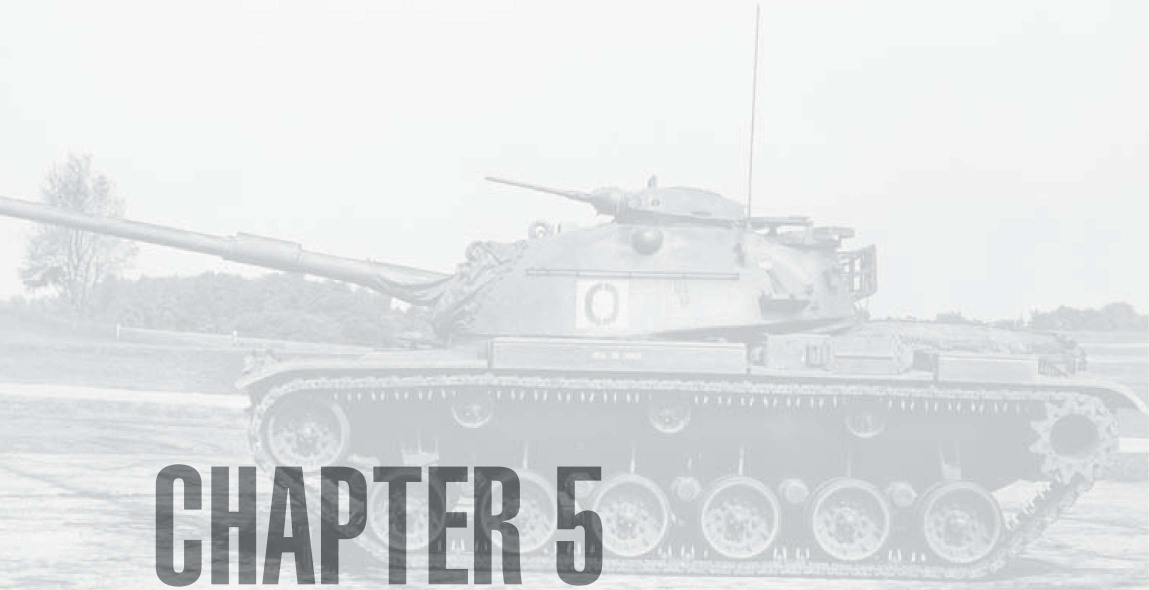
In almost all cases the tanks were the French Renault FTs, which were produced during the war in the largest number and which were the only tanks available in quantity after the war. They were generally well regarded and were well suited to the close support of the infantry, which dominated the contemporary tactical thinking. Moreover, they were relatively simple and economical to operate.

The largest number of the Renaults went to Poland. It amounted to about 120 tanks, which formed the equipment of a regiment organized in 1919 by the French Army as part of a Polish corps created in France to aid the newly independent Polish Republic. The tanks took part in the Polish-Russian War of 1920–21 but were not suited to its fluid character and made little impact on it by their small scale actions.[25]

The 120 tanks given by France to Poland constituted, for a time, the fourth largest tank force in the world, which highlights the small size of the tank forces after the First World War. Further illustration of this is provided by Italy, which had the next largest tank force of 100 Fiat 3000s. Belgium, which followed in terms of size in Europe, had a force of 49 tanks, while Finland bought 32 Renault FTs in 1919.[26] Still smaller numbers were acquired by half a dozen other European countries, including Switzerland, which bought two, and Sweden, which bought one for evaluation.

A few more were delivered farther afield, with Brazil ordering 12 in 1919 when the Imperial Japanese Army procured a similar number of Renaults from France as well as some Medium A tanks from Britain. Soviet Russia also acquired some Renaults by capturing tanks sent by France to support the anti-Bolshevik forces during the Russian Civil War, to which were subsequently added 15 copies built at the Sormovo plant by a remarkable piece of 'reverse engineering'.[27] The Red Army also captured 25 Mark V heavy tanks sent by Britain to support the White armies. But all this only brought the total number of tanks possessed by the Red Army in 1923 to 77.[28]

Only France had a large number of tanks for some time after the First World War, having been left with more than 3,000 Renault FTs.[29] This was more than the total number of tanks that the rest of the world had at the time, and together with the prestige that the French Army enjoyed after the war made its ideas prevail for several years. But its stock of wartime tanks was a wasting asset, and after a time other ideas emerged elsewhere and gradually gained strength, even though the number of tanks outside France remained small.



CHAPTER 5
Britain's Lead and Failings

The aftermath of the First World War produced a variety of ideas and opinions about the future of tanks. At one extreme were views that tanks would be of no further use. At the other extreme there were claims that in the future existing armies would be replaced by fleets of tanks.

An example of the former attitude is the often quoted remark made by Major General L. Jackson, Master General of the Ordnance, in December 1919 at the Royal United Service Institution that 'The tank proper was a freak. The circumstances which called it into existence were exceptional and are not likely to recur'.[1] To some, evidently, the usefulness of tanks was confined to trench warfare and the latter was not expected to occur again.

The other extreme is exemplified by a paper entitled 'A tank army' written during the war by Captain G. le Q. Martel, who assisted Colonel Fuller at the headquarters of the Tank Corps. It described a future army composed almost entirely of different types of tanks corresponding to the principal types of contemporary warships.[2] Fuller himself adopted similar ideas and immediately after the war began to write of 'tank fleets' and of battles that in future would 'more and more approximate to naval actions'.[3]

The appeal of the naval model is understandable in view of the fact that warships represented an earlier form of mobile weapon platforms, which is what Fuller rightly recognized tanks to be.[4] However, the environments in which warships and tanks operated were obviously very different. Armies could not, therefore, be expected to operate on land as warships did at sea. Nevertheless, as late as 1931 Fuller was still forecasting that tanks 'will operate on somewhat similar lines to a fleet at sea'.[5]

The policy that armies generally adopted was to accept tanks but only as an auxiliary of the infantry and operating at the pace of the latter. A possible advance on the prevailing stance was indicated by a study produced in 1919 by General Estienne at the request of the French commander-in-chief. In it Estienne foresaw the existing Renault FT light tanks being replaced by more powerful *chars de combat* that would play a leading role in future battles.[6] Two years later Estienne enlarged on his views in a lecture delivered in Brussels in which he spoke of the potential strategic and tactical advantages of a future mechanized army of 100,000 men that would include 4,000 tanks and armoured infantry and was capable of moving 80km in one night.[7] However, his views were ignored. In particular, while he and a few other French Army officers advocated the creation of an independent tank arm, the headquarters of the *artillerie d'assaut* that provided tank units with a degree of autonomy were abolished in 1920. Instead, tank units were put under a subdivision of the Infantry Department, which stultified further tactical and technical development.

A similar situation arose in the United States, where the wartime Tank Corps was abolished under the National Defense Act of 1920 and tanks were assigned to the infantry, becoming its auxiliaries. In keeping with this the General Staff declared in 1922 that 'the primary mission of the tank is to facilitate the uninterrupted advance of the rifleman in the attack'.

Apart from France and the United States only Britain had the means at the time to develop the use of tanks further. In consequence it was left to the British Army to take the lead in the development of a more mobile and effective use of tanks.

The lead that the British Army took was due to a large extent to the conjunction of two events. One was the establishment of the Royal Tank Corps, which in 1923 succeeded the wartime Tank Corps and became a separate arm, due to a considerable extent to the efforts of Fuller. Its strength amounted to only four tank battalions and some armoured car companies, but its status provided a degree of freedom to explore new methods of operation free of the constraints of infantry tactics.

The other event underlying the British Army's lead was its acquisition of tanks that were in advance in several respects of other contemporary tanks and that lent themselves to the development of new tactics. One of their features was a considerably higher speed than that of the earlier tanks, which was a consequence of them being designed as an alternative to Johnson's Light Infantry Tank referred to in the previous chapter and ordered in 1920 at the instigation of Fuller.[8] This prompted the War Office department responsible for the procurement of equipment to order another light tank from the Vickers company. Experimental versions of both tanks were built and tested by the end of 1921, with Johnson's proving capable of more than 20mph while Vickers' was slower than the wartime Medium C (which had a maximum speed of 7.9mph), as Fuller gleefully observed in his memoirs.[9]

However, in other respects Vickers' tank was better, in spite of the praise bestowed on Johnson's model. In particular, its general configuration was superior, being more like that generally adopted for tanks later, and it was the first British tank to have a rotating turret, while Johnson's still had a fixed superstructure with a fighting compartment similar to that of the Medium D, which was considered unsatisfactory by General Elles, the wartime commander of the Tank Corps. Moreover, Johnson's tank was only armed with machine guns while Vickers' also had a 47mm gun. Otherwise both tanks represented an advance on the wartime British tanks in having sprung suspensions instead of rigidly mounted track rollers, but that of the Vickers tank was more robust.

Low speed, the one major shortcoming of the Vickers tank, was due to its use of an unconventional hydrostatic transmission. This type of transmission was used successfully on warships, but Vickers' designers did not appear to appreciate how inefficient it would be when used to drive vehicles, with the result that much of the engine power was dissipated as heat and far less of it was consequently available to drive a vehicle.

As a result of its poor automotive performance Vickers' original tank was abandoned in 1922, as was Johnson's development work. However, in the same year Vickers came up with a second tank and this was adopted by the War Office as Vickers Light Tank Mark I, although it became far better known by its later name of Vickers Medium.

The first Vickers Medium was delivered in 1923. It weighed 11.75 tonnes and looked as if it had been hastily put together by mounting the turret of a

Rolls-Royce armoured car on the chassis of a high speed artillery tractor. However, it retained the best features of Vickers' original design, which included a 47mm gun mounted in a rotating turret that was large enough to accommodate not only a gunner but also a tank commander free to exercise tactical control and ensure a more effective use of the tank. At the same time Vickers Medium was almost as fast as Johnson's tank, its nominal maximum speed being 18mph but in practice it was capable of more than 20mph.

Eventually 166 Vickers Medium Tanks Marks I and II were built for the British Army, which was just enough to equip the tank battalions of the Royal Tank Corps, and they were the only new tanks to appear in quantity anywhere in the world between the end of the First World War and 1929. During this period they were also by far the fastest tanks in service, their maximum speed being almost four times that of the typical contemporary tank, which was still the Renault FT. The Royal Tank Corps was therefore uniquely well equipped to develop new, more mobile methods of employing tanks and to some extent these were driven indirectly by its tanks.

At first new ideas about the employment of tanks came primarily from Fuller, who wrote extensively on the subject. The writings started in 1919 with an essay which won a Royal United Service Institution competition and in which Fuller proposed a 'New Model Army' built around the capabilities of tanks. The divisions of this army were to incorporate 12 infantry battalions each with an integral tank company as well as a divisional tank battalion and two regiments of horse cavalry. This amounted to a surprisingly gradualist proposal for the future use of tanks, although ultimately Fuller expected tanks to replace infantry and cavalry.[10]

The publication of Fuller's essay led to a meeting with Captain B. H. Liddell Hart and a long association between the two.[11] In 1922 Liddell Hart followed Fuller by also writing about a 'New Model Army' but proposed a more practical organization for its divisions, which were to have separate tank and infantry battalions – the latter in armoured carriers – and no horse cavalry. But he did not differ greatly from Fuller in expecting further mechanization to lead to ground forces being 'composed primarily of tanks'. However, he did not propose to dispense entirely with the infantry, a small contingent of which would be retained as 'land marines'.[12]

Like Fuller, Liddell Hart wrote extensively on the use of tanks and related matters, and both assisted the development of new methods of employing tanks through personal contacts and by publicity, particularly in the case of

Liddell Hart who in 1925 became the military correspondent of *The Daily Telegraph*. Their writings made Fuller and Liddell Hart well known internationally, and on the strength of their writings they came to be regarded as the apostles of mechanized warfare.

However, the actual development of new and more effective methods of using tanks was carried out by others. It began with a memorandum written in 1924 by Colonel (later Brigadier) G. M. Lindsay, the inspector of the Royal Tank Corps, in which he proposed the establishment of an 'Experimental Mechanical Force'. As nothing happened, Lindsay repeated his proposal in another memorandum, which he submitted to the chief of the Imperial General Staff, General Milne, through Fuller, who was Milne's military assistant. Milne agreed with Lindsay's ideas and consequently an Experimental Mechanized Force was assembled in 1927 on Salisbury Plain.[13] Fuller was offered the command of it but rejected the offer because of dissatisfaction with some of the administrative arrangements, losing thereby the opportunity of putting some of his ideas into practice.[14]

In spite of this, the composition of the Experimental Mechanized Force reflected the ideas of Fuller as well as those of Lindsay, who wanted it to be predominently a force of tanks and other armoured vehicles. Its principal components were therefore a battalion of Vickers Medium tanks and a mixed battalion of armoured cars and tankettes, which were supported by four batteries of motorized and one of self-propelled artillery and a motorized engineer company. There was no infantry in it except for a motorized machine gun battalion that could only play a relatively passive role of holding ground.

To some extent the Experimental Mechanized Force was a scratch collection of the available units and its vehicles were of several different types, which made it difficult to co-ordinate the action of its components.[15] Nevertheless, it was the first mechanized formation ever to be assembled and its organization and operational trials aroused considerable interest in Europe and the United States.

Experiments in which the Experimental Mechanized Force took part in 1927 were followed by others during the 1928 training season, by which time it was renamed the Armoured Force, but it was then dissolved. A conclusion drawn from the experiments that had been carried out was that the unarmoured components of the force were a drag on the armoured ones, which reinforced the idea that mechanized formations should consist almost entirely of tanks.

This idea was embodied in the first armoured force manual entitled *Mechanised and Armoured Formations* and popularly known as the 'Purple Primer', which was issued by the War Office in 1929.[16] The manual was drafted by a Royal Tank Corps officer, Lieutenant Colonel C. Broad, and envisaged a future army that would include light and medium tank brigades consisting very largely of tanks as the principal mechanized formations. Their proposed composition severely limited the ability of the brigades to carry out independent operations but, nevertheless, an 'all-tank' brigade became the basis of further experiments.

A tank brigade was actually formed on a provisional basis when experiments were resumed during the 1931 training season. It consisted of three mixed battalions of light and medium tanks and one of Carden Loyd machine gun carriers, which were used in lieu of light tanks of which there was a shortage. The relatively homogeneous composition of the brigade made it easier to develop new methods of controlling and manoeuvring tank units, which involved among other things pioneering the use of radios, which began to be available in 1929. By the end of the 1931 training season the brigade demonstrated that it could manoeuvre as a whole and not merely operate as so many individual tanks.[17]

The Tank Brigade was assembled again in 1932, and after a break was reassembled and put on a permanent footing in 1934. For the following four years it constituted the only mechanized formation of the British Army and contained most of its tanks. In the course of its existence it made important advances in the technique of mobile mechanized operations, but it was clearly not a self-contained formation of several complementary arms capable of a variety of offensive and defensive operations, instead being only capable of strategic manoeuvres that seem to have been expected to yield success without too much fighting.

The emphasis on operational mobility rather than tactical effectiveness based on fighting ability, which characterized the atmosphere in which the Tank Brigade was created and developed, also applied to the design of British tanks during the 1920s and 1930s.

The first tank to come after the Vickers Medium was the outcome of an apparent if only temporary revival of interest in trench warfare by the War Office, which in 1922 asked Vickers to produce the design of a heavy tank that would replace the wartime Mark V.[18] It was to be turretless but have a hull-mounted 47mm gun and small sponsons with machine guns, which made its configuration resemble that of the wartime Mark VI designed in 1917 but never built, and showed that the War Office was still thinking in terms of the original types of tanks. In contrast Vickers offered as an alternative a very original design. This was accepted, the resulting tank being given the A.1 designation and later called Independent. Its principal feature was that it had as many as five turrets: a main turret mounting a 47mm gun and a machine gun and manned by a crew of three, and around it four small, one-man machine gun turrets. A.1 was not the first tank to have more than one turret, as the French 2C heavy tank already had a second turret at the rear of its hull and US Model 1921 and Model 1922 experimental medium tanks had a small machine gun turret on top of their main turret. However, A.1 was the first tank to have more than two turrets. As such it aroused considerable interest but only one other tank, the Soviet T-35, followed its example in having five turrets, although several other tanks built later had three turrets.

Auxiliary turrets apart, the general configuration of the A.1, which incorporated a driver's station in the front of the hull and an engine compartment at the rear, represented a considerable advance on that of the Vickers Mediums. But, in spite of its weight of 32 tonnes, its main armament was not more powerful than theirs and its armour was only slightly thicker than that of the Renault FT light tank. However, it was relatively mobile, having a maximum speed of 20mph.

Only one A.1 was actually built, but it attracted attention around the world when it appeared in 1926 at a large scale demonstration of armoured vehicles staged for the benefit of the British government and Commonwealth prime ministers. The 'Independent' name later given to it led to suggestions that it was intended for strategic strikes carried out independently by mechanized forces, but there is no evidence of this.[19]

The construction of the A.1 was followed by the development of a new medium tank, which was designated A.6 but came to be known generally as the 'Sixteen Tonner'. The A.6 was designed at Vickers to an outline specification produced by a committee of the Royal Tank Corps of which Fuller was a member, but followed the general configuration of the A.1, or Independent, and like the latter was actually designed by C. O. Woodward working under the general direction of Sir George Buckham. However, it had only two auxiliary machine gun turrets instead of four. Its main turret again mounted a 47mm gun and was large enough not only to accommodate the optimum size crew, consisting of a commander, gunner and loader, but also an observer, whose inclusion was an indulgence in view of the extra space and weight that this involved.

The first two of three prototypes of the A.6 were ready in 1928 and it was generally highly regarded. In fact, a 1930 War Office document described the A.6 as 'probably the best medium tank in the world'.[20] In spite of this the A.6 was not adopted by the British Army. Instead, a decision was taken in 1928 to base on it a new Mark III medium tank. This turned out to be very similar to the A.6 except for the main turret, which had a crew of three instead of four and a bustle to house the radio that had come into use.

Two Medium Mark III tanks were built by the Royal Ordnance Factory at Woolwich in 1929 and one by Vickers in 1931.[21] Trials of them were successfully completed by 1933 but General A. Brough, who became Director of Mechanization in 1932, decided to abandon the development of the Mark III because it was considered too expensive to produce in any quantity, particularly in the prevailing economic circumstances. Instead, he decided to develop a simpler and less expensive medium tank. His decision has been severely criticized later, to the extent of being called 'a fatal mistake'.[22] In fact, a similar decision to build a simpler and less expensive medium tank than the Mark III had already been taken in 1928 by Brough's predecessor. It resulted in the A.7 tank, two of which were built by the Royal Ordnance Factory by the end of 1929.

The A.7 very sensibly dispensed with the auxiliary machine gun turrets, which were replaced by a single machine gun simply mounted in the front of the hull and operated by a gunner sitting alongside the driver, while the main turret was manned by a crew of three. This meant that the configuration of the A.7 was basically the same as that adopted later during the Second World War for most tanks and in advance of that of the Mark III Medium. In other respects, such as armour and main armament, the A.7 did not differ from the Sixteen Tonner and the Mark III. It could therefore have been developed into a medium tank that was as effective as the Mark III but was simpler, lighter and should have cost less to produce. However, it was not adopted, although a number of its features were incorporated later in other tanks.

When the decision was taken to abandon the Mark III, the development of a simpler and less expensive medium tank was started afresh in 1934 at what had become Vickers Armstrongs after Carden Loyd Tractors' takeover in 1928. It was carried out under the direction of Sir John Carden, who came to be highly regarded as the designer of the Carden Loyd machine gun carriers and light tanks. Carden decided that the new tank should still have two auxiliary machine gun turrets, like the Sixteen Tonner and the Mark III.[23] For its main turret he adopted more wisely a three-man turret similar to that of the A.7 and designed a tank that did not differ from the latter in terms of its 47mm gun main armament, armour and maximum speed, but had the looks of the Sixteen Tonner and the Mark III.

When the prototype of the new tank appeared in 1936 under the A.9 designation nobody seemed to like it. There was a strong case therefore for the development of another tank that would replace the Vickers Mediums, which were becoming obsolete but were still virtually the only gun-armed tanks of the Royal Tank Corps. However, instead of concentrating on the development of a better medium tank, the available engineering resources were split up by a decision to divide tank units into two separate categories.

One of them was to provide close support for the infantry, and in 1934 one battalion of the Royal Tank Corps was separated from the rest and assigned to this role. At the same time Vickers Armstrongs were asked to produce a tank specifically for infantry support. The initial response to this demand was the A.10 tank, which was very similar to the A.9 but had armour up to 30mm instead of 14mm thick and was relieved of the auxiliary machine gun turrets. But although its armour was thicker than that of the medium tanks it was not considered sufficient for the infantry support role. In view of this and the contemporary financial restrictions, Carden proposed a very different type of tank that would be much more heavily armoured and at the same time cheap to produce. The idea of such a tank was accepted in 1935 and led to the A.11 infantry tank, which appeared in prototype form a year later.

The A.11 was a slow, 11-tonne vehicle with a one man turret mounting a single machine gun. Its frontal armour was up to 65mm thick, which put it ahead of most other contemporary tanks, but otherwise it was a throwback to the First World War, conceptually little different from the Renault FT. Nevertheless, it was the type of tank favoured by General Elles, who in 1934 became the Master General of the Ordnance and as such was able to direct tank development. The A.11 was consequently adopted as Infantry Tank Mark I and Vickers Armstrongs proceeded to produce 139 of it.

However, the shortcomings of the A.11 quickly became evident and in 1936 a decision was taken to design a successor to it, which became the A.12 and later Infantry Tank Mark II and which was usually called Matilda.

Design of the A.12 was carried out by the Royal Ordnance Factory in collaboration with the Vulcan Foundry and was based on the A.7 mentioned earlier, except that it had no hull machine gunner. Because no sufficiently powerful engine was available at the time in Britain, the A.12 followed the example of the A7E3 version of the A.7 in being powered by two bus-type diesels geared to a common output. It also incorporated novel features of its own, such as dispensing with the angle-iron frame to which armour plates were previously riveted in all other British tanks. Instead its castings and plates were bolted together, thereby saving weight. At 78mm its frontal armour was thicker than that of any other contemporary tank and made it immune to the existing anti-tank guns. The armour made it weigh 26.5 tonnes, which was more than the weight of any British tank since the A.1 Independent, but neither this nor its low maximum speed of 15mph detracted from its effectiveness. In fact, ignoring the limitations of its intended role, the A.12 Matilda was the most successful British tank design of the 1930s.

The one major shortcoming of the A.12 was its main armament, which consisted of a 40mm 2-pounder gun that succeeded the obsolescent 47mm 3-pounder at the time of its development. As a weapon against enemy tanks the new gun was comparable to the best of the contemporary tank and anti-tank guns, but this was achieved by firing solid, armour-piercing shot that was relatively ineffective against anti-tank guns, weapon emplacements and similar targets. What was needed, particularly for a tank that was to support the infantry, was high explosive ammunition, but this was not provided for the 40mm gun, although Renault FT already had high explosive ammunition for its 37mm gun 20 years earlier.

An even better solution would have been to arm the A.12 with a larger calibre, dual purpose gun. A small proportion of the A.12, which were designated 'close support tanks', was in fact armed with a 3in. (76.2mm) howitzer instead of the 40mm gun, and this was provided with high explosive rounds, but its main role was to fire smoke shells.[24]

Another problem with the A.12 Matilda was the lack of experience in the development of tanks and the limited resources of the Vulcan Foundry, which was entrusted with its production because the only experienced producers of tanks, Vickers Armstrongs, were already fully occupied with other work. As a result only two A.12 Matildas were completed by the outbreak of the Second World War.

While the A.11 and the A.12 Matilda were being developed for infantry support, tanks were also needed for the other category of tank units that formed part of the mobile armoured forces. By 1937 these took the form of the Mobile Division, which incorporated the Tank Brigade but was not an 'all-tank' formation of the kind Fuller and some of the protagonists of mechanized forces advocated. However, it was not an effective all-arms combat formation either. In fact, it was still considered to be a mobile force for sweeping flanking manoeuvres rather than direct confrontation with the enemy's main forces. In this respect it could be, and was, regarded as a successor of the cavalry divisions, and its role was limited to that to which horse cavalry was reduced during the 19th century. All this influenced the characteristics of the tanks developed for the Mobile Division and its successors.

The most powerful tanks already being produced for the Mobile Division were the A.9 medium tank, which was re-branded a 'cruiser tank', and the A.10, which was not considered to have sufficient armour for an infantry tank and which became a 'heavy cruiser' although it was only 1.75 tonnes heavier than the A.9. The A.9 had a maximum speed of 25mph, which was not considered fast enough for the Mobile Division, and this applied even more to the 16mph maximum speed of the A.10. However, in the absence of other candidates, both were adopted for limited production. The first was delivered in 1939 and eventually the number built totalled 295 tanks.[25]

In the meantime another and more mobile cruiser was developed following a visit to the Soviet Union in 1936 by Martel, who was by then Assistant Director of Mechanization at the War Office. During the visit Martel attended Red Army manoeuvres and became impressed with the Soviet BT tanks and in particular with their suspension.[26] It was apparently new to him, although the experimental tank built in the United States by J. W. Christie on which the BTs were based had already attracted widespread interest in 1928 when it set up a speed record of 42.5mph.[27] This prompted the US Army to order five tanks from Christie in 1931 and to take over two more ordered by the Polish government, which had defaulted, while the Soviet authorities reacted even earlier by ordering two chassis in 1930. However, it was only eight years after the appearance of Christie's high speed tank that Martel took note of it and proceeded to advocate the development of a cruiser tank based on it. To speed this up, Martel arranged the purchase of a vehicle that Christie still happened to have by the Morris car company, and its head, Lord Nuffield, undertook to develop the new cruiser tank.[28]

A new company called Nuffield Mechanization was set up for this purpose with the approval of General Elles, who was still Master General of the Ordnance and who wanted to create competition for Vickers Armstrongs, who until then enjoyed virtual monopoly in the production although not in the design of tanks.[29]

Nuffield Mechanization worked with remarkable speed and, although they had not produced tanks previously, built the first prototype of the new tank within 12 months of receiving an order for it. The tank, which was designated A.13 and later Cruiser Tank Mark III, was very different from Christie's tanks. In particular, it had a very different and much more sensible configuration similar to that adopted earlier for the A10E1 version of the A.10 and almost simultaneously for the A.12 Matilda. The only thing in common with Christie's tanks apart from the suspension was the Liberty engine, a First World War American aircraft engine whose production was revived by the Nuffield organization. This V-12 engine developed 340 horsepower, which made it more powerful than any engine available for British tanks since the A.1 Independent of the mid-1920s and provided the A.13 with a high power-to-weight ratio of 24hp per tonne. As a result the A.13 was faster than all earlier British medium or cruiser tanks, having a nominal maximum speed of 30mph and in practice being capable of almost 40mph.

The armour of the A.13 cruiser was still no thicker than that of the Sixteen Tonner or Carden's A.9, but its maximum thickness was doubled to 30mm on the second version. The need for heavier armour led to the idea of a 'heavy cruiser', which originated with the A.10, and the design of two different versions of such a tank was ordered in 1938. One of them, the A.14, was designed with the co-operation of the London, Midland and Scottish Railway (LMS) company and the other, the A.16, was designed by Nuffield Mechanization. They differed in engines, transmissions and suspensions but their general configuration was the same, and in addition to the main turret both had two auxiliary machine gun turrets, like the Sixteen Tonner, after which those who ordered them apparently still hankered.

The maximum thickness of armour of the A.14 and A.16 was 30mm, which by the time they were built was not more than that of the second version of the A.13. They did not, therefore, offer any advantage so far as armour protection was concerned, nor were they better armed as their main armament still consisted of a 40mm gun. In consequence the development of both was, very sensibly, abandoned.

However, when the A.14 was abandoned LMS were asked to design a simpler cruiser tank with the same layout and Christie suspension as the A.13 but with armour up to 40mm thick. This tank was called Covenanter and had a special, 12-cylinder horizontally opposed engine and a significantly lower silhouette but was still armed with a 40mm gun. Nuffield Mechanization designed its turret, but instead of participating in its production offered in mid-1939 to design their own version of a 'heavy cruiser' from the basis of the A.13 and using the Nuffield Liberty engine. The offer was accepted and in August 1939, just one month before the outbreak of the Second World War, an order was given for the production of the tank, designated A.15 and later called Cruiser Tank Mark VI Crusader.[30] The A.15 resembled the Covenanter but was larger and somewhat heavier, weighing 19 compared with 18 tonnes. It was armed with the same 40mm gun as the Covenanter and, showing how hard old habits die, it still had one auxiliary machine gun turret, which resulted in it having a crew of 5.

The eight medium and cruiser tanks developed between 1934 and 1939 differed from each other in several respects except for their main armament, which in all cases consisted of the same 40mm 2-pounder gun. This showed that, by comparison with all the effort devoted to the development of engines, transmissions, suspensions and other components, little attention was paid to the development of more powerful armament. In particular, no attempt was made to arm any of the medium or cruiser tanks with a dual purpose 75 or 76mm gun comparable to those mounted in medium tanks that were being developed by then in at least two other countries.

To be fair, in some of the medium and cruiser tanks the 40mm gun was replaced by what was originally called a 15-pounder mortar and then a 3.7in. (94mm) howitzer and later by a 3in. (76.2mm) howitzer. But these were limited purpose weapons intended primarily to fire smoke shells, as already mentioned in connection with the Matilda infantry tank, although they were also provided with some high explosive rounds. However, they were not provided with armour-piercing ammunition. They were not therefore comparable to the dual purpose 75 or 76mm guns mounted in Soviet and German tanks with which they were often wrongly equated.[31] The latter were, admittedly, short-barrelled low-velocity weapons, but they could still knock out contemporary tanks, if only by smashing their relatively thin armour by the sheer mass of their projectiles. At the same time they could effectively engage anti-tank guns, machine gun emplacements and similar targets with high explosive shells.

The lack of medium calibre dual purpose guns did not seem to concern those involved with the development of British medium and cruiser tanks, who thought more in terms of sweeping mobile manoeuvres rather than of fighting hostile armoured forces and, even less, of engaging in all phases of offensive operations. In consequence, they only expected tanks to be armed with 'one small gun and several machine guns', to quote a contemporary opinion.[32] Such views contributed, among others, to the repeated attempts to develop tanks with additional machine gun turrets. As to the calibre of tank guns, a 1937 Tank Brigade report endorsed by the General Staff stated emphatically that a gun larger than the 40mm 2-pounder was not required.[33]

To make matters worse, the 40mm gun was not provided with high explosive ammunition with which it could engage unarmoured or 'soft' targets with some degree of success. In contrast to the corresponding 37mm tank guns used in other countries, the only ammunition provided for the 40mm gun was solid shot, which was good at perforating the armour of the opposing tanks but not against other targets.

The effectiveness of the 40mm guns and of the earlier 47mm guns was reduced further by the adoption by the Royal Tank Corps of the practice of firing on the move, which kept up the tactical mobility of tanks and at the same time emulated the warships that served as their model. In fact, the influence of warships on tank gunnery extended from the adoption of naval training devices to the performance in at least one of the tank training exercises of the classic naval gunnery manoeuvre of 'crossing the T' (that is sailing in line across the path of the enemy fleet to bear the maximum number of guns on it), although the relevance of the latter to tank warfare was doubtful.[34] Some rightly questioned at the time the ability of tanks to fire accurately when moving over rough ground.[35] However, in spite of this, firing on the move instead of at the halt continued to be favoured, but it was only after the Second World War, when stabilized gun controls were developed, that it became effective.

An entirely different aspect of the development of tanks in Britain was that of the light tanks. It originated with the ideas that emerged after the First World War about the use of very light armoured vehicles to help the infantry advance in the face of opposition. Very similar ideas had already led to the development in France of the Renault FT light tank, but what began to be considered in Britain during the early 1920s were even lighter vehicles. To further the development of this kind of vehicle, Major Martel built in

1925 in his own garage a very light one-man half track. This was followed by an enlarged two-man version, eight of which were built by Morris Motors for use by the Experimental Mechanized Force in 1927.[36]

Interest aroused by Martel's vehicle encouraged another private venture, which was the construction of a one-man wheel-and-track vehicle by J. Carden and V. Loyd, who were then running a large garage in London. Their original vehicle was enlarged into a tracked two-man version, and eight were also ordered for the Experimental Mechanized Force.

After the 1927 trials it was decided that what was needed were two different types of light tracked armoured vehicle. One of them was a fast turreted reconnaissance or scout vehicle for use by the tank battalions of the Royal Tank Corps. The other was an open-top machine gun carrier for use by the infantry. By 1928 Carden responded to these requirements by designing the Carden Loyd Mark VII light tank, a 2.5-tonne two-man vehicle with a turret mounting a machine gun, and the Carden Loyd Mark VI, a small low silhouette two-man machine gun carrier weighing about 1.7 tonnes.

The Mark VI led eventually to the development of the Bren Gun Carrier, which the British Army used on a large scale during the Second World War. During the 1930s several other armies also adopted versions of the Mark VI with head covers or a raised and enclosed superstructure as ultra light weight low-cost light tanks. However, their capabilities were extremely limited and they could only be justified as training machines.

On the other hand, Carden Loyd Mark VII became the forerunner of a series of Vickers Carden Loyd light tanks, which came to be the most numerous British tanks after the mid-1930s and commercial versions of which were sold by Vickers Armstrongs to several countries. They were mechanically successful, being relatively reliable, and capable of speeds of up to 35mph, and together with the Mark VI they earned their designer, who became Sir John Carden, the high reputation mentioned earlier. But their fighting capabilities were restricted by their armament, which in most cases consisted only of a single rifle calibre machine gun. This might have been adequate for policing the North West frontier of India, where some of the light tanks were employed, but it was ineffective even against other light armoured vehicles.

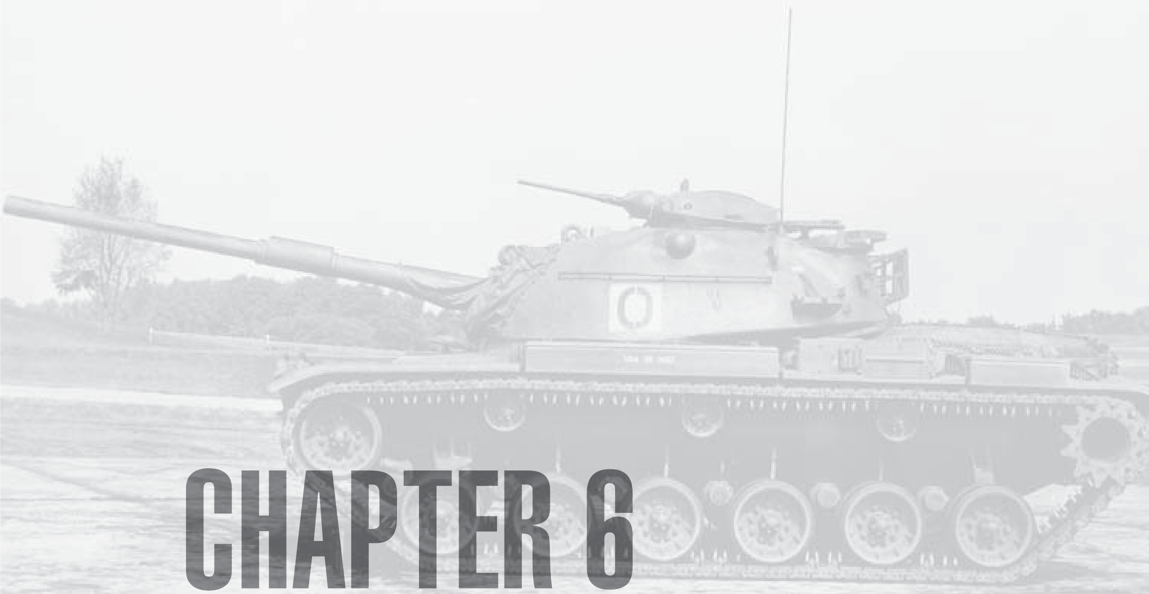
It was also realized, in contrast to the attitude that prevailed in France, that the one-man turrets of the original Vickers Carden Loyd light tanks expected their occupants to perform too many tasks, particularly in rapidly changing mobile operations. In consequence, Light Tank Mark V, which was introduced in 1934, was provided with a two-man turret that enabled the functions of the tank commander and of the gunner to be separated so that they could operate a tank more effectively. Mark V and the very similar Mark VI were also armed with a Vickers 0.5in. (12.7mm) heavy machine gun in addition to the usual 0.303in. (7.7mm) rifle calibre machine gun. But no significant improvements were made to the chassis, which remained much the same as that of the Mark IV, with the result that the larger turret made the marks V and VI top heavy, looking as if they would topple over at the slightest provocation. Martel rightly argued at the time that the Mark VI was too short, which implied that it did not have sufficient length of track on the ground for a good ride over rough terrain, and that it was overloaded.[37] Nevertheless, a 1936 memorandum by the secretary of state for war claimed that the Mark VI was 'superior to any light tank produced by other nations'.[38] Moreover, light tanks kept being produced and by the outbreak of the Second World War the number built had risen to 1,002.[39]

In fact, the Mark VI was inferior in several respects to light tanks being produced elsewhere. One of them was the L.60, a 7.5-tonne tank developed by 1934 in Sweden by the Landsverk company with the help of German engineers, which was armed with a 20mm cannon and specimens of which were sold to Austria, Hungary and Ireland before it was developed further for the Swedish Army into the Strv m/38 armed with a 37mm Bofors gun. By 1935 the Czech company Ceskomoravska Kolben Danek also started producing 50 TNH light tanks armed with 37mm guns for Persia (now Iran), which became the forerunners of the TNHP tanks taken over by the German Army in 1939 and used by it successfully as PzKpfw 38(t) during the early stages of the Second World War.

What is more, as early as 1928 Vickers Armstrongs brought out a tank armed with a 47mm gun and a coaxial machine gun, which they designed on their own initiative prior to taking over Carden Loyd Tractors and the light armoured vehicles that the latter were developing. The tank was the 7.4-tonne Type B version of the Vickers Six Ton Tank, which had a single two-man turret in contrast to the Type A version that had two side-by-side one-man machine gun turrets, like some of the early armoured cars. The 47mm gun of the Type B was short barrelled but of the same calibre as the guns of the Vickers Medium tanks, the Sixteen Tonner and all the other British medium tanks up to the original version of the A.9. Because of it Type B was greatly superior in terms of gun power to all the Vickers Carden Loyd light tanks. At the same time its armour protection was similar to that of the contemporary medium tanks and its production cost was considerably lower. Development of this type of tank might therefore have been a better investment for the British Army than all the multi-turreted medium tanks or the light tanks armed only with machine guns, particularly at a time of financial stringency that is often blamed for the shortage of well-armed British tanks on the eve of the Second World War. In fact, the British Army did consider it only to reject the Vickers Six Ton Tank, apparently because of its slow-motion double bogie suspension.[40]

However, rejection of the Vickers Six Ton Tank by the British Army did not discourage eight other armies from buying it. One was also borrowed by the US Army and after being tested at the Aberdeen Proving Ground was virtually copied in 1932 as the T1E4 experimental light tank, which represented a major step forward in the development of US light tanks.[41] This eventually led to the M3 or Stuart light tanks, which the British Army was glad to receive from the United States in 1941.

Two of the armies that procured Vickers Six Ton Tanks went further and produced copies of them in quantity. One was the Polish Army, which bought 38 Six Ton Tanks in 1931 and subsequently developed an improved single turret version armed with a 37mm Bofors gun, 120 of which were produced by the outbreak of the Second World War.[42] The other was the Red Army, which in 1930 signed a contract with Vickers Armstrongs for the delivery of 15 Type A tanks, copies of which began to be produced in the Soviet Union as T-26 tanks a year later. As many as 1,626 were built by 1934 but production was then switched to the single turret model, which was armed with a 45mm gun and was obviously much more effective. By the outbreak of the Second World War in 1939 the total T-26 models that had been built rose to about 8,500, making Vickers Armstrongs' Six Ton Tank in Soviet guise the most numerous tank at the time in the world.[43]



CHAPTER 6

Tank Development in Europe and America

The development of more mobile and effective methods of using tanks initiated after the First World War by the British Army was not followed by other armies for a number of years. However, while other armies did not advance beyond the use of tanks in support of the infantry, they proceeded to develop them and then to produce them in increasing numbers.

French tanks

The prime example of this was the French Army. By 1926 it decided that it wanted three new types of tanks. One was a light tank of 13 tonnes for close support of the infantry, which would be in effect a successor of the Renault FT. The second was a 'battle tank' of about 20 tonnes armed with a 75mm gun, which would co-operate with the lighter tanks in defeating more serious opposition, including enemy tanks. The third type was to be a heavy tank weighing up to 70 tonnes.[1]

The French Army's requirements were anticipated by the Renault company, which developed the NC light tank that was a somewhat heavier and faster version of the Renault FT. The French Army ordered two in 1923, but it did not adopt them and only some were subsequently sold to Japan and one to Sweden. However, in 1928 one NC was modified to meet the French Army's requirements for a light tank and a year later was transformed into the prototype of the D1 light tank, ten of which were delivered by Renault in 1931. Subsequent orders resulted in the production of more D1 tanks, which by 1935 totalled 160.[2]

D1 was a tank of 14 tonnes with armour up to 30mm thick and with a turret mounting a short-barrelled 47mm gun as well as a coaxial machine gun. It was also provided with radio for inter-tank communication. In all these respects it represented a considerable advance on the Renault FT. But its turret was still occupied by only one man. This meant that its occupant was expected to load, aim and fire the two weapons mounted in it as well as to command the tank, which was bound to have an adverse effect on its performance on the battlefield. D1 did have one more crewman than the Renault FT, but he sat in the hull and only operated the radio.

Although the armour of D1 was thicker than that of most contemporary medium tanks, in 1930 the Directorate of Infantry demanded the development of a new tank based on it but having even more armour. A prototype of such a tank with armour up to 40mm thick was built by Renault in 1932 and two years later an order was placed for the production of 50 tanks of this type, which was designated D2. However, no further orders were issued, partly because of mechanical problems and partly because of a decision to divert production effort to the manufacture of more powerful tanks armed with 75mm guns. At about the same time D2 as well as D1 were reclassified as medium tanks and the infantry demanded that light tanks weigh less than was specified in 1926, implying a weight of 6 to 8 tonnes.[3]

The infantry's new requirements were issued in 1933 and led to a competition won by Renault, who built a prototype a year later. This was submitted to the usual development trials, but before they were completed a decision was taken in 1935 to adopt the tank because of the deteriorating political situation brought about by the re-armament of Germany and in particular the remilitarization of the left bank of the Rhine. In consequence an order was placed in 1935 for 300 tanks under the name Char léger modèle 1935 R, usually abbreviated to R 35. Further orders followed and eventually by May 1940 the total number of R 35 produced amounted to about 1,200.

R 35 weighed 10 tonnes but had armour up to 40mm thick, which was thicker than that of most contemporary tanks, and was one of the first tanks to have much of its hull as well as its turret made of castings instead of the less efficient method of riveting armour plates on to a frame. It was not very fast, its maximum road speed being 12.5mph, but it could be argued that this was sufficient for a tank intended for close support of the infantry. What was much more difficult to defend was its one-man turret, which was open to the same criticism as that of the NC tank, and its main armament, which consisted of the same short-barrelled 37mm gun as that mounted 17 years earlier in the Renault FT. The need for a longer barrelled 37mm gun that would be effective against enemy armoured vehicles was only recognized in 1938, when one was adopted, but this happened too late to arm the R 35, although it was mounted in its ultimate development, the R 40.

Until light tanks began to be armed with the longer barrelled 37mm guns, fighting enemy tanks was, so far as the infantry was concerned, primarily the task of the 'battle tanks', which came to be represented by the Char B. Work that led to this tank began as early as 1921 under the direction of General Estienne. It resulted in the first instance in the construction by industry of five different prototypes which, nevertheless, had one feature in common, namely a hull-mounted 75mm gun, like the original French tanks. Each also had a turret but armed only with a machine gun.[4]

Experience with the five prototypes led to a new design, which followed theirs in incorporating as the main armament a hull-mounted short-barrelled 75mm gun. Three prototypes based on this design were ordered in 1926 and the first of them was completed three years later. Trials of the prototypes were successful, but in 1930 the minister for war called for an improved battle tank, which resulted in a series of changes including an increase in the maximum thickness of armour from 25 to 40mm and the replacement of the machine gun turret by one with a 47mm gun – the same in fact as that adopted for the D2 tanks. In its modified form the battle tank was finally adopted in 1934 under the designation B1, and an order was issued for its production, although initially of only seven tanks. Further small orders followed and by 1937 these brought the number of B1 tanks to 35 – just enough for one tank battalion.

In the meantime demand arose for further increases in armour protection, which led to studies of new battle tanks, but in the end it was decided to proceed with an improved version of the B1, up-armoured to 60mm and fitted with a new turret with a more powerful 47mm gun as well as a more powerful 300hp engine. The improved tank was designated B1 bis and the first 35 were ordered in 1936, but only 137 were produced by the outbreak of the Second World War in 1939.[5] However, the number built eventually rose to about 340.

Char B1 bis was in some respects an impressive tank. In particular, it was well armoured, which was reflected in its weight of 32 tonnes, and this made it heavier than almost any tank in use in the late 1930s. It was also heavily armed. But the effectiveness of its armament was reduced by the way in which it was mounted. This applied especially to its hull-mounted 75mm gun, which could be elevated but not traversed independently of the hull, so that the whole tank had to be turned to aim it. In consequence the driver also had to act as the gunner, and he was also expected to fire a machine gun fixed in the front of the hull. The other weapons, which consisted of the 47mm gun and coaxial machine gun, were mounted in the turret that was occupied by the tank commander, who was handicapped by having to perform too many functions, as were the occupants of the other one-man turrets of French tanks. In addition to the driver/gunner and commander/gunner, the B1 and B1 bis tanks also carried a loader of the 75mm gun and a radio operator, but they were seated in the hull and only performed their respective functions.

Turning the B1 and B1 bis tanks to traverse their 75mm guns was greatly facilitated by the development of a double differential steering system with a hydrostatic steering drive, which provided very fine control over turning movements. The steering system of the B1 was in fact well in advance of others but it could not compensate for the difficulty of driving a tank and firing its 75mm gun at the same time. Such an arrangement might have worked at low speeds and in simple tactical scenarios and was in keeping with the origins of the type B tanks, which were conceived as tanks that would work closely with the infantry in breaking through enemy defences. But it was not suited to more mobile warfare in which the situation could change rapidly and when there were moving targets, such as enemy tanks.

Mobile operations were not, of course, the domain of the French infantry and of the tanks with which it was entrusted in 1920. Any development of more mobile tanks and their use had to come therefore from the cavalry, although its activities were originally restricted to armoured cars.

French cavalry became involved with armoured cars soon after the outbreak of the First World War, as mentioned in Chapter 1, and when the war ended it had 205 of them, newly built on American White truck chassis as well as 67 older Renault and Peugeot armoured cars.[6] The White cars remained the cavalry's principal armoured cars well into the 1930s, but as early as 1921 development began of new armoured vehicles for it. One outcome of this was a four-wheeled Panhard TOE 165/175 armoured car, more than 50 of which were produced between 1929 and 1932, with one half being sent to Morocco, which was then a French protectorate.[7]

A different response to the cavalry's requirements was a half-track armoured car designed in 1923 by Citroën in collaboration with the Schneider company and incorporating rubber band tracks developed in Russia by A. Kegresse, a French engineer who had been in charge of the tzar's garages. Sixteen of the Citroën-Kegresse-Schneider armoured cars were produced by 1925 and they were also sent to Morocco, but the performance of the Kegresse tracks proved disappointing. However, two years earlier a team of five Citroën cars fitted with Kegresse tracks made the first automobile crossing of the Sahara and this boosted the reputation of the Kegresse tracks, which came to be highly regarded because they were quieter than the conventional metallic link tracks and because they were claimed to have a relatively long life of about 2,000 miles on roads.[8] There was therefore good reason for Citroën to persevere with them and to design another half-track armoured car with Kegresse tracks, for which they received an order for 100 in 1925. Schneider became the prime contractors for their production, and together with about 90 of the modernized White-Laffly version of the wartime armoured cars they became the principal armoured vehicles of the French cavalry in the early 1930s.

Twelve additional P.16 Schneider half-track armoured cars were ordered in 1930 and a year later they were followed by an order for 50 Citroën-Kegresse armoured cars of a lighter type. These were the last to have Kegresse band tracks. This was due to the appearance in Britain of the Carden Loyd short pitch metallic tracks. A Carden Loyd carrier with this type of track was tested in France in 1930 and was found to be as fast on roads, and better off the roads, than a Citroën-Kegresse vehicle with band tracks. In consequence Renault designed a small two-man supplies carrier on the lines of the Carden Loyd Mark VI armoured carrier to meet a requirement for such a vehicle by the French infantry, which adopted it in 1931. The Renault *chenillette* was a peculiarly French vehicle, which was produced in quantity, so that there were already 700 in 1936 and eventually the total built reached 6,000, to the detriment of the production of more effective armoured vehicles.[9]

Having designed the *chenillette* for the infantry, Renault also used it as the starting point of the development of a new armoured vehicle for the cavalry. This 5.5-tonne vehicle not only had the Carden Loyd short pitch metallic track but also the general configuration of the early Vickers Carden Loyd two-man light tanks, which meant that it had a one man turret mounting a single machine gun and an engine compartment alongside the driver.

By the time this vehicle began to be developed in 1931, the cavalry decided to divide its armoured vehicles into three categories. One consisted of *autos-mitrailleuses de découverte*, or AMD, whose function was long-range reconnaissance and which were wheeled. The second category consisted of *autos-mitrailleuses de reconnaissance*, or AMR, whose function was tactical reconnaissance. The third category consisted of *autos-mitrailleuses de combat*, or AMC, which were expected to be able to fight enemy armoured vehicles. An outcome of this was the adoption by the cavalry of its first fully tracked armoured vehicle, which was called AMR Renault Modèle 1933 or AMR 33, and 123 of which were ordered with deliveries commencing in 1934.

In spite of being designated an *auto-mitrailleuse*, AMR 33 was in fact a light tank, but it was not designated as such because tanks were supposed to be the preserve of the infantry. It was followed by AMR 35, which was somewhat larger and heavier and was armed in some cases with a 13.2mm heavy machine gun and finally with a high-velocity 25mm cannon instead of a rifle calibre machine gun, which armed most of the 200 vehicles that were produced.

By the time AMR 35 began to be developed in 1933 the cavalry had progressed from simply including an armoured car regiment in its horse cavalry divisions to assembling a fully motorized formation, which a year later became its first *division légère mecanique*, or DLM. Its organization foreshadowed that of the armoured divisions but its intended role was limited, being similar to that to which horse cavalry had been reduced. However, even then the DLM required vehicles more powerful than AMR 33 and 35. In consequence the cavalry issued a new requirement in 1934 for what was still called an *auto-mitrailleuse de combat* but which was to have armour up to 40mm thick and be armed with a high-velocity 47mm gun.

This led a subsidiary of the Schneider company, the Societé d'Outillage Mécanique et d'Usinage d'Artillerie or Somua, to design a 19.5-tonne tank designated S 35, which came to be regarded as one of the best of its period.

In addition to its armour and armament it incorporated a number of novel features, including a hull made of only three large castings and a double differential steering system with a mechanical steering drive thatwas ahead of its time. It also had an adequately high road speed of 25mph. However, S 35 suffered from the same major weakness as all the other French tanks built until then, which was its one-man turret. In consequence its occupant had to act, once again, as a gunner and loader as well as the tank commander. S 35 did have a third crewman who sat next to the driver, but he only operated the radio.

The first 50 S 35s were ordered in 1936 and further orders brought the number produced by the outbreak of the Second World War to 261 and eventually to about 416.[10] In addition to the S 35 the cavalry also wanted a light tank for the DLM, and to meet this requirement it adopted the H 35 produced by Hotchkiss, which was originally designed for the infantry but had been rejected by it in favour of the R 35. Having a maximum speed of 23mph H 35 was considerably faster than the R 35, but it was otherwise very similar to it, to the extent of having the same turret with the same old short-barrelled 37mm gun as well as a machine gun. However, an improved H 39 version had a longer barrelled 37mm gun. Like the R 35, the H 35 was first ordered in 1935 and a total of 400 was built; it was then succeeded by the H 39, 680 of which were built by May 1940.[11]

The cavalry acquired one other tank, which was designed by Renault to meet the same requirement as the S 35. This tank, the AMC 35, had the same armament as the S 35 and was as fast, but the maximum thickness of its armour was only 25mm. Nevertheless, it was superior to the S 35 in having a two-man turret so that its commander did not have to double as a gunner and could therefore employ the tank more effectively. Industrial problems that followed the nationalization of the Renault armoured vehicle manufacturing facilities in 1936 delayed its production so that the first was not completed until the end of 1938, and of the 100 eventually built 25 went to the Belgian Army.

The only other French tank to have a turret occupied by more than one crewman was the 68-tonne 2C conceived during the First World War. Six of the ten tanks completed in 1921 were still in service in 1940, although work on improving them ceased in 1932. They were eventually blown up by their crews to prevent them falling into German hands without ever going into action.

US tanks

Like the French Army, the US Army retained heavy tanks designed during the First World War for several years after the conflict ended. In this case the tanks were the Mark VIII, the last of the rhomboidal tanks, 100 of which were completed in 1921. They were not withdrawn from service until 1932.[12] The US Army also resembled the French in continuing to use what were copies of the Renault FT, 952 of which were built between 1918 and 1919.

In keeping with the policy of the US War Department that the role of tanks was to assist the infantry, tanks were distributed between ten separate companies assigned one each to the infantry divisions and to three tank battalions.[13] However, in 1928, after he observed the manoeuvres of the British Experimental Mechanized Force, the US Secretary of War, D. F. Davis, directed the US Army to develop a mechanized force. Elements of such a force were duly assembled at Fort Meade, its core elements consisting of a battalion of the Renault FT-type M1917 light tanks and a battalion of Mark VIII heavy tanks. However, the available tanks were too slow to emulate the British experiments and after a few weeks the force assembled at Fort Meade was disbanded.[14]

The only positive outcome of the Fort Meade experiment was that it led two years later to the assembling of another, although small, mechanized force at Fort Eustis. Apart from ten armoured cars, the armoured component of this force consisted of a company of light tanks, 11 of which were still of the M1917 type but four others were the new T1E1 light tanks.[15] The new tanks were three times as fast as the others, which indicated that better tanks were being developed, although they still had to come into service.

The US Army had in fact embarked on the development of new tanks in 1919. Its original objective was to develop a medium tank similar to the British Medium D. The initial outcome of this was the 18.6-tonne Medium Tank M1921, which was completed in 1921. It was not as fast as the Medium D as its maximum speed was only 10mph, but it had a more sensible general configuration, which included a separate driver's station at the front of the hull and a three-man rotating turret mounting a short barrelled 57mm gun and a coaxial machine gun. It also had a second machine gun in a small turret on top of the main turret, which constituted an original if questionable design feature.

Before a second medium tank was designed, information was received about the use in the British Medium D of a cable-connected single spring suspension system, and it was decided to incorporate it together with Johnson's peculiar tracks with pivoted wooden shoes in what became the M1922 medium tank. Not unexpectedly, the suspension and tracks proved unsatisfactory on trials that began in 1923, and the M1922 medium tank was abandoned in favour of the third prototype, which was designated Medium Tank T1. This tank, which was completed in 1927, reverted to a more robust multi-bogie suspension and looked like the M1921 tank, but had a more reliable engine as well as a more advanced skeleton type track. In the course of its trials the T1 had its 57mm gun replaced in 1928 by a short-barrelled 75mm gun, and in that form it could have placed the US Army well ahead of others.[16] Instead it was succeeded by a very different front-engined T2 medium tank, which had an ungainly appearance similar to that of the British Vickers Mediums. Like the latter it had a turret-mounted 47mm gun but this was not apparently considered sufficient as it also had a 37mm gun mounted in the front of the hull alongside the driver. T2 was designed down to a weight of 14.2 tonnes specified by the infantry and it was powered by the same 338hp engine as the Mark VIII heavy tank, which resulted in it having a high power-to-weight ratio of 24hp per tonne and a maximum speed of 25mph. Otherwise there was nothing to commend it and its development was abandoned around 1932.

In the meantime the infantry, which had originally agreed to the development of a medium tank, had become more interested in light tanks. This led to the construction in 1927 of the T1 light tank prototype, which was approved by the chief of infantry and was followed by four similar T1E1 tanks. The T1 was a two-man front-engined, 7-tonne tank, which looked like an agricultural tractor with a turret. Its main armament consisted of a short barrelled 37mm gun, which was the same as that of the M1917 light tank, but it had a maximum speed of 17.5mph and was therefore significantly faster than the latter, as already mentioned.

Little further progress took place until 1932 when one of the T1E1 tanks was rebuilt into the T1E4, which followed the lines of the Vickers Six Ton Tanks, one of which had been tested in the United States at the Aberdeen Proving Ground. This involved relocating the engine at the rear of the hull and adopting a Vickers-type bogie suspension and short pitch tracks. T1E4 became the basis of further development of US light tanks, but this was split between the infantry and the cavalry and was challenged by vehicles built by an independent developer of armoured vehicles, J. W. Christie.

The cavalry, which until then had confined its activities to armoured cars, became involved with tanks as the result of a decision taken in 1931 by the US Army Chief of Staff, General D. MacArthur, to disband the mechanized force assembled at Fort Eustis and assign the development of mechanization to the cavalry. By law tanks remained the preserve of the infantry and to enable the cavalry to use them its tanks were called 'combat cars' and not tanks, even though they might be the same vehicles as the tanks used by the infantry.

Christie became involved with tracked vehicles as early as 1918, when his company built a 'motor gun carriage' for an 8in. howitzer.[17] This was the first of his 'convertible' vehicles, which could run on tracks or, if the tracks were removed, on its road wheels and thereby offered the prospect of vehicles that would be able to operate on roads on wheels and would only put on tracks when about to go into action off the roads. In principle this promised to reduce track wear, which was a major contemporary problem.

The encouraging performance of Christie's first convertible vehicle led to an order for a convertible tank, which he designated M1919, but which was not completed until two years later than this date would suggest. It did not prove a success when tested and consequently Christie modified it at his own expense into the M1921 model. The modifications included springing the front two of its wheels and the removal of the turret, from which its 57mm gun and coaxial machine gun were transferred to the front of the hull – a weapon installation that Christie came to prefer. However, the 1921 version did not prove more successful than the original and was abandoned in 1924.

Undaunted, Christie persevered and in 1928 produced another convertible vehicle, which attracted worldwide attention because of its remarkable performance. It was a turretless vehicle weighing 7.8 tonnes and therefore was lighter than Christie's previous models, but in spite of this it was powered by a much more powerful 338hp Liberty engine, which provided it with an exceptionally high power-to-weight ratio of 43.3hp per tonne. In consequence it was able to achieve speeds of 70mph on wheels and 42.5mph on tracks, which were much higher than those of any tank built until then. It also had a novel independent suspension with four large road wheels on each side of the vehicle individually sprung by coil springs, which allowed them to rise as much as 280mm from their normal position when going over rough ground and consequently made it possible for the vehicle to move over it at higher speeds.

After protracted negotiations, Christie's 1928 vehicle was accepted by the US Army's Ordnance Department and he received an order for seven similar vehicles, the last of which was delivered by his company in 1932. Of the seven, three went to the infantry as T3 medium tanks and were armed with short barrelled 37mm guns while the other four went to the cavalry as T1 combat cars and were only armed with 0.5in. machine guns as their main armament. All seven had their guns mounted in one-man turrets and weighed 9.5 tonnes, which made the infantry classify them as medium tanks.

The seven vehicles derived from Christie's M1928 represented a major advance in the mobility of tanks but were deficient in other respects, such as having one-man turrets. To overcome some of the deficiencies, the infantry asked for an improved version of the T3 medium tank with a two-man turret and a machine gun in the front of the hull operated by a fourth crewman. Five of the resulting T3E2 tanks were ordered in 1932 but not from Christie, because of further disputes with him. Three years later further development took place with the building at the Rock Island Arsenal of a new T4 medium tank. This retained Christie's independent suspension and the ability to operate on wheels or tracks, but like the T3E2 it had a shorter pitch track, which generated less vibration and noise than Christie's original plate tracks. It weighed 12 tonnes and, as it was powered by a 268hp Continental engine, it had a good power-to-weight ratio of 22hp per tonne and a maximum speed of 23.9mph. Like the T3E2 it had a four-man crew and armour up to 16mm thick.

In all these respects the T4 medium tank compared well with other contemporary light/medium tanks and could have been a good basis of further development, particularly if the US Army had dispensed with its ability to run on wheels and concentrated on the best of Christie's ideas, which was his independent suspension. This is what the British Army was about to do at the time and what the Red Army did a few years later. However, the only development of the T4 was the replacement on a version of it of the two-man turret by a crude, box-like superstructure or 'barbette' with machine guns mounted in its four sides, which resulted in the T4 having a total of six of them, one of which was a 0.5in. machine gun. Nothing more powerful was mounted in the basic turreted version of the T4, which was completely out of keeping with its potential. Nevertheless, 16 T4 were built, as were three T4E1s with their primitive 'barbettes'.[18]

T4 was the last of the medium tanks based on Christie's ideas built for the US infantry. However, some more vehicles based on them were built for the cavalry. In addition to the T1 combat car, they included the T2 combat car, which the cavalry specified following Christie's 1928 demonstration but which he would not agree to build. In consequence a prototype was built in 1931 at the Rock Island Arsenal, but its performance proved unsatisfactory. The T4 combat car was very similar to the infantry's T4 medium tank and like some of the latter had its turret replaced ultimately by a 'barbette'.

The development of tanks took a new and different turn in 1933, when the US secretary of war directed that future combat cars as well as light tanks should weigh not more than 6.8 tonnes and have a speed of at least 30mph. This led to the construction at the Rock Island Arsenal of the T2 light tank and T5 combat car, which were demonstrated in 1934 at the Aberdeen Proving Ground. The two vehicles were very similar, having the same four-man crew as well as the same armament, consisting of turret-mounted 0.5in. and rifle calibre machine guns and another machine gun in the hull by the side of the driver. They also had the same power train. The principal difference between them was that the T2 light tank had a single two-man turret and, like the T1E2, a suspension and short pitch track similar to those of the Vickers Six Ton Tank, while the T5 combat car had two side-by-side one-man turrets, like the less successful version of the Vickers Six Ton Tank. It also had a new suspension with four road wheels per side sprung in pairs by volute springs, as well as a new type of track with rubber block, double pin links and rubber bushed track pins. The suspension and tracks of the T5 combat car proved superior to those of the other vehicle and became models for most US tanks built from then on until the end of the Second World War.

Demonstration of the T5 combat car was followed by the replacement of its two turrets by another primitive 'barbette' superstructure, but eventually sense prevailed and a single two-man turret was used for the final version, which was adopted by the Cavalry and put into production in 1935 as the M1 combat car. By 1937 a total of 89 M1 combat cars was built and they became the basic equipment of the first permanently organized US mechanized formation, the 7th Cavalry Brigade, which was created in 1938 at Fort Knox, Kentucky.

Before this happened the cavalry made one last attempt to develop a Christie-type convertible light tank, which appealed because of its smoother operation off the roads and its high road speeds. An M1 was consequently transformed in 1938 into the T7 combat car with three large pneumatic-tyred road wheels per side. When tested the T7 proved faster than the M1, but the latter, which had a maximum road speed of about 45mph, had sufficient operational mobility to meet the requirements of the cavalry and cost less to produce and to operate. Development of the T7 was therefore abandoned after one year.[19]

As a result of the superior performance of the suspension and tracks of the T5 combat car, the T2 light tank was retrofitted with them, which made the two vehicles even more like each other, and the modified T2E1 was adopted and put into production as the M2A1 light tank. But only nine were built in 1936, when the infantry took the surprising decision to fit its tanks with two side-by-side turrets, which the cavalry had already rejected having tried them on the T5 combat car. Moreover, twin turrets were also being abandoned elsewhere, having been recognized as inferior to single turrets: the Red Army had already stopped producing the twin turret version of the T-26 light tank and in 1937 the Polish Army stopped developing the twin turret version of the Vickers Six Ton Tank in favour of the single turret model.

Except for its two turrets, the resulting M2A2 light tank was very similar to the M2A1 and had approximately the same weight of 8.7 tonnes and the same 16mm maximum thickness of armour. A total of 237 vehicles was produced between 1935 and 1937, and they became the most numerous US tanks before the outbreak of the Second World War. The M2A2 was followed in 1938 by the M2A3, which was similar to it but had thicker 22mm armour. It was consequently somewhat heavier, weighing 9.5 tonnes, but was still capable of a maximum road speed of 36mph. However, its production was limited to 73 vehicles.

Progressive improvements of a stable design, which remained basically unchanged from the T5 combat car to the M2A3 light tank, produced vehicles that were robust and reliable as well as highly mobile. However, in one respect there had been no progress, namely in the armament of the tanks, which still consisted of nothing more powerful than 0.5in. machine guns, when elsewhere comparable tanks were already being armed with high-velocity 37mm guns. It was only at the beginning of 1939 that an M2A3 was modified into an M2A4 and armed with such a gun. But production of the M2A4 only began in May 1940, and consequently none was available when the Second World War broke out.

The inadequate armament of the light tanks was not compensated for by better-armed medium tanks, as their development was not resumed until 1937. This led to the construction a year later of the T5 medium tank prototype and its evolution into the M2 medium tank, 18 of which began to be built in the summer of 1939. Mechanically the M2 medium tank was, in essence, a scaled-up version of the successful M2 light tank, with a lengthened hull and six instead of four road wheels per side. But its superstructure was a curious combination of a 'barbette', which continued to have a peculiar attraction for US tank designers, and a two-man turret mounted on top of it. The turret was armed with a high-velocity 37mm gun and a coaxial machine gun, while the 'barbette' had a small sponson with a machine gun in each of its four corners, which together with two machine guns fixed in the front of the hull made up a record total of seven machine guns. Fully equipped and with a crew of five the M2 medium tank weighed 17 tonnes, which was on a par with other contemporary medium tanks, but its development was overtaken by the outbreak of the war and its only contribution was to provide a chassis for other tanks.

Italian tanks

As in the United States, a medium tank was also being developed on the eve of the Second World War in Italy. But its background was not as extensive as that of the US M2 medium tank and it was not followed by equally important developments. However, its antecedents were shared to the extent that the first tanks produced in quantity in Italy were copies of the Renault FT, like the M1917 light tanks produced in the United States.

The Italian tank was the Fiat 3000 and 100 of them were completed in 1921, as mentioned in Chapter 4. Nothing more happened until 1929 or 1930, when 48 tanks were modified into Model 30 armed with a medium-velocity 37mm gun instead of the twin machine guns of the original Model 21 version. Little change had also taken place in the role of the Italian tanks, which remained confined to close infantry support, as did the contemporary French and US tanks.

The first tentative move towards a more effective use of tanks took place during manoeuvres in Piedmont when Fiat 3000 were tried, with the inevitable result that they were not considered agile enough for use in mountainous terrain, although they had a maximum road speed of 14mph or almost twice that of the Renault FT. Attention then switched to the British Vickers Carden Loyd Mark VI tankette, which was considered to have sufficient agility for operation in Northern Italy, a fact that was of particular concern to the Italian Army. A Mark VI was consequently demonstrated in Italy with the agreement of the British military authorities and in 1929 the Italian Army ordered four Mark VI from Vickers Armstrongs, following this with the acquisition of 21 more vehicles.[20]

The 25 Carden Loyd Mark VI type vehicles were adopted by the Italian Army as Carro Veloce 29, or CV 29, and on their basis Ansaldo and Fiat proceeded to develop an improved model that was adopted by the Italian Army in 1933 as CV 33. This was followed by an order for about 250 and in 1935 by a second order for about 500. As a result CV 33 became in the mid-1930s the principal and in effect the only Italian tank, as the only other was the by then obsolete Fiat 3000.

CV 33 was a turretless vehicle only 1.28m high and weighing 3.4 tonnes; it was manned by a crew of two and was armed with a single or, later, twin machine guns, which had limited traverse. Mechanically it was the most successful of the various derivatives of the Carden Loyd Mark VI, but its capabilities as a fighting vehicle were still extremely limited. It was also a very questionable choice for a vehicle intended for use in mountainous terrain, which generally provides few opportunities for the manoeuvres that vehicles with limited traverse weapons have to perform to use them effectively. The harmful consequences of this choice were demonstrated in 1935 during the war in Ethiopia, when a platoon of six CV 33s was ambushed in the Dembeguina Pass and, unable to manoeuvre, was destroyed by the Ethiopians.[21]

Some of the CV 33 were assigned to the cavalry to support it as *carro veloce* or fast tanks, although they were not exceptionally fast, having a maximum speed of 26mph. Others were issued to the tank regiments for infantry support and were designated *carro d'assalto* or assault tanks, although they could only act as such in particularly favourable circumstances where they could exploit their low silhouette and speed because their armour was only 13.5mm thick. In neither guise were they able to fight other tanks, which, curiously, does not appear to have been considered at the time by the Italian Army.[22]

The inability of the CV 33 to fight other tanks was not a problem during the 1935–36 war in Ethiopia, in which 498 CV 33s were ultimately deployed.[23] However, the neglect of this capability resulted in the Italian corps sent to support the Nationalists during the Spanish Civil War of 1936–39 having no tanks to counter Soviet tanks armed with 45mm high-velocity guns that were operated by the Communist forces, although the corps had two battalions of CV 33s.

Nevertheless, the Italian Army ordered a new version of the CV 33, which went into production in 1936 as the CV 35. The two versions were ultimately designated L3/33 and L3/35 and the total number of them produced for the Italian Army reached a total of 1,395.[24] About 400 more were produced for export to about 11 different countries as far afield as Brazil and China as well as Hungary.

The first step towards the development of more effective tanks was taken in 1935 when Ansaldo built an 8-tonne turretless tank armed with a hull mounted short-barrelled 37mm gun, which was to replace the obsolete Fiat 3000 still regarded with little justification as a 'breakthrough' tank.[25] It constituted a singularly inept design and, deservedly, was not adopted. But its running gear was used in the prototype of the next tank, which began to be tested in 1935 and which, after further development, was adopted in 1939 as the M 11/39 medium tank.

The M 11/39 still had a hull-mounted 37mm gun, but this was longer barrelled and therefore potentially more effective against armoured vehicles. In addition it had a one-man turret with twin machine guns. The limited traverse of its main armament was in keeping with its breakthrough role, which implied leading set piece infantry attacks against enemy positions. However, this was a severe handicap in mobile manoeuvre warfare. In relation to such warfare it was conceptually similar to some extent to the French Char B, although it was far less powerful. In some other respects it was comparable to the US M2 medium tank, and like the latter was beginning to be produced when the Second World War broke out. But by the time Italy entered the war in June 1940 the number of M11/39s that had been completed still amounted to only 70.

Soviet tanks

What progress was made in Italy and the United States and indeed in any other country in the 1930s was dwarfed by the development of tanks in the Soviet Union. At first the only tanks the Red Army had were British and French tanks captured during the Civil War and the 15 copies of the Renault FT mentioned in Chapter 4. But in 1928 production began of the first Soviet designed tank, the T-18 or MS-1. This was in effect another, somewhat lighter, 5.2-tonne version of the Renault FT with a more supple suspension. Although it was the first indigenous tank to be built it was produced in quantity, with the result that a total of 959 was built by the time its production came to an end in 1931. Moreover, while production was still under way, nine T-18s were sent into action in 1928 against Chinese forces on the Manchurian frontier as the result of a dispute about the Chinese Eastern Railway.[26]

Soon after launching the development of the T-18 light tank in Leningrad, the Red Army recognized the need for a heavier tank and in 1927 set up a facility for the development of one at Kharkov. The first tank to come out of this was the T-12, a 20-tonne vehicle that was essentially a scaled-up T-18 but with a 45mm instead of a 37mm gun and with a small machine gun turret on top of the main turret, like the US M1921 and M1922 medium tanks. A prototype of the T-12 was completed in 1929 but after trials it was abandoned in favour of a major re-design of it designated T-24. This had the same general configuration as the T-12, including a small machine gun turret on top of the main turret, but also had an additional machine gun in the front of the hull operated by a gunner, sitting alongside the driver, who brought the crew of the tank up to five instead of four men. The first T-24 was completed in 1931 and during that year 24 more were built.[27]

The design of the T-24 was basically sound but its performance was not apparently entirely satisfactory, and it was abandoned while the Red Army turned to foreign models. The change was driven by the ambitious plans of the Red Army for a rapid and large scale acquisition of tanks, and it was decided in 1929 that such plans could be more successfully fulfilled by exploiting foreign expertise. In consequence, I. A. Khalepskii, the head of the Red Army Directorate of Mechanization and Motorization, went in 1930 on a 'shopping tour' of Europe and the United States. As a result, the Red Army purchased two tank chassis from J. W. Christie, which were exported from the United States as 'agricultural tractors'. It also purchased, with the approval of the British government, several vehicles from Vickers Armstrongs, including 15 Vickers Mediums, 15 Vickers Six Ton Tanks, 8 Vickers Carden Loyd amphibious light tanks and 26 Carden Loyd Mark VI tankettes.

By the time they were purchased Vickers Mediums were obsolescent if not obsolete and they were quickly relegated to a training role, although surprisingly some were employed in 1941 in the Finnish-Russian War.[28] But the others became models for armoured vehicles that were mass produced for the Red Army.

The first of these was the T-27 tankette, which was based on the Carden Loyd Mark VI. Production of it began in 1931 and by the time it was terminated in 1934 amounted to a total of 3,328 vehicles.[29] T-27 was a 2.7-tonne turretless two-man vehicle armed with a single machine gun. Its effectiveness as a fighting vehicle was extremely limited, as was that of all the other tankettes based on the Carden Loyd Mark VI, but it was of use as a training vehicle.

The Vickers Six Ton Tank, which was copied as the T-26, was a very much more effective vehicle, although the 15 which the Red Army purchased were of the original type with two side-by-side turrets. However, after 1,627 copies of it were built between 1931 and 1934, production switched to the much more effective single turret version, which was armed with a high-velocity 45mm gun and weighed 9.6 tonnes. This became the standard infantry support tank of the Red Army, and to fulfil the requirements of this role several hundred were produced each year until 1941, by which time the total number built reached 11,218, making T-26 the most numerous tank to be produced until then.[30]

An even more successful purchase proved to be that of the two Christie tank chassis. These became the basis of a series of *bystrokhodny* or 'fast' tanks, which provided the Red Army with tanks that were more mobile than all but a few of their contemporaries. They also became the basis of further successful tank development. The first of the Christie-based tanks, which were designated BT-2, were completed in 1931. They weighed 11.3 tonnes and like their Christie prototypes could run either on their tracks, at up to 32.5mph, or on their wheels after the removal of the tracks at up to 45mph.[31] But they could not run on their wheels on soft ground or over obstacles because their drive was confined to the two rear wheels, which meant that on wheels they were, in automotive parlance, only 8x2 vehicles, and because the road wheels had relatively narrow, solid rubber tyres. On the other hand, when they retained their tracks, their Christie-type independent suspension allowed them to ride over rough ground at higher speeds than other tanks.

Production of BT-2 was followed in 1933 by that of BT-5, which retained the same general configuration, including a two-man turret, but was armed with a 45mm instead of a 37mm gun. The latter was produced under licence from Rheinmetall and its replacement by a high-velocity 45mm gun put

BT-5 ahead of other contemporary tanks. Further developments of the BT series included the adoption of welding instead of the riveting of armour plates on the BT-7, which began to be produced in 1934. BT-7 was also fitted with a much shorter pitch track, which reduced the vibration and noise commonly associated with the Christie-type running gear, and 155 BT-7As were armed with short barrelled 76mm guns instead of the 45mm guns. The final version of the series, designated BT-7M and later BT-8, was powered by a newly developed V-2 diesel instead of the gasoline engines of the earlier tanks, which more than doubled its operating range. All the modifications led to the weight of BT-7M rising to 14.65 tonnes, but it was still capable of a road speed of 39mph on tracks.[32] Prototypes of BT-7M were built as early as 1938 but production of it did not start until after the outbreak of the Second World War, and when it came to an end in 1940 the total number of the BTs produced came to 8,122, making them the second most numerous Soviet tanks.[33]

Although tanks that were mass produced in the Soviet Union during the 1930s were based on foreign designs, this did not prevent further indigenous development. One outcome of it was the T-28 medium tank, which in some respects resembled the British A.6 Sixteen Tonner and in other respects was a continuation of the work on the T-24. Like the British tank, the T-28 had three turrets: a large three-man turret and a small one man machine gun turret on either side of the driver's station. The large turret of its prototype mounted a 45mm gun, which so far as its calibre was concerned was comparable to the 47mm gun of the Sixteen Tonner. But by the time the prototype was completed in 1932 German medium tanks, which were being tested secretly in Russia, were already armed with 75mm guns, and the Russians followed their example and armed the production version of the T-28 with a 76mm gun. The gun originally mounted in it was short barrelled but in 1938 this was succeeded by a longer barrelled model, which was more effective as an anti-tank weapon. The armour of the T-28 was also improved during the course of its production, which increased its thickness from 30 to 80mm and with it its weight from 28 to 32 tonnes.[34] Production of the T-28 ended in 1940, by which time about 600 are estimated to have been built.[35]

Concurrently with the development of the T-28 medium tank, the nascent Soviet tank industry also developed the T-35 heavy tank. Work on it began in 1929–30 and its design appears to have been inspired by the British A.1 Independent, as it had the same general configuration incorporating five turrets. But while the main turret of the British tank was only armed with a 47mm gun, that of the T-35 had a 76mm gun. Moreover, two of the T-35's auxiliary turrets initially mounted 37mm and later 45mm guns and not only machine guns, as did its two other turrets and all four auxiliary turrets of the Independent. To operate all these weapons the T-35 required a crew of 11 men.

A prototype of the T-35 was completed in 1931 and production of it began in 1933. It continued to be produced in small batches until 1939, by which time about 60 had been built. During the course of its production the weight of the T-35 rose from 42 tonnes of the prototype to 50 tonnes and eventually to 55 tonnes because of increases in the thickness of its armour and other changes.[36] This made the T-35 the next heaviest tank in service at the outbreak of the Second World War after the obsolete French 2C. But its large size made it difficult to manoeuvre, so much so that it could not be turned when stationary because of the long length of its tracks in contact with the ground in relation to their spacing.

In addition to those already mentioned, Soviet industry also produced a considerable number of amphibious and other light tanks. They resembled Vickers Carden Loyd two-man light tanks armed with machine guns and were in general equally ineffective.

Once production of all the Soviet tanks began in earnest in 1932 it continued at the rate of more than 3,000 vehicles per annum until 1939, except for 1937 when it fell to one half of what it was in the other years. That year saw the beginning of Stalin's campaign of terror, which resulted in the execution of three of the Red Army's five marshals and many of its officers as well as others. Among those who perished were I. A. Khalepskii, who brought in foreign models to accelerate Soviet tank development, Professor V. I. Zaslavsky, who directed the design of the first purely Soviet tank, and A. O. Firsov, the head of the Kharkov tank design bureau, who was blamed for the troubles with the transmission of the BT tanks.[37]

Nevertheless, in spite of the chaos and the loss of experienced personnel caused by the campaign of terror, new tanks began to be developed in 1937 when the Red Army asked the Kharkov plant to design another 'convertible' tank to replace the BTs. This led to the A-20, an 18-tonne tank still armed with a 45mm gun in a two-man turret that could, like the BTs, run on wheels or on tracks. However, to make it better able to operate off the roads on its wheels than the earlier tanks with their Christie-type 8x2 wheel drive, the A-20 was provided with a novel shaft drive to six of its eight wheels, so that it could operate as an 8x6 vehicle. But this ultimate attempt to keep alive Christie's idea of a 'convertible' tank was doomed to fail because the road wheels of the A-20 still had relatively narrow solid rubber tyres that severely restricted its ability to move over soft ground. Moreover, the head of the Kharkov design bureau, M. I. Koshkin, came to advocate an alternative design of a tank that operated only on its tracks. The alternative, which was designated T-32, was consequently simpler, easier to produce and could have thicker armour without being significantly heavier. In fact it weighed 19 tonnes while having armour up to 30 instead of 20mm thick, and was armed with a 76mm instead of a 45mm gun. Prototypes of both the A-20 and the T-32 were completed by mid-1939 and by the end of that year an up-armoured version of the T-32 was accepted as the T-34 medium tank. A prototype of it was built a month later and 115 vehicles were completed by the end of 1940.[38]

The T-34 constituted a major step forward in tank development, but its features were not as original as is often portrayed. However, this did not detract from the overall success of its design. In fact, a wise selection of proven features or components was responsible for much of its success, and they were available because of the progressive, evolutionary character of Soviet tank development.

Some of the T-34's features can be traced, through the BTs, back to the vehicles that Christie built in the United States ten years earlier. This applies in particular to its independent suspension and the tracks driven through their guide horns instead of toothed sprockets. The excellent 500hp V-2 diesel engine that powered it had been used already in the BT-7M, while the adoption of a 76mm gun as the main armament, when medium tanks in other countries were still being armed with 37, 40 or at most 47mm guns, followed the use of guns of this calibre not only in the T-28 medium and T-35 heavy tanks but also in BT-7A and even in some T-26s, all due to the early recognition by the Russians of the importance of gun power.

The one feature of the T-34 that is most often cited and praised as if it were novel and even revolutionary was its sloping armour. In fact, armour had been inclined to increase its effectiveness on a number of earlier vehicles, including experimental models of the BT series and armoured cars, such as the German SdKfz 231 six-wheeled armoured car produced between 1932 and 1937.[39] The armour of the T-34 was undoubtedly effective, but this was due to it being thick as well as sloped. In particular, its frontal hull armour was 45mm thick as well as being inclined at 60° from the vertical, which implied a horizontal shot line thickness of 90mm. On the other hand the A-20, which had very similar sloping armour that was, however, only 20mm thick, had a horizontal shot line thickness of only 36mm, similar to the armour of other contemporary tanks.

As well as enjoying several advantages, T-34 also suffered from a number of shortcomings. The principal one was its turret, which was cramped and made more so by the adoption of a 76mm instead of 45mm gun. The turret had a two-man crew with the commander also acting as the gunner, which prevented him from effectively controlling the tank and who was further handicapped by poor vision from within the tank.

Soon after issuing the requirements that led to the T-34, the Red Army also requested a competitive development of a new heavy tank. It still envisaged a multi-turreted vehicle, and this led to the design of two large tanks of more than 50 tonnes, which had two turrets arranged in a very peculiar way. Thus, one of the turrets, which was armed with a 45mm gun, was mounted above the driver's station, while the other, which was considerably larger and carried a 76mm gun, was mounted behind the first and towered above it, raising the overall height of each tank to more than 3m. Prototypes of the two tanks, which were designated T-100 and SMK, were built in 1939, but so, at the instigation of its designer, was a single turret version of the SMK, which was by far the most sensible of the three vehicles and which was adopted as the KV-1 heavy tank.[40]

Production of KV-1 began in 1940, like that of the T-34, and it was armed with a similar 76mm gun as well as being powered by a higher rated version of the same V-2 diesel engine as the latter. At 43 tonnes it was significantly heavier than the 26-tonne T-34 and its frontal armour was thicker but, as it was only slightly inclined, it was not more effective. In fact, its only advantage over the T-34 was its larger and more roomy three-man turret. Otherwise T-34 made KV-1 unnecessary and it might have become a 'universal' tank, as its successors did several years later. However, at the time the Red Army was still wedded to the concept of the separate categories of medium and heavy tanks, as well as to that of the third category of light tanks for close infantry support or reconnaissance.

German tanks

A similar policy of fielding three different categories of tanks was pursued at the time in Britain and France, but it was not adopted by the German Army when it began to develop tanks again in the mid-1920s. In spite of being forbidden by the Versailles Treaty to have tanks, the German Army awarded contracts in 1927 to three companies – Daimler Benz, Krupp and Rheinmetall – for each to design and build in secret two tanks in the 16-tonne class armed with 75mm guns. To disguise their development they were called *Grosstraktoren* or 'large tractors'. A year later a contract was also awarded to Krupp and Rheinmetall for each to develop two light tanks of about 8 to 9 tonnes armed with a 37mm gun, which were called *Leichttraktoren* or 'light tractors'.[41]

Although the tanks could be designed and built in secret in Germany, they could not be tested there without attracting the attention of the British or French authorities. However, a way round this was found as the result of a rapprochement between Germany and the Soviet Union, which led to the setting up of a joint German-Soviet test and training centre in Russia, at Kama near Kazan. All six *Grosstraktoren* were shipped there in 1929 and trials of them went on until 1932.

Grosstraktoren were well armed with short-barrelled 75mm guns mounted in two-man turrets, in addition to which they had a one-man machine gun turret at the rear of the hull, like the French 2C heavy tanks. They followed the example of the original British heavy tanks in locating the commander of the tank in the hull, alongside the driver, which severely restricted his field of view and which was not repeated in the design of any other tank. They were relatively fast, having a maximum road speed of 25, and as they were relatively large in relation to their weight of 16 tonnes they had sufficient buoyancy to float and could propel themselves in water at up to 2.5mph by means of two screws. But their ability to float indicated that they were not heavily armoured, the maximum thickness of their armour being only 14mm, like that of other contemporary tanks.[42]

Leichttraktoren were also sent to Kama for their trials, which began in 1930. They looked somewhat old fashioned with their front-engined configuration resembling that of the LK-II light tank, which was about to be produced in Germany when the First World War ended. Their best feature was a two-man turret mounting a high-velocity 37mm gun, which was very similar to that made in Sweden for the L 30 wheel-and-track tank built later by the Landsverk company. They were also in the forefront of the use of radios for inter-tank communication having, like the *Grosstraktoren*, a radio operator sitting next to the driver.[43]

All ten tanks sent to Kama were shipped back to Germany in 1933.[44] In the meantime discussions with the Russians, who had already embarked on the development of the T-28 medium tank, led to a decision to follow the *Grosstraktoren* with a *Neubaufahrzeug* or NbFz, a new vehicle of 20 tonnes still armed with a low-velocity 75mm gun but mounted together with a high-velocity 37mm gun.[45] It also had two auxiliary machine gun turrets, one in front and one behind the main three-man turret. The latter represented a major improvement on the *Grosstraktoren*, as it had the commander located in it and was provided with an observation cupola. Contracts for the development of the NbFz were awarded in 1933 to Krupp and Rheinmetall, and two mild steel and three armoured prototypes were completed by 1936. But after trials they were relegated to a training role. However, in 1940 the three armoured NbFz were landed in Oslo during the German invasion of Norway. Their appearance on that occasion led to rumours about a new category of German heavy tanks of 36 tonnes, armed with 75 or 105mm guns and called PzKpfw V and VI, which were perpetuated in British and US Army handbooks about enemy forces issued in 1940 and 1941, as well as other publications.[46, 47] In fact, development of Nb Fz never proceeded beyond the five prototypes.

Development of the *Leichttraktoren* was also followed by a new requirement, in this case for a light vehicle with a rear mounted engine. In 1931 Krupp were awarded a contract for such a vehicle, which was to weigh only 3.5 tonnes and which was called *Kleintraktor*, or 'small tractor'.[48] To gain time its design was based on that of the British Carden Loyd light tanks and consequently three chassis were purchased from Vickers Armstrongs in 1932.[49] The *Kleintraktor* chassis designed by Krupp was accepted and in 1935 Krupp received a contract for 135, while each one of five other firms received a contract for three more chassis to provide them with experience of producing tanks. The chassis were given the cover name *Landwirtschaftlicher Schlepper*, or LaS, meaning 'agricultural tractor'. However, they were subsequently fitted with armoured superstructures and turrets and towards the end of 1934 the Henschel company built the first three complete tanks. They became PzKpfw I after Hitler repudiated the terms of the Versailles

Treaty in 1935, and the original order for 135 vehicles was quickly followed by another for 450 vehicles. By June 1937 when production ended the total number built amounted to 1,493 tanks.[50]

Originally the *Kleintraktor* was to be armed with a 20mm cannon, but in 1932 General O. Lutz, the Inspector of Motorized Troops, decided that the tank which was to become PzKpfw I should be armed with machine guns only. This may have facilitated quantity production and speeded up the equipping of troops with tanks, but it did not make PzKpfw I very effective. General H. Guderian, who was Lutz's chief of staff, defended the decision many years later, writing in his memoirs that PzKpfw I was only a 'training tank' adopted pending the development of more effective models.[51] But there is no evidence that it was regarded as such at the time.

By 1934 General Lutz appears to have recognized the shortcomings of PzKpfw I and, according to Guderian, decided to order a second stopgap – a light tank armed with a 20mm automatic cannon.[52] As a result the Ordnance Office of the German Army issued orders for the production of such a tank, which became the 7.9-tonne PzKpfw II, the first of which was completed in 1936. By then other tanks of its kind were already being armed with 37mm or even, in the case of the Soviet T-26, 45mm guns. The 20mm cannon of PzKpfw II enabled it at least to perforate the armour of enemy light tanks or even that of some medium tanks but not of others, particularly as armour began to grow on the eve of the Second World War. Nevertheless, PzKpfw IIs were produced in quantity so that by the outbreak of the war in 1939 there were 1,223 of them, or almost as many as there were PzKpfwIs.[53]

Tanks that Lutz and Guderian really wanted were the PzKpfw III and IV. Like the NbFz that preceded it, PzKpfw IV was armed with a low-velocity 75mm gun mounted in a three-man turret. But, very sensibly, it dispensed with the auxiliary machine gun turrets as well as the 37mm gun mounted alongside the 75mm gun. Instead, it had a machine gunner-cum-radio operator alongside the driver. This meant that its general configuration was the same as that originally devised in 1929 for the British experimental A.7 medium tank and which was still the best choice, as shown by its widespread and successful adoption during the Second World War. PzKpfw IV became the most powerful tank to be issued to the *Panzer Truppen* before the war, although its armour was originally only 15mm thick. The contract for its development was issued to Krupp in 1935 and production of the first batch of 35 began in 1937. This was followed by an order for 176 more tanks, so that by the outbreak of the war the German Army had 211 PzKpfw IVs.[54]

The PzKpfw III began to be produced at about the same time as the PzKpfw IV but at an even lower rate. It had the same general configuration but its main armament was a high-velocity 37mm gun instead of a low-velocity 75mm weapon. It was designed to be a vehicle in the 15-tonne class but once it began to be produced its weight approached that of PzKpfw IV, making the two tanks very similar except for their main armament. Their concurrent production was therefore very questionable, particularly from the point of view of logistics. Nevertheless, Guderian considered a tank of the PzKpfw III kind to be the right vehicle for the three light companies of a tank battalion, while tanks of the PzKpfw IV type would equip its medium tank company.[55] The assignment of PzKpfw IV to the medium tank companies of tank battalions showed once again that they were not in the same category as the British close support tanks, as a number of writers have claimed. In fact, they were much more versatile and effective, being able to engage enemy tanks as well as other targets, which the close support tanks were never able to do.

Only ten PzKpfw III were initially produced in 1937 and by the outbreak of the war in 1939 there were still only 98 in the German Army inventory. However, by then the German Army had acquired a number of other tanks armed with 37mm high-velocity guns as a result of the annexation of Czechoslovakia in 1939. The number of Czech tanks acquired by the German Army has often been exaggerated, but the total of 469 armoured vehicles of various types that the Czech Army had included 298 LT vz 35 tanks armed with 37mm high-velocity guns. These 10.5-tonne tanks were taken over by the German Army as PzKpfw 35(t) and 202 of them were in its inventory when the war began.[56] In addition, production of new Czech TNHPS tanks, which were also armed with 37mm guns, continued after the annexation and about 100 were completed by the outbreak of the war as PzKpfw 38(t).

Polish and Swedish tanks

Apart from Japan, the only other countries to develop tanks before the Second World War were Poland and Sweden. As already mentioned in the previous chapter, Poland produced 120 7TP tanks based on the Vickers Six Ton Tank, and it also produced 440 TK3 and TKS turretless tankettes developed from the basis of the Carden Loyd Mark VI. In 1936 the Polish

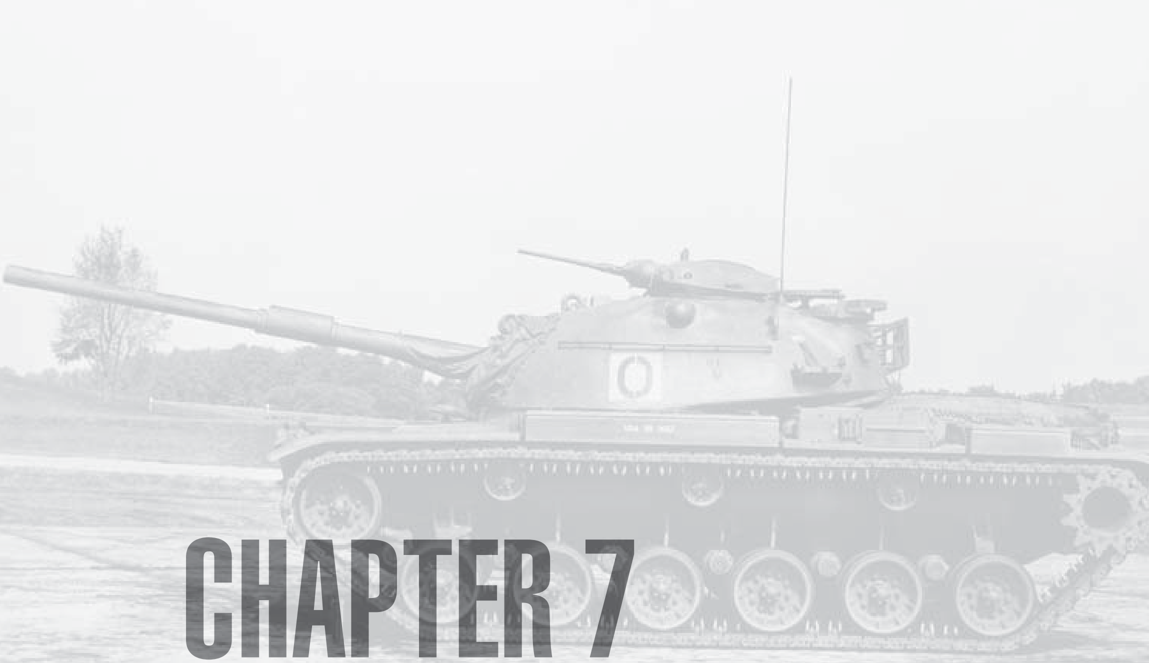
Army also started working on a convertible tank with a Christie-type running gear, which led to the 10TP, a 12.8-tonne tank with the same two man Bofors turret and 37mm gun as the 7TP.[57] However, its development had not advanced beyond the construction of a single prototype when an end was put to it by the German invasion of Poland.

Development of tanks in Sweden benefited from the links between Swedish and German industries, and in particular from the takeover by the German Gute Hoffnungs Hutte steel company of the Swedish Landsverk company. As a result of this, in 1928 Landsverk began working on the development of armoured vehicles, which could not be pursued at the time in Germany because of the restrictions imposed on it by the Versailles Treaty. The first outcome of this was an unusual vehicle that could run on wheels or tracks, but not by converting from one mode of operation to the other using the same running gear like Christie's convertible tanks. Instead it had separate sets of tracks and wheels that could be used alternately. This vehicle was the idea of J. Vollmer, the designer of the German tanks of the First World War and supervisor of the construction of the first Swedish tank, the Strv 21, which was based on the German LK II light tank prototype. The wheels-and-tracks tank was designated Landsverk 5, or L 5, weighed 7 tonnes and was armed with a 37mm gun. Gute Hoffnungs Hutte sent it in 1930 to the German-Soviet test centre at Kama, while Vollmer tried to have it adopted by the Red Army.[58] However, after three years of negotiations the Russians rejected it in 1930.[59]

This did not put an end to the development of the wheels-and-tracks tank, as a modernized version of it was ordered by the Swedish Army in 1931. Landsverk designated it L 30 and the Army Strv fm/31. It was delivered in 1935, but although it proved capable of 47mph on wheels as well as 22mph on tracks the Swedish Army did not proceed with it beyond trials. However, in 1931 it ordered three L 10s or Strv m/31s, which was a much more sensible, tracks-only version of the L 30 and which was delivered in 1934 and 1935.[60] They weighed 11.5 tonnes and were armed with a 37mm Bofors gun mounted in a two-man turret, which, together with their general configuration, put them on a par with the best of the contemporary tanks of their kind.

In the meantime Landsverk developed the L 60, which had a configuration similar to that of the L 10 but which was more advanced from the automotive point of view, having an independent suspension with torsion bar springs. Specimen L 60 armed with 20mm cannon were sold to Austria, Ireland and

Hungary, and in the case of the latter 200 were later produced under licence. In Sweden the L 60 was developed into the Strv m/38, an 8.7-tonne tank with a three-man crew armed with a 37mm Bofors gun that constituted an effective, modern design. Sixteen were ordered by the Swedish Army in 1937, but further orders, for the very similar Strv m/39 and m/40, were not issued until after the outbreak of the war.



CHAPTER 7
Creation of the Armoured Forces

When tanks were slow and few in number, as they were in general during the 1920s, their effectiveness was confined to leading small scale infantry attacks in face of enemy machine gun fire and suppressing it by their own fire. But as they grew faster and potentially more numerous, prospects emerged of creating a new type of armed forces based on tanks that was more mobile and more effective than the existing armies consisting of infantry and cavalry.

Some, and in particular Fuller and Liddell Hart in Britain and Estienne in France, foresaw tank-based armies in the early 1920s. What is more, in the following years tentative steps were taken in Britain and then in a few other countries towards the creation of mobile forces based on tanks. But in most armies the view was held that tanks were only an auxiliary to the infantry and that their role was to support it closely, and this view remained firmly entrenched in military doctrine.

The principal exponent of this doctrine was the French Army. Its tanks were a part of the infantry and were organized into independent battalions. When equipped with light tanks these were to be allocated in the event of offensive operations to infantry divisions on the scale of one battalion per division and were designated *chars d'accompagnement.* More powerful tanks, which were called *chars de manoeuvre d'ensemble*, were to lead more concentrated attacks along the main line of thrust of an infantry division or corps. However, until 1931, when the first D1 tanks were produced, the French Army had nothing other than the Renault FT light tanks, which were only suitable for close infantry support. It had no means therefore of implementing or even exploring other uses of tanks.

It was therefore only in 1932 that exercises were carried out to examine some of the other possibilities.[1] But they did not lead to any significant progress so far as the employment of tanks by the infantry was concerned. On the other hand, they were followed by a major advance in the more mobile use of tanks by the cavalry.

Five years earlier French cavalry began to motorize some of its horse mounted units by converting them into *dragons portés* – riflemen carried in unarmoured Citroën-Kegresse half-tracks. This led to each horse cavalry division having a battalion of *dragons portés* as well as four battalion-size horse cavalry regiments. Even earlier, in 1923, it was proposed to provide the cavalry with a light tank, and in 1931 a requirement was actually issued for one, which became the AMR 33. Then in 1934 the cavalry formed a *division légère mécanique*, or DLM, which became one of the first formations of its kind to be placed on a permanent footing.

When fully established, the DLM consisted of a brigade of tanks, a three-battalion regiment of *dragons portés* and a regiment of artillery as well as other, supporting units. Eventually, by 1939, it was equipped with 220 tanks, which included 80 S 35 (Somua) medium tanks and 80 H 39 (Hotchkiss) light tanks as well as 60 AMR 33 or 35 light tanks that were part of the *dragons portés* battalions.[2] However, to start with it only had the AMR 33, with which it began to be equipped in 1934.

Its organization shows that the DLM had the makings of an armoured division, but it was not regarded as such. Instead, it was considered to be a successor of the horse cavalry divisions and therefore inherited the latter's limited roles of reconnaissance, screening operations and delaying actions carried out for the benefit of infantry formations – the roles to which horse cavalry was reduced by the beginning of the 20th century. The evolution of the DLM from the basis of horse cavalry carried with it therefore a historical impediment, which it would have to overcome if it were to become an armoured division capable of independent offensive action.

As it was, the conversion of cavalry into tank units was strongly opposed by many cavalrymen who continued to believe in the effectiveness of horse cavalry and who resented having to give up their horses.[3] The creation of the DLM was actually opposed by the inspector of cavalry as well as the inspector of infantry and others.[4] In the circumstances little further progress could take place.

An exception to the prevailing attitude was provided by Colonel Charles de Gaulle, who in a book entitled *Vers l'Armée de Metier* published in 1934 advocated the creation of a professional army of 100,000 men. The core of this army was to be six mechanized or armoured divisions, each of which was composed of a brigade of tanks, a brigade of infantry and two regiments of artillery. Such an organization was similar in principle to that already adopted for the DLM and the German panzer divisions, and de Gaulle's book had no impact on the development of armoured forces in France nor, contrary to numerous claims, elsewhere. However, de Gaulle's ideas prompted Paul Reynaud, who was later to become prime minister, to advocate in 1935 in the Chamber of Deputies the creation of an armoured force capable of offensive action. But the response to it by the Minister of War, General Maurin, was that the creation of such a force would be 'useless and undesirable'.[5]

A year later the French Commander-in-Chief, General Gamelin, was also against the creation of armoured divisions.[6] The most he would recommend was the formation of a second DLM, which was put into effect in 1937, while a third DLM was only created in 1940, after the outbreak of the Second World War. However, at a meeting of the War Council in October 1936 Gamelin admitted that the French Army lacked the necessary offensive capability possessed by the German armoured divisions, which led him to recommend that the problem be studied.[7] The sequel to it was that the Army Council agreed to the creation of two armoured divisions in December 1938.[8] But their constituent elements were not assembled until the outbreak of the war and the two divisions did not come into being until January 1940.

Each of the armoured divisions or *divisions cuirassées* (usually abbreviated to DCRs) contained two tank battalions with a total of 68 B1 tanks, two battalions with 90 H 39 light tanks, one battalion of motorized infantry and a regiment of artillery, as well as supporting units.[9] They had therefore some of the characteristics of combined arms armoured formations. But the French Army doctrine did not envisage their use as an independent mobile striking force. Instead they had a more limited offensive role, which was to be carried out under the control of infantry corps or other large formations within the prevailing concepts of continuous fronts and methodical operations. In fact, the DCRs were primarily concentrations of the infantry's heavy tanks, which were not very suitable for mobile operations, and their low proportion of infantry to the 158 tanks limited their ability to operate independently.

The DCRs did not therefore provide the French Army with armoured divisions capable of offensive mobile operations but with limited purpose formations, like the DLMs, while the majority of its tanks remained dispersed in separate battalions assigned to close infantry support.

The situation arrived at by the French Army on the eve of the Second World War was duplicated in some respects by the British Army. In particular, like the French, the British Army divided its tanks between the support of the infantry and the carrying out of the role previously performed by the cavalry. But the French Army reached this situation by simply perpetuating the traditional division of armies into infantry and cavalry, whereas the British Army regressed to it after trying to develop a more effective use of tanks.

The turning point came in 1934 when the Tank Brigade, which had carried out the pioneer experiments in the more mobile use of tanks, was put on a permanent basis. Later that year a decision was also taken to divide tanks between army tank battalions, which were to be allocated to infantry divisions to support them like the French *chars d'accompagnment*, and a mobile division, which was considered to be a successor to the cavalry division, like the French DLM.

However, the composition of the Mobile Division was to be very different from that of the DLM. One of its major components was the Tank Brigade, whose commander Brigadier P. C. Hobart would have preferred it to be composed mainly of tanks.[10] But others, in particular Brigadier G. M. Lindsay, who set off the sequence of events that led to the creation of the Tank Brigade, came to advocate its combination with a motorized infantry brigade. Such a combination was actually tried during the 1934 manoeuvres, but the experiment proved to be a fiasco and there was to be no infantry in the Mobile Division.[11] On the other hand it was to contain a cavalry brigade, which constituted its other major component. The cavalry brigade was to consist of a regiment of light tanks and three regiments mounted in trucks, which, like the *dragons portés*, would have provided the equivalent of the motorized infantry that the Mobile Division needed. But this was not a role congenial to the cavalry, which preferred to be mounted in light tanks if, very reluctantly, it had to give up its horses.[12] A small scale experiment at converting cavalrymen into motorized riflemen was initiated in 1935 but by 1937, when the Mobile Division was finally established, this approach was abandoned and a decision was taken that its cavalry regiments be equipped with light tanks.[13]

As it came into being, the Mobile Division retained the Tank Brigade but with three instead of its original four tank battalions. On the other hand its cavalry component was increased to two brigades, each with three regiments, which were, in effect, light tank battalions. This meant that the Mobile Division had a total of nine tank battalions with a nominal strength of more than 500 tanks, which resulted in an unbalanced organization with too many tanks in relation to the other components of the Division and in particular its two motorized infantry battalions. Moreover, most of its tanks were light tanks armed only with machine guns.

Some of the shortcomings of the Mobile Division were rectified in 1939, when its name was changed to that of an armoured division and the number of its brigades was reduced to two. One of them was called the Light Armoured Brigade and consisted of three regiments or battalions equipped with a mixture of cruiser and light tanks, while the other was called the Heavy Armoured Brigade and had three regiments equipped with cruiser tanks. Between them the two brigades were to have 108 light and 213 cruiser tanks. This was a more practical number of tanks than that originally proposed, but the divisional troops were also reduced to one motorized infantry battalion and a small artillery regiment. In consequence, although the number of tank battalions was reduced from 9 to 6, the proportion of infantry to tanks became even smaller, almost as if the 'all-tank' ideas were being subscribed to again. Nevertheless, the General Staff planned in 1939 to have three such divisions as well as five brigades of army tank battalions.

Before much of the plan could be implemented, the war broke out, and the British Army entered it with its armoured forces divided between two armoured divisions, which were still being organized, and about three brigades of army tank battalions. The division of British tanks between the two categories of units persisted even after the striking success in France in 1940 of the German armoured forces, which eschewed such a division. Their success led the British Army to plan the formation of seven more armoured divisions which came into being between September 1940 and August 1941.[14] But their basic organization still followed that of the Mobile Division and their intended role bore traces of the latter's origin as a successor of the horse cavalry division. In fact, as late as May 1944, an Army training pamphlet still declared that armoured divisions are only 'designed for exploitation after the enemy's position has been broken'.[15]

However, in practice, in Libya in 1941 and 1942 and in Normandy in 1944, the armoured divisions were not confined to exploitation but acted as versatile fighting formations. Their organization changed also in 1942 from the two armoured brigade pattern inherited from the Mobile Division to a single armoured brigade with three tank and one infantry battalions backed by a three-battalion infantry brigade. The change reduced the tanks per division from the 386 they had in 1941 to about half that number. But at the same time it increased the number and proportion of the motorized infantry in belated recognition of its importance as a complement to tanks, which even Fuller, who has been regarded as the principal exponent of the 'all-tank' concepts, had recognized seven years earlier.[16]

Towards the end of the war the number of British armoured divisions declined to five, although each now had 294 medium and light tanks.[17] The number of (army) tank brigades also declined but to a lesser extent, so that there were still eight of them compared with the maximum of 11 in 1942.[18] Thus right up to the end of the Second World War the British Army continued to divide its armoured forces into two separate categories according to the traditional division of armies into infantry and cavalry, which other armies ceased to do.

Like the British and French armies, the Red Army also came to divide its tanks between supporting the infantry and more mobile operations. But for several years after the First World War the only tanks it had were British and French tanks captured during the Civil War and the few native copies of the Renault FT. Little attention was paid to them and in 1922 some were even sent to the Ukraine to help with agricultural activities.[19] Nevertheless, some members of the Red Army, such as K. Kalinovskii and V. Triandafillov, began to consider the future of tanks and their deliberations led to the PU-29 Field Service Manual of 1929, which became for several years the main statement of Soviet tank doctrine. It stated that the main role of tanks was paving the way for the infantry, but added that they should be divided in action between PP or close infantry support tanks, and DD or 'long range' tanks that would thrust into an enemy's positions, attacking his artillery and disorganizing his rear echelons.[20]

The concept of DD tanks became a major feature of Soviet tank doctrine and was expanded into the idea of deep thrusts by mechanized forces, which was then elaborated into the concepts of deep battle and deep operations. The latter has been described as the 'brainchild' of Marshal M. Tukhachevski but, apart from the contribution to it by others, its origins can be traced back to centuries of offensive raids carried out on the plains of Eastern Europe by forces of cavalry.[21] The most recent examples of them were the raid carried out in 1919 during the Russian Civil War by the White Cavalry led by General K. K. Mamontov, which inspired the subsequent operations of the Red Cavalry, and the break through the Polish front in 1920 during the Polish-Russian War by the Red Cavalry Army led by S. Budennyi.[22] There was even a motorized forerunner of the deep thrusts in the raid carried out in 1920 by a Polish force consisting of armoured cars, truck-borne infantry and artillery, which penetrated more that 40 miles in a day into enemy held territory to seize the important railway junction of Kowel in the rear of Tukhachevski's troops retreating from the gates of Warsaw.[23]

However, for all its historical antecedents, the concept of deep thrusts by mechanized forces and the employment of tanks in the DD role did not prove easy to implement. To test some aspects of it, a decision was taken in 1929 to form a mechanized regiment, which was quickly expanded into a brigade consisting of a two-battalion tank regiment with a total of 60 tanks, an infantry battalion and an artillery battery.[24] The brigade was put to test during the 1930 manoeuvres but its performance proved disappointing, partly because the MS-1, or T-18, tanks that were used were too slow, particularly in the role of DD tanks.

More mobile tanks, such as the BTs, did not begin to be produced until a year later, but they then became available in increasing numbers as a result of the large scale production programme launched in 1927 as part of Stalin's first Five Year Plan. Under this plan the Red Army was urged to acquire quantities of the latest equipment and it responded by asking for about 1,500 tanks. But the Politburo tripled their number.[25] The demand for such a large number of tanks was partly driven by grossly exaggerated estimates of the numbers of tanks possessed by other armies, in particular by the Polish Army, which was regarded as the principal enemy.[26]

As large numbers of tanks began to come out of the factories, it became possible for the Red Army to create an increasing number of armoured units. Thus in 1932 it decided to organize two mechanized corps, each of which was composed of two mechanized and one motorized infantry brigades. The mechanized brigades consisted of three battalions of tanks, one of machine guns and an artillery battery, the tanks being T-26s in the case of one of the two brigades and BTs in the other.[27] In total each corps had 490 tanks. In addition to the mechanized corps, each infantry division was to receive a battalion of 57 tanks for close support and each cavalry division was to have a regiment of 64 tanks. There were also independent tank brigades at the disposal of the High Command.

In 1934 two more mechanized corps were created, and the corps became the Red Army's mobile strike force on which would rest the execution of any deep operations. One of the corps put on an impressive appearance at the 1935 Kiev manoeuvres, in which more than one thousand tanks were said to have taken part. They demonstrated that the Red Army was well ahead of others so far as the size of the armoured forces was concerned – in fact, it already had more tanks than all the other armies put together. They also demonstrated that the Red Army was ahead of others in creating mechanized or armoured formations.

But how the mechanized forces were to be employed was a matter of continued debate. In their existing form the corps were considered to be unwieldy, and in response to criticism the number of tanks in each was reduced.[28] Their T-26 tanks were also, very sensibly, replaced by BT tanks, which were far more suited to them. However, the employment of tanks in the DD role and in particular their co-operation with other arms had still not been fully developed. What is more, because of the difficulty of implementing it, there was growing dissatisfaction with the whole concept of deep battle of which the mechanized corps were an integral part.[29]

Before any of the issues could be resolved, Tukhachevski and many others involved in the development of Soviet armoured forces were executed in 1937 in Stalin's reign of terror. Inevitably, this had an adverse effect on the concepts of the mobile offensive employment of mechanized forces with which those executed were associated.

At about the same time Soviet tanks were used in combat, first in the Spanish Civil War and then in the clashes with Japanese forces on the Manchurian and Mongolian borders. Their deployment in Spain began with the delivery of 50 T-26s with Russian crews only three months after the outbreak of the Civil War in July 1936. Other deliveries followed and by the end of the year the Soviet General D. Pavlov, who assumed command of the armoured units of the Republican Army, was able to organize an armoured brigade with four tank battalions having a total of 230 T-26 tanks. Ten months later this was followed by the formation of a division with two brigades of T-26 tanks and a regiment of 50 newly delivered BT-5s.[30]

The total number of Soviet tanks delivered to Spain amounted to 331.[31] This represented a large tank force by contemporary standards, and the Soviet tanks outnumbered as well as outgunned the 106 German PzKpfw I tanks sent to aid the Nationalist forces of General Franco.[32] However, the Republican Army failed to capitalize on its tank strength. On one occasion, in preparation for the Battle of Brunete in July 1937, it assembled 130 tanks, but they were used in a dispersed manner and suffered heavy losses, as they did on other occasions when they were used in small packets poorly co-ordinated with other arms.[33]

A year later units of the Red Army clashed with Japanese forces at Lake Khasan, 70 miles from Vladivostock. The Japanese were eventually forced to withdraw, but because of its poorly co-ordinated frontal attacks the Red Army suffered relatively heavy losses, including that of 85 T-26 tanks out of the 257 that were employed.[34] In August 1939, just before the Second World War broke out in Europe, another clash occurred, this time on the border of Outer Mongolia at what is described as Khalkhin-gol in Russian accounts and as the Nomonham Incident by the Japanese. This time the Red Army deployed a force commanded by General G. K. Zhukov, the future Deputy Supreme Commander of the Soviet Army, which included six mechanized and tank brigades with a total of more than 500 tanks, primarily BT-5 and BT-7. Zhukov employed them as a mobile striking force on the lines envisaged previously for the mechanized corps to carry out a double envelopment by which they defeated the Japanese forces.

But the success of this operation did not restore the faith of the Red Army leaders in the concept of deep battle and in an independent use of mechanized forces. A major factor in this was the view derived from the Spanish Civil War that tanks had become very vulnerable to anti-tank weapons – a view which was widely held at the time. It was argued therefore that tanks needed to be supported by infantry and artillery and could only achieve success if closely tied to them and not in more independent, mobile operations. Pavlov, who returned from Spain to become the head of the Armoured Force after two of his predecessors were executed, even went so far as to claim that the whole concept of DD tanks was flawed.[35]

All this led the Red Army to begin a reorganization of its armoured forces in 1938. The name of the four mechanized corps was changed to tank corps and they were deprived of their motorized infantry brigades and supporting troops. Similarly, the tank brigades were deprived of their organic machine gun battalions. As a result the tank corps became almost 'all-tank' formations and were no longer capable of carrying out independent mobile operations. But these changes did not satisfy men like Pavlov who considered the existence of the tank corps to be pointless.[36] In consequence the Main Military Council of the Red Army decided in November 1939, two months after the German invasion of Poland, to disband the tank corps. At the same time it directed that tank brigades should co-operate more closely with infantry and cavalry divisions. This meant that, so far as the concepts of the employment of tanks were concerned, the Red Army regressed to where it was ten years earlier when the use of tanks was subordinated to the infantry.

Before the reorganization took place the Red Army had four tank corps, 24 independent tank brigades, and 11 tank regiments as well as battalions of T-26 tanks attached to infantry divisions and regiments of BT tanks attached to cavalry divisions. The total number of tanks that all these units and formations had was still greater than that of all the other armies. But the Red Army was no longer in the forefront of the development of mechanized or armoured forces.

The lead in this field was seized in the mid-1930s by the German Army, in spite of the handicap that for more than a decade it was forbidden to have any tanks by the terms of the Versailles Treaty. However, the latter could not prevent studies of the future of tanks. These were carried out against the background of Germany's strategic situation, which included the possibility of war on two fronts and the relatively small size of its army restricted by the Versailles Treaty. This led the head of the German Army, General H. von Seeckt, to adopt the policy that a small army had to be highly mobile and to favour offensive warfare. At first von Seeckt assigned an important part in mobile operations to the cavalry, but he and other German officers took an increasing interest in motorized troops and in tanks, slowly recognizing the possible use of tanks in mobile warfare. This was inspired in part by the appearance in 1924 in Britain of Vickers Medium tanks, which represented a considerable advance on earlier tanks in terms of speed, and subsequently by the manoeuvres in 1927 of the Experimental Mechanized Force on Salisbury Plain.[37]

An indication of the views that were emerging is provided by a rare but widely consulted book on tanks written in 1925 by an Austrian officer, Captain F. Heigl, who considered that the faster tanks that were appearing were eminently suited to mobile warfare and should not be restricted to operating at the pace of the infantry.[38] In his second book published a year later Heigl went on to argue that, instead of supporting the infantry in the customary frontal attacks, tanks would be better employed in mobile operations against the flanks and the rear of an enemy. He concluded that in the future armies would consist of tanks accompanied by infantry in light armoured vehicles and by artillery equipped with tracked self-propelled guns.[39]

Similar views were gradually adopted by others. They included Captain (later Major) H. Guderian, who became interested in tanks in the early 1920s and who came to play a leading role in the evolution of their tactics and organization. In the course of his activities Guderian became a prominent exponent of the mobile use of tanks and an ardent advocate of their concentration in large, independent armoured formations.

According to his memoirs, in 1929 Guderian reached the view that to be fully effective tanks had to be supported by other arms but brought up to their level of mobility.[40] This view may have been influenced to some extent by the importance of inter-arm co-operation, which had been instilled into the German Army by von Seeckt and was in striking contrast to the 'all-tank' views favoured in Britain at the time.[41] It led to the balanced, all-arms composition of the panzer divisions, which made them superior in this respect to other armoured formations.

The combined arms approach was adopted after the 1932 German Army manoeuvres by General O. Lutz, who became Inspector of Motorized Troops and made Guderian his chief of staff. The manoeuvres were still carried out with dummy tanks but Lutz proceeded in the following year to argue that tanks should be concentrated in large, independent mechanized formations that would become the core of an offensive strike force.[42] Steps towards the achievement of this objective were taken in 1934 when, as part of the German Army's expansion that followed Hitler's rise to power, approval was given for the creation of three panzer divisions. This was followed by the assembly for the manoeuvres in mid-1935 of an improvised panzer division and the calling into being of three panzer divisions in October of that year, with Guderian being given command of the 2nd Panzer Division.

The organization of the panzer divisions was worked out in 1934 and was based on a tank brigade with two two-battalion tank regiments backed by a motorized infantry brigade with a two-battalion truck-borne regiment and a motorcycle battalion, an armoured reconnaissance battalion, an anti-tank battalion, an artillery regiment and an engineer company, as well as supporting units.[43] Each of the division's 16 tank companies was to have 32 light tanks, which, together with command tanks, would have given it a total of 561 tanks.[44]

Such a large number of tanks would have made the division unwieldy, but it was a common characteristic of the early ideas on the composition of armoured formations, as shown by the British Mobile Division and the early Soviet mechanized corps. As many as 500 tanks also featured in a detailed proposal for a tank division made in a book by another Austrian officer, General L. von Eimannsberger, which was published a year before the first panzer division came into existence and provided another indication of contemporary ideas.[45] Like the panzer division, Eimannsberger's tank division combined tanks with a motorized infantry brigade and a regiment of artillery that, with remarkable foresight, he expected to act in an anti-aircraft as well as ground roles, as the German 88mm anti-aircraft guns later did so effectively from the Spanish Civil War onwards.

When the panzer divisions were actually being formed and began to receive more effective equipment than the PzKpfw I light tanks, the number of their tanks was brought down to a more manageable level by a reduction in the number of companies per battalion to three and of tanks per company to 22 or 19. As a result by 1939 each division was to have 324 or 328 tanks. These were to include the more powerful PzKpfw III and PzKpfw IV, but although the allocation of the two tanks was relatively modest there were still not enough of the former to meet the requirements of the panzer divisions, particularly as their number grew to six, two more being created in 1938 and one in 1939.

Nevertheless, in spite of the shortage of medium tanks, the six panzer divisions constituted a highly effective mobile force. Its effectiveness was based to a large extent on the balanced composition of the panzer divisions and the close inter-arm co-operation between their units, as well as methods of command and control that were superior to those of other contemporary mechanized formations. The last involved the first large scale use of radios for inter-tank communication: even the light two man PzKpfw I tanks were fitted with radio receivers, and other tanks, starting with PzKpfw II, had transmitters as well as receivers. The extensive use of radios is sometimes ascribed to Guderian, who was a signals officer in the First World War, but provision for radios was already incorporated in the *Leichte* as well as *Grosstraktoren*, which were designed before Guderian became involved with tank development.

The panzer divisions made the most of the majority of tanks the German Army had by concentrating them so that they could be used massed, as Guderian repeatedly advocated. The only exception to this were the four light divisions created by the German cavalry, which, as in other armies, originally opposed mechanization and then proceeded to develop motorized formations of its own. Each of the resulting light divisions contained one or two tank battalions and what were in effect three to four motorized infantry battalions, as well as the usual divisional troops.[46] Guderian opposed their creation instead of additional panzer divisions, but after the 1939 campaign in Poland, in which they were found to lack offensive power, they were converted into panzer divisions. However, as there was a shortage of German medium tanks, the 1st Light Division, which became the 6th Panzer Division, was partly equipped with ex-Czech Army PzKpfw 35(t) and the 2nd and 3rd light divisions, which became the 7th and 8th panzer divisions respectively, were partly equipped with newly built Czech PzKpfw 38(t) tanks, all of which were armed with 37mm guns similar to those of the German PzKpfw III.

A far greater shortage of medium tanks afflicted the armoured forces that were being created in Italy. In fact, none was available for them until shortly before Italy entered the war in June 1940.

The first step in the development of Italian armoured forces was taken in 1936 when a Brigata Motomeccanizzata was formed in Sienna. It consisted of a battalion of tanks, a two-battalion regiment of *bersaglieri* or light infantry, and an artillery battery. A year later it was renamed Brigata Corazzata, or armoured brigade, and became the first fully mechanized formation of the Italian Army. A second brigade was formed at about the same time in Milan and in 1939 the two brigades were transformed into the Centauro and Ariete armoured divisions. One more division was created later in the same year by the conversion of the Littorio infantry division.

The organization of the three armoured divisions followed that originally adopted in 1937 for the first armoured brigade. This meant that each had a tank regiment, a *bersaglieri* regiment with one battalion of motorcyclists and one of truck-borne riflemen, an artillery regiment and an engineer company.[47] The tank regiment had a nominal strength of four battalions but in practice it had only two.

In theory the three divisions had a well-balanced combined arms organization. However, until 1940 the most powerful tanks available for them were the 50 obsolete Fiat 3000B tanks armed with medium-velocity 37m guns. Otherwise the only armoured vehicles with which they could be equipped were the turretless machine gun armed CV 33 or CV 35 tankettes. In consequence, the three divisions were incapable of carrying out effectively offensive mobile operations or the *Guerra di rapido corso* that was proclaimed by Mussolini and that became official doctrine in 1938.[48]

The effectiveness of the Italian armoured divisions would not have been increased to any great extent if some of their tankettes had been replaced by M 11/39 medium tanks when they began to be produced in 1939, because of the shortcomings of these tanks described in the previous chapter. It was only in mid-1940 when a derivative of the M 11/39 with a turret-mounted 47mm gun began to be produced that the Italian armoured units were provided with a tank whose characteristics approached international standards.

In the meantime some Italian tank units had been engaged in combat, first in Ethiopia and then in Spain, where two battalions were sent to support the Nationalist forces in the Spanish Civil War. The intervention in Spain involved the sending of 149 CV 33 or CV 35 tankettes, 56 of which were eventually lost.[49] On several occasions they led the advances of the Italian expeditionary corps, the Commando Truppe Volontarie or CTV, but they were helpless when they encountered Soviet T-26 tanks, which outgunned them completely. One particularly noteworthy action in which they took part was the failed offensive of the CTV at Guadalajara in March 1937, which was widely claimed at the time to have demonstrated the ineffectiveness of mechanized forces. In fact, the offensive was not carried out by mechanized forces but by four divisions of infantry supported by only four companies of tankettes.[50]

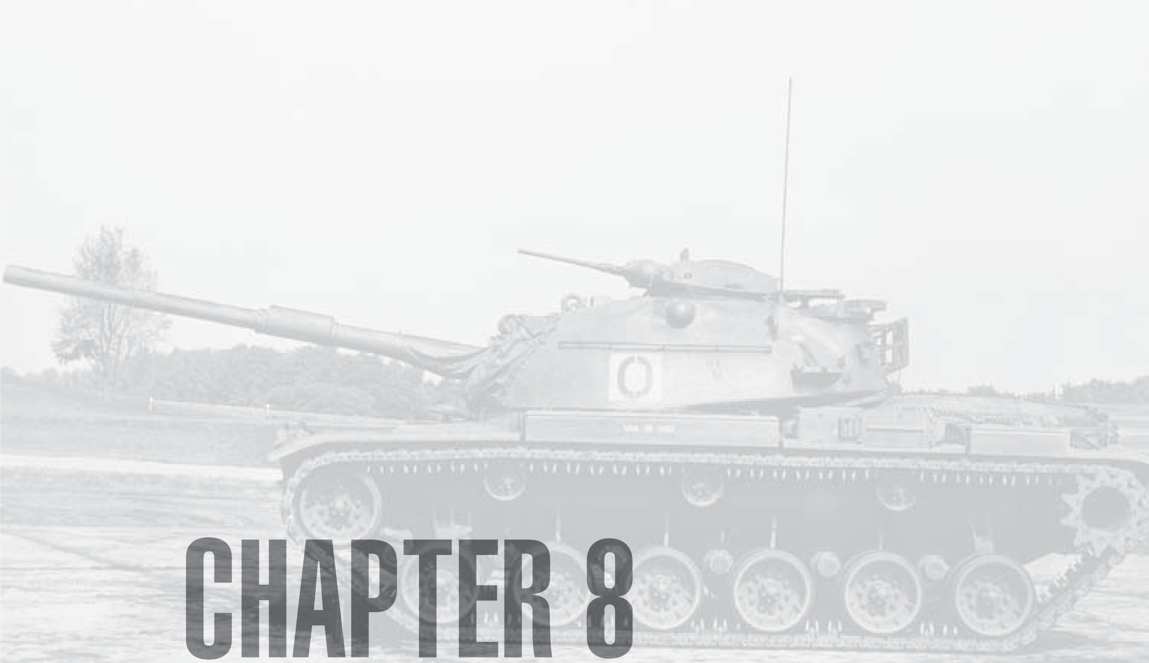
Nevertheless, the erroneous perception of what happened in Spain became the basis of arguments against the development of mechanized forces. This happened, among others, in the United States, where the development of mechanized forces was largely in the hands of the cavalry, whose more conservative officers regarded it, like their counterparts in other armies, as primarily a threat to horse cavalry.[51] The development began with the short-lived Experimental Mechanized Force, which was inspired by the experimental British force of 1927 and which was assembled at Fort Meade in the following year. This was followed by another experimental force assembled at Fort Eustis in 1930 but which was disbanded a year later, when the decision was taken to mechanize one horse cavalry regiment. But this regiment only began to train with tanks in 1933 when it was transferred from Texas to Fort Knox in Kentucky, where it was equipped with 'combat cars' or light tanks. In the meantime, in 1932, a mechanized cavalry brigade was called into being, but it did not become effective until 1938 after a decision was taken to mechanize a second cavalry regiment.

Much of the mechanization of the cavalry was due to the efforts of Colonel (later General) A. R. Chaffee, who became the commander of the mechanized brigade and who persuaded the chief of cavalry to recommend to the War Department in 1937 the formation of a mechanized cavalry division. However, until the outbreak of the Second World War the 7th Cavalry Brigade (Mechanized), to give it its full title, with its two cavalry regiments and a nominal total of 112 combat cars remained the only mechanized formation of the US Army.

Further progress only took place in 1940 when a motorized infantry regiment was added to the cavalry brigade, as Chaffee had long advocated, to make the brigade more operationally independent and effective. Then during Army manoeuvres carried out in Louisiana in the same year, the cavalry brigade was combined with a provisional tank brigade made up of the infantry's tanks to form an improvised armoured division.[52] Shortly afterwards, spurred by the success just scored by the German armoured divisions in France, the US War Department decided, in July 1940, to create an armoured force with two armoured divisions based on the 7th Cavalry Brigade and the infantry's Provisional Tank Brigade.[53]

At that stage the US Army had a total 464 tanks, including 18 obsolescent T4 medium tanks.[54] But now each of the armoured division was to have an armoured brigade with two regiments of light tanks and one regiment of medium tanks, containing a total of 273 light and 108 medium tanks. In addition, the armoured brigade included an artillery regiment and was supported by a two-battalion armoured infantry regiment, an additional artillery battalion and an engineer battalion, as well as a reconnaissance battalion. The organization of the armoured divisions was clearly based on that of the 7th Cavalry Brigade, but on manoeuvres in 1941 it was found to be unwieldy. In consequence, in March 1942, shortly after the United States entered the war and before the armoured divisions went into action, their organization was changed. This involved the elimination of the brigade echelon and the introduction under the division commander of two combat command headquarters that could control any combination of the division's units. It also involved a reduction in the number of armoured regiments to two, but each of them now had two medium and one light tank battalions, which provided the division with almost the same total number of tanks as before but reversed the ratio of light to medium tanks, there being 143 of the former and 232 of the latter. At the same time the infantry regiment acquired a third battalion, which increased the proportion of infantry to tanks, and the artillery was reorganized into three battalions.

In addition to improving their organization the armoured divisions grew in number, three more being activated before the United States entered the war.[55] As defined in a contemporary armoured force manual, their role was 'the conduct of highly mobile ground warfare, primarily offensive in character, by self-sustaining units of great power and mobility'.[56] There was no question of them being confined to exploitation or other limited roles, although the manual recognized that they were 'especially suited' for it.[57]



CHAPTER 8

Panzers and their Second World War Opponents

The outbreak of the Second World War on September 1, 1939 brought into immediate action a large number of tanks, as all six regular and one provisional panzer divisions as well as four light divisions took part in the German invasion of Poland. Between them these 11 formations had 2,682 tanks[1] out of the 2,980, excluding command tanks, which the German Army had at the time.[2]

While almost all the available tanks were concentrated in the armoured formations, the panzer divisions were distributed among corps consisting primarily of infantry divisions. Nevertheless, they spearheaded the rapid thrusts that resulted in the envelopment and destruction of the strategically exposed and inadequately armed Polish forces in less than four weeks. The speed with which the campaign was conducted led to it being called *blitzkrieg*, or lightning war. This name has since come into widespread use to describe a particular kind of warfare, although it was not a German military term but merely a catchword which the Western press picked up and started using even before the fighting died down.[3]

The cost of the campaign to the German armoured forces was the loss of 231 tanks.[4] Most of them were PzKpfw Is and IIs, but even PzKpfw IIIs proved vulnerable to Polish 7.92mm anti-tank rifles as well as Polish-made 37mm Bofors anti-tank guns.[5] Not surprisingly, PzKpfw IV was singled out by Guderian as a highly effective weapon that should be produced in quantity.[6] On the other hand, commanders of PzKpfw II complained about the inadequate vision provided by the single although rotatable Zeiss periscope with which their model and many other tanks were fitted at the time. As a result PzKpfw IIs were provided with a ring of eight fixed periscopes around the commander's hatch, which set a new standard in all-round vision from within tanks.

German tanks encountered little opposition from Polish tanks as there were few of them and the tanks that were available were not very effectively employed. The largest units were three battalions of tanks, two of which had 49 7TP light tanks each. They were used separately and fought split up into companies without adequate logistics support, as a result of which a number of tanks was destroyed by their crews when they ran out of fuel and ammunition. The third battalion was equipped with 49 R 35 tanks, which was all the Polish Army was able to procure from France before the war. This battalion was held in reserve and was eventually ordered to cross the frontier into Romania without ever firing a shot.[7] Ironically, the final employment of Polish tanks came after the campaign, when the Germans refurbished 21 captured 7TP tanks and equipped Hitler's escort battalion with them.[8]

An entirely different by-product of the campaign in Poland has been the myth of Polish cavalry charges against German tanks. It arose out of a charge on the first day of the war by two squadrons of a Polish cavalry regiment, which was misrepresented in some German accounts as having been carried out against tanks.[9] The charge was actually against infantry, but the myth of it being carried out against tanks has persisted into the 21st century.[10]

While few tanks opposed the German tanks in Poland, even fewer opposed the Red Army when it invaded Finland in November 1939. In fact, the Finnish Army only had 26 Vickers Six Ton Tanks and not all of them had yet been armed with 37mm Bofors guns.[11] On the other hand the invading Soviet forces had about 1,500 tanks.[12] However, their frontal assault on the Karelian Isthmus failed, as did the offensive operations on other parts of the front, and they suffered heavy losses in tanks. But after the failure of their original offensive, Russian forces reorganized and launched another assault on the Finnish defences. This time they employed about 1,330 tanks, which attacked in close co-operation with the infantry and overwhelmed Finnish defences, leading to an armistice in March 1940.[13]

Soviet tanks were mostly T-26s, which proved vulnerable to Finnish 37mm Bofors anti-tank guns, as they did three years earlier in Spain to German 37mm anti-tank guns, because of their relatively thin armour and inept employment. This was equally true of the BTs, almost all models of which were used against the Finns. The Soviet forces also used T-28 medium tanks, 97 of which were destroyed, and also T-35 heavy tanks with five turrets, several of which were also destroyed.

During the first offensive the Red Army tested two of its new KV-1 heavy tanks as well as its unsuccessful, multi-turreted T-100 and SMK competitors, all of which proved immune to Finnish 37mm anti-tank guns, and during the second offensive it also deployed the recently developed 52-tonne KV-2 armed with a 152mm howitzer.[14] The new T-34 medium tank was also to be tested on the Finnish front, but did not arrive until after the armistice. For its part the Finnish Army captured a total of about 600 armoured vehicles, and the recovered T-26s became its principal tanks.

The one-sided employment of large numbers of tanks that characterized the German invasion of Poland and the Soviet assault on Finland came to an end on May 10, 1940 when the German Army launched its offensive against the Netherlands, Belgium and France. Since the campaign in Poland, German armoured forces had been reorganized, as a result of which the four light divisions were converted into panzer divisions so that there were now ten of them. Moreover, panzer divisions were concentrated into panzer corps and two of the panzer corps were combined to form a panzer group.

However, the tank inventory had only risen slightly to 3,379 tanks and the number actually deployed by the ten panzer divisions was 2,574, which was fewer than the number used against Poland.[15] Of this total, 523 were still the light PzKpfw I armed only with machine guns, which had already proved deficient in Poland as well as Spain, and the number of PzKpfw IV had only increased by 69, in spite of Guderian's recommendation mentioned earlier. The only significant improvement was an increase in the number of PzKpfw IIIs from 98 to 329.

The French Army, which bore the brunt of the German offensive, had approximately the same number of tanks, namely about 3,650.[16] But whereas German tanks were concentrated in the panzer divisions, one third of the

French tanks, which consisted primarily of R 35 light tanks, were distributed between 25 independent battalions spread out over the French front stretching from the Swiss border to the English Channel. The heavy B1 and B1 bis tanks, of which there were about as many as there were German PzKpfw IVs, were allocated to the three *divisions cuirassées*, or DCRs, but the first two of them only began to be organized when the war broke out eight months earlier and the third was created less than two months before the German offensive. In consequence their organization was incomplete and their units had little opportunity to train together, let alone practice mobile operations. In addition to the more modern tanks, there were also seven battalions of obsolete Renault FT tanks and one battalion of six 68-tonne 2C heavy tanks that should have been relegated by 1940 to a museum.

The only fully organized and trained mechanized formations of the French Army were the three *divisions légères mécaniques*, or DLMs. Two of them formed a cavalry corps commanded by General R. Prioux, which provided the traditional cavalry screen for the French forces moving into central Belgium, where the main German thrust was expected to come. In the course of performing its mission, Prioux's corps met two advancing panzer divisions and engaged them in what was the first tank versus tank battle of the Second World War. The battle took place east of Gembloux, after which it is generally called, and involved around 400 French and 600 German tanks. The former included about 160 S 35s (Somua) medium tanks, whose frontal armour was not only thicker than that of the German tanks but virtually impervious to their guns, while the 47mm guns of the S 35 were superior in terms of armour penetration to the 37mm and 75mm of the German PzKpfw III and IV, although not to the extent that is sometimes claimed.[17] But, like other French tanks, the S 35s were severely handicapped by having one-man turrets, which overtaxed their crews. This was aggravated by the poor vision from within the S 35 as well as other French tanks, which restricted the situation awareness of their crews and together with the lack of radios in other French tanks inhibited co-ordinated action. All this contributed to the operation of French tanks in small, isolated groups, which was noted by German tank crews and helped them to outmanoeuvre French tanks.

Nevertheless, the cavalry corps accomplished its mission, albeit at the cost of 105 tanks, and fell back, but its tanks were then distributed along a defence line established by infantry divisions, despite complaints by General Prioux. In the meantime the French High Command was taken completely by surprise by the advance of the panzer group of five divisions through the Ardennes Forest, which was considered to be a major obstacle to mechanized forces. The panzer group, which included a corps commanded by Guderian, crossed the River Meuse and broke through the French front at Sedan, while two other panzer divisions, one of which was commanded by General E. Rommel, crossed the Meuse north of it. After the breakthrough, the panzer divisions advanced rapidly towards the Channel and cut off French and British forces in Belgium from the rest.

Farther north the remaining panzer division invaded the Netherlands, and after four days of fighting the Dutch Army, which had no tanks, capitulated.

On the French front, the scattered battalions of R 35 tanks could offer little resistance to the onslaught of the panzer divisions. What is more, not only were the R 35 battalions used piecemeal, but their tanks, like most other French light tanks, were armed with short-barrelled low-velocity 37mm guns dating from 1918, which their opponents described as 'worthless'.[18] The three DCR were held in reserve behind the front line in the region of Chalons, and in response to the German offensive the 1st was sent to Charleroi in Belgium, where it became involved in some heavy fighting with Rommel's 7th Panzer Division. During the fighting some of its B1 tanks were surprised while refuelling, while others were abandoned after they ran out of fuel, and the division was destroyed in the same piecemeal fashion as it was employed. The 2nd DCR was wasted by being spread out in small units or even single tanks to guard the crossings of the Oise River. The 3rd DCR was sent to attack the southern flank of Guderian's corps, but instead was dispersed into defensive positions and was then committed piecemeal to the defence of Stonne.[19]

One more DCR, the 4th, was assembled hastily during the course of the campaign, and under the command of Colonel (later General) de Gaulle attacked the advancing panzer divisions from the south, at Montcornet and Laon, and then attacked the German bridgeheads over the Somme near Abbeville, but the attacks only achieved local tactical successes. The bridgeheads had also been attacked, two days earlier, by two brigades of the British 1st Armoured Division, which had just landed in France to protect the right flank of the British Expeditionary Force. The two brigades were sent into action without infantry or artillery support and were repulsed, losing many of their tanks. The only other tanks the BEF had, apart from the Mark VI light tanks of the seven divisional cavalry regiments, were those of the 1st Army Tank Brigade, which consisted of two battalions with a total of 58 Mark I and 16 Mark II (Matilda) infantry tanks. Backed by two battalions of infantry and accompanied by the 3rd DLM, the Tank Brigade struck Rommel's panzer division near Arras, inflicting considerable casualties, and was only brought to a halt by the fire of the divisional artillery and 88mm anti-aircraft guns, as German 37mm anti-tank guns proved ineffective against the thick armour of the Matildas.[20]

The attack at Arras was the largest tank action carried out by the BEF before most of it was evacuated from Dunkirk, together with the troops of the French First and Seventh Armies, after abandoning its remaining tanks. While the evacuation was taking place, the panzer divisions were regrouped, and after the fall of Dunkirk they attacked again, breaking through the defence line set up along the Somme and Aisne rivers by General M. Weygand, who replaced General G. Gamelin as commander-in-chief of the French Army. In an attempt to restore some of its armoured forces, the French Army re-created the three DLM with personnel evacuated via England from Dunkirk and even created two new DLM, the 4th and 7th. After the German breakthrough, tanks of the 7th DLM, as well as remnants of the 3rd DCR, put up a stiff fight in the region of Juniville, but like the other DLM, it had by then only about 20 tanks and could do little to prevent the defeat of the French Army.[21]

After the Armistice was signed on 22 June 1940, some of the cavalry regiments were re-formed in the unoccupied part of France. However, by agreement between the German authorities and the Vichy government, their equipment was confined to a total of 64 Panhard 178 armoured cars, with a reserve of 28, and they had their 25mm guns removed, leaving them armed only with machine guns.[22]

The German armoured forces suffered a total loss of 770 tanks during the campaign in France, excluding command vehicles, most of which – 611 – were destroyed during the first month of the campaign. The armour of PzKpfw III and IV was found to be inadequate and inferior to that of the French tanks, but German tanks increased their survivability by mobile tactics, which reduced their chances of being hit by French guns. The guns of the German tanks, and in particular the 37mm L/45 of PzKpfw III, which was regarded as the principal anti-tank weapon, proved to be inadequate and ineffective against the frontal armour of S 35 and, even more against the B1bis tanks. In the circumstances, the most effective weapon against French tanks was the 75mm L/24 gun of PzKpfw IV, in spite of being short barrelled and having a low muzzle velocity.[23]

The campaign in France led inevitably to demands for a larger calibre gun for PzKpfw III, which were in fact anticipated by the development of a 50mm L/42 gun. According to his memoirs, Guderian wanted such a gun as early as 1932, but at the time the chief of ordnance and the inspector of artillery considered that a 37mm gun would be adequate and would ensure commonality with the infantry's contemporary 37mm anti-tank guns.[24]

In consequence the first PzKpfw III with a 50mm L/42 gun was not produced until July 1940. By then another and considerably more effective 50mm gun, the L/60 with a longer barrel and a higher muzzle velocity, had been developed to replace the 37mm anti-tank gun. Hitler saw it and ordered that PzKpfw III be armed with it. But in April 1941 he found that his order had not been implemented and insisted that it be put into effect immediately, which according to Guderian it could have been and would have placed PzKpfw III ahead of most contemporary tanks.[25] As it was, the first tank with the 50mm L/60 was not produced until December 1941, and tanks with the shorter barrelled 50mm L/42 continued to be produced until 1942. In addition, no decision was taken until November 1941 to produce a more powerful 75mm gun than the L/24 mounted in PzKpfw IV, although the armour-piercing performance of the latter had fallen behind not only that of the 50mm L/60 but also of the 50mm L/42. Yet three different experimental vehicles with a more powerful, long-barrelled 75mm gun were built by Rheinmetall to an order issued by the Ordnance Office in 1934.[26]

Soon after the campaign in France, Hitler ordered that the number of panzer divisions be doubled. As a result ten new panzer divisions were created by the beginning of 1941, but the increase in the number of the divisions was achieved at the expense of the number of tanks in each. Thus, when the reorganization was complete, no panzer division had a tank brigade with two regiments any longer, but had a single regiment with two or three battalions. Each battalion had a medium tank company, generally with 20 but in some cases with 30 or even 36 PzKpfw IV, and two or three light tank companies equipped mainly with PzKpfw IIIs or PzKpfw 38(t)s. In consequence, the strength of the divisions varied from 145 to 265 tanks.[27]

The reorganization was barely completed when six of the panzer divisions spearheaded the invasion of Yugoslavia and Greece in April 1941. Once again they were largely responsible for a rapid victory, which resulted in the surrender of the Yugoslav Army after only 11 days of fighting and of the Greek Army six days later. The cost reported by five of the six divisions amounted to a loss of 56 tanks.[28]

In the meantime the Italian army in Libya threatened to invade Egypt, and the British forces stationed there launched an offensive against it. This involved a battalion of 45 Matilda infantry tanks, which led the assault by an infantry division on a series of fortified camps established by the Italian army after its initial advance. At about the same time the British 7th Armoured Division, which was equipped with a mixture of A.9, A.10 and A.13 cruiser tanks as well as Mark VI light tanks, attacked other objectives. In total the British forces had 275 tanks. The Matildas proved impervious to Italian anti-tank weapons and completely outclassed Italian M 11/39 tanks, 23 of which were knocked out in one of the camps.[29] In the final stages of the offensive, in February 1941, cruiser tanks of the 7th Armoured Division attacked retreating Italian units, which included new M 13/40 tanks. Unlike the M 11/39, these had turret-mounted 47mm guns that were about as good as the 40mm guns of the British cruisers, and their armour was thicker. But they went into action in small packets and by the end of the day 112 had been knocked out or had been abandoned by their crews.[30]

This completed the destruction of the Italian army in Cyrenaica, which prompted Hitler to dispatch to Libya the 5th Light and 15th panzer divisions under the command of General Rommel to bolster the Italian army in Tripolitania. The latter had already been reinforced by the arrival of the Ariete armoured division, which was followed by the German 5th Light Division. The disembarkation of this division in Tripoli was completed a month later, when its tank strength reached 151 tanks, including 61 PzKpfw III and 17 PzKpfw IVs.[31] Then, without waiting for the 15th Panzer Division, Rommel decided to take the offensive and in two weeks drove British forces back to the Egyptian border, destroying their 2nd Armoured Division.

A counter-offensive code-named *Battleaxe* was mounted by the British forces in June 1941 after a convoy brought reinforcements from Britain, which included 135 Matildas and 82 cruiser tanks. Among them for the first time were Crusaders, which were more heavily armoured than the earlier cruisers. The German forces had also been reinforced by the arrival of the 15th Panzer Division, and the counter-offensive was repulsed with the loss of 92 British tanks compared with 12 German tanks. The principal cause of the failure of the British counter-offensive was the institutionalized division of tanks between infantry support and more mobile roles, which led to a dispersal of tank units and their tendency to act by themselves that contrasted with the very effective co-operation of German tanks with anti-tank guns, which included 88mm anti-aircraft guns used in a ground role.

In November 1941 what had become the British Eighth Army launched another offensive under the code name *Crusader*, for which 756 gun-armed tanks had been assembled while 259 more were held in reserve and 231were in two armoured divisions undergoing training. The tanks that were assembled included 336 cruisers, which by then were mostly Crusaders but still included a number of A.13s and even 26 A.10s, and they also included 225 infantry tanks consisting not only of Matildas but also of Valentines.[32]

The Valentine was the last of the British tanks designed before the war, and it differed from the others in not being designed to a War Office specification but in having been originated by Vickers Armstrongs. It was based on the proven chassis of what was originally the A.10 infantry tank but had frontal armour 60 to 65mm thick, which made it second in this respect only to the Matilda and as good as the French B1 tank. Not to overload the chassis, its weight was kept down to 16 tonnes and as a result of this it was provided with a turret for only two men, instead of a three-man turret like other British and German tanks.[33] The War Office objected to the turret but, nevertheless, production of the Valentine was ordered and the first was completed in May 1940, when Britain badly needed tanks. Eventually, 8,275 Valentines were built, including 1,420 built in Canada, and their production exceeded that of any other British tank of the Second World War. Apart from being numerous, Valentine was also more reliable than other contemporary British tanks, which was attributable to it being developed by the only British company with several years' experience in the design and production of tanks.

Like other contemporary British tanks, Valentine was armed with the 40mm 2-pounder, and some time after it was deployed in Libya comments appeared that this gun was inferior to the guns of the German tanks, and, by implication, that it was responsible for the reverses suffered by British tank units. In fact, its armour penetration was slightly greater than that of the 50mm L/42 gun of PzKpfw III as well as being greater than that of the 75mm L/24 of PzKpfw IV.[34] However, the armour-piercing projectiles of German tank guns from the 37mm gun onwards contained an explosive charge with a delay fuse, which made them more deadly when they penetrated armour than the solid shot fired by the 2-pounder and which has been ignored in almost all the accounts of the fighting in North Africa.

Tanks assembled for Operation *Crusader* also included 195 US M3 light tanks. They were the first of the large number of American tanks supplied during the Second World War to the British Army, in which they were called Stuarts after the Confederate cavalry leader of the American Civil War. The design of the M3 or Stuart was somewhat dated and it had a cramped two-man turret, but the armour penetration of its 37mm gun was slightly greater than that of the German 50mm L/42. It was also fast and proved very reliable, thanks to the extensive development work that preceded its production. At the same time its armour protection as well as armament were comparable to those of the British cruisers. It was therefore regarded as a 'light cruiser' and the whole of one British armoured brigade was equipped with it.

When Operation *Crusader* began, the two panzer divisions of what became the Afrika Korps had a total of only 145 PzKpfw III and 38 PzKpfw IVs, while the Italian armoured units had 146 M 13/40s. Nevertheless, they managed to repulse the initial attacks of the British tank units, which were committed in a dispersed and disjointed way that nullified their overall numerical superiority. By comparison, German formations acted in a more coherent fashion and, as before, very effectively combined the action of their tanks with that of the anti-tank guns. However, in the end Rommel's much depleted forces were forced to retreat to the border of Tripolitania. But only two weeks later and having received reinforcements, which brought up its strength to 77 PzKpfw III and ten PzKpfw IVs, Rommel's Afrika Korps went on the offensive and drove British forces back to the Gazala line in Cyrenaica. During the four months' lull that followed, both sides built up their tank strength. On the German side the number of tanks rose to 242 PzKpfw IIIs, including for the first time in Libya 19 Model Js armed with the long-barrelled 50mm L/60 gun, and 38 PzKpfw IVs, while the number of Italian tanks amounted to 230 M 13/40s. On the British side the number of tanks rose to a total of 850, backed by a reserve of about 120 and 300 more held in Egypt.[35] Tanks available to the British forces included for the first time 167 American-built Grants armed with a medium-velocity 75mm gun, which was superior in terms of armour penetration to German tank guns except for the 50mm L/60 to which it was equal, and it fired high explosive as well as armour-piercing projectiles, which enabled British tank units to counter for the first time the threat of anti-tank guns.

The tactical effectiveness of the Grant's 75mm gun was somewhat reduced by it not being mounted in a turret but in the hull and therefore having limited traverse. Grants did have a turret, but this only mounted its secondary armament of a 37mm gun. Because its 75mm gun was mounted in the hull, some Francophile historians have suggested that its design was inspired by the French B1. In fact, it had nothing to do with the latter, having originated in 1939 with an experimental T5E2 version of the contemporary US medium tank, which had a 75mm howitzer mounted in its hull instead of a turret with a 37mm gun.[36] Subsequently T5E2 became the only available basis on which medium tanks with a 75mm gun could be quickly produced when the use of PzKpfw IV armed with a 75mm gun in the 1940 German campaign in France showed that the US Army urgently needed a tank with a similar armament. In consequence, a new M3 medium tank was developed from the T5E2 and was ordered in 1940 not only for the US Army but also, in a modified form, for the British Army, which called its version General Grant while the US version was called General Lee, after the Confederate commander.[37] Prototypes of the M3 medium tank were completed in May 1941 and deliveries from production commenced only two months later. Eventually the total number of the US M3 medium tanks and of the British version that were produced amounted to 6,352.

Whatever their shortcomings, Grants provided the Eighth Army with tanks that were better armed than any it previously had. It also enjoyed, once again, numerical superiority. In spite of all this, when the Afrika Korps attacked the Gazala line the Eighth Army was defeated piecemeal, and having lost most of its tanks had to retreat into Egypt. It was pursued to within 60 miles of Alexandria when it halted the enemy advance by a series of counter-attacks at Alamein, where another battle took place three months later that changed radically the course of the war in North Africa.

In the meantime, on 22 June 1941 the German Army invaded the Soviet Union. The invasion was spearheaded by four panzer groups, each of which consisted of three to five panzer divisions and which between them contained 17 out of the existing 20 divisions. The panzer groups drove deep into Soviet territory and in a series of envelopments inflicted enormous losses on Soviet forces. They were only halted in the winter of 1941 at the gates of Moscow and Leningrad and deep in the Ukraine by a combination of their own exhaustion, Soviet counter-attacks and the weather.

When the invasion began, Soviet armoured forces were in a state of flux. The successes of the German armoured forces in Poland and in France led in July 1940 to a reversal of the earlier decision to disband large mechanized formations. There were now to be eight mechanized corps and in February 1941 Soviet High Command called for 21 more to be formed. Each of the mechanized corps was to consist of two tank and one motorized infantry divisions and to have 1,031 tanks. Each of the tank divisions was to consist of two tank regiments with a total of 375 tanks, one motorized infantry regiment and a battalion each of reconnaissance, anti-tank, anti-aircraft, engineer and signals troops.[38]

The organization of the new formations had hardly settled when the German forces struck. Moreover, the leadership of the Soviet armoured forces had not recovered from the murderous purges of the previous four years. Many of the Soviet tanks were also claimed to be in need of overhauls or at least of spare parts that would enable them to operate for any length of time. But, for all the shortcomings of its armoured forces, the Red Army had a total of 24,000 tanks, according to what Stalin himself told Harry Hopkins, the US president's personal representative.[39] Post-war Soviet accounts put the total at a slightly lower figure of 22,600, but in any event by the end of 1941 the Soviet Army had lost 20,500 of them, which means that during the first phase of the German-Soviet war virtually the whole of the pre-war Soviet tank strength was wiped out.[40]

The 17 panzer divisions that were largely responsible for this remarkable achievement started the campaign with a total of only 3,266 tanks, including command tanks. The most numerous of them were PzKpfw IIIs, 707 of which were now armed with the 50mm L/42 gun, but 259 were still armed with the 37mm tank gun that had already proved inadequate during the campaign in France. There were also 625 PzKpfw 38(t)s and 155 PzKpfw 35(t)s armed with similar Czech-made 37mm guns. The most powerful tank continued to be the PzKpfw IV, which was still armed with the short-barrelled 75mm L/24 gun, but there were only 439 of them.[41]

Most of the Soviet tanks were T-26s and BTs which were armed with 45mm guns that were as good as the German 50mm L/42, but their armour was relatively thin and the vision from their turrets was confined to a single rotatable periscope that limited their commanders' situation awareness, so much so that Finns fighting them a year earlier observed that they appeared to be 'blind'. The situation was aggravated by the design of their two-man turrets in which the commander acted as the gunner, in contrast to other tanks with two-man turrets, like the British Valentine, in which the commander acted as the loader and had therefore a better chance of observing what was going on around him.

German PzKpfw III and IV tanks, with their three-man turrets and a commander free to observe the tactical scene, could therefore outmanoeuvre Soviet tanks, and they proved more than a match for them.

However, on the first day of the invasion some panzer divisions also ran into the Soviet KV and T-34 tanks, which were a complete surprise to them and caused considerable consternation because they proved almost immune to the panzers' guns. Yet the two new Soviet tanks had been in production for more than a year and by the time the Soviet Union was invaded as many as 636 KVs and 1,215 T-34s had been produced.[42] Moreover, Soviet authorities made no particular secret of the existence of the T-34, as a month before the invasion they allowed a well-known American photographer, Margaret Burke-White, to visit a tank school outside Moscow and take pictures of the T-34 that were then published in the United States in the widely read *Life* magazine.

However, in spite of being a nasty surprise to the panzer divisions and superior to their tanks in terms of armour protection as well as gun power, the deployment by the Red Army of the KV and T-34 had no effect on the overall course of the campaign. This fact was obscured for a number of years by contemporary Soviet propaganda, which falsely claimed that the T-34 was only deployed when the German forces were approaching Moscow and that it was responsible for them being driven back.

The appearance of the T-34 inevitably led to demands by German tankmen for new and more powerful tanks, and consequently a special commission consisting of the leading German tank designers visited Guderian's panzer group in November 1941 to assess the situation at first hand. Soon afterwards contracts were awarded to the Daimler Benz and MAN companies, which had done some studies since 1938 of a 20-tonne tank, for the development of a new 30-tonne tank armed with a very long barrelled 75mm L/70 gun. In May 1942 Hitler opted for the MAN design, and after trials of prototypes the first two production vehicles were completed in January 1943.[43]

The new tank, which was called Panther, outgunned the Soviet T-34 and had thicker armour. It was also larger, having a five-man crew, and as a result of this and its thicker armour it was also heavier, weighing 43 tonnes. In spite of this, it performed well over soft ground due to its wide tracks and a suspension with interleaved road wheels that spread the load over the earth, and its design scored well from the point of view of what was later called 'fightability'. In fact, it came to be widely regarded as the best medium tank of the Second World War, although it suffered at first from mechanical problems due to its hurried development.

Production of the Panther was preceded by that of another powerful German tank, the 570-tonne Tiger armed with an 88mm L/56 gun. The development of this heavy tank was not begun, as is sometimes claimed, in response to the appearance of the T-34, but can be traced as far back as 1935 when the Ordnance Department first considered a 30-tonne tank armed with a 75mm gun that would be effective against French 2C, 3C and D heavy tanks.[44] This was not a well-informed objective as 2C was already obsolete and 3C and D heavy tanks never existed, but in 1937 the Henschel company was asked to design a 30-tonne DW or breakthrough tank. By 1940 a 30-tonne tank was also designed by Ferdinand Porsche and in 1941 Krupp was awarded a contract for the development of a turret mounting a tank version of the 88mm L/56 anti-aircraft gun that had proved so effective in a ground role in Spain and in France. This was followed a month before the invasion of the Soviet Union by an order issued to Porsche and to Henschel to develop a tank in the 45 tonne class, which they did on the basis of their earlier 30-tonne tank designs. Porsche, who was apt to adopt novel but not always very practical ideas, produced a tank that had problems with its electric transmission and novel suspension and this led to Henschel's tank being selected and produced as the Tiger.

As soon as they were ready, Hitler foolishly ordered four Tigers to be used on the Leningrad front, where they first saw action in October 1942. They were employed over unsuitable swampy terrain and one had to be abandoned in a peat bog from which it was recovered intact in January 1943 by the Russians, who were consequently not only forewarned of the existence of the new tank but were able to assess its characteristics in detail.[45] In spite of this inauspicious debut, Tiger I or Model E became for a time the most powerfully armed tank in the world as well as having thicker armour than the British Matilda and the Soviet KV, and the 1,354 that were produced took a heavy toll of enemy tanks.

While the production of Tiger I and of the Panther was getting under way, a more immediate answer to the new Soviet tanks was found in PzKpfw IV re-armed with a long-barrelled 75mm L/43 gun instead of its original 75mm L/24. As a result PzKpfw IV not only caught up with Soviet tanks, which were re-armed two years earlier with a 76mm gun, 41.5 instead of 30.5 calibres long, but outperformed them. The first of the re-armed PzKpfw IV was produced in March 1942 and it remained effective until the end of the war, by which time 7,419 had been produced.

When the decision was taken in November 1941 to arm PzKpfw IV with the 75mm L/43 Hitler decided that the *Sturmgeschutz* or assault guns should also be armed with it. *Sturmgeschutz*, or StuG for short, were originally developed as a result of the acceptance by the German High Command of the policy advocated before the war by General Lutz and Guderian of concentrating all the available tanks in mobile formations and not allocating any to infantry support. This led the infantry to demand an armoured vehicle that could provide it with close support assault and anti-tank artillery. An order was consequently issued in 1936 for the development of such a vehicle and the first was produced in 1940. It was based on the chassis of the PzKpfw III and was armed with the same 75mm L/24 gun as the PzKpfw IV but mounted in the hull.

StuG was in effect a 'turretless tank'. Because it had no turret, it had a lower silhouette and thicker armour in relation to its weight, as well as being cheaper to produce than a tank. It was less suitable for mobile warfare because of the limited traverse of its armament, but when armed with the 75mm L/43 it proved to be a highly effective anti-tank vehicle, so much so that it was credited with the destruction of 20,000 enemy tanks by 1944.[46] On the eve of the invasion of the Soviet Union the German Army had 391 StuGs, and subsequently their number rose steadily. By the end of the war, a total of 9,409 had been produced and in spite of losses there were still 3,831 in use, making StuG the most numerous German armoured fighting vehicle at the time. Except when there was a shortage of tanks in the latter part of the war, StuG were not issued to the panzer regiments but were organized into separate battalions, which were used primarily to support infantry divisions.

When StuG and PzKpfw IV, armed with the 75mm L/43 and later L/48, began to be introduced in the spring of 1942 and were followed by the first Tigers and then by Panthers, the German Army reversed the situation in which it found itself when it invaded the Soviet Union and ran into the new

Soviet tanks. It now possessed qualitative superiority that was to last until the end of the war.

In contrast, the Red Army did not for a time make any major changes to the tanks it had already developed, but concentrated on producing the maximum number of them to make good the losses suffered in 1941 and to regain numerical superiority. The continued production of a virtually unchanged T-34 is particularly noteworthy in view of the recognition of its shortcomings, which were brought home by the evaluation of two PzKpfw III purchased in the summer of 1940 when the relations between the Soviet Union and Germany were still amicable. Compared with the PzKpfw III, the T-34 had superior armour and armament, but its cramped two-man turret was obviously inferior to the three man turret of the German tank and it lacked the latter's commander's cupola, which provided good all-round vision. The torsion bar suspension of the PzKpfw III was also found to be superior to the Christie-type coil spring suspension of the T-34.[47] As a result, a new T-34M tank was hastily designed incorporating a three-man turret and torsion bar suspension. Two prototypes began to be assembled in March 1941, but three months later the Soviet Union was invaded and further development of the T-34M, which is seldom mentioned in all the writing about the T-34, was abandoned.[48]

Large scale production of the T-34 continued, although it suffered a temporary setback when the Kharkov plant where it originated was threatened by the German advance and a decision was taken in September 1941 to evacuate it as well as other plants, including the Leningrad plant producing KV heavy tanks, to the Urals. For a time this left the Stalingrad plant as the only major producer of T-34s, but a most remarkable industrial effort resulted in the first T-34 being produced in the Urals as early as December 1941.[49]

In spite of the temporary interruption of tank production and the staggering losses suffered during the first six months of the war, the Red Army had 7,700 tanks at the end of 1941.[50] This compared well with the total of 5,004 tanks that the German Army had at the time. Some of the Soviet tanks were in the Far East facing a possible Japanese threat while some of the German tanks were being sent to North Africa, but nevertheless the Red Army continued to enjoy considerable numerical superiority over the German Army. This became much more marked during 1942 when Soviet industry produced a total of 24,668 tanks, including 12,527 T-34s. As a result of this and in spite of further heavy losses, by the end of the year the Red Army had 20,600 tanks, whereas the German had only increased the number of its tanks to 5,931, although it had also increased the number of StuGs to 1,039.[51] During 1943 the Red Army lost almost the equal of that year's output of 24,000 tanks and assault guns, which included 15,833 T-34s. But in the following year production exceeded losses, and by the end of it the number of tanks and assault guns the Red Army had rose to 35,400. The number the German Army had also increased, but only to 12,451, and by then its panzers were facing not only Soviet tanks but also thousands of American and British tanks in Western Europe.

Their numerical inferiority did not prevent German armoured forces destroying more Soviet formations when these counter-attacked around Kharkov in May 1942 and later at Rzhev. But when they took part in the German offensive in June, Hitler split them between an assault on the industrial city of Stalingrad and an equally misguided drive aimed at the Caucasus oilfields, which overstretched their resources. This helped the Red Army to break through the German front in November 1942 and led to the encirclement of Stalingrad, where the remnants of the Sixth Army, including three panzer divisions, surrendered in January 1943. However, a month later panzer formations under the command of Field Marshal E. von Manstein smashed another Soviet offensive in the Donets basin and at Kharkov in what became a classic example of manoeuvre warfare.

The German High Command then conceived the idea of an offensive code-named *Zitadelle* against a Russian salient around Kursk, which was to use the revitalized panzer formations to destroy a large number of Soviet divisions and thereby weaken the offensive capabilities of the Red Army. Guderian and other generals objected to it and even Hilter had qualms about it, but the offensive went ahead in July 1943.[52] Seventeen panzer divisions were assembled for it with a total of about 2,450 tanks and assault guns.[53] They included 133 Tigers[54] and 184 brand new Panthers.[55] But the offensive took little advantage of the mobile warfare skills of the panzer forces. Instead, they were made to assault where the Red Army expected them and where it had prepared extensive minefields and other defences backed by about 2,950 tanks.[56] In consequence they became involved in a battle of attrition and failed to achieve the planned encirclement of the Soviet forces, although they inflicted heavy losses on them.

Particularly intensive fighting took place near the railway junction of Prokhorovka, which has been described since as the greatest tank battle. In fact, it was a meeting engagement between the 2nd SS Panzer Corps, which had 294 tanks and assault guns including 14 Tigers, and the reinforced 5th Guards Tank Army, which had about 850 tanks. The latter were mainly T-34s but included 260 T-60 light tanks, which were easy targets for German guns, while the T-34s were completely outranged by the Tigers and consequently charged to close with them.[57] In spite of this, by the end of the day the 5th Guards Tank Army had lost as many as 600 of its tanks, 334 of which were completely destroyed, while the SS Corps suffered a total loss of only 36 tanks and assault guns.[58] These figures refute the description in some books of the Battle of Prokhorovka as a 'death ride' of the panzer divisions.[59] In fact, over the whole of the Kursk salient the German Army lost 278 tanks and assault guns, including 13 Tigers and 44 Panthers, compared with a total loss of 1,254 tanks suffered by the Red Army.[60]

However, German offensive operations were stopped after the Battle of Prokhorovka by Hitler, who became concerned about the Anglo-American landings in Sicily that had just taken place, and decided to withdraw the SS Panzer Corps so that it could be transferred to the West. The remaining panzer formations retained their qualitative superiority and the ability to score tactical successes and to inflict heavy losses on their enemies. But *Zitadelle* was their last major offensive on the Eastern Front. In its aftermath strategic initiative passed into the hands of the Red Army, which became increasingly proficient at the offensive operations that came to dominate the latter part of the war in Eastern and Central Europe.

At the beginning of the war, the Red Army had 30 of the mechanized corps it started creating in 1940, but most of them were quickly destroyed and in July 1941 they were officially abolished.[61] Instead the remaining tank units were reorganized into independent brigades that were confined to close support of the infantry. Each brigade had 46 to 93 tanks made up of a mixture of KVs, T-34s and whatever light tanks were available. But as the Red Army began to regain its strength, it re-created four tank corps in March 1942. Initially each had two tank and one motorized infantry brigades, but a third tank brigade was added later, which brought their strength up to 98 T-34s and 70 light tanks.[62] At the same time they dispensed with the KVs, which were not mobile enough for them and which were organized into independent tank regiments that would be used for infantry support.

By the end of 1942 the Red Army already had 28 tank corps. It had also created eight mechanized corps, each of which had one tank brigade and three mechanized brigades consisting of three motorized infantry battalions and a tank regiment, and each had a total of 100 T-34s and 104 other tanks.[63] The tank and the mechanized corps were well designed for mobile operations of limited scope, but for larger scale penetrations of the enemy front and encirclement several would have to be combined, which led to the creation in May 1942 of the first two tank armies that corresponded to the German panzer corps, just as the Soviet tank corps corresponded to the panzer divisions.

The reorganization of the Soviet armoured forces did not prevent their defeat in the Battle of Kharkov in May 1942, but they played a major role in the encirclement of Stalingrad and after the Battle of Kursk they led the offensives that restored Soviet control over Ukraine, Belarus and the Baltic states. During this period new types of armoured vehicles came into use, starting in 1943 with the SU-122, a 'turretless tank' on the lines of the German assault guns, which consisted of a 122mm howitzer mounted in the hull of the T-34. It was relatively ineffective and was quickly superseded by the SU-85, which was very similar except for being armed with a long-barrelled 85mm gun. Adoption of the 85mm gun was prompted by firing tests carried out with the Tiger captured on the Leningrad front, which brought out the need for a more powerful weapon than the 76mm guns of the contemporary Soviet tanks to defeat its 100mm thick frontal armour. About 2,050 SU-85s were produced by the autumn of 1944 when the SU-85 was succeeded by the SU-100, which was similar except for being armed with a long-barrelled 100mm gun. The gun of the SU-100 was an adaptation of a naval gun, just as the 85mm gun of SU-85 was an adaptation of an anti-aircraft gun, which speeded up its development and facilitated the production of about 1,200 by the end of the war.[64] The guns of SU-85 and SU-100 made them effective as tank destroyers, and the T-34 chassis on which they were based provided them with the mobility required for operation with armoured forces.

Before SU-85 and SU-100 were developed, a small number of another turretless assault gun was used at the Battle of Kursk. This was the 45.5-tonne SU-152, which represented the second and much more sensible attempt to mount a 152mm howitzer on the KV tank chassis than the first, which involved mounting it in a huge turret. The resulting KV II was used in 1940 in the assault on Finnish defences, but proved unsuitable for more mobile warfare and disappeared shortly after the German invasion in 1941.

New types of tanks were also developed during 1943. One of them was the new version of the T-34 armed with an 85mm gun mounted in a three-man turret, the first of which was issued to Soviet tank units in March 1944.[65] It was still inferior to the German Panther so far as its gun performance and frontal armour were concerned, but it outnumbered the latter, 18,000 having been produced by the end of the war compared with 5,966 Panthers, not all of which were of course available for the Eastern Front. New heavy tanks were also developed, first by re-arming the KV with the same 85mm gun as that originally mounted in the SU-85 to produce the KV-85, of which only 130 were built in 1943. It was followed by Iosef Stalin, or IS, which had a more heavily armoured KV chassis and dispensed with the fifth crew member, who was the hull machine gunner. IS-1 was armed with an 85mm gun but IS-2 was armed with a 122mm gun.[66] The gun was once again an adaptation, in this case of an artillery gun, and with it the 46-tonne IS-2 matched the Panther and the Tiger in gun power, but its rate of fire was slow and it only carried 28 rounds of ammunition. IS-2 began to be produced by the end of 1943 and to be issued in the spring of the following year to independent heavy tank regiments, which were used to support medium tanks by their fire.

To counter IS-2, the German Army had the 68-tonne Tiger II, as well as the turretless Jagdpanther armed with a 88mm L/71 gun that was longer barrelled and more powerful than the 88mm L/56 gun of Tiger I. Eventually 489 Tiger IIs were built, but they were completely outnumbered by IS-2, the production of which amounted to 3,207 tanks by the end of the war.[67] The German Army also had the Jagdtiger armed with a long barrelled 128mm gun, the first of which was built in October 1943 but whose production was disrupted by air raids, so that only five were in the hands of the troops in June 1944. The 70 tonne Jagdtiger was the most powerfully armed and the most heavily armoured vehicle of the Second World War, having 250mm thick frontal armour, but only 77 were built.[68]

The Red Army made full use of its numerical superiority by launching simultaneous offensives along different parts of the Eastern Front and destroying separately parts of the German Army. In this it was helped by Hitler's disastrous strategy, which required German forces to hold on to their positions instead of being allowed to operate more freely. In particular they were expected to hold on to cities and towns designated *Feste Platze*, or fortresses, which were to break the momentum of the Soviet onslaught.

What this did instead was to split German forces between isolated strong points in which they could be more easily encircled and destroyed piecemeal.[69] These methods contributed, among others, to the destruction of the Army Group Centre in June 1944 in Belarus, which came to be regarded as an even greater catastrophe for the German Army than Stalingrad.

The offensives of the Red Army brought it in April 1945 to the gates of Berlin, which it stormed, delivering a *coup de grâce* to Hitler's Reich. The forces that assaulted Berlin included four tank armies and a total of 6,250 tanks and assault guns. Determined resistance in urban terrain far less suitable for the operation of armoured forces than the plains of Eastern Europe exacted a heavy toll on the Soviet armoured units, which lost 1,997 tanks and assault guns, more than the 1,519 the German defenders had when the assault on Berlin began.[70]

As they were being overwhelmed on the Eastern Front, German forces were also gradually overcome in the west. The process began at the Second Battle of Alamein in October 1942, when the British Eighth Army commanded by General B. Montgomery attacked the German and Italian forces that had advanced into Egypt. The latter included two panzer divisions with a total by then of 211 PzKpfw IIIs and IVs and two Italian armoured divisions with 280 M 13/40s. The Eighth Army facing them had three armoured divisions, two of which were reinforced by the attachment of a second armoured brigade, and two independent armoured brigades. In total, therefore, it had seven armoured brigades and 1,441 tanks backed by a reserve of 1,230 tanks held in Egypt in depots, workshops and training units.[71] The disparity in the resources was therefore considerable and even greater than these figures would indicate because, of the German tanks, only 30 were PzKpfw IV armed with the long barrelled 75mm L/43 gun, whereas tanks deployed by the Eighth Army included not only 170 Grants but also 252 newly arrived US-built M4 medium tanks, which the British Army called Shermans.

Shermans were armed with 75mm guns that were somewhat better at penetrating armour than the 75mm guns of the Grants, although not as good in this respect as the 75mm L/43 guns of PzKpfw IV. However, unlike the hull-mounted guns of the Grants, those of the Shermans were mounted in turrets, which made them tactically more effective, and they also fired high explosive as well as armour-piercing ammunition unlike British-built tanks, most of which were still armed with 40mm 2-pounders that only fired solid shot.

Taking advantage of its newly received tanks and its numerical superiority, the Eighth Army wore down the tank strength of the German and Italian forces in a series of attacks that on the 13th day of the battle forced them to retreat, at which stage they were left with ten German and no Italian tanks.

The M4 medium tank, or Sherman, which the British Army first used at Alamein was developed as a result of decisions taken by the US Army as early as August 1940, even before the M3 medium tank and its British Grant version were designed, to follow them as soon as possible with a tank also armed with the 75mm gun but mounted in a turret. Not to delay production, the M4 used basically the same chassis as the M3 medium tank while its general configuration followed that of PzKpfw IV. A pilot model was completed in September 1941 with series production beginning in February 1942.[72] Apart from light tanks, the M4 became almost the only tank used by the US Army up to the end of the Second World War, by which time a total of 49,234 were produced.[73] It also became the principal tank of the British Army.

The Sherman was used to an increasing extent by the British Army after the Battle of Alamein not because there was a shortage of British tanks but because of their shortcomings. In fact, the number of tanks produced in Britain in 1940 was the same as that produced in Germany and in 1941 it overtook the latter, producing 4,811 compared with 3,114. Even more were produced in Britain in 1942 when the annual output rose to 8,611 tanks, which was more than twice the number produced in that year in Germany.[74]

Unfortunately, much of the considerable British production effort was misdirected or even wasted. The extreme example of this is the Covenanter cruiser tanks, 1,365 of which were produced but none of which was considered fit for battle.

The failings of the Covenanter were due to a considerable extent to the company responsible for it having little experience of tank design. A similar situation existed in the case of other tanks, such as the A.13 and Crusader cruiser tanks, which acquired a reputation for unreliability when used in North Africa. Some of the problems were aggravated by the way in which tanks like the Covenanter and Crusader were rushed into production, and these persisted because rectifying them would have interfered with the production of the maximum number of tanks that was demanded after the defeat of France in 1940, when the British Expeditionary Force lost about 700 tanks. The perceived shortage of tanks that drove the demand for the production of the largest possible number of tanks was exaggerated by

Churchill, who stated two years later in the House of Commons that 'we had … in the United Kingdom less than 100 tanks'.[75] In fact, production records that have come to light since then indicate that in spite of the tanks lost in France and some 300 sent to the British forces in Egypt, there must have been still at least 700 tanks in Britain.[76]

There was also a perception that British tanks were outgunned by German tanks. Actually, the 40mm 2-pounder gun of the British tanks could perforate thicker armour than the 37mm and 50mm L/42 guns of most German tanks, and it was only the long-barrelled 50mm L/60 introduced in 1942 that was superior to it. Where the British tanks were consistently deficient was in not having a gun capable of firing effective high explosive as well as armour-piercing ammunition, like the 75mm gun of the PzKpfw IV even in its original short-barrelled L/24 form. When the British tanks finally advanced beyond the 40mm gun, they went no further than the 57mm 6-pounder with which the Crusader was re-armed in 1942. The 6-pounder was a very effective anti-tank gun, as good in fact in this respect as the long-barrelled 75mm L/48 gun of the PzKpfw IV, but as a high explosive firing weapon it has been described as 'useless'.[77] Thus it was only with the arrival in 1942 of the American-built Grants and then of Shermans armed with 75mm guns that British armoured units were equipped with tanks capable of firing not only armour piercing but also effective high explosive ammunition.

Yet in 1943 and even in 1944 the General Staff and the War Office were unable or unwilling to accept that both types of fire should and could be delivered by every tank. They accepted, rather reluctantly, that some British tanks might be armed with 'dual purpose' guns, but expected that others would specialize in one or the other of the two functions.[78] This would have perpetuated the specialization that bedevilled British tank development, manifesting itself in the division into infantry and cruiser tanks and the arming of tanks with the 40mm 2-pounder whose ammunition was only effective against other tanks. It was only during the last two years of the war that this tendency to over-specialize began to fade away.

In the meantime, the Eighth Army chased what was left of the Afrika Korps out of Egypt and pursued it across Cyrenaica into Tripolitania, where it was reinforced by the remaining Italian armoured division, the Centauro. However, the latter was still only equipped with M 13/40s or the very similar M 14/41 tanks, which were by then completely outgunned by tanks like the Sherman. After some delaying actions, the German and

Italian forces retreated into Tunisia until they reached the Mareth Line of fortifications built before the Second World War by the French against an Italian invasion from Libya.

Two months earlier, in November 1942, Anglo-American forces landed on the Moroccan and Algerian coasts of what was then French North Africa and after overcoming some French resistance advanced on Tunisia. The German High Command reacted by landing a panzer division as well as other troops, including some Tiger tanks, in Tunisia. Having built up their strength, the German forces in Tunisia severely mauled the US 1st Armoured Division that had advanced from the west to the Kasserine Pass, destroying more than one hundred of its tanks, which included Lees, the US equivalent of the British Grants, as well as Shermans.[79] They then turned against the British Eighth Army but were repulsed at Medenine. The Eighth Army subsequently stormed the Mareth Line, in which Valentine tanks played a prominent part, but after one more major action in Tunisia units equipped with them were provided instead with Shermans. The Crusaders, with which the British 6th Armoured Division was partly equipped when it landed in Algeria, were also replaced at the time by Shermans.

Towards the end of the campaign in Tunisia, which ended with the surrender of the German and Italian forces in May 1943, British forces were reinforced by two brigades, or about 300 Churchill infantry tanks. These 39-tonne tanks were designed during the ‘Phoney War’ that preceded the fall of France in 1940, when tanks were expected to have to operate over shell-torn ground similar to that encountered during the First World War. They were relatively slow but better armoured than the Matilda infantry tanks. However, in spite of their weight, they were originally only armed with 40mm 2-pounders, although the Mark I version also had a 3in (76.2mm) howitzer mounted in place of the hull machine gun. But before they were deployed in Tunisia they were re-armed with the 57mm 6-pounders, which, together with their ability to operate over difficult ground, made them effective in the close mountainous terrain in which the Tunisian campaign was fought. On the other hand, the 52 Tigers that were sent by the German High Command to Tunisia were misused there when they could have been better employed on the Russian Front, where the open country made their 88mm guns much more effective.[80]

After their victory in Tunisia, Anglo-American forces invaded Sicily and then advanced slowly up the Italian peninsula, where the terrain generally restricted movement off the roads. The scale of tank operations was therefore limited, and they commonly consisted of small scale actions in close support of the infantry. By the same token, the incidence of tank versus tank fighting was low, although Allied forces included a considerable number of armoured units. These included an armoured division and eight separate tank battalions in the case of the US Fifth Army and, eventually, three armoured divisions and two independent tank brigades in the case of the British Eighth Army. The opposing German forces included, at different times, one or two panzer divisions and an independent heavy tank battalion with up to 45 Tigers, as well as another battalion equipped with 76 Panthers that first went into action against the Allied landing at Anzio in February 1944.[81, 82]

All the British as well as US tank units in Italy were equipped with Shermans, except for a number of US-built M5 light tanks, which were a direct development of the earlier M3 light tanks, and the Churchill infantry tanks of the two British independent tank brigades. The same types of tanks were used by the Allied forces that landed in Normandy in June 1944, except for some British armoured units that were equipped with a new type of cruiser tank, the 27.5-tonne Cromwell, instead of Shermans.

Development that led to the Cromwell started in 1941 with the design of the very similar Cavalier and then Centaur cruiser tanks. Both were intended to be more heavily armoured successors of the Crusader, but were powered by the same Nuffield Liberty engine as the latter and were armed with the same 57mm 6-pounder as Crusader III. However, Centaur was subsequently fitted with a more powerful 600hp Meteor engine, which was a de-rated unsupercharged version of the Rolls-Royce Merlin aircraft engine that powered the Hurricane and Spitfire fighter aircraft of the Royal Air Force, and this, together with the Merritt-Brown transmission proven in Churchill tanks, converted it into the Cromwell and enabled the latter to overcome the reputation for unreliability acquired by British tanks. Except for its early versions, which were still armed with the 6-pounder, Cromwell was armed with a 75mm gun that fired the same ammunition as the 75mm gun of the Shermans.

In several respects Cromwell represented a considerable advance on earlier British tanks. However, so far as its principal characteristics – its gun and its armour – were concerned, it was no better than the Soviet T-34 that had been introduced three years earlier. When the writer brought this out some years later, the originator of the British cruiser tank development, General Martel, took exception to it and ignoring the facts claimed that the T-34 was 'far inferior to the Cromwell'.[83] The Russians did not think so, for when they were offered Cromwells in 1943 under the military assistance programme they turned them down.[84] Instead they asked for more Valentines, which the Red Army was using as light tanks. A total of 2,394 of them was sent from Britain to the Soviet Union in addition to all but 30 of the 1,420 Valentines produced in Canada, although about 300 were sunk *en route* in Arctic convoys.

Like the Shermans, Cromwells were outgunned by the German tanks, but a more immediate problem facing British and US armies was that of landing on heavily defended beaches and then breaking through the coastal defences. This called for tanks that could be launched from ships and swim ashore, a capability foreshadowed in 1924 during a US Marine Corps exercise when an armoured amphibious vehicle built by J. W. Christie swam from a battleship to a Puerto Rican beach.[85] In 1931 Vickers Armstrongs built two prototypes of the first successful amphibious light tanks, the A4E11 and A4E12, which were copied in the Soviet Union as the T-37 and T-38 and about 4,000 of which were produced for the Red Army between 1933 and 1939.[86] But they were small 3-tonne two-man tanks armed with a single machine gun that could only swim in calm inland waters. Heavier tanks could not be made to float except by attaching large pontoons to them, which was not very practicable, until an ingenious system was devised in Britain by N. Straussler, a Hungarian engineer who had previously designed armoured cars for the Royal Air Force and for the Netherlands East Indies Army.

Straussler's system involved the use of a canvas floatation screen that, when erected, provided the necessary buoyancy and when collapsed enabled a tank to operate in the usual way. In water a tank could propel itself at up to 6mph by means of two propellers driven by its tracks, which came to be called 'Duplex Drive' or DD, by which tanks fitted with the floatation system are generally known. The first to be modified into a DD tank was a 7.5-tonne Tetrarch light tank, which was tested in 1941. It was followed by the conversion into DD tanks of some 600 Valentines, which were only used by the British Army for trials and training, and then by the heavier 30-tonne Shermans, which in their DD form equipped three US as well as three British and two Canadian battalions or regiments that were earmarked for the assault landings in Normandy. In the event, four out of the eight units did not swim ashore but, because of rough seas, were taken directly on to the beaches by the landing craft. The fortunes of the other four units varied considerably: one of the US battalions, on Utah beach, landed all but one of the 30 tanks launched into the sea from landing craft, but of the 29 tanks launched by another US battalion 27 sank well short of the Omaha beach they were to assault.[87]

The British, but not the US, Army also made considerable use of tanks modified to perform special tasks, and together with the DD tanks they formed the 79th Armoured Division. Its units included three regiments of Shermans fitted with mine-detonating flails, which were called Crabs, and three regiments of Assault Vehicles Royal Engineers, or AVREs, which were Churchill tanks re-armed with spigot mortars that fired large demolition charges. AVREs were also made to carry fascines, or large bundles of brushwood, which were used as in the First World War to fill trenches for crossing them, and they also carried assault bridges and rolls of hessian carpet that were unrolled over patches of soft ground that was difficult for vehicles to cross.

Tanks of the 79th Armoured Division, which led the assault in the British sector, won the fire fight on the beaches and enabled the infantry to follow on to their objectives at relatively low cost. An exception to this were three battalions of searchlight tanks, code-named Canal Defence Lights or CDL, which played no effective part in the Normandy campaign. Development of searchlight tanks began well before the Second World War and they were originally expected to dazzle the enemy, or to 'attack by illumination' as General Fuller described it, arguing, somewhat naively, that they were a means of winning wars.[88] In fact, they were only used once or twice in the closing stages of the war for night illumination. Much the same applied to the CDL tanks of the US Army, which followed the British example and raised six battalions of them. But development of the CDL tanks proved to be a fiasco and the resources devoted to them would have been better spent elsewhere.

Once they created a bridgehead in Normandy the Anglo-American forces faced the reaction of the German forces and in particular of the panzer formations stationed in France. The latter had a total of 1,673 tanks and assault guns made up of 758 PzKpfw IVs, 655 Panthers, 102 Tigers and 158 StuGs.[89] All outgunned British and US tanks, except for some Shermans armed with the British 76mm 17-pounder that outranged the 75mm L/48 gun of the PzKpfw IV and was comparable to the 75mm L/70 gun of the Panther.[90] However, German tanks were deprived of some of their advantage by the hedgerows of the Normandy *bocage*, which restricted the range at which targets could be engaged. The overall effectiveness of the panzer formations was also reduced by their piecemeal deployment and by Hitler's irrational operational orders.

Nevertheless, panzer formations inflicted severe losses on the Allied forces and checked a thrust out of the bridgehead, called Operation *Goodwood*, by three British armoured divisions with a total of about 700 tanks. But in the end they succumbed to the superior numbers of Allied tanks, backed by massive aerial bombardment. In the US sector, five armoured divisions with a total of about 1,500 tanks broke through at St Lô, while on their left the British Second Army attacked with three armoured divisions and two armoured brigades, or more than one thousand tanks, and a week later the First Canadian Army attacked with two more armoured divisions and two armoured brigades. In the meantime Hitler issued an order for a counter-offensive against the flank of the American advance, which proved disastrous as it exposed the attacking German forces to envelopment and led to them being trapped in the Falaise Pocket. Many of the German troops managed to escape, but most of their equipment was lost. More of what was left was subsequently lost when the remnants of seven panzer divisions retreated across the Seine under aerial attack, so that they were only able to bring out about 100 or 120 tanks.[91]

The 11 or 12 Allied armoured divisions that broke out of the Normandy bridgehead and then advanced rapidly across France to the Belgian and German borders were all equipped with Sherman and M5 light tanks, except for the British 7th Armoured Division, which was equipped almost entirely with Cromwells, and two other British and one Polish armoured divisions, which had one regiment of Cromwells in addition to three regiments of Shermans. Both Shermans and Cromwells were armed with 75mm guns that could not perforate the frontal armour of the German Panthers and Tigers even at point blank range, while the latter could perforate theirs at 2km. To some extent Allied tanks were able to redress the balance by exploiting their numerical superiority and mobility to attack the more vulnerable sides of the German tanks. But qualitatively German tanks were superior.

The need for a more powerfully armed British tank had been recognized two years earlier and led to the development of the Challenger armed with the 76mm 17-pounder anti-tank gun. The new tank was, in effect, a lengthened Cromwell with a large, clumsy turret and did not prove entirely satisfactory. Nevertheless, 200 were ordered in 1943 and some were later used by the Cromwell equipped regiments as 'tank killers'. In the meantime it was found that the 17-pounder could be squeezed into the turret of the Shermans, and this proved to be a better way of using it. In consequence, employment of the 17-pounder was concentrated on the Shermans and tanks re-armed with it, called Fireflies, were issued to British tank units on the scale of one 17-pounder tank to three 75mm gun tanks. Initially only 84 were actually deployed and by the end of the second month there were still only 235 of them in the field.[92] However, by the end of the war the British 21st Army Group had 1,235 Shermans with 17-pounders compared with 1,915 others still armed with 75mm guns, and they provided it with tanks which were at last as well armed as the Panther.[93]

The 17-pounder was made even more effective by the introduction towards the end of the campaign of Armour Piercing Discarding Sabot (APDS) ammunition with projectiles consisting of a hard high-density tungsten carbide sub-calibre shot within a pot-like aluminium carrier or sabot that separated from the shot at the muzzle. In spite of the loss of some of the kinetic energy imparted to the projectile by the gun to the sabot, most of it was still in the shot, which because of its smaller cross-sectional area penetrated more of the target than a conventional full calibre projectile.

Tungsten-cored ammunition was actually provided for the 37mm guns of German tanks as early as the 1940 campaign in France, but in their case the carrier did not separate from the shot and the velocity and penetration of the latter fell off rapidly with range. This type of ammunition was called Armour Piercing Composite Rigid (APCR), and after 1940 was used by German tank guns on the Eastern Front and in North Africa, but on a limited scale because of shortages of tungsten.

APDS ammunition was superior to APCR because its performance did not fall off as rapidly with range. It was first provided in Normandy for the 57mm 6-pounders that were still mounted in some of the Churchill tanks. However, most Churchills were by then armed with 75mm guns so this had little impact on the situation. It was only when APDS began to be provided for the 17-pounders of the Fireflies that its effectiveness began to tell. In fact, its armour penetration was 40 per cent greater at 1,000m than that of the conventional APCBC (Armour Piercing, Capped, Ballistically Capped) ammunition, although its dispersion and therefore loss of accuracy limited the range at which it could be effectively used.

For all this, the re-arming of the Shermans with the 17-pounder was only a makeshift solution that was adopted pending the development of a new and equally well-armed tank. Challenger failed to become one and before another attempt was made to develop it the General Staff opted for another stopgap, which was a derivative of the Cromwell armed with a new lower powered version of the 17-pounder called the Comet. Four regiments were equipped with it and it saw some action in the closing stages of the war. In the meantime, in May 1944, a decision was finally taken to develop another cruiser armed with the 17-pounder. Six prototypes of this 42-tonne tank called the Centurion were rushed to Germany in May 1945, which was too late for them to see any action, but the Centurion became one of the most successful British tanks ever built.

At about the time the Challenger began to be developed in Britain in 1942, US Ordnance also saw the need for tanks to be armed with a gun more powerful than the 75mm gun of the Shermans and started to develop such a gun. This led to a 76mm gun with a higher muzzle velocity and therefore greater armour penetration, but its adoption was not pursued with any urgency largely because the Army Ground Forces commanded by General L. J. McNair, which controlled the acquisition of equipment, regarded armoured forces as no more than a reincarnation of the 19th century cavalry that should be used for exploiting the successes won by other arms and not to fight enemy armoured forces. Tanks were not to be armed therefore to fight other tanks, which were to be fought instead by units of tank destroyers, such as the M10, which had a more powerful 3in. gun mounted in open-top turrets on less heavily armoured M4 medium tank chassis. The tank destroyers were much favoured by General McNair, and his views on the limited, exploitation role of tank units were shared on the eve of the landings in Normandy by some of the senior US Army commanders, including General G. Patton, who considered the 75mm gun-armed M4 tanks entirely adequate for the exploitation role.[94]

It was eventually agreed that one third of the M4s should be armed with 76mm instead of 75mm guns, but the first of the 76mm gun tanks were only produced five months before the landings in Normandy and none took part in them. However, once US armoured units came up against German tanks, it became obvious that tanks had to be able to fight other tanks and there was an urgent demand for tanks better armed than the M4s with their 75mm guns. In consequence, M4s with 76mm guns were rushed to Europe and the commander of the US 12th Army Group even asked for tanks with the British 17-pounder.[95] As it happens, none was available, and even when the 12th Army Group reached the Belgian border only 212 of its 1,579 M4s or Shermans were armed with 76mm guns. But by the end of the war the number of Shermans with 76mm gun deployed by the US forces in Germany rose to 2,151, out of 4,123, or to just over one half of the total.[96]

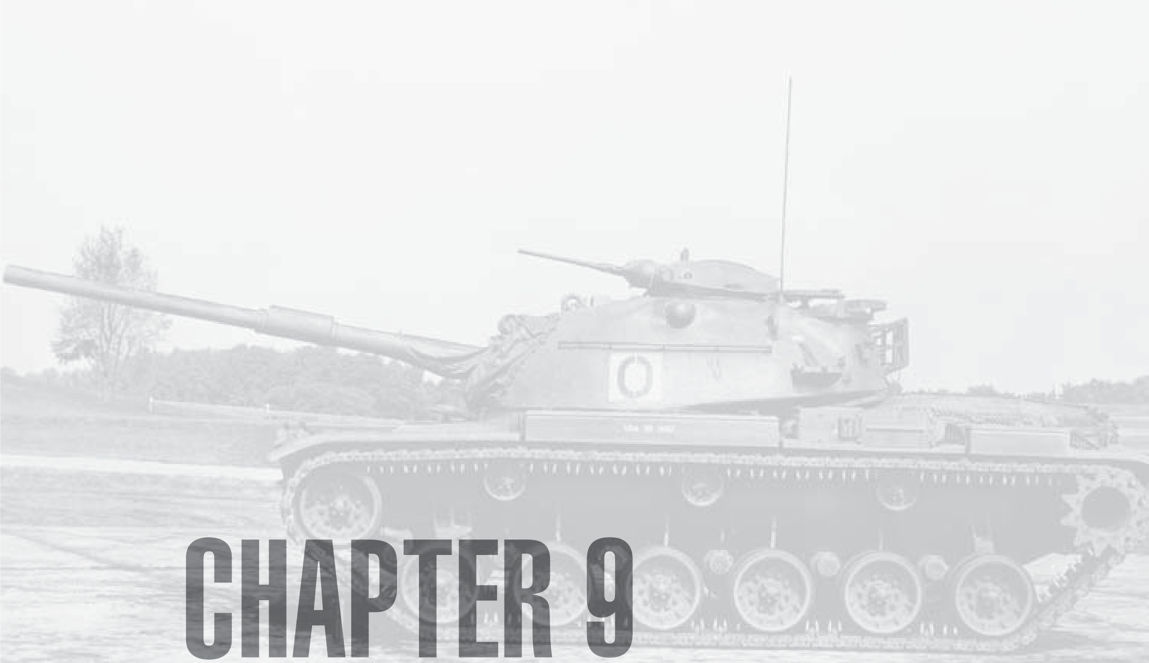
The armour penetration of the 76mm gun was still considerably less than that of the Panther's 75mm L/70 and of the 17-pounder, but it was at least slightly better than that of the 75mm L/48 gun of the PzKpfw IV. However, during the final months of the war its performance was improved by the introduction of APCR or High-velocity Armour Piercing (HVAP) ammunition, which increased armour penetration at 1,000m by 46 to 53 per cent compared with its standard armour-piercing ammunition.

Views responsible for the late deployment of Shermans with 76mm guns also contributed to the delays in the development of a new and more powerful US tank armed with a 90mm gun. The Ordnance Department began to consider the installation of such a gun on the Sherman in 1942 and a year later the Armored Force requested 1,000 Shermans armed with it. But Ordnance rejected this request in favour of a new tank that was still armed with a 75 or 76mm gun, while Army Ground Forces objected to it on the grounds that a powerful gun would encourage tanks to fight other tanks and thus divert them from the exploitation role![97]

In consequence, a series of experimental tanks was built with 75 or 76mm guns while the Army Ground Forces continued to favour Shermans armed with 75mm guns. By May 1943 Ordnance recommended that some of the experimental tanks be armed with 90mm guns, and in spite of opposition from the Army Ground Forces 50 tanks armed with them, designated T25E1 and T26E1, were built a year later. Shortly afterwards US armoured units landed in Normandy, and as the shortcomings of their tanks' 75mm guns became painfully obvious the Armored Force requested that high priority be given to the production of the T26E1, recommending that 500 be built. Army Ground Forces refused to approve this but eventually 250 were ordered. Twenty of the first 40 to be produced were shipped to Europe in January 1945 as M26 Pershing heavy tanks, and they saw some action in the last two months of the war, by the end of which there were a further 270 in Europe. Production of the 41-tonne Pershing continued until the end of 1945, when it had reached a total of 2,428.[98]

The 90mm gun of the Pershing represented a significant advance on the 76mm and even more on the 75mm guns of the Shermans, but in terms of its armour penetration it was still not quite as good as the British 17-pounder or the German 75mm L/70, and it was completely outclassed by the 88mm L/71 of the Tiger II heavy tank that first saw action a year earlier. But only about 100 Tigers could be mustered in December 1944 for the abortive Ardennes offensive, which was the last major effort of the panzer forces in the West. The German High Command could still assemble ten panzer divisions in March 1945 for a counter-offensive against the Soviet forces in Hungary, but the number of tanks at its disposal was generally considerably smaller than those of the opposing armies as a result of the lower scale of their production in Germany.

The differences are clearly shown by the totals of tanks produced in the different countries during the Second World War, which also illustrate the scale on which tanks were used during that conflict. Thus the total number of tanks produced in Germany from 1939 to 1945 amounted to 24,242.[99] During the same period the number of tanks produced in Britain was 30,396.[100] The corresponding figure for the Soviet Union was 76,186.[101] The number of tanks produced in the United States was even higher, being 80,140.[102] The total for the three countries fighting Germany was consequently 186,722 tanks, or almost eight times the number of German tanks.



CHAPTER 9

The Cold War's Five Dominant Countries

Tanks emerged from the Second World War as the pre-eminent component of the ground forces. However, their importance did not remain unchallenged, mainly because of the development during the latter part of the war of weapons firing projectiles or missiles with shaped charges. The very high-velocity metallic jets formed by these charges could perforate very thick armour, and this enabled relatively light weapons, and consequently infantrymen, to knock out tanks and therefore to reduce their effectiveness.

The armour-piercing capabilities of shaped charges had already led Hitler to believe that they would reduce the importance of tanks when they were incorporated in German artillery shells in 1943.[1] However, shaped charges did not become a serious threat to tanks until they became the warheads of rockets fired from simple tubular light weight launchers. The use in this form was pioneered by the 2.36in. (60mm) rocket launchers that the US Army first used in North Africa in 1942. The launchers were called 'bazookas' after the pipe-like musical instrument, and this became the popular name for weapons of their kind.

In 1944 the German Army introduced another and simpler shaped charge weapon, the *Panzerfaust.* Instead of rocket propelled grenades, this fired a grenade from a disposable recoilless launch tube, and in spite of its short range of 30 to 60m was responsible for killing a considerable number of tanks in the closing stages of the war. By the end of the conflict the US Army developed a more powerful 3.5in. (89mm) bazooka that could penetrate 280mm of armour, which was more than the thickness of armour of any contemporary tank. It also developed 75mm and later 105mm recoilless guns or 'rifles' that fired shaped charge shells. Unlike the bazookas, they could not be carried by one man but could be mounted on jeeps or other light trucks.

The development of such weapons led to the view, particularly in the United States, that henceforth the armour of tanks could be easily defeated and that their effectiveness was therefore greatly reduced. Such views were advanced, among others, by Dr Vannevar Bush, the head of the US Office of Scientific Research and Development during the war, in his influential book *Modern Arms and Free Men* published in 1949.[2] Similar views were also held by the US Secretary of the Army, F. Pace, who shortly before the outbreak of the war in Korea in 1950 stated at the West Point Military Academy that tanks were obsolescent.[3]

Soviet Union

In contrast to the views held in the United States and elsewhere, the Red Army, which in 1947 was renamed the Soviet Army, continued to regard tanks as a major component of the ground forces. It retained large numbers of them and kept acquiring new tanks, increasing its tank strength well above the 25,400 that it was estimated to have at the end of the war.[4] In consequence, Soviet tanks dominated the post-war scene and, given the aggressive stance of the Soviet Union, drove the development of tanks in other countries as a counter to them.

The roots of the development of the new Soviet tanks lay in a number of experimental vehicles built during the war. The earliest of them was the T-43, which was an attempt to revive the development of the improved T-34M version of the T-34 abandoned in 1941 because of the German invasion, as mentioned in Chapter 8. However, by the time the prototype of the T-43 was built in 1943, its 76mm gun was no longer considered adequate. In consequence it was abandoned in favour of the T-44, which was much more heavily armed as well as being superior in several other respects. One of them was the new transverse location of its diesel engine, which made the engine compartment and the hull more compact, although the engine itself was the same as that of the T-34. Like the T-43, it also had a torsion bar suspension instead of the Christie coil spring suspension, and it also abandoned the Christie-type long pitch tracks of the T-34. Anticipating the general trend, the T-44 also dispensed with the hull machine gunner, which reduced its crew to four and contributed further to making the tank compact.

Prototypes of the T-44 were built as early as 1944 and were armed with 122mm as well as 85mm guns, but the larger gun was found to be incompatible with the 32-tonne tank and it was the version armed with the 85mm gun that went into production in 1945. The first batch was produced just in time to be sent to the Far East for the Soviet offensive against the Japanese forces in Manchuria in August 1945.[5]

Production of the T-44 was not continued for long, but it served as a model for the T-54 that succeeded it and which, with the very similar T-55, became the principal Soviet tank of the mid-20th century. T-54 and T-55 also became the most numerous tanks ever built, the total number produced amounting to about 100,000, including tanks produced in Poland and Czechoslovakia and T-54s built in China as Type 59. They have also been the most widely employed, starting with the use of the T-54 by the Soviet forces that suppressed the Hungarian uprising in 1956, through the Arab-Israeli Six Day War of 1967, the final stages of the war in Vietnam and the 1980s wars in Afghanistan and Angola to the Second Gulf War of 2003.

The first two prototypes of the T-54 were built in 1945 and production of it began two years later. That of the T-55 followed in 1958 and continued until about 1980, although by then solely for export to some of the 40 Soviet client states and neutral countries. The principal difference between these models and their T-44 forerunner was that they were armed with a larger calibre 100mm gun mounted in a ballistically better-shaped hemispherical turret with 200mm thick frontal armour. Yet, in spite of their heavy armour, they only weighed 36 tonnes due to their very compact design, although the latter also resulted in them being cramped inside.

The armour of the T-54 and T-55 was actually thicker than that of the Soviet IS-2 heavy tank and comparable to that of the heaviest wartime tank, the German Tiger II. Nevertheless, the Soviet Army continued to develop heavy tanks with even thicker armour. The most significant of them was the

IS-3, which stemmed from the experience of the 1943 Battle of Kursk. This battle emphasized the importance of frontal armour and led to the design of the IS-3, which was in effect an IS-2 but with a ballistically much better shaped turret and hull front. The armour of IS-3 was actually 120mm thick at the front of the hull, but because of the way it was angled it was equivalent to about 330mm against conventional armour-piercing projectiles, which was more than the armour of any tank produced before its appearance.

The development of the IS-3 started in 1944 and it was put into production with remarkable speed at the beginning of 1945. But only a few were completed by the time the war ended and so none saw any action in it. Production of it continued until 1959 and totalled 2,311 tanks.[6]

The existence of the IS-3 was revealed to the outside world when 52 took part in the Allied Victory Parade in Berlin in September 1945. After the parade Marshal Zhukov, the Soviet commander in Germany, is reported to have told Stalin that IS-3 made a great impression on Western observers.[7] In fact, the IS-3 came to be considered the principal threat to Western armies during the early days of the Cold War, and as 'Stalin tanks' they became something of a bogey. However, they suffered from various shortcomings including cracking of the welded joints between their armour plates, some of which was due to them being rushed into production, and they had to undergo a number of modifications that went on until the late 1950s. When they were eventually used in combat, they also proved less formidable than was expected. This was the case in 1956, when some were destroyed in the streets of Budapest during the Hungarian uprising, and when the Israeli forces destroyed or captured 73 of the 100 IS-3s the Egyptian Army employed during the Six Day War of 1967.

The IS-3 was followed after the Second World War by the development of other heavy tanks. First came the IS-4, which was also armed with a 122mm gun but had thicker frontal armour, as a result of which it weighed 60 tonnes compared with the 46.5 tonnes of the IS-3. It was produced from 1947 to 1949 but only about 200 are believed to have been built. Next came the IS-6, which was essentially an IS-4 but with an electric instead of a mechanical transmission. It proved a failure. The third tank to be built was the IS-7, which was armed with a more powerful 130mm gun based on a naval gun. It weighed 68 tonnes, which made it the heaviest tank built in the Soviet Union. Design of the IS-7 was begun in 1945 and a series of four was completed in 1948, but after accidents during trials further development of it was abandoned.[8]

There was one more heavy tank that was originally called IS-8 but which after Stalin's death in 1953 was re-designated T-10, breaking the connection of the heavy tanks with the Soviet dictator. In essence, the T-10 was an improved version of the IS-3, and it was armed with a similar 122mm gun but it had thicker armour as a result of which it was heavier, weighing 50 tonnes. It began to be produced in 1950 and continued to be built until 1957, when it was succeeded by an improved T-10M version that was produced until 1962. By then the number of T-10 and T-10M that were produced amounted to about 8,000 tanks.

Four more heavy tanks were developed by 1957, three of them armed with 130mm guns and all weighing between 55 and 60 tonnes. However, none was adopted and further development of heavy tanks was discontinued as a result of a decision taken against it in 1960 by Nikita Krushchev, who came to power in the mid-1950s and who doubted the future of tanks because of the appearance of anti-tank guided missiles.

Krushchev's views did not put an end to the development of other types of tanks, but they steered some of it in a new direction. This manifested itself from 1957 onwards in a flurry of designs of tanks armed with missiles instead of guns. The earliest Soviet anti-tank guided missiles did not lend themselves, like those produced elsewhere, to installation in tanks, primarily because of the large span of their fins. They were therefore mounted initially on top of BRDM wheeled reconnaissance vehicles. But as new and less cumbersome missiles were developed, a T-62 tank was retrofitted with a new low profile turret out of which popped a launcher with a 3M7 'Draken' missile. Work on this missile-armed tank began as early as 1952 and a number was produced between 1968 and 1970 as IT or Istrebitel Tank (Tank Destroyer). Two battalions were equipped with it, but it was withdrawn from service in 1970.[9]

Two more missile tanks were developed by 1961 or 1962, both based on the then newly built T-64 and both with only a two-man crew. In one of them, called Object 287, both crew members were seated in the front of the hull and operated an unmanned turret by remote control, the turret being fitted again with a pop-up launcher, in this case with a 3M15 Taifun missile. In the other tank, called Object 775, both crewmen were in the turret, which mounted a short-barrelled 125mm gun that fired unguided rockets or Rubin guided missiles. In their different ways, objects 287 and 775 embodied major departures from conventional tank designs and the latter was as adventurous in some respects as the US-German MBT-70 that began to be designed in

1964. In particular, it had its driver in a rotating turret, like the MBT-70, but whereas the latter still had three men in the turret Object 775 had only two. It was also one of the first tanks to be fitted with an adjustable hydropneumatic suspension, which, when it squatted, enabled it to reduce its already low overall height of 1.65m to even less.[10]

The 125mm gun/missile launcher of Object 775 was conceptually similar to the 152mm XM81 gun/launcher adopted at about the same time for the US M551 Sheridan light tank and the M60A2 battle tank, but it was in advance of it in having an automatic loading system. However, it suffered from a number of serious problems, related among others to the radio command link of its missiles and the inevitable complication of driving controls created by the location of the driver in a rotating turret. The problems were not resolved and development of Object 775 was abandoned, but its combination of a gun with missiles launched through the gun tube foreshadowed a system later widely used in Soviet tanks.

In the meantime, Soviet tank development took another major step forward with the design of the T-62 tank, which was a derivative of the T-55 but armed with a 115mm smooth bore gun that fired arrow-like projectiles instead of the traditional, full calibre projectiles that until then were the standard armour-piercing ammunition of the Soviet tanks. Its projectiles, which came to be known as Armour Piercing Fin Stabilized Discarding Sabot or APFSDS projectiles, were fired with a muzzle velocity of 1,680m/s, which was higher than that of any other tank gun ammunition in use at the time, and this, together with the slender shape of the projectiles, resulted in greater armour penetration.

Development of the T-62 began in 1958 and was almost concurrent with that of the 90 and 105mm smooth bore guns firing APFSDS projectiles that were being developed in the United States for the T95 tank.[11] But whereas the results obtained in the United States were unsatisfactory and the development of the T95 was terminated in 1961, the T-62 was developed successfully and was accepted for use in that year. It was produced in its original form until 1972 and with modifications until 1983, by which time as many as 20,000 are believed to have been built. Most went to the Soviet Army but a significant number was delivered to the Egyptian and Syrian armies, which first used them in combat during the Arab-Israeli War of 1973. They were also supplied to Iraq and to North Korea, where the T-62 has been developed further.

The T-62 was the first tank to come into use armed with a high pressure smooth bore gun firing APFSDS, and as such ushered in the worldwide adoption of this type of armament, which superseded almost all other types of tank guns and kinetic energy ammunition during the 1980s and 1990s. In spite of having an advanced gun armament, the fire power of the T-62M was augmented in 1983 by the provision of guided missiles that could be launched from its gun. The missiles were the 9M117 Bastion laser beam-riders, which were the same as those launched from the 100mm gun of the T-55M and significantly increased the range at which both tanks could engage targets. However, the T-55M and T-62M were not the first to be provided with gun launched missiles in addition to conventional ammunition. This distinction belonged to the T-64 tank, the T-64B version of which, introduced in 1976, fired 9M112 Kobra missiles out of its 125mm smoothbore gun.

Kobra was also fired by the T-80B tank, which was introduced two years later. Its semi-automatic guidance system incorporated a radio command link, and this potentially vulnerable link was still used in the 9M124 Agona missile system introduced in 1988. But it was superseded by laser beam riding guidance when new tube launched missiles were introduced in the 1980s. These included not only the Bastion but also the 9M119 missile, which was part of the Refleks system installed in T-80U and T-90 and of the Svir system of the T-72B and T-72S, all of which were introduced between 1983 and 1993.[12]

The T-64, in which gun launched missiles were first installed, was the outcome of a programme initiated in 1954 to develop a new tank with a much more compact power pack. To achieve this objective, the designers of the T-64 took advantage of the resources made available to them by the Soviet system to devise a novel closely integrated engine-transmission assembly, instead of combining separately developed engines and transmissions as other designers generally had to do. The engine chosen by them was a two-stroke opposed-piston diesel similar to the Junkers Jumo diesel developed in Germany in the 1930s for aircraft, which enjoyed a reputation for high thermal efficiency.[13] The engine was mounted transversely and, unlike any other, was coupled directly on either side of the cylinder block to a multi-speed epicyclic transmission. This eliminated the need for several shafts and gears required by more conventional installations, and resulted in the engine compartment of the T-64 being little more than one half of that of the T-54. In addition, the engine installation of the T-64 incorporated a novel cooling system that used an exhaust gas ejector to suck cooling air through the radiators and thereby eliminated the need for cooling fans as well as simplifying the engine installation. The original four-cylinder engine of this type developed 580hp, but most of the T-64s were powered by a five-cylinder engine that developed 700hp and in its final form by a six-cylinder engine of 1,000hp.

In spite of its potential advantages the original design, designated Object 430, was not pursued at first beyond the construction of three test vehicles because it did not offer sufficient advantage as a fighting vehicle over the T-55, being armed with the same 100mm gun as the latter. When development was resumed in 1961, the T-64 was armed with a 115mm gun similar to that adopted at the time for the T-62. But because of the smaller size of the T-64's fighting compartment, its crew could not handle the large one-piece ammunition used in the T-62. The T-64 was therefore provided with two-piece ammunition and an automatic loading system of the carousel type installed under the turret, which not only solved the ammunition handling problem but also eliminated the need for a human loader and consequently reduced the crew of the tank to three men.

T-64 was also provided with an optical rangefinder, which increased its probability of hitting targets, but its most important feature was its novel and greatly improved armour protection. This involved a departure from the traditional solid steel armour and the use instead of a sandwich of steel plates and layers of a glass-fibre plastics composite on the front of the hull and of a ceramic material within cavities of the turret. In consequence the frontal protection of the T-64 rose to the equivalent of about 400mm of steel both against kinetic energy and shaped charge projectiles, which was twice the level of protection possessed by earlier Soviet tanks such as the T-55 and T-62.[14] In addition, the T-64 was provided with a liner of a nuclear radiation absorbing material.

The T-64 began to be produced in 1963, but within a year it was followed by the T-64A, which was armed with a new 125mm smooth bore gun. This gun fired APFSDS projectiles with a velocity of 1,715m/s, which was higher than that of other contemporary tank guns. Thus, when the T-64A came into service with the Soviet Army in 1968, it provided it with a tank which was well ahead of others in terms of gun power and was also well armoured, and yet weighed only 38 tonnes.

T-64A and the very similar T-64B became the main tanks of the T-64 series and T-64B continued to be produced until 1987. How many were built is not clear, but in 1990, before the collapse of the Soviet Union, Soviet authorities reported under the terms of the Conventional Forces in Europe (CFE) Treaty that there were 3,982 T-64 series tanks west of the Urals. Whatever the total produced, all T-64s went to the Soviet Army as none was exported, in contrast to other Soviet tanks.

For all its virtues, T-64A was open to criticism, mainly on account of its engine being expensive to produce, difficult to start in cold weather and unreliable. This led to a decision in 1967 to develop an alternative engine for the T-64, which took the form of a 1,000hp gas turbine.[15]

The use of gas turbines to power tanks began to be considered in the Soviet Union as early as 1949. It may have been prompted, like the contemporary development of gas turbines for tanks in Britain, by the exploratory work on them in Germany towards the end of the Second World War, but nothing came of it until 1955 when development began of a pair of 1,000hp gas turbines that were to power a heavy tank. But the latter was never built as a result of the decision taken by Krushchev to end the development of heavy tanks. However, in 1963 experiments began with helicopter gas turbines installed in T-62 and T-64 tank chassis. The results were discouraging, largely because of the high fuel consumption of the gas turbines, which was to be expected. Nevertheless, a decision was taken to produce a tank powered by a gas turbine, which became the T-80.

Compared with the Avco Lycoming AGT-1500 gas turbine that was being developed at about the same time for the US M1 battle tank, the Soviet GTD-1000T gas turbine was simpler and more robust, having a two-stage centrifugal compressor instead of a multi-stage axial flow compressor, and it was more compact as it had no recuperator, or heat exchanger, to recover some of the heat from the exhaust gases and improve thereby the thermal efficiency of the engine. The use of recuperators has been considered essential for automotive gas turbines to make them viable, but the developers of the T-80 have subsequently claimed in justification of their decision not to use one that recuperators do not work very efficiently when the output of engines fluctuates, as it does when they power tanks. Moreover, they have claimed that the vehicle weight saved by the smaller size of a gas turbine without a recuperator compensates to some extent for its higher fuel consumption, so that the overall fuel consumption of a tank would be much the same whether it had a gas turbine with a recuperator or not.[16]

Be that as it may, the fuel consumption per mile of the T-80 proved to be twice that of a similar tank powered by a conventional four-stroke diesel. At the same time the cost of producing the GTD-1000T was almost 11 times that of the latter.[17] On the other hand, GTD-1000T offered a higher power-to-weight ratio and therefore greater agility than that of the T-64 with the 700hp 5TDF two-stroke diesel, although the latter was eventually replaced by the 6TD of 1,000hp while the gas turbine was developed into the GTD-1250 of 1,250hp. Other advantages of the gas turbines included much more reliable starting at low ambient temperatures, elimination of water cooling and low lubricating oil consumption.

Before it was adopted, the gas turbine was extensively tested under a variety of climatic conditions mounted in more than 60 test vehicles based on the T-64 chassis, and the tank that it powered was finally accepted for service with the Soviet Army in 1976 as the T-80. Production began at the same time and continued until 1987.

Engines apart, the T-80 was very similar to the T-64A on which it was in fact based. It had the same general configuration, a similar 125mm smooth bore gun with a carousel-type automatic loading system, and comparable armour protection. The only major difference between the two was the T-80's greater agility, but this hardly justified its development, particularly in view of its higher production cost and the additional logistics burden it created.

A much more rational move than the production of the T-80 was the development of another variant of the T-64, which was powered by an uprated version of the 12-cylinder diesel that had powered most Soviet tanks from the BT-7M of 1939 onwards. By adding a mechanically driven supercharger, the output of this remarkably durable engine was raised from the 580hp of the naturally aspirated V-55 model that was used in the T-62 to 780hp of the V-46 version, and this made it a potential alternative to the two-stroke engine of the T-64 and the gas turbine of the T-80.

Use of the V-46 as a back-up engine for the T-64 began to be considered as early as 1961 and was pursued between 1966 and 1969, leading to the conclusion that the mobility of the T-64 when powered by it would be as good as that of the standard version.[18] After modifications, particularly to its suspension and autoloader, what was basically a T-64 with the V-46 engine was accepted in 1973 as the T-72.[19] Once its production began, the T-72 was built on a large scale, the number produced amounting to more than 30,000 according to its manufacturers.[20] However, the number reported in 1990 under the terms of the CFE Treaty to be west of the Urals was only 5,092, and of the total produced 6,000 were exported to several countries.[21] The T-72 was also built in a number of countries, sometimes under different designations, including India, Iran, Poland, Slovakia and Yugoslavia.

During the course of its production the T-72 was improved in several respects, as were the T-64 and T-80. This included improvements to their protection, the most important of which was the addition of explosive reactive armour or ERA. (For details of this see Appendix II.) Its adoption increased considerably the protection of Soviet tanks against shaped charge anti-tank weapons and because of this caused consternation in NATO, which relied to a large extent on such weapons to counter a possible onslaught by Soviet armoured formations in Central Europe.

ERA was originally put to use by Israeli forces, appearing for the first time on Israeli tanks in 1982 during the operation 'Peace for Galilee'. This incursion by Israeli forces into the Lebanon involved clashes with the Syrian forces, which are widely believed to have captured an Israeli tank with ERA and to have passed it on to the Soviet Union, where the ERA was copied. In fact, the Russians had been working on ERA for several years prior to this, but because of accidental explosions and other problems decided not to use it until they saw it on Israeli tanks, when they took it up again.[22] The decision to use ERA was taken quickly and in 1983 T-64BV began to be produced with it, at the cost of an increase in weight from about 40 to 42.4 tonnes. Two years later ERA also began to be fitted to the T-72 and T-80.

In addition to adopting ERA on a large scale, the Russians developed it further following the original or 'light' type, which was effective only against shaped charges, with a 'heavy' or Kontact 5 type effective also against the long-rod penetrators of APFSDS projectiles. The essential difference between the two types was that the steel plates of the steel-explosive-steel sandwiches of the original or 'light' ERA were only 2 or 3mm thick, whereas those of the 'heavy' ERA were considerably thicker, typically of the order of 15mm.

The Russians were also the first to develop a much more sophisticated type of protection against anti-tank guided missiles in the form of the Drozd active protection system. This appeared for the first time in 1983 on a T-55AD and consisted of a millimetre wave radar to detect incoming threats and a cluster of four launchers on each side of the turret with 107mm rockets, one of which would be fired at a threat missile at the appropriate moment determined by the system's computer to shower it with fragments and thereby damage or destroy it.[23] In contrast to other active protection systems developed elsewhere several years later that provided all-round protection, Drozd's rocket launchers only covered a frontal arc of 80º, but this would have been sufficient for tanks used for frontal assaults. In addition to T-55AD, Drozd was also installed on some T-62D tanks, but its use has been limited, other Soviet tanks continuing to rely on ERA to augment their built-in passive armour protection.

When the last of the trio of Soviet tanks, the T-80, was adopted in 1976, the T-72 was already in production and so, even more, was the T-64. This created a bizarre situation, as it meant that the Soviet Army had three tanks armed with the same 125mm gun and with basically much the same combat capabilities but powered by different engines and having different hulls, running gear and fire control systems. These differences were bound to create operational as well as logistics problems, and there were also considerable differences in the production costs, that of the T-80 being almost twice the cost of the T-72. Rationalization was inevitable and very sensibly resulted in concentration on the tank that cost least to produce and to operate, which was the T-72. But concentration on the T-72 was not implemented for some time.

The T-80U continued to be built on a small scale, partly to provide work for the factory in Omsk that produced it, and a new, T-80UD version powered by a more powerful 1,000hp 6TD diesel instead of the gas turbine was adopted in 1985. However, it ceased to be available to the Russian Army after the collapse of the Soviet Union because it was built in the Ukraine.

The collapse of the Soviet Union also created a problem of disposal of the large fleet of armoured vehicles belonging to the Soviet Army. On the eve of its collapse, the Soviet Union reported to the United Nations that on 1 January 1990 it had 63,900 tanks and in 1990, under the terms of the CFE Treaty, 21,296 tanks were declared to be west of the Urals. By 1997 the Russian Army was reported to have been left with a total of 5,546 tanks there. What happened to the rest is not clear, except that negotiations held in Tashkent in 1992 allocated 6,400 of the former Soviet tanks to Russia, 4,080 to the Ukraine, 1,800 to Belarus and 200-odd to each of the four newly independent republics.[24] But this accounted for only 13,150 tanks. Some of the older vehicles, which included T-34-85, were no doubt scrapped, but many others must have been retained east of the Urals, and in 2006 the Russian Army was still stated to have about 20,000 tanks.[25]

Some further development and small scale production of the T-80 and T-72 took place during the period of dissolution of the Soviet Union. In particular, improvements were made to the T-72, which included the installation of a more advanced fire control system already used in the T-80 and of the Shtora infrared jammer or missile decoy system as well as an uprated 840hp V-84 version of the venerable V-54 engine. While it was still being tested, the improved T-72BU was accepted in 1992 for service by the Russian Army as the T-90, and four years later it was confirmed that it would be the only tank produced for it, although the T-80U continued to be offered for export and a small number was actually sold to Cyprus and to South Korea.

Production of the T-90 for the Russian Army has been at a low rate and only about 300 are believed to have been built by 2006.[26] However, in 2001 the Indian Army ordered 310 of the T-90S export version, deliveries of which commenced in 2004. Subsequently a licence agreement was reached for the production of 1,000 T-90S in India, and in 2007 a contract was signed for 347 additional T-90S to be supplied in kit form. Thus, when all the tanks are built, the Indian Army should have 1,657 T-90S.

T-90S tanks of the Indian Army retain the 9M119 Refleks system with guided missiles launched out of their 125mm smooth bore guns, but they are powered by an uprated turbo-charged V-92S development of the V-46 engine that develops 1,000hp and consequently increases the agility of the 46.5 tonnes tank.

By a quirk of fate, the procurement by India of T-90S tanks was driven by the acquisition of another tank of Soviet origin, the T-80UD, by its traditional enemy, Pakistan. Both tanks were derived from the T-64 and were very similar except for their engines, but the T-90S was produced at Nizhny Tagil in Russia whereas the T-80UD was built in Kharkov in the Ukraine. As a result, after the break-up of the Soviet Union the production of T-80UD became separated from that of tanks in the Russian Federation, and this helped Pakistan to order it. The order, issued in 1996, was for 320 tanks, all of which were delivered by 2002.

T-80UD was developed further in Kharkov by its designers, the Morozov design bureau, into the 46-tonne T-84, which was basically similar but had improved protection and a more powerful 1,200hp 6TD-2 version of their two-stroke diesel. The Morozov bureau then developed the T-84 into the T-84-120, which departed from what had been the two standard features of Soviet/Russian/Ukrainian tanks for more than 30 years. One of them was the use of a Soviet-designed 125mm gun, which was replaced by a 120mm smooth bore gun that fired NATO standard ammunition. The other standard feature of Soviet designed tanks was a carousel-type autoloader located under the turret, which was abandoned in the T-84-120 in favour of a bustle autoloader. This was an inevitable consequence of the adoption of the 120mm gun, as its one-piece ammunition could not be accommodated in the carousel. But it also made the tank less vulnerable, because it relocated most of its ammunition in the turret bustle and separated it from the crew by a bulkhead that protected it in the event of an ammunition explosion, as the bustle compartment did in US M1 tanks.

A similar change was made in the mid-1990s in Russia, where the experimental T-80UM2 Black Eagle tank was also fitted with a bustle autoloader instead of the carousel type, although it retained the 125mm gun of its predecessors. Another and much more advanced tank, called the T-95, had been worked on in Russia since the mid-1990s, but its development was abandoned in 2010.

United States

The importance that the Soviet Army consistently attached to tanks stood in marked contrast to the fluctuating attitude towards them by the US Army. Thus at the end of the Second World War the US Army had 16 armoured divisions incorporating 52 tank battalions and 65 independent non-divisional tank battalions. But within three years of the end of hostilities, hasty demobilisation and doubts about the future of tanks reduced US armoured forces to a single division.[27] This represented a sweeping reduction not only in absolute but also in relative terms, as the rest of the Army consisted at the time of nine infantry divisions, while during the war the ratio of armoured to infantry divisions was approximately one to five. In contrast, the Soviet Army not only maintained large armoured forces, estimated at the time at 35 to 70 divisions, but increased considerably their number in relation to the rest of its forces.[28]

The one US armoured division had a nominal strength of 373 tanks. The only other tanks the US Army had were in the divisional tank battalions and the regimental tank companies of the infantry divisions, each of which had a nominal total of 147 tanks. There were no independent tank battalions and no battalions of tank destroyers, the number of which had grown to 106 during the war but which disappeared in its aftermath with the abolition of the Tank Destroyer Command. The disappearance of the latter was in itself unlamented because of the harmful influence its existence had on US tank development during the war.

The situation changed dramatically in June 1950 when North Korean troops led by about 140 Soviet-built T-34-85 tanks almost overran South Korea, which altered radically the perception of tanks in the United States. The immediate reaction consisted of the deployment of US tanks available in the area, but they were confined to four companies of M24 light tanks that were part of the US infantry divisions on occupation duty in Japan. Moreover, the M24 tanks with their medium-velocity 75mm guns were no match for the T-34-85, and the balance was not redressed until the arrival in August from the United States of five tank battalions equipped with Shermans and M26 Pershings.

At about the same time the number of armoured divisions was raised to six, although four of them were only training formations, and one of the two that was combat-ready was sent in 1951 to Germany to counter a possible Soviet threat in Europe. Until then the only mobile US forces in Germany consisted of three constabulary brigades, which had some light tanks.

The outbreak of the war in Korea also accelerated the development of new tanks. Equipment boards convened just before the end of the Second World War and immediately after it called for the development of three categories of light, medium and heavy tanks. However, funds available to the US Army were limited, defence budgets being dominated by nuclear weapons and their delivery systems. In the circumstances it was considered more productive to develop new components rather than new tanks. This policy resulted in the production of new engines, transmissions and other components, and when the threat posed by the Soviet Union was belatedly recognized these were used to improve the capabilities of the most effective of the available US tanks, which were the M26 Pershings. When re-engined these became M46 Pattons, and in 1949 there were already enough of them to equip one of the five battalions sent a year later to bolster US forces in Korea.

As the number of Pershings available for conversion was limited some new M46s were produced, but once the war in Korea broke out more modern tanks were demanded. The design of a new T42 medium tank had actually begun in 1949, but it had not advanced sufficiently by 1950 for it to go into production. This led to an emergency programme that resulted in the combination of the new turret of the T42 with the proven chassis of the M46. The first of the M47 tanks that came out of this was produced in 1951. Its general characteristics were not very different from those of the M46, but its 90mm gun was somewhat more powerful and it was the first US tank to have an optical (stereoscopic) range finder, which increased the gun's probability of hitting targets. At 45.5 tonnes it was 2 tonnes heavier, but it was powered by a similar 810hp V-12 air-cooled gasoline engine and had the same maximum road speed of 30mph.

Production of the M47 continued at a high rate until 1953, when it reached a total of 8,576 tanks.[29] It was criticized for its extremely short operating range of 70 miles, even on roads, and for problems with its stereoscopic rangefinder, which was difficult to use. However, the US Army did not have to use it for long as after a few years most M47s were passed on to Allied armies when a new US medium tank became available. The principal recipients of the M47 were the German Army, which received the first in 1956, and the French Army. When others followed, the M47 became almost the standard Western European tank of the late 1950s and early 1960s.

The new US medium tank was the M48, which had much the same automotive characteristics as the M47 and was armed with a 90mm gun similar to that of its predecessor. But it dispensed with the hull machine gunner, which reduced its crew to four and contributed to it having a ballistically better-shaped elipsoidal hull. It also had an almost hemispherical turret and a lower silhouette. Production of it began in 1952, only two years after its design was started, and continued until 1959, by which time 11,703 had been built. Most went to the US Army but, once again, a significant number was supplied to Allied armies and in particular to the German Army, which received the first of 1,666 M48 tanks at the end of 1957.[30] Eight years later some of them were passed on to Israel.

Because they were rushed into production, early M48s suffered from a number of problems and many had to be rebuilt before they could be issued to the armoured units. But once the problems were rectified, M48 proved to be a good and robust tank that matched its potential adversary, the Soviet T-54, although it was armed with a 90mm rather than a 100mm gun.

So far as the gun power of US tank units was concerned, the M48 was to be backed by a more powerfully armed heavy tank. A tank of this kind, the 56.5-tonne M6, armed with a 3in and then 105m gun was designed in

1940, but although 43 were built none was sent to the fighting fronts because the US Army preferred to have medium tanks, two of which could be shipped for each heavy tank.[31]

Nevertheless, other heavy tanks began to be developed towards the end of the Second World War. The first was the turretless T28 assault tank, which had frontal armour 305mm thick and weighed as much as 84.8 tonnes. However, only two were completed after the war. Other experimental heavy tanks were turreted. Their general configuration was similar to that of the M26 Pershing and they shared some of their components with it. But two of them, designated T29, were armed with 105mm guns, while two T30s were armed with 155mm guns, and the T34 that followed was armed with a modified 120mm anti-aircraft gun whose armour-piercing performance was superior to that of the other guns. In all cases the weight of the tanks was much the same, being in the range of 63 to 64 tonnes.

The development of the US heavy tanks was inspired by the appearance of the German Tiger II heavy tank, and at one stage the procurement of as many as 1,200 T29s was contemplated.[32] However, only eight T29s were eventually built, two or three years after the war. By then a new threat had emerged in the shape of the Soviet IS-3 heavy tank, and this spurred further development of heavy tanks in the United States.

The only available design was that of the T34, but the Army objected to its 64-tonne weight. A lighter 56-tonne version was therefore devised and was adopted as the T43 and later M103 heavy tank. Prototypes of it were built in 1951 and 300 were produced between 1953 and 1954, but, oddly enough, only 80 went to the US Army, which in 1958 deployed a single battalion of 72 tanks in Germany. The rest went to the US Marine Corps, which used them until 1973.[33]

An unusual feature of the M103 heavy tank was its large turret, which had a crew of four as it included two loaders to handle the heavy ammunition of the tank's 120mm gun, one round of which weighed 48.8 kg. In contrast, the Soviet IS-3 heavy tank retained the customary turret crew of three, in spite of having a 122mm gun, by using ammunition with separate projectiles and propellant charges and accepting a slower rate of fire.

A solution to the problem of handling heavy ammunition was sought in the use of the oscillating or trunion mounted turret pioneered by the French AMX 13 light tank, a prototype of which was tested in the United States in 1950. Two experimental heavy tanks with oscillating turrets on T43 tank chassis were consequently built between 1951 and 1957, the T57 with a 120mm gun and the T58 with a 155mm gun. In both cases the guns were automatically loaded, but neither tank was accepted and they were the last of the separate category of heavy tanks to be built in the United States.

The third type of tank envisaged by the US Army after the war was the M41 light tank, a 22.9-tonne vehicle with a crew of four and a 76mm gun. It was the first of the post-war generation of US tanks and it began to be developed as early as 1946. But its development proceeded slowly until the outbreak of the war in Korea, when it was rushed into production, continuing until 1954 when 3,729 had been completed.[34] The haste with which it was produced led initially to problems, but its general design was sound. However, it was too large for a reconnaissance vehicle and not powerful enough to be an effective combat vehicle, even though its 76mm gun fired projectiles with a higher muzzle velocity than that of the guns of the wartime M4 medium tanks. It was not therefore very profitable for the US Army to devote some of the limited amount of money it had in the immediate post-Second World War period to the development of what was originally designated the T37 and then M41 light tank.

Medium tanks were certainly a better investment, but to remain effective over a number of years they required continuous development. By the mid-1950s this was focused on the M48, which was gradually improved by being retrofitted with a diesel derivative of its gasoline engine that increased its operating range on roads from about 70 to 300 miles. Its stereoscopic rangefinder was also replaced by one of an easier to operate coincidence type. Finally, by about 1959, its 90mm gun was replaced by a much more effective 105mm gun. Yet its weight only increased from the 44 tonnes of the original M48 to the 48 tonnes of the final M48A5.

Attempts to increase the gun power of the M48 started as early as 1951, and led initially to two experimental T54 versions with 105mm guns. One of them had an oscillating turret and automatic loading of its gun, but neither was adopted. Another attempt made later resulted in the T77 armed with an automatically loaded 120mm gun, but this was also abandoned in 1957.[35]

In 1954, instead of trying to make the M48 more powerful, the US Army decided to develop an entirely new tank, the T95. This was to be armed with a 90 or 105mm smooth bore gun firing what was then a new APFSDS type of projectile capable of perforating thicker armour than the traditional kinetic energy ammunition. In consequence, the T95 was considered to be a successor to heavy as well as medium tanks. The first of nine experimental T95s was built in 1957, but problems were encountered with the smooth bore guns, which included a high dispersion of their fin-stabilized projectiles, and in 1958 a group of senior US Army officers concluded that the T95 offered only a marginal improvement over the M48A5 and that the desired increases in firepower and mobility could be achieved at less cost by upgunning the M48A2 and replacing its gasoline engine by a diesel.[36] This was accepted and work on the T95 and the smooth bore guns was terminated. Had it been pursued, the US Army might have been the first to field a smooth bore tank gun. As it was, this was left to the Soviet Army, which was developing smooth bore tank guns at about the same time and produced the first tank armed with one, the T-62, in 1961, as mentioned earlier in this chapter.

The place of the T95 was taken by an 'interim main battle tank', which became the M60, and was in effect an M48A2 armed with a US M68 version of the British 105mm L7 gun and powered by an AVDS-1790 diesel engine. The M60 was adopted in 1959 and began to be produced a year later, after which it continued to be built, with modifications, until 1987 when a total of 15,221 had been produced for the US Army and a number of friendly countries.

The adoption of the 105mm M68 gun for the M60 was well justified, as the L7 gun from which it was derived was probably the best gun that was available in 1959 because of the performance of its APDS ammunition. However, the concurrent US Army decision to abandon the development of smooth bore guns was short sighted, as they were to prove superior in the long run to rifled tank guns. In fact, in 1960 the US Army was on the verge of successfully developing one, the 120mm Delta gun. This gun fired APFSDS projectiles with a velocity of 1,615m/s, which was higher than that achieved with APDS ammunition fired from any rifled gun.[37] Fortunately the example of the Delta gun was taken up in Germany, where the Rheinmetall company successfully developed a similar 120mm smooth bore gun for the Leopard 2 tank, and some 20 years later this gun was also adopted by the US Army for its M1 tank.

One reason why the US Army did not pursue the development of the Delta gun was that those in charge of US tank development became beguiled by the perceived performance of guided missiles. This manifested itself in 1957 when the ARCOV (Armament for Future Tanks and Similar Combat Vehicles) committee established by the US Army Chief of Staff to review the development of tanks recommended that future tanks should be armed with guided missiles. The recommendation was accepted and in 1959 the Aeronutronics Division of the Ford Motor Company started to develop the Shillelagh, a semi-automatic command-to-line-of-sight or SACLOS missile, and a short-barrelled 152mm gun launcher from which the missile could be fired and which could also fire conventional medium-velocity projectiles.

The 152mm gun launcher was envisaged to be the main armament of battle tanks as well as that of an air-transportable light armoured reconnaissance vehicle that was expected to take the place of more conventional light tanks. To start with, it was decided to install it in some of the M60 tanks. The latter were modified by being provided with a novel low frontal area turret, which was meant to reduce the area they exposed to enemy fire. But their silhouette was ruined by the addition of an exceptionally large commander's cupola that increased their overall height to 3.3m, or one metre more than the overall height of the contemporary Soviet tanks.

The installation of the 152mm gun launcher in the M60 was originally thought to be a relatively simple matter of upgunning an existing well-established tank. But it proved to be problematic and this delayed the deployment of the resulting M60A2, of which 540 were produced. A prototype of the M60A2 was built in 1967, but the first of six battalions, each equipped with 59 tanks, was only deployed in Europe in 1975. When it finally came into use, the M60A2 was not popular because it was complicated and difficult to maintain, and it was taken out of service after a few years.[38]

In addition to being used as battle tank armament, the 152mm gun launcher appeared to be a solution to the problem of combining low vehicle weight with powerful armament. It was therefore adopted as the armament of the Armored Reconnaissance/Airborne Assault Vehicle, which began to be studied in 1959 and which became the M551 Sheridan. The armament of this light tank made it remarkably powerful in relation to its weight of 15.8 tonnes, but it suffered from a number of problems, which included smouldering debris left in the gun by the combustible cases of its conventional ammunition and the jolt this ammunition gave to the vehicle on firing, which made the missile system inoperable as well as threatening injury to the crew. Nevertheless, Sheridans began to be produced in 1966, and in 1969 two squadrons with 64 of them, stripped of their missile systems, were sent to Vietnam, where they proved vulnerable to mines because of their light armour and where they were less popular than M48 tanks. Others were then sent to the US forces in Europe where they replaced M41 light tanks. But in 1978 most were withdrawn from service.[39] Of the 1,662 that were produced, only one battalion was retained as part of the 82nd Airborne Division. During the First Gulf War of 1991, this battalion with its 56 Sheridans was flown to Saudi Arabia in C-5 Galaxy transport aircraft and was then deployed within the theatre by a shuttle of six C-130 Hercules aircraft, but in the course of the operations against the Iraqi forces fired only one Shillelagh in anger.[40]

Soon after the US Army decided that future tanks should be armed with guided missiles, the United States entered into discussions with Germany about the joint development of a new battle tank. This was promoted by the US Secretary of Defense, R. S. McNamara, as a means of saving money by sharing costs, and was agreed to by the two countries in 1963. Concept studies began a year later and the first of six prototypes of the selected design, which was called MBT 70, was built in 1967.[41]

The 50-tonne MBT 70 was expected to advance the state of the art in almost every respect, which resulted in it incorporating several components and features that were new and relatively untried. The most novel of them was the turret, which contained the whole of its three-man crew, including the driver. Within the turret the crew would be protected against nuclear radiation and chemical contamination, and the driver's location in the turret helped to lower the silhouette of the tank but required providing him with a counter-rotating capsule that complicated controls and did not entirely prevent disorientation.

In keeping with the contemporary adoption of the 152mm gun launcher and the Shillelagh missiles for the M60A2 and the Sheridan, the US Army wanted the MBT 70 to have a similar armament, but the German Army preferred, wisely, a gun firing high-velocity kinetic energy projectiles. The difference was resolved by the development of a new version of the 152mm gun launcher with a barrel 30.5 instead of 17.5 calibres long, which could fire APFSDS projectiles with a muzzle velocity of 1,478m/s but that could still also fire Shillelagh missiles.

Development of the various new components and their integration into the MBT 70 created problems that considerably increased its cost. By 1969 this was estimated to have risen to one million dollars or four times the cost of an M60A1. The high cost drew the attention of the US Congress, which forced the US Army to terminate the development of MBT 70. At the same time Germany withdrew from the joint programme. The US Army tried to continue the development by itself of an 'austere version' designated XM 803, which it claimed would cost 600,000 dollars. But Congress considered that each might still cost more than one million dollars and declared that MBT 70/XM 803 was 'unnecessarily complex, excessively sophisticated and too expensive'.[42] In consequence Congress put an end to its further development in 1971 – an ironic end to a tank programme that was touted by McNamara as a cost saver.

Although Congress withheld funds for further development of the MBT 70/XM 803, it recognized that the US Army needed a new tank and in 1972 authorized the design of one that would cost no more than 500,000 dollars. An Army task force then drew up a set of design criteria, and in 1973 Chrysler and General Motors were awarded contracts for the construction of prototypes for competitive evaluation. One prototype of each competing XM1 tank was completed in 1976, and later that year the Chrysler design was selected for further development, ostensibly because it was offered at a lower price.

Both XM1 prototypes had the same conventional configuration and four-man crew, and both were armed with the same 105mm M68 rifled gun as that already used for several years in the M60. However, the 105mm gun had been given a new lease of life by the development of ammunition with a slipping driving band that prevented it being spun by the rifling. This enabled it to fire fin-stabilized projectiles, including APFSDS, which perforated thicker armour than the APDS projectiles on which it previously relied. The improved performance made the 105mm gun competitive with larger calibre British and German guns, but although it was adopted in preference to them it was decided that the XM1 would be armed at a later stage with the 120mm smooth bore gun developed in Germany by Rheinmetall.

In contrast to the MBT 70, in the specification of which firepower and mobility preceded survivability in the order of importance, the latter became a priority in the design of XM1 and a critical issue, since it was being designed in the aftermath of the Arab-Israeli War of 1973, which gave rise to doubts about the future of tanks because of their perceived vulnerability to anti-tank guided missiles. But, fortunately for the XM1, the head of the task force set up to define its characteristics, General W. R. Desobry, happened to visit in 1972 the British Fighting Vehicles Research and Development Establishment (FVRDE) and learnt of the development there of a new type of armour, called Chobham armour after its location, which was much more effective against shaped charge weapons than steel armour.[43] This led to the adoption of Chobham armour by the US Army and a visit to FVRDE in 1973 by Chrysler and General Motors engineers, who subsequently modified their prototypes of the XM1 to incorporate the new type of armour in them instead of the simple spaced armour or the arrays of several separated steel plates that they were originally meant to have and that represented the best form of protection devised until then against shaped charges.

The principal difference between the two prototypes was their engines. That of the General Motors prototype was a 1,500hp Teledyne Continental AVCR-1360 similar to one of the engines of the MBT 70. It was an unconventional variable compression ratio air-cooled diesel based on some research in Britain, which delivered more power in relation to its capacity than conventional diesel engines. But it was more complicated and had difficulty in achieving good combustion over the whole of its operating range, which manifested itself at times in clouds of black exhaust smoke. The Chrysler prototype was powered by a 1,500hp Avco Lycoming AGT-1500 gas turbine which was originally designed for the MBT 70 but was never tested in it.[44] The available evidence indicated that its fuel consumption would be significantly higher than that of a diesel and it was considerably more expensive to produce, which forced Chrysler engineers to economize on the fire control system and other components of their tank in order to remain within the overall cost target. However, the gas turbine had its proponents in the US tank community, who claimed that its fuel consumption would be only slightly higher than that of the diesel.[45] The writer was drawn into the ensuing debate and estimated that the fuel consumption of a tank powered by the AGT-1500 would actually be 60 to 70 per cent higher than that of a tank powered by a good diesel, which the AVCR-1360 unfortunately was not.[46] In fact, the situation proved to be even worse, as demonstrated several years later when the gas turbine powered M1 tank competed unsuccessfully with the German diesel-powered Leopard 2 for a Swedish Army order, and over the same extensive mileage used twice as much fuel.[47]

Nevertheless, the Chrysler design was approved for production in 1979 and began to be built in the following year as the M1 Abrams. But in 1982 Chrysler Defense Division was sold to the General Dynamics Corporation, who then produced most of the M1s. After 2,374 of the original 105mm gun-armed version were completed in 1985 production switched to the

M1A1, which was armed with the US version of the 120mm smooth bore Rheinmetall gun. The M1A1 version began to be issued to US armoured and infantry divisions in Germany in 1988 and its production continued until 1993, when a total of 8,141 M1 series tanks was completed for the US Army. In addition, 221 M1A1s were produced for the US Marine Corps and 315 and 218 were also built respectively for Saudi Arabia and Kuwait, while Egypt ordered 555 M1A1s and partly produced them itself, eventually raising the total of M1A1 tanks it had to 1,055.

M1 tanks were first used in action in 1991 during the First Gulf War, for which as many as 3,113 were transported from the United States to the Middle East.[48] During the 100-hour land campaign they destroyed a number of Soviet-built T-72s while avoiding destruction themselves, partly because of the advantage of having thermal imaging sights that enabled them to detect targets when their opponents could not. A much smaller number was used during the invasion of Iraq in 2003, when they again outgunned the opposing T-72 as well as T-55 tanks but proved vulnerable to attack at close quarters by RPG-7 rocket propelled anti-tank grenades. The massive fuel demands of the M1 tanks were met on both occasions by a very extensive logistics support organization, but in 1997, when trying to sell more M1 tanks, General Dynamics recognized the objections to their gas turbine and replaced it by the German-developed Europack based on a MTU MT 883 diesel. This reduced the fuel consumption significantly, but its use did not advance beyond a prototype.

Studies of a potential successor to the M1 started soon after its production began, but only led to a series of abortive development programmes. The first of them, called the Future Close Combat Vehicle Program, came into being in 1981 and was aimed at a family of armoured vehicles based on a common chassis which meant, among other things, that an infantry fighting vehicle would use the same chassis as a battle tank. However, the programme only led to further studies under the Heavy Forces Modernization and Armored Systems Modernization programmes, the last of which was reduced to the upgrading of the M1 by 1993 when the Soviet threat had receded.

Development of subsystems and components that was pursued in parallel with the vehicle programmes produced more concrete results. One of them was the Tank Test Bed, which consisted of an M1 tank chassis with an automatically loaded 120mm gun mounted in an unmanned low frontal area turret remotely operated by a crew of three located in the front of the hull.

Work on this experimental vehicle began in 1981 and was completed five years later, but, surprisingly, it was abandoned without being fully developed. Another significant development was that of a 140mm smooth bore gun, which started in 1985 and led to its installation, together with a bustle autoloader, in a modified M1 tank. Guns of a similar 145mm calibre were already specified for tanks under the Future Close Combat System Vehicle Program, and the 140mm XM 291 gun became part of the Future Tank Main Armament Programme set up in collaboration with Britain, France and Germany. The gun began to be tested in 1987 and its APFSDS projectiles had twice the muzzle energy of 120mm gun projectiles, but it came to be considered unnecessary for the defeat of enemy tanks and was not adopted.

An entirely different series of developments was initiated in 1973 by the Defense Advanced Research Projects Agency (DARPA), which was prompted by two events.[49] One of them was the progress being made at the time with smooth bore guns firing APFSDS, which were becoming more effective than the standard 105mm tank guns using APDS ammunition and looked like being able to replace the latter when of smaller 75mm or even 60mm calibre, in which size they could be mounted in lighter vehicles. The other happening was the contemporary concern about the survivability of tanks, which gave rise to the belief that this could be improved by making tanks much more agile. All this led to the construction and tests of the High Mobility Agility (HIMAG) experimental vehicle armed with a high-velocity automatic 75mm ARES gun firing APFSDS ammunition. The HIMAG vehicle was based on a M1 tank chassis and its weight could be varied from 29.5 to 38.1 tonnes, so that its power-to-weight ratio could be as high as 50.8hp per tonne compared with 26hp per tonne of the M1A1, and it was consequently more agile than other contemporary tracked armoured vehicles.

Tests of the HIMAG vehicle, which the writer was able to follow closely as a member of a DARPA advisory group, began in 1977 and continued until 1981 but without resolving the power-to-weight issue, while the 75mm ARES gun was overtaken by the development in Germany by Rheinmetall of a low recoil impulse version of the 105mm L7 tank gun, which could be fired from vehicles weighing only 14 tonnes. At the same time, APFSDS ammunition was developed for 105mm guns, which made the Rheinmetall gun more effective than the 75mm ARES gun. In fact, it became a model for the armament of other gun-armed light armoured vehicles.

Changes in the political situation in the Middle East that followed the fall of the shah in 1978 created a need for rapid deployment forces, which led the US Army to formulate a requirement for an air-transportable Mobile Protected Gun System, subsequently renamed the Armored Gun System. Several companies responded to it but the requirement was not funded and none of the vehicles proposed in the mid-1980s was adopted. All were armed with 105mm guns on the Rheinmetall model except for a light tank built by the AAI Corporation, which was an offshoot of the HIMAG programme and was still armed with a 75mm gun.

The requirement for an air-transportable gun system was revived in 1992, and after another competition the vehicle proposed by United Defense LP, which was a modified version of the one built in 1985 for the previous competition, was adopted as the M8 Armored Gun System or AGS. It was a vehicle with a crew of three and an automatically loaded 105mm gun that weighed 18 to 23.6 tonnes depending on the amount of add-on armour it carried and, like all the other AGS candidates, it was transportable in Lockheed C-130 aircraft. The first was completed in 1994 and there were plans to produce 237, but a year later, when only six prototypes had been built, development of the M8 AGS was terminated, which deprived the US Army of having an armoured vehicle suitable for airborne operations.

In the meantime studies were restarted of a potential replacement of the M1 tank in 1993, which was called the Future Main Battle Tank or FMBT. They envisaged a tank with a 120mm gun in an unmanned remotely operated turret and with a crew of three located in the hull, a configuration which was anticipated ten years earlier by the Tank Test Bed, except that FMBT was to have its engine at the front. By 1997 studies of FMBT gave way to the Future Combat System concept, which reached the stage of a full-size mock-up. This showed it to be another tank with an unmanned remotely operated turret, but with a crew of only two men at the front of the hull and an engine at the rear. It was to weigh 36 tonnes and, in spite of all the evidence against it, a gas turbine was again considered for it as an alternative to a diesel.[50]

All these tentative moves towards a new battle tank came to nothing in 1999 when the then Chief of Staff of the US Army, General E. K. Shinseki, announced his plans to transform the Army into a force that would be more mobile strategically. This involved the adoption of armoured vehicles that were considerably lighter than the M1 tanks and that were wheeled, as the latter were mistakenly assumed to be more mobile overall than tracked vehicles. Initially these were to be off-the-shelf Interim Armoured Vehicles, but they were to be followed by the development of a family of sophisticated wheeled armoured vehicles that would form part of the Future Combat Systems and all of which would be transportable in Hercules C-130 aircraft.

The vehicle ultimately chosen as the basic Interim Armoured Vehicle was the eight-wheeled Piranha armoured carrier designed in Switzerland by Mowag and produced under licence in Canada by General Motors as the Light Armoured Vehicle or LAV. It was chosen in preference to a tracked vehicle partly because General Shinseki and others in the US Army had become mesmerized by the operational mobility of wheeled vehicles, which was undoubtedly greater than that of tracked vehicles and which was vividly demonstrated during the 1999 Kosovo crisis when a Russian unit equipped with eight-wheeled armoured carriers drove at high speed from Bosnia and seized control of Pristina airport ahead of the slower moving NATO troops. In fact, an 'operational march to Pristina' became the criterion by which wheeled vehicles were chosen, which ignored the greater tactical mobility of tracked vehicles and their inherently lighter weight and smaller size than that of comparable multi-wheeled armoured vehicles.

The LAV was adopted in 2000 and was named the Stryker. Soon after the invasion of Iraq in 2003, Strykers began to be deployed there and became involved in urban counter-insurgency operations for which they were not designed and in which their light armour made them vulnerable. To improve their protection they were hastily fitted with slat armour, which provided a partial answer to the rocket propelled RPG-7 anti-tank grenades used extensively by the insurgents, and with thick underbelly plates against the explosions of improvised mines. But the improvements to their protection increased their weight to well over 17 tonnes, which was the most they could weigh if they were to be transportable in C-130 aircraft over operationally useful distances.

Studies of the Future Combat Systems vehicles that were to follow the Strykers started in 2000 and their development was formally launched three years later. At first they were to be wheeled, but once their development began in earnest common sense prevailed and they became tracked. The most challenging of them was the Mounted Combat System, which was to take the place of tanks. Like the contemporary versions of the latter, MCS was to be armed with a 120mm gun while its general configuration was a mixture of concepts that had already been proposed since the Tank Test Bed of the early 1980s. Thus, it had an unmanned remotely controlled turret and the crew located behind the engine, like the FMBT, but the crew consisted of only two men, as in the FCS of the late 1990s.

As MCS and the other FCS vehicles were to be C-130 transportable, they could not have much armour. Instead, they were to rely for their survivability on being part of a networked system, which, through information dominance, would enable threats to be detected and defeated before they could act. However, fighting in Iraq demonstrated once again that combat at close quarters could not be avoided, and that situation awareness, no matter how good, was no substitute for armour protection. In consequence, the armour of MCS was increased, in spite of the resulting increase in its weight, to more than the 18 tonnes originally specified. The need for such an increase was actually recognized at an early stage of the development, when it was considered necessary to allow the weight of the MCS to rise to 22 tonnes and virtually give up the idea of transporting it in C-130 aircraft. By 2008 the armour of the MCS was increased further and its weight rose to 24.5 tonnes. However, even this further increase in armour protection was not considered sufficient, and in 2009 the development of MCS and of the other Manned Ground Vehicles that formed part of the Future Combat Systems was abandoned in favour of a more realistic and inevitably heavier Ground Combat Vehicle.

Britain

When the Second World War came to an end, the British Army, like the US Army, reduced its armoured forces to a single armoured division but stationed it in Germany where the threat of Soviet aggression was greatest. Moreover, it continued with little interruption the development of tanks initiated in the closing stages of the war.

However, the ideas underlying the development of British tanks were changing, moving away from the unrealistic and harmful division into infantry and cruiser tanks towards the concept of a single type of battle tank. The most important protagonist of this concept was General, later Field Marshal, B. Montgomery who, according to his principal critic on this issue General G. Martel, came to favour it as early as 1943 on the basis of his observations of the successful advance across North Africa by the Eighth Army, which he commanded.[51] Montgomery subsequently outlined his views on the single type of what he called a 'capital tank' in a lecture given in London in 1945 and when he became Chief of the Imperial General Staff development of such a tank became official policy.[52]

The changes were not, of course, immediately or generally accepted. Just before the end of the hostilities, War Office studies still saw the need for separate infantry and cruiser tanks, and as late as 1950 generals Fuller as well as Martel were writing letters to *The Times* in support of two types of tanks with different functions. The General Staff also needed time to come to terms with the concept of a 'dual purpose' tank gun, agonizing over how tanks should be divided between those armed with what were primarily anti-tank weapons and others intended principally to fire high explosive ammunition – as if high-velocity tank guns could not fire high-explosive shells as well as armour-piercing projectiles.[53]

The actual development of a single type of tank started, oddly enough, in 1944 with the design of the A.45, a 55-tonne infantry support tank that was to complement the A.41 Centurion, which was originally regarded as a cruiser tank. A.45 was never built, but it was transformed in 1946 into a 'universal tank', which, apart from its basic role of a gun tank, was to be readily adaptable to or could be modified to perform a variety of specialized roles inspired for most part by the special purpose tanks of the 79th Armoured Division created for the 1944 landings in Normandy. A prototype of the basic FV 201 gun tank began to be tested in 1948, but the idea of incorporating in it a wide variety of specialist features proved impracticable and they were, in any case, superfluous so far as its main function was concerned. In consequence, the concept of a multi-functional 'universal tank' was abandoned in 1949.[54]

What was left was the basic FV 201. It was to be armed with the newly developed 83.8mm 20-pounder, but this quickly came to be considered insufficiently powerful to defeat the IS-3 and other heavy tanks that were expected to be fielded by the Soviet Army. A larger calibre 120mm gun, which was considered necessary for this purpose, was too heavy to be installed in the Centurion and it was decided therefore to mount it on the FV 201, which was modified consequently into FV 214. As no 120mm tank gun had yet been developed in Britain, it was decided to use an American gun of this calibre, which had been developed from an anti-aircraft gun for the US T34 heavy tank designed in 1945. However, the British version of this gun was provided with two new types of ammunition. One was the tungsten-cored

APDS, which took the place of the traditional full calibre armour-piercing shot; the other was HESH, or high explosive squash head, which took the place of conventional high explosive ammunition.

FV 214 came to weigh 65 tonnes and was called Conqueror. Trials of its prototype began in 1952, and three years later it started to be delivered to British armoured units to serve as a heavy gun complement of the Centurions. However, a total of only about 180 was produced, and although it remained in service until 1966 it was made redundant well before this by the re-arming of the Centurions with the 105mm L7 gun.

While the Conqueror was still being developed studies began in 1950 of an even more heavily armed tank called FV 215. This tank was to be armed with a 183mm gun that fired massive, 160kg HESH projectiles and became the world's largest calibre tank gun. FV 215 did not advance beyond a full-size wooden mock-up and its development was discontinued in 1957. However, the 183mm gun was not only built but was successfully fired from a Centurion chassis and is preserved at the Tank Museum at Bovington.[55]

In the meantime, Centurion became almost the only tank of the British Army. Although it was conceived during the war as a 'heavy cruiser' and was later designated a medium gun tank it was, for most of its life, a very well armed universal tank. The first few were still armed with the wartime 76mm 17-pounder, but in 1948 the Mark III version was armed with the much more powerful 83.8mm gun, or 20-pounder, as it was called under the archaic system of gun designation still used by the War Office. Design of the 83.8mm gun was strongly influenced by that of the German 8.8cm KwK 43, which armed Tiger II heavy tanks and was probably the most effective tank gun of the Second World War. Like the latter, the 83.8mm gun was still designed to fire conventional full calibre armour-piercing projectiles, but it was also provided with APDS ammunition fired with a muzzle velocity of 1,465m/s, which was higher than that of other types of tank gun ammunition produced until then and which greatly increased the armour-piercing capabilities of the gun, making it the most effective of its day.

Armed with the 83.8mm gun, Centurion performed with credit when it was first used in 1951 during the Korean War, and the three Centurion-equipped British armoured divisions stationed in Germany during the 1950s formed the most effective counter to the Soviet armour massed in what was at the time East Germany. The capabilities of the Centurions came to be highly regarded and led to their acquisition during the 1950s and 1960s by no fewer than 16 different countries, either by direct purchase, like Sweden, Switzerland and Israel, or under US military aid programmes, like the Netherlands and Denmark. In fact, more than half of the total production of 4,423 tanks was exported.

The successful development of the 83.8mm gun and its APDS ammunition was followed by its evolution into a 105mm gun, which proved even more successful. The original experimental version of this gun was actually made in 1954 by simply boring out an 83.8mm gun barrel to 105mm, and with new APDS ammunition developed in the 1960s it could penetrate 120mm of steel armour inclined at 60º at a range of 1,830m, which was about twice what the earlier type of full calibre armour-piercing projectiles fired from a gun of the same calibre could penetrate.

On the strength of its performance, the 105mm L7 gun began to replace the 83.8mm gun in the Centurions of the British Army in 1959, and in 1958 it was adopted by the US Army in preference to two American guns as the main armament of the US battle tank of the 1960s and 1970s, the M60. It was also adopted, with or without modifications, for several other tanks including the German Leopard 1, Swedish S-tank, Swiss Pz 61, Indian Vijayanta, Japanese Type 74, Israeli Merkava and even the original version of the US M1 tank designed in the mid-1970s, as well as the South Korean K 1 designed still later and the Chinese Type 80. Altogether about 35,000 different tanks have been armed with the 105mm L7 and its derivatives, making it the most widely used tank gun outside the Soviet bloc since the Second World War.

In Britain the development of the Centurion was followed by that of the Chieftain, which originally was to be another medium gun tank but became a main battle tank after the Tripartite – American, British and Canadian – conference in Quebec in 1957 decided to adopt the concept of such a tank in place of the earlier policy of developing medium and heavy tanks. Studies leading to it started in 1951, but a prototype was not built until 1959. It embodied a number of novel features, one of which was a supine position for the driver that reduced the height of the hull and consequently of the whole tank, making it a more difficult target for enemy guns. The lower hull also helped to keep the weight of the Chieftain down to 55 tonnes compared with 65 tonnes of the Conqueror in spite of having thicker frontal armour. In fact, the horizontal shot line thickness of Chieftain's frontal armour was 388mm compared with 258mm of the

Conqueror and was greater than that of any other tank available to the NATO forces until the 1980s.

At the time, Chieftain was also NATO's most powerfully armed tank, being armed with a new 120mm rifled gun. The gun used two-piece ammunition with separate bagged propellant charges inspired by naval gunnery practice and adopted in preference to the traditional brass cartridge cases because they were thought to be less of a fire hazard in the event of the tank's armour being perforated by enemy weapons. They were also lighter and therefore easier to handle. However, they complicated the handling and the logistics of the ammunition and they required not only two but three parts, the third being a separate ignition or 'vent' tube.

In contrast to the Centurion and the Conqueror, which were powered by V-12 Meteor petrol engines based on the Rolls-Royce Merlin aircraft engine, Chieftain was powered by a six-cylinder opposed-piston two-stroke diesel based on the Junkers Jumo engine developed in Germany before the Second World War for aircraft. A Junkers engine preserved at the Science Museum in London was actually referred to when Chieftain's engine was being designed, and it was used as a model because it was particularly well suited in principle to operating on a wide range of fuels, which came to be required under a policy adopted in 1957 by NATO that fighting vehicles should be powered by multi-fuel engines.

Development of Chieftain's engine was ordered in 1958 and it was built remarkably quickly, with the first running a year later. The company responsible for it, Leyland Motors, was Britain's leading manufacturer of conventional four-stroke truck diesels but had no previous experience of Junkers-type engines. As a result the engine they built initially produced only 585hp instead of the 750hp it was expected to deliver, and although this power level was eventually attained the engines remained troublesome. Their problems also delayed the introduction of Chieftain into operational use until 1966, although a small batch was completed in 1963. Production for the British Army continued until 1971, by which time 810 were produced, but in that year 780 more were ordered by Iran, which asked for a further 150 in 1975, and Kuwait also ordered 150 in the same year.[56]

In spite of its novel features, Chieftain still had the general configuration of a conventional turreted tank with a four-man crew. But even before a prototype of it was completed, the Fighting Vehicles Research and Development Establishment, which was responsible for its design as well as that of other post-war British tanks, began to work on other radically different tanks. The most radical of them was, very appropriately, called Contentious. Work on it started in 1956 in response to the possibility of what was at the time called 'nuclear warfare', which placed greater emphasis than ever on mobility. This led to a requirement for a smaller and lighter tank of 20 to 30 tonnes, which would be air-transportable and even parachuteable and yet enjoy a high level of protection against nuclear as well as conventional threats. To this end, the crew of Contentious was reduced to two and it dispensed with a turret, its gun being mounted in the hull, which provided it with limited, 20° traverse but no elevation, which was achieved by tilting the whole hull by means of an adjustable suspension. All these features were embodied in a test vehicle but were not pursued beyond trials, which continued into the mid-1960s.

Another departure from convention explored by FVRDE involved the mounting of guns on pedestals instead of in turrets. This was considered as early as 1951, in the initial stages of the design studies that led to the Chieftain, as a way of keeping down the weight of tanks. It was not adopted at the time, but in the 1960s FVRDE returned to it as it offered the advantage of a smaller frontal area, particularly in defensive hull-down positions, as well as concentrating the crew in the hull where they could be better protected. However, pedestal mounted guns required an appropriate and highly reliable automatic loading system as manual loading was impracticable, and they were more vulnerable. FVRDE pursued its investigations to the point of building an experimental vehicle called COMRES 75 in 1968, which became the first tank with a pedestal mounted gun.

The concept of tanks with pedestal mounted guns was carried into the initial stages of the Anglo-German Future Main Battle Tank programme, which was agreed to by the governments of the two countries in the pious hope that it would lead to a sharing of costs and a common battle tank, in spite of the fact that the joint US-German MBT-70 programme had just failed to achieve the same objectives. The concept of a medium weight tank with a pedestal mounted gun was however rejected after an Anglo-German symposium in 1972, and the principal British contribution to the FMBT programme became the study of a turretless tank with a semi-fixed gun.

Contemporary interest in turretless tanks was due to a large extent to the development in Sweden of the S-tank. This was the first and still the only tank with a gun fixed in the hull, which offered a number of advantages over earlier turretless tanks as well as over tanks with turrets, and it attracted a great deal of attention when it appeared in the early 1960s. One consequence of this was that two S-tanks were brought to Britain in 1968 for tests, and subsequently the British Army borrowed 10 S-tanks for tactical trials in 1973 by one of the British armoured regiments stationed at the time in Germany. But the outcome of all this was a recommendation against the development of turretless tanks for the British Army.

Nevertheless, a turretless experimental vehicle called the Casemate Test Rig, or CTR, was built in 1973–74. It differed from the S-tank in having a mounting which, like that of the German *Sturmgeschutz*, provided its gun with some elevation and traverse independently of the hull, meaning that the CTR did not require an adjustable suspension and did not depend entirely for aiming in azimuth on the steering system. The CTR was also heavily armoured, weighing an estimated 54 tonnes compared with the 39 tonnes of the S-tank. However, development of it was not taken beyond 1976 when the Anglo-German FMBT programme was terminated after the German as well as British armies rejected the various proposed departures from conventional designs.

Further development of conventional designs was greatly encouraged by the contemporary development in Britain of a new type of armour much more effective against shaped charge weapons. The latter were only recognized in Britain as a major threat to tanks after the appearance of the first anti-tank guided missiles with shaped charge warheads in the late 1950s. When this happened a research programme was initiated at FVRDE in 1963 into armour against shaped charges, and after two years it led to the development of a new type that was more than twice as effective, on a weight basis, against shaped charges than solid steel armour. The nature of this armour, which came to be called Chobham armour after the location of FVRDE, is still held to be a secret by the British Ministry of Defence, although it is widely known in principle and is obviously a form of spaced armour incorporating non-metallic materials as well as steel. Work on its application to tanks began in 1968, and two years later a decision was taken to build an experimental tank with it. This was accomplished at FVRDE with remarkable speed, resulting in 1971 in the FV 4211, which became the first tank with the new type of armour.

As a result of the close military and political links between the United Kingdom and the United States, the chief scientific adviser to the UK government informed his US counterpart about the development of

Chobham armour as early as 1964. This was followed by technical presentations to those involved in US tank development but they showed remarkably little interest, ostensibly because they considered Chobham armour to be too bulky to be of practical use. It was therefore only in 1972, after the chance visit to FVRDE by General Desobry described earlier in this chapter, that Chobham armour was taken up by the US Army. It was then incorporated in the prototypes of the US M1 tank, and when the latter went into production in 1980 it was ahead of any tank with Chobham armour produced for the British Army.

The Iranian Army might also have acquired tanks with Chobham armour before the British Army. This possibility arose out of the large purchases of Chieftains by Iran mentioned earlier, which were followed in 1974 by orders for a new version with a more powerful engine and then for another not only with a new engine and hydropneumatic suspension but also with Chobham armour. There were to be 125 of the first version and 1,225 of the second, called respectively Shir 1 and Shir 2. They constituted a very major export order that would have been of considerable economic benefit to the UK. But they also created a bizarre situation, because they meant that the British government was agreeing to the export of tanks with a new type of armour that the British Army was not going to have for a number years, and which the British Ministry of Defence still held to be highly secret more than 30 years later, to a country whose stability was questionable and whose regime had been overthrown once already by elements hostile to Britain.[57]

As it was, no Shir 2 was ever delivered to Iran because its development was overtaken in 1978 by the overthrow of the shah, after which the new Iranian regime cancelled the order for it. However, by then five prototypes of Shir 2, or FV 4030/3 as it was designated in the UK, had been built, and they became the basis of the first tanks with Chobham armour produced for the British Army.

Originally this tank was to be MBT-80, work on which began in 1976 after the collapse of the Anglo-German FMBT programme. MBT-80 was to be a relatively heavy conventional turreted tank of about 55 tonnes, which was designed from the basis of FV 4211 but which was not yet ready to go into production when the shah fell. In the meantime, the consequences of the Iranian revolution meant the principal British tank factory in Leeds, which had fulfilled the orders it had for Chieftains, was faced with the prospect of having no tanks to produce for several years. To prevent this happening and to preserve employment in the British tank industry, the Ministry of Defence decided in July 1980 to abandon MBT-80, which was not going to be ready for some time, and order a limited number of a derivative of FV 4030/3 that was called Challenger. The first of the 240 ordered in 1981 was delivered with commendable speed by the end of the following year and further orders brought the total to 420, the last of which was built in 1990. The continuity of work at the Leeds and other factories was also bolstered by the production of Shir 1, or FV4030/2, which had already started and which continued after 274 were sold to Jordan, which renamed them Khalids.

Thanks to its Chobham armour and a more powerful as well as less problematic 1,200hp Rolls-Royce diesel engine, Challenger represented a considerable advance on the Chieftain in terms of its survivability and mobility. But in other respects it was, in effect, a Chieftain. This applied in particular to its main armament, which consisted of the 120mm L11 rifled gun that was being overtaken by the more powerful 120mm smooth bore gun adopted already for the German Leopard 2 tank and chosen for the second version of the US M1 tank. Suggestions that the writer and others made that this type of gun should also be adopted for the Challenger were dismissed on the grounds that this could not be done without major modifications to its turret and also that of the Chieftains, which were to continue to be used alongside Challengers in a mixed fleet of about 1,200 tanks. It was also argued that the 120mm rifled gun had to be retained in order to fire HESH or other high explosive projectiles as well as armour-piercing ammunition, which was simply not true.

What is more, the British Army was slow to recognize that APFSDS ammunition with its fin-stabilized long rod penetrators was inherently superior to APDS. Yet it was already evident by 1973 that APFSDS represented as much of an advance on APDS as the latter did on the original armour piercing ammunition.[58] Nevetheless, when the writer raised the matter at the time, he found the official view to be that APDS was superior to APFSDS.[59] This could be attributed in part to the great success that the developers of British tank gun systems had achieved with APDS ammunition and that made them reluctant to admit that another type of ammunition could be even better. By the time they did, APFSDS was already becoming established elsewhere, and the UK had lost the world lead which it enjoyed as a result of the development of th 83.8 and 105mm guns and their APDS ammunition.

To catch up with the use of APFSDS, the Ministry of Defence authorized the development of an 'operational emergency' round, which came into service in the mid-1980s. This rectified the lack until then of APFSDS ammunition, but its use was handicapped by the fire control system of the Challenger, which was basically the same as that of the Chieftain devised 30 years earlier. How much it had fallen behind other more recently developed fire control systems was brought out by the dismal performance of the Challengers in the 1987 Canadian Army Trophy Competition run by NATO involving engaging targets on the move, in which they came well behind the US M1 and the German Leopard 2.[60]

The outcome of the competition finally moved the Ministry of Defence to formulate a requirement for a replacement for the Chieftains, of which the British Army still had more than 700. Vickers Defence Systems, who by then had taken over the Leeds tank factory from Royal Ordnance, responded by offering an improved Challenger 2 provided with a new turret and a new fire control system and armed with a new high pressure 120mm L30 rifled gun. This gun could also be retrofitted in Chieftain as well as Challenger 1, if this were still required, and it continued the use of the three part ammunition. However, such was the dissatisfaction with Challenger 1 that the procurement of the US M1A1 and of the German Leopard 2 were considered as an alternative, and extensive trials of these two tanks were rin in 1989 at the Royal Armoured Corps Centre. In the end Challenger 2 was chosen, but the contemporary collapse of the Soviet Union and the consequent reduction in the size of the British Army resulted in only 127 being ordered in 1991. At fist it was planned to upgrade the Challenger 1 fleet, but this was subsequently abandoned, and instead 259 additional Challenger 2s were ordered in 1994. The last of them was delivered in 2002 and they replaced Challenger 1, most of which were transferred to the Jordanian Army under a government-to-government agreement, while the Chieftains were demilitarized and disposed of.

The decision to adopt Challenger 2 was influenced by the perceived performance of Challenger 1 in the Gulf War of 1991, in which it was claimed to have achieved a high level of availability, in spite of its history of reliability problems that involved the replacement of virtually every tank's power pack during the course of the short campaign. However, Challenger 2 successfully took part in the invasion of Iraq in 2003 for which it, like Challenger 1 before it, was fitted with additional second generation Chobham armour, called Dorchester, and with explosive reactive armour, which raised its weight from

62.5 to 66 tonnes. During the course of their operations, Challenger 2s demonstrated their complete dominance of the older types of tanks when 14 of them met a counter-attack by the same number of Iraqi T-55 tanks near Basra and destroyed every one of them without suffering any losses themselves.

Even more modern Soviet tanks than the T-55 encountered in Iraq by British and US tanks did not constitute a major challenge to their guns. A much more serious challenge emerged out of studies of the possible armour protection of future Soviet tanks, which began in 1982 and led to a requirement for a 140mm tank gun. Similar studies were carried out in the United States and other countries and led to an agreement between the UK, US, France and Germany for the development of a 140mm gun as the future main tank armament, as already mentioned earlier in this chapter. In keeping with this agreement, a 140mm gun was designed in the UK and by 1993 prototypes of it were test fired, some from Centurion tank chassis. However, in the late 1990s the British as well as other armies lost interest in 140mm guns and decided to continue using 120mm guns.

The continued use of 120mm guns in British tanks implied a possible and long overdue replacement of their rifled guns by a smooth bore gun of the Rheinmetall Rh 120 type, which had been adopted by the US and all major European as well as several other armies. The adoption of this type of gun would make the armament of British tanks interoperable at last with those of their allies and provide them with inherently more effective APFSDS ammunition, because its one-piece rounds made possible longer penetrators as well as eliminating the complication of three-piece ammunition.

The use of the Rh 120 gun began, in fact, to be investigated in 2004 and by 2006 one was retrofitted in a Challenger 2. The case for adopting it became even stronger after 2010 when, as a result of the defence reviews carried out by the British government, the tank strength of the British Army was cut down to only three regiments with a total of 168 Challenger 2s, which made further development of their 120mm rifled gun and its ammunition completely uneconomical.

France

In contrast to the continuity of tank development in Britain and the other major participants in the Second World War, their development in France was interrupted by the defeat of 1940 and was only resumed four years later. However, even before the whole of France was liberated, its government decided that it should produce a tank more powerful than the US built M4 Shermans with which the re-created French armoured divisions, of which there were three, were equipped at the time.

The development of such a tank began before the end of 1944 from the basis of clandestine studies pursued under the German occupation, and the first was built in 1946 at the the Atelier de Rueil arsenal, after which it was designated ARL 44. Production of 600 was planned, but only 60 were actually built between 1947 and 1949. One tank regiment was equipped with them in 1950, but their service life was short as they did not prove entirely satisfactory, being a mixture of new and old components rapidly put together. The former consisted of an adaptation of a 90mm anti-aircraft gun, which made the 50-tonne ARL 44 well armed while the latter were exemplified by the obsolete type of running gear that resembled that of the Char B of the 1930s and made ARL 44 look distinctly old fashioned. Nevertheless, ARL 44 served to restart French tank industry as a *char de transition*.[61]

The stopgap nature of ARL 44 was emphasized by the fact that even before the first was built, development began of a much more modern and powerful tank, the AMX 50. Work on it started two months before the end of the war and it was incorporated in the French Army's post-war re-equipment programme. It was included in the latter as the only type of battle tank and represented therefore an advance on the policies pursued by the Soviet, US and British armies, which did not give up dividing their tanks between medium and heavy categories for several more years.

The design of AMX 50 was heavily influenced by the German Panther and Tiger II tanks and was aimed at a tank that was as mobile as the Panther and at least as well armed as the Tiger. It even incorporated components, such as the engine and transmission, developed for one or the other of the two German tanks and it could draw on further experience with the Panthers, as from about 1946 to 1950 one French tank regiment was equipped with them. However, AMX 50 incorporated at least one major novelty in the shape of an oscillating or trunion mounted turret. Unlike conventional one-piece turrets, this consisted of two parts, the upper being mounted on trunions in the lower part and with the gun mounting fixed to it, so that the gun was elevated or depressed with it. This greatly simplified gun sights and made possible the installation of a relatively simple automatic loading system in the turret bustle, since there was no relative movement between it and the gun mounting.

The first prototype of AMX 50, which was completed in 1949, was armed with a 90mm gun comparable to the 88mm gun of Tiger II, but a year later both this and a second prototype were re-armed with 100mm guns. Then, in 1951, it was decided to arm AMX 50 with a 120mm gun, and one of the three prototypes that had been built by then was re-armed with a gun of this calibre capable of firing the same ammunition as the US M103 heavy tank. Two more prototypes armed with 120mm guns were built after this, one of which was much more heavily armoured and consequently weighed 70 instead of the 59 tonnes of the standard version.[62]

Production of about 100 was envisaged, but by the mid-1950s the development of AMX 50 was abandoned, mainly for financial reasons. In addition, enthusiasm for very heavy tanks of its kind had waned as the value of their heavy armour was reduced by the development of shaped charge weapons, and the French Army began to receive several hundred M47 tanks under US military aid programmes. As a result of this, from 1952 onwards the M47 replaced the M4 Sherman tanks with which French armoured forces were still equipped, although by then their M4 tanks were of the improved type armed with 76 instead of the original 75mm guns.

Although AMX 50 was abandoned, its original features, namely the oscillating turret and bustle autoloader, were perpetuated in the AMX 13 light tank that was also developed as part of the French Army's post-war re-equipment programme. AMX 13 was conceived in 1946 as a well-armed air-transportable light tank that could be flown, when required, in the projected Cormoran transport aircraft to French overseas territories. As it happens, Cormoran was never built and the idea of deploying AMX 13 by air was not very realistic, but its combination of gun power with light weight made it one of the outstanding tanks of the 1950s. Its 75mm gun was actually as powerful as that of the German Panther and yet its weight was only 14.5 tonnes instead of 43, and thanks to its autoloader, which contained two six-round magazines, it was operated by a crew of three instead of five.

The first prototype of AMX 13 was completed in 1949 and the second a year later, when it was sent for trials in the United States, where its turret attracted considerable interest and later inspired the design of experimental tanks with similar turrets. Its production was launched in 1950 with US financial support and led to the first 23 being completed in the early part of 1952, which was a remarkable achievement, all the more so in view of the state of the French industry after the ravages of the Second World War and the novel features incorporated in the AMX 13.[63]

As soon as it appeared, AMX 13 attracted worldwide attention and during the following two decades it was procured by a dozen different countries, the first being Switzerland, which ordered 200 even before it began to come off the production line. Eventually, the total produced for the French and other armies reached 2,800 tanks.

Sixty AMX 13s were obtained in 1955 by Israel and were successfully used by it during the 1956 Suez campaign but when used again 11 years later during the Six Day War it was found that their 75mm guns could not defeat the armour of Soviet-built T-54 tanks, which the Egyptian Army had by then acquired. The French Army had already considered in 1954 the possibility of replacing the 75mm gun of AMX 13, which still fired the traditional full calibre armour-piercing projectiles, with a more effective 105mm gun that fired the newly developed Obus G – a projectile with a shaped charge mounted on ball bearings within the shell that prevented it being degraded by the spin imparted to the shell by the rifling of the gun. A prototype armed with the 105mm gun was built in 1958, but the French Army did not adopt this version of the AMX 13. However, it was taken up by the Netherlands Army, for which it began to be produced in 1963, and it was subsequently also procured by Ecuador as well as Argentina and Peru.[64]

For its part, the French Army decided in 1964 to re-arm its AMX 13 with a new 90mm gun firing fin-stabilized shaped charge projectiles. In that form AMX 13 was allocated to mechanized infantry units to augment their anti-tank capabilities, while those of the armoured units were increased by the allocation to each tank regiment of a squadron or company of AMX 13s with four SS-11 anti-tank guided missiles mounted on the front of their turrets, which constituted the first if rather crude use of guided missiles as tank armament.

Some of the AMX 13s re-armed with 90mm guns were used by the French Army until 1987, but others, still armed with the original 75 or 105mm guns, continued to be used into the 21st century by other armies, including those of Indonesia and Singapore, which became their largest scale users. In addition, the most important feature of the AMX 13, which was its oscillating turret with an automatically loaded gun, was perpetuated by the SK 105 Kurassier produced in Austria.

Kurassier was developed as a result of the peace treaty imposed on Austria after the Second World War, which among other things banned it from acquiring anti-tank guided missiles and made the Austrian Army look for alternative ways of improving its anti-tank capabilities. This led to a decision to develop a 'tank destroyer' by mounting the turret of the AMX 13 with its 105mm gun on a much modified chassis of an armoured personnel carrier already being produced in Austria by the Saurer company. Development of the resulting 17.7-tonne SK 105 Kurassier began in 1965, and the first pre-production vehicles were delivered four years later. By that time the Saurer company was taken over by the Steyr-Daimler-Puch company, which produced 286 Kurassiers for the Austrian Army. More were produced for Tunisia, Morocco, Argentina, Bolivia and Botswana, and as late as 2000 17 Kurasiers were ordered by the Brazilian Marine Corps, which brought the total produced to about 700 tanks.

When production of the Kurassier was under way, Steyr began to consider arming it with a more powerful gun than the one it inherited from the AMX 13 and prompted Rheinmetall to develop a low recoil force version of the widely used 105mm L7 tank gun. This was fitted with a muzzle brake and provided with recoil travel twice as long as that of the standard gun, which reduced the recoil force to one third of what it was and made the gun compatible with a tank as light as the Kurassier. A low recoil force gun was consequently installed in a prototype of a new SK 105 A3 version of the Kurassier, which was built by1988 but which was not put into production. However, Rheinmetall's development of the low recoil force 105mm gun inspired the construction during the 1980s and 1990s of several experimental light tanks armed with similar guns.

In the meantime the French Army had acquired another type of tank. This originated with an agreement reached in 1957 between France and Germany to develop a standard European tank. The agreement led to a specification that envisaged a tank of 30 tonnes armed with a 105mm gun and a decision to build prototypes based on each country's design. The prototypes were subjected to competitive trials in 1961 and 1962 but in 1963 each country decided to produce its own design, which in the case of France became the AMX 30.

The first two were completed in 1965 and they were followed by quantity production, which led to the entry of AMX 30 into service in 1967, when it began to displace the US-built M47 tanks that until then formed the principal equipment of French armoured units. Production continued until 1977, by which time 1,084 were built for the French Army. More than 600 were also built for Saudi Arabia, Greece, Venezuela and other Arab and South American countries, and 399 more were built under licence in Spain.

AMX 30 weighed 36 tonnes, which made it lighter than the Soviet T-54, but it was less well armoured. In contrast to AMX 50 and AMX 13, it had a conventional instead of an oscillating turret, the advantages of which came to be considered outweighed by its greater weight and the difficulty of sealing it against radioactive dust and airborne chemical agents as well as against water during submerged crossing of rivers. The turret mounted a 105mm gun rifled gun firing Obus G that could perforate the armour of contemporary battle tanks and that was more accurate at long range than the fin-stabilized shaped charge or HEAT ammunition developed in the United States. But it was expensive to produce and AMX 30 was not provided with any kinetic energy armour-piercing ammunition, in particular with APDS, because this was considered unnecessary and required rifling with more twist than that adopted to suit Obus G.

In service the transmission of AMX 30 proved troublesome, and this and other problems led to an improved version that incorporated a new transmission and an integrated fire control system with a laser instead of an optical rangefinder. Moreover, its gun was provided with APFSDS ammunition fired with a muzzle velocity of 1,525m/s, which was being recognized as the most effective type of anti-armour ammunition. The first of the improved AMX 30 B2 was delivered in 1982 out of a total of 166 newly built tanks, while previously built tanks were gradually brought up to B2 standard.[65]

To improve their protection, particularly against shaped charge weapons, some AMX 30 B2s were fitted in the mid-1990s with explosive reactive armour, which involved the installation of 112 ERA cassettes and an increase in weight of 1.7 tonnes. However, this improvement was confined to the tanks of only one regiment, which were designated AMX 30 B2 Brenus.

A very different attempt to improve the effectiveness of the AMX 30 was made several years earlier, when it was fitted with a new turret mounting a short-barrelled 142mm gun launcher that fired ACRA anti-tank guided missiles as well as fin-stabilized multi-purpose projectiles. This was comparable to the contemporary development of the M60A2 with the 152mm gun launcher in the United States, but the ACRA missile was basically superior to the US Shillelagh missile as it used laser beam riding guidance instead of command-to-line-of-sight guidance. However, development of the ACRA missile and the 142mm gun launcher was abandoned in 1972 because of their complexity and cost as well as the advances in the accuracy of gun systems, which made them less attractive as tank armament than they appeared when their development started in the mid-1960s.[66] A similar conclusion was reached in the United States but not apparently in the Soviet Union.

While work on converting AMX 30 into AMX 30 B2 was still under way, studies began in 1975 of the possibility of further improvements to its design and this led to AMX 32, which was aimed at the export market. It was similar to AMX 30 B2 but for a number of improvements, the most important of which was more effective spaced armour instead of solid steel armour, which increased its weight to 38 tonnes. The first prototype was completed in 1979 and three more were built in 1986, but AMX 32 was not adopted by any army.

The same fate befell a further development of AMX 30 for export, which was designated AMX 40. Its principal features were a 120mm smooth bore gun, which fired APFSDS ammunition similar to that of the guns already adopted for the German Leopard 2 and US M1 tanks, and a more powerful 1,100hp engine that more than compensated for an increase in weight to 43 tonnes. But, for all its gun power and increased agility, AMX 40 did not advance beyond four prototypes built between 1983 and 1985. However, it served to advance French tank technology beyond that of the AMX 30 and in some respects paved the way for the next French tank, although the latter represented a much greater advance.[67]

Studies of the next tank were initiated in 1975 and included a critical analysis of the future role of tanks, which reaffirmed their position as the *engin principal de combat* or EPC. To explore the range of possibilities, in 1977 four different designs were produced of a tank of about 40 tonnes with a three-man crew and an automatically loaded 120mm smooth bore gun mounted in different turrets on front and rear engined chassis. But two years later French and German authorities entered into discussions about the development of a common tank, which came to be called Tank 90 or Napoleon. This led to two years of further studies at the end of which the two countries parted company again, largely because the proposed tank would have little French content.

As a result, more studies were carried out for a purely French tank which included designs with overhead gun installations and the crew located in the hull. But in the end the choice already made in 1983 was confirmed. This amounted to a tank of 56 tonnes with a conventional configuration but with a two-man turret and a bustle autoloader with 22 rounds. Its design was finalized in l986, when it was called Leclerc, and the first of six prototypes was completed three years later.[68]

Production of the Leclerc resulted in the commencement of its deliveries to the French Army in 1992 and continued until 2006, when 406 were completed. A year after the first Leclerc was delivered to the French Army it was also adopted by the United Arab Emirates, which ordered 388. Tanks ordered by UAE differed from the French Army version in being powered by MTU MT 883 diesels of 1,500hp instead of the SACM V8X of the same power. The former was the most successful of the turbo-charged diesels developed for tanks since the 1970s and was as compact as the latter, which was more complicated, incorporating as it did the Hyperbar supercharging system that was comparable to the addition of a small gas turbine, and which consumed significantly more fuel.

Both versions of the Leclerc enjoyed the advantage over other contemporary Western tanks of having an automatic loading system, particularly when it came to firing on the move. Their autoloader could also accommodate a wider range of ammunition than the carousel-type autoloaders of the Soviet tanks, including projectiles with longer penetrators. They could also accept larger calibre ammunition. This was demonstrated in 1996 when, as a result of earlier decisions that a 140mm gun might be necessary to defeat future enemy tanks, a Leclerc was successfully modified to mount a gun of this calibre, even to the extent of containing the same number of rounds in its autoloader as the standard 120mm gun version.[69]

The inherent advantage of the Leclerc in this respect was not exploited, as the change in the political situation resulting from the collapse of the Soviet Union removed the need for 140mm guns. Instead, Giat Industries (now Nexter), the manufacturers of Leclerc, addressed the problem of tank operation in urban areas brought out by the US invasion of Iraq in 2003. This led to improvements to Leclerc in all-round observation and protection, particularly against attack at close quarters, or in what were called *Actions en Zone Urbaine*, AZUR.

The number of Leclerc tanks retained by the French Army was also reduced to 208 as a result of the changes in the political situation, which represented the strength of its remaining four tank regiments.

Germany

While the development of tanks in France was interrupted for four years by the Second World War, there was none in Germany for 11 years after that conflict. Its revival only stared in 1956 with a requirement formulated by the newly re-created German Army for a highly mobile tank of 30 tonnes. A year later this requirement was incorporated in a specification agreed to with France for a standard European tank, and the two countries proceeded to design and built prototypes of it. But after competitive trials each country decided in 1963 to adopt its own design, as mentioned in the previous section of this chapter.

Production of the German tank, which came to be called Leopard 1, was preceded by the construction of as many as 26 prototypes for engineering and troop tests and was followed by a pre-production batch of 50 tanks built for further trials, all of which safeguarded against problems arising during production and service and ultimately contributed to the reputation for reliability that the Leopard 1 acquired. The first prototypes were armed with 90mm guns made by Rheinmetall, who had also developed a 105mm gun, but this did not prove entirely satisfactory and the British 105mm L7 gun was adopted instead. This ensured that Leopard 1 was well armed and that it could use the same ammunition as the M60 and Centurion tanks of its allies. The 660hp V-8 diesel installed in the early prototypes was replaced during the course of the development by a 830hp V-10 diesel, which provided a high level of agility in spite of a gradual increase in the weight of the tank from 34.8 tonnes of the prototype to 42.4 tonnes of the final version.[70] During the course of its production a number of modifications were made to Leopard 1, including the fitting of additional armour to its turret, but its armour remained inferior to that of other contemporary tanks such as the US M60 and the Soviet T-55 and T-62.

Series production resulted in the first Leopard 1 being delivered to the German Army in 1965, when it began to replace some of the US-built M48 tanks that had been procured by the German Army. Leopard 1 was also adopted in 1967 by the Belgian Army and a year later by the Netherlands and Norway. In 1970 200 Leopard 1s were ordered by Italy, which was involved in the 1958 specification for a European tank, and which eventually acquired 920. Leopard 1 was also adopted in 1975 by the Australian Army and two or three years later by the Canadian Army, in both of which it replaced British-built Centurions, and it was also ordered in 1974 by the Danish Army. More were ordered in 1980 by Turkey and in 1981 by Greece.

All the orders for it resulted in the production of Leopard 1 continuing until 1984, when it reached a total of 4,744 tanks, 2,237 of which were built for the German Army. In addition to the gun tanks, a considerable number of derivatives have also been produced, including anti-aircraft tanks, recovery vehicles, engineer tanks and bridgelayers. When international tension was lowered by the collapse of the Soviet Union and the withdrawal of Soviet troops from Eastern Europe, several NATO countries reduced their tank fleets and passed on some of their Leopard 1s to other countries, thus spreading their use even more widely. Thus Belgium sold one third of its Leopard 1s to Brazil, while the Netherlands sold almost one half of its fleet to Chile. Germany itself transferred many of its Leopard 1s to Turkey and Greece and disbanded its last Leopard 1 battalion in 2003.

Forty years earlier, when series production of Leopard 1 was about to begin, the German Army took the first steps towards the development of another and more powerful tank. They consisted of an agreement signed by Germany and the United States for the joint development of a tank that would be used by the armed forces of the two countries. It was to be designed separately in them but in both cases it was to have the same general characteristics, including a turret containing all three crewmen, a 152mm gun launcher and a high power-to-weight ratio of 30hp per tonne. The first automotive test rigs were assembled in both countries in 1967 and were followed by a total of seven prototypes, which began to be tested a year later. However, the advanced features and the complexity of its design made MBT-70, or KPz 70, difficult and expensive to develop, which made Germany pull out of the joint project in 1969.[71]

Even before this happened, studies began of possible further improvements to Leopard 1 which would provide a fall-back solution to KPz 70, and in 1971 they were followed by an experimental version armed with a new 105mm smooth bore gun. The latter was adopted as the basic feature of a new tank that would also incorporate the German 1,500hp power pack of MBT-70. The resulting tank was called Leopard 2 and the first of

16 prototypes of it was completed in 1972. Ten of them were still armed with a 105mm gun, but the others were armed with Rheinmetall's new 120mm smooth bore gun and they were officially adopted as Leopard 2.[72] However, no decision was taken to produce them until 1977. The delay was due initially to extensive engineering and troop trials in Germany, Canada and the United States and then to new negotiations with the United States about both countries fielding the same type of tank. The German candidate for this was Leopard 2 AV, or 'Austere Version'. Two prototypes of this 54.5-tonne tank were flown across the Atlantic in C-5 Galaxy aircraft of the US Air Force and were subjected to competitive trials with US XM1 prototypes from 1977 to 1978.[73] But in the end each country went ahead with the production of its own tank, which in the case of Leopard 2 resulted in the first being delivered to the German Army in 1979.

Concurrently with the development of Leopard 2, Germany embarked on a wide ranging exploration of alternatives to the conventional, turreted tanks. The principal and by far the most interesting outcomes of this were experimental turretless tanks with two guns that could fire salvoes to ensure hitting targets and that would zig-zag to avoid being hit themselves. The construction of these vehicles was preceded by test bed vehicles, such as the remotely controlled TVR-02 based on the chassis of the US M41 light tank but fitted with a 1,800hp engine, which gave it an exceptionally high power-to-weight ratio of 82hp per tonne, or almost four times that of the most mobile of ordinary tanks. This enabled it to zig-zag very rapidly and thereby avoid being hit by anti-tank guided missiles.[74] Trials with TVR-02 were followed in 1972 by orders for an experimental VT 1-1 tank with two 105mm guns, which could be elevated but not traversed independently of the tank, and then for a similar VT 1-2 with two 120mm guns as well as five others with laser gun simulators for tactical trials. The trials, which went on until 1980, demonstrated that the twin-gun tanks could hit targets when zig-zagging if they fired their guns when in coincidence with the gunner's independently stabilized sight that had acquired the target. However, further development was abandoned, as the number of areas in Central Europe in which tanks could zig-zag for any distance was limited and as tactical control of tanks zig-zagging was considered difficult. Moreover, the contemporary development of new and more effective types of armour, such as Chobham, made hit avoidance by missiles less critical, while advances in the accuracy of tank gun systems demolished the case for firing salvoes.

The turretless two gun tanks were initially part of the Anglo-German Future Main Battle Tank programme, but experiments with them continued after that programme came to an end in 1976, and it was only then that another new concept began to be evaluated with the construction of VTS-1. This consisted of a pedestal mounted 105mm gun on the chassis of a Marder infantry fighting vehicle. VTS-1 was tested until 1983, but the concept of a tank with a gun mounted on a pedestal above the hull and with all the crew in the hull was eventually rejected, as was an earlier British proposal for such a tank.

A less radical departure from the conventional tank design was then considered within the framework of the Franco-German KPz 90 programme initiated in 1979. German studies under this programme were focused on a reduced frontal area 'flat turret' with a crew of two and a bustle autoloader mounted on a Leopard 2 chassis. However, this was not put into effect.

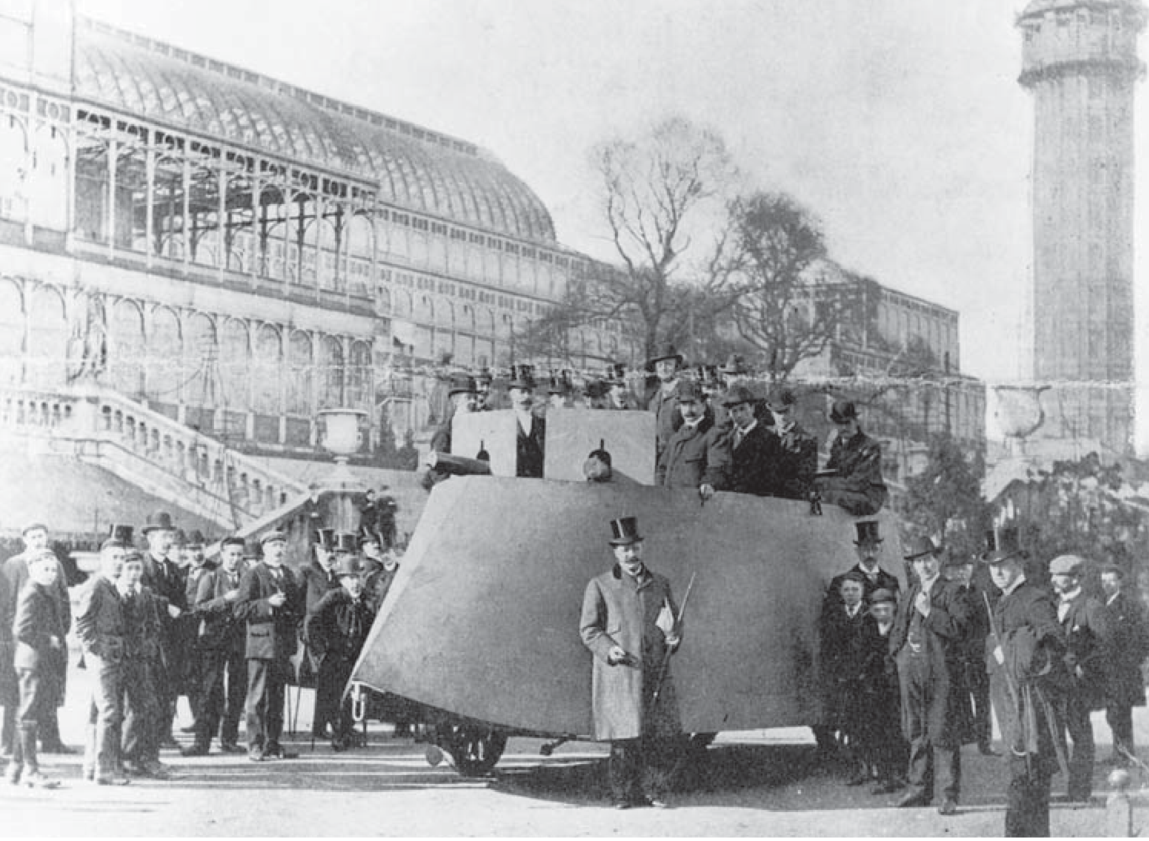
Yet another and very different alternative to the conventional tank was explored in the early 1990s under the Panzerkampfwagen 2000 programme. It involved a reduction of the crew to two men and their location in the front of the hull, which was adopted in order to make the tank more compact and therefore able to have more armour within a given weight limit. The practicality of this was investigated using the VT 2000 experimental vehicle based on a Leopard 2 chassis and a specially built EGS tank demonstrator, which could be heavily armoured and which was also designed to have low thermal and radar signatures to minimize the probability of detection. A two-man crew was viable from the technical point of view, and it was argued that it could also be made viable tactically by providing each tank with a follow-up crew of two. However, such an arrangement was unlikely to work in the course of mobile operations. It was not in fact accepted, which is not surprising as tactical operation of tanks generally calls for a crew of three to deal effectively with the separate tasks of command and control, gunnery or weapon operation and driving or navigating.

While the search for alternatives went on, Leopard 2 was developed further, although its production for the German Army came to an end in 1992 when 2,125 had been built for it. In the first instance, it was agreed to modify 225 of the Leopard 2A4s already built to what was called the Mannheim Configuration, which implied major improvements to the armour protection as well as the fire control system and an increase in weight from 55.15 to 59.7 tonnes of the resulting Leopard 2A5. The first Leopard 2A5 was delivered in 1995 and when the modifications of the last of the

225 were completed 125 more A4s were modified to the A5 standard. All the 350 Leopard A5s were then converted into the A6 version, which involved them being re-armed with a new 120mm gun with a barrel 55 instead of 44 calibres long that fired APFSDS projectiles with a muzzle velocity of 1,750 instead of 1,650 m/s and was therefore capable of penetrating even thicker armour. The German Army received the first of the Leopard 2A6s in 2001, which were then provided with additional protection against mines but at the cost of a further increase in weight to 62.5 tonnes.[75]

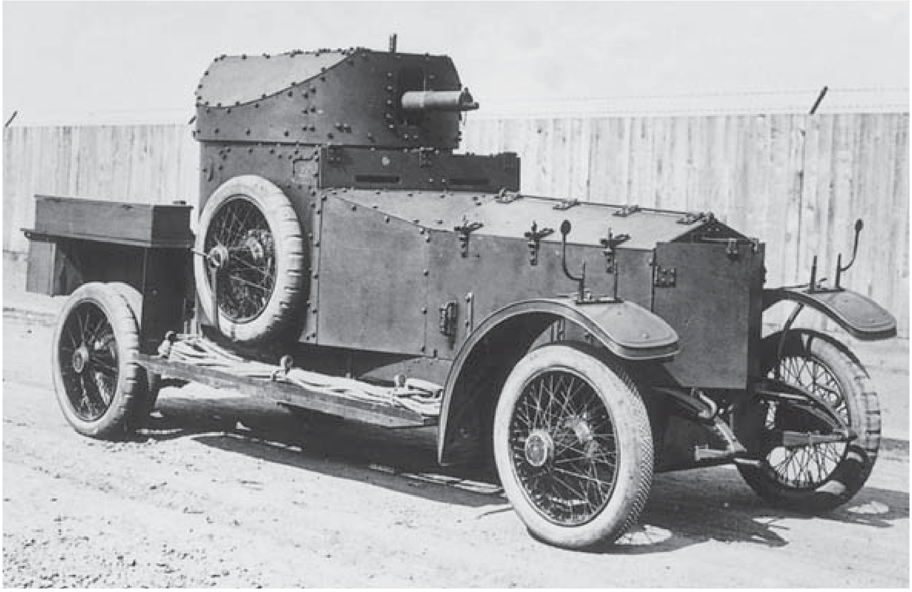
Design studies were also carried about concerning arming Leopard 2 with a much more powerful 140mm gun. As in other NATO countries, they began in 1982 and led to an experimental installation of a 140mm gun in a Leopard 2, but further development was abandoned in 1995.[76]

The lowering of international tension that followed the collapse of the Soviet Union led to dramatic reductions in the size of the Western armies and in particular of their tank fleets. The German Army was no exception to this and its tank force, which at one time was to consist of 85 battalions with a total of 5,136 tanks, was reduced to six battalions with a total of 395 tanks, and then to four battalions and 225 tanks. However, Leopard 2 continued to be used on a large scale, but scattered in lots of 50 to 300 between countries that had originally procured them and others that acquired tanks that had become surplus to the original users' requirements. There were also some newly produced tanks, which included 120 Leopard 2Ss modified to Swedish requirements, 219 Leopard 2Es produced in Spain and 170 Leopard 2HELs built in Greece. The total number of Leopard 2s that has been produced thus came to 3,459 and they have come to be used by 12 different countries, ranging from Finland and Norway to Singapore and Chile, in addition to the original users, namely Germany and Switzerland.



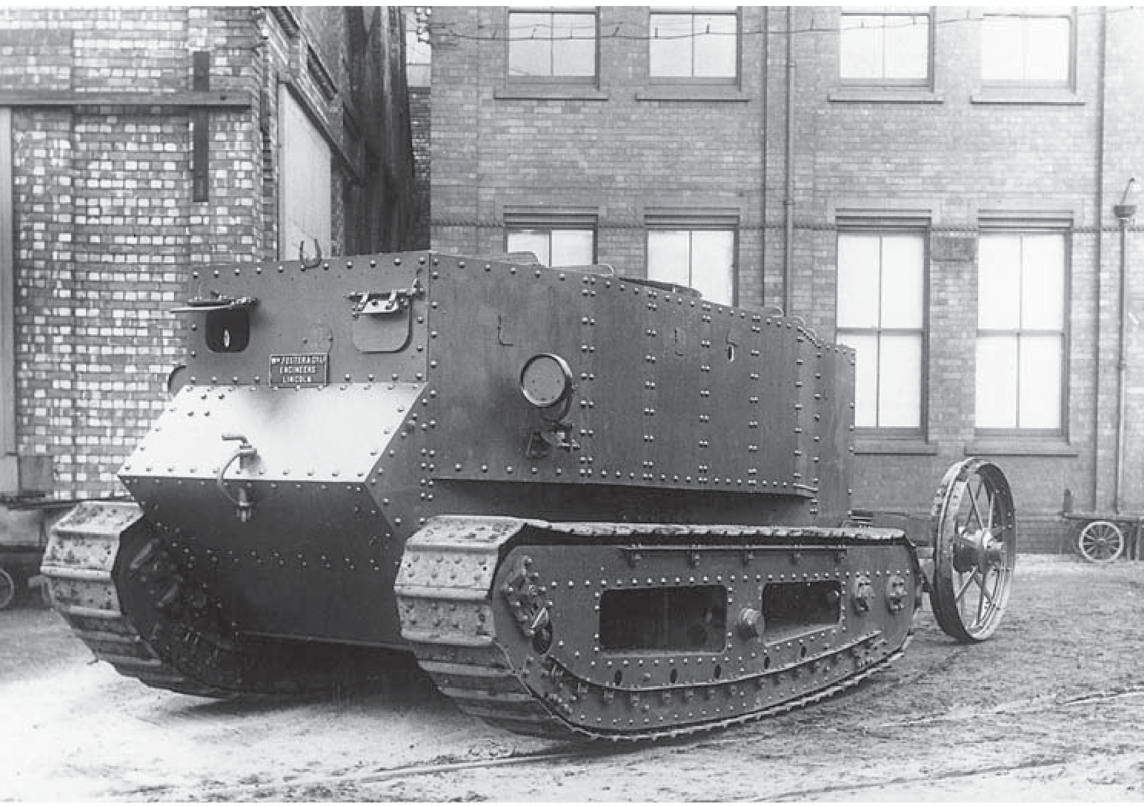
ABOVE • Simms' 'War Car', the first vehicle that was armed and armoured demonstrated at the Crystal Palace in London in 1902. (Simms Motor & Electronics Corporation Ltd)

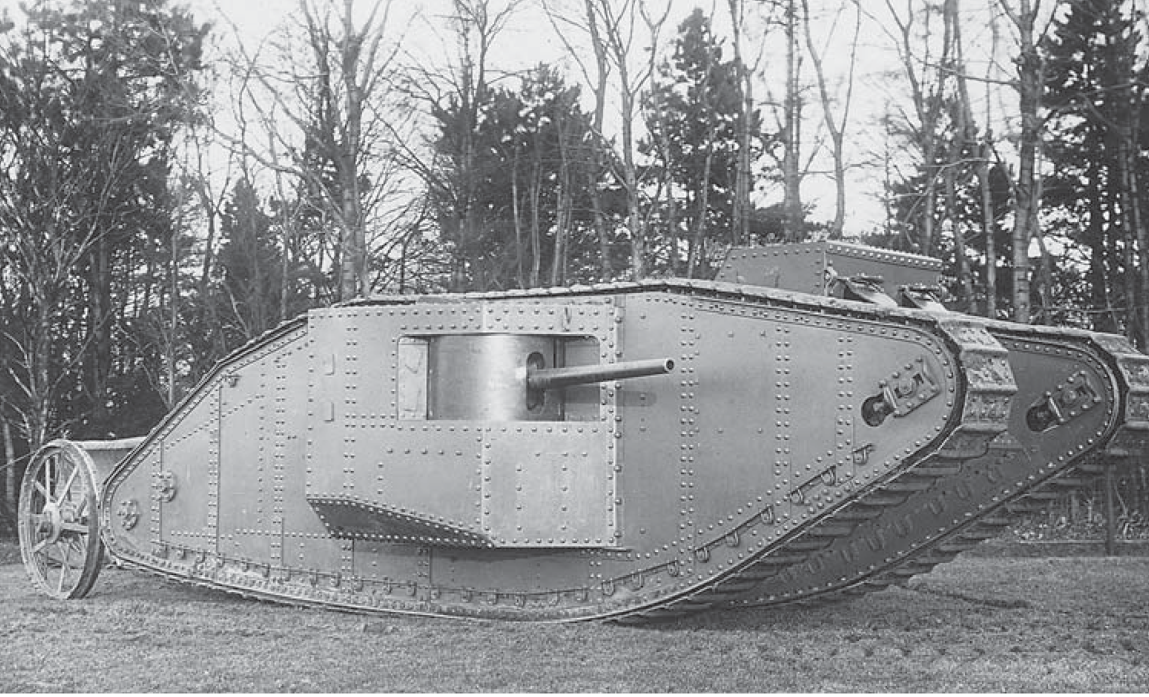
BELOW • Hornsby tractor during British Army trials at Aldershot in 1910. (The Tank Museum)



ABOVE • Armoured car built in 1915 on the Rolls-Royce 'Silver Ghost' chassis for the Royal Naval Air Service. (Imperial War Museum, Q 14632)

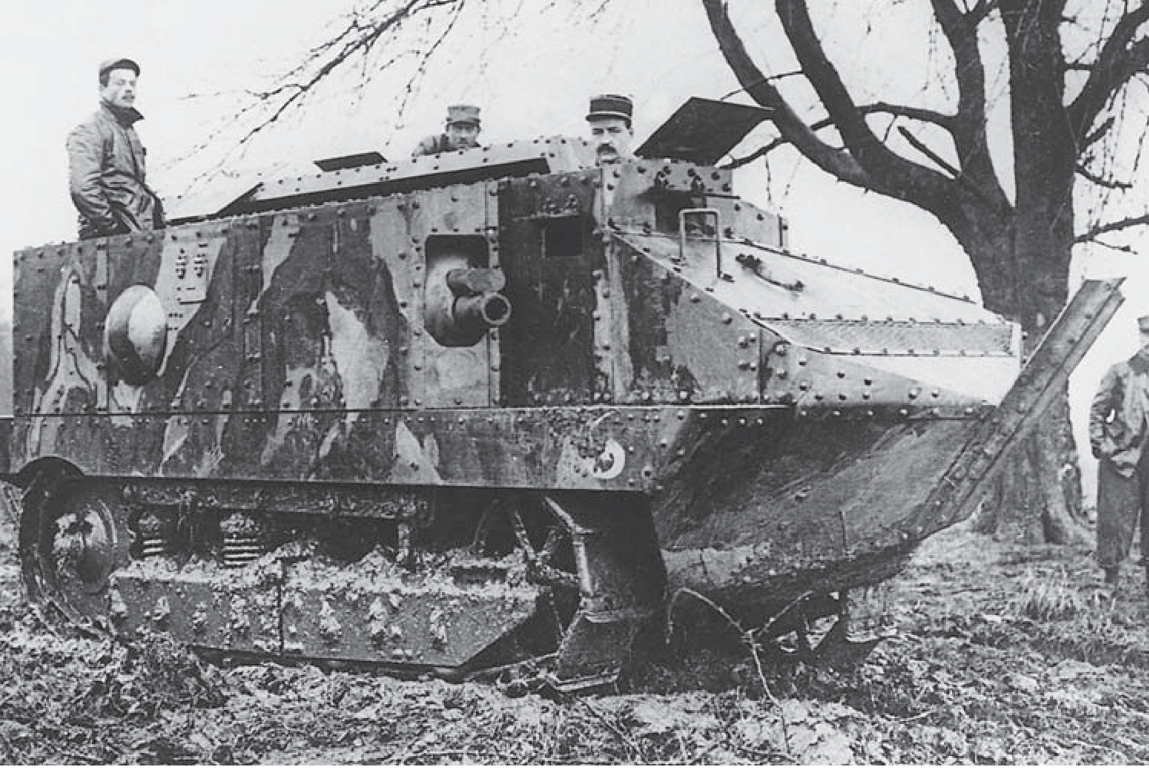
BELOW • 'Little Willie', the first tank, completed in September 1915. (William Foster & Co Ltd)





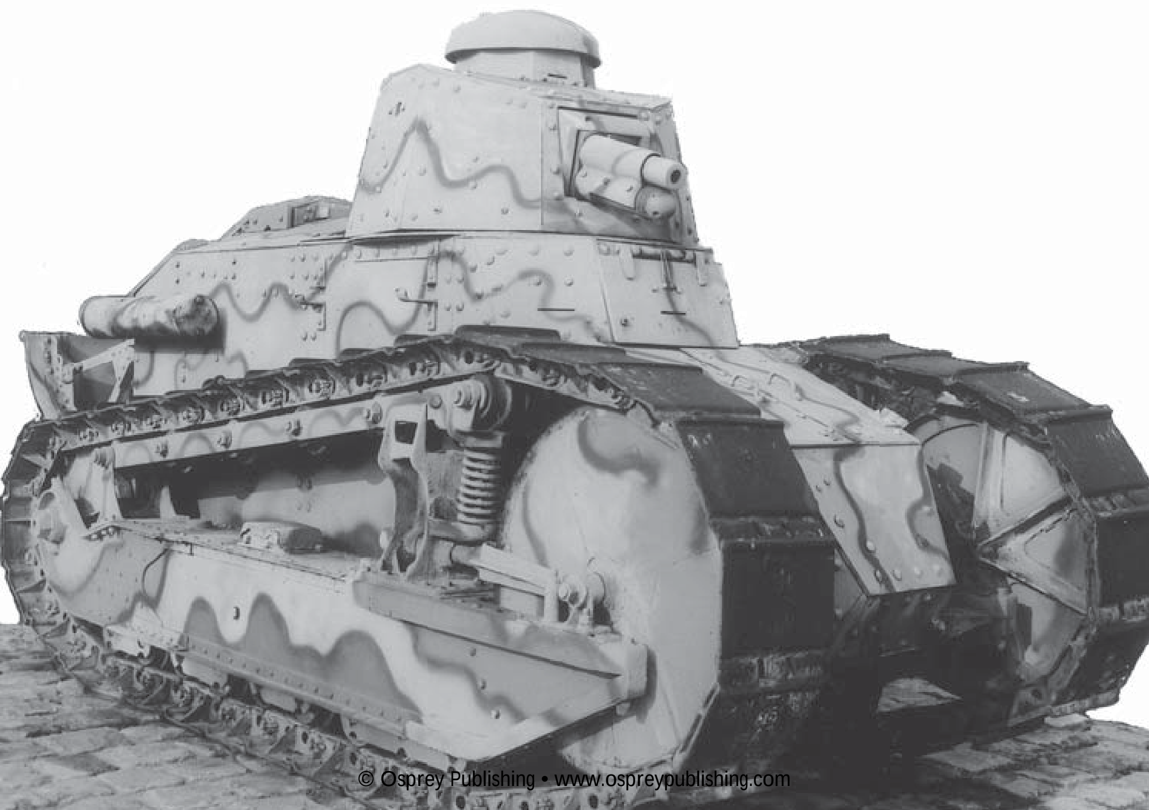
ABOVE • 'Mother', the progenitor of the rhomboidal British tanks of the First World War, at its presentation in January 1916. (Imperial War Museum, Q 70935)

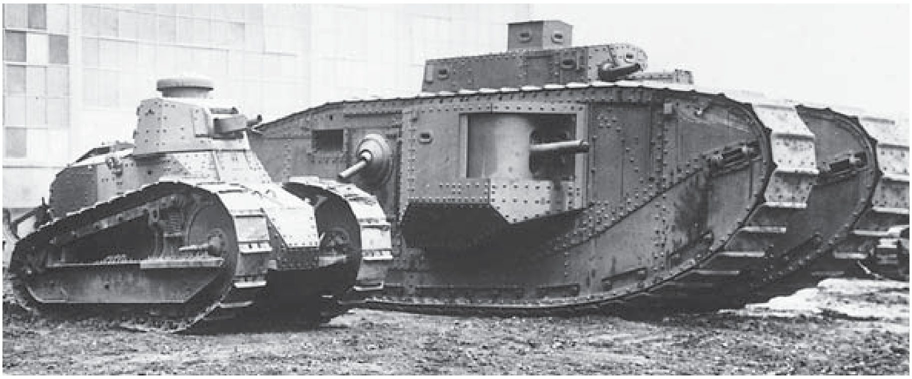
BELOW • Mark I tank during the first tank action in September 1916. (Imperial War Museum, Q 2486)

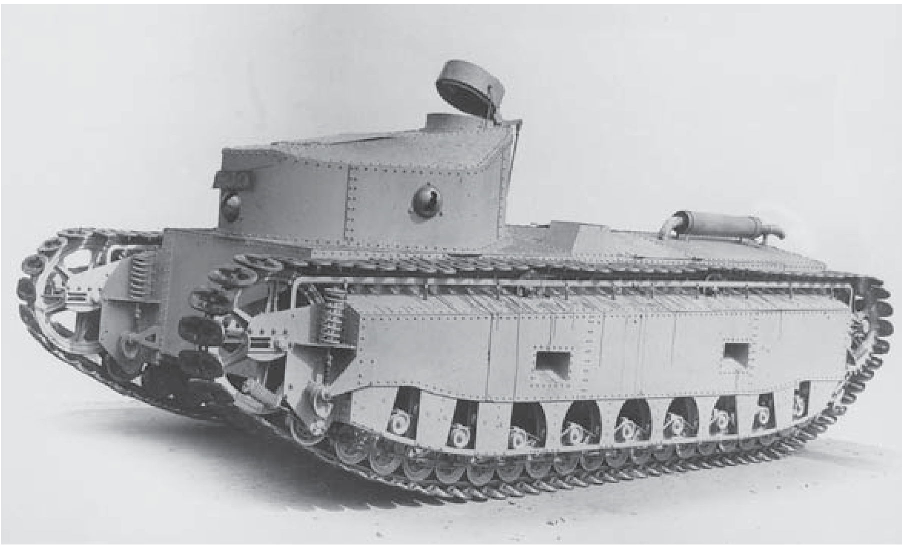


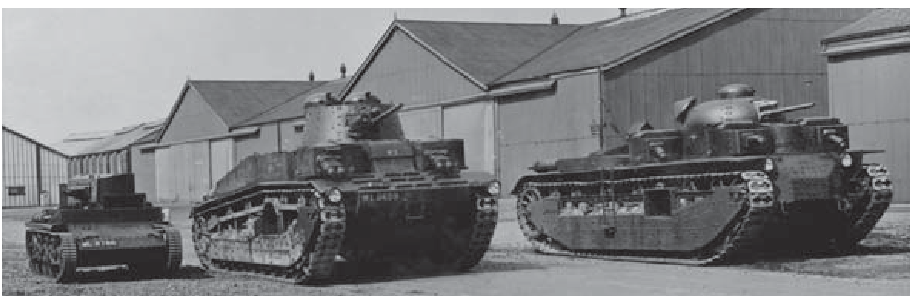
ABOVE • The first French tank built in September 1916 by the Schneider company, after which it was named. (Imperial War Museum, Q 57721)

BELOW • The French Renault FT light tank, the world's most numerous and the most widely used tank from the end of the First World War until the 1930s.





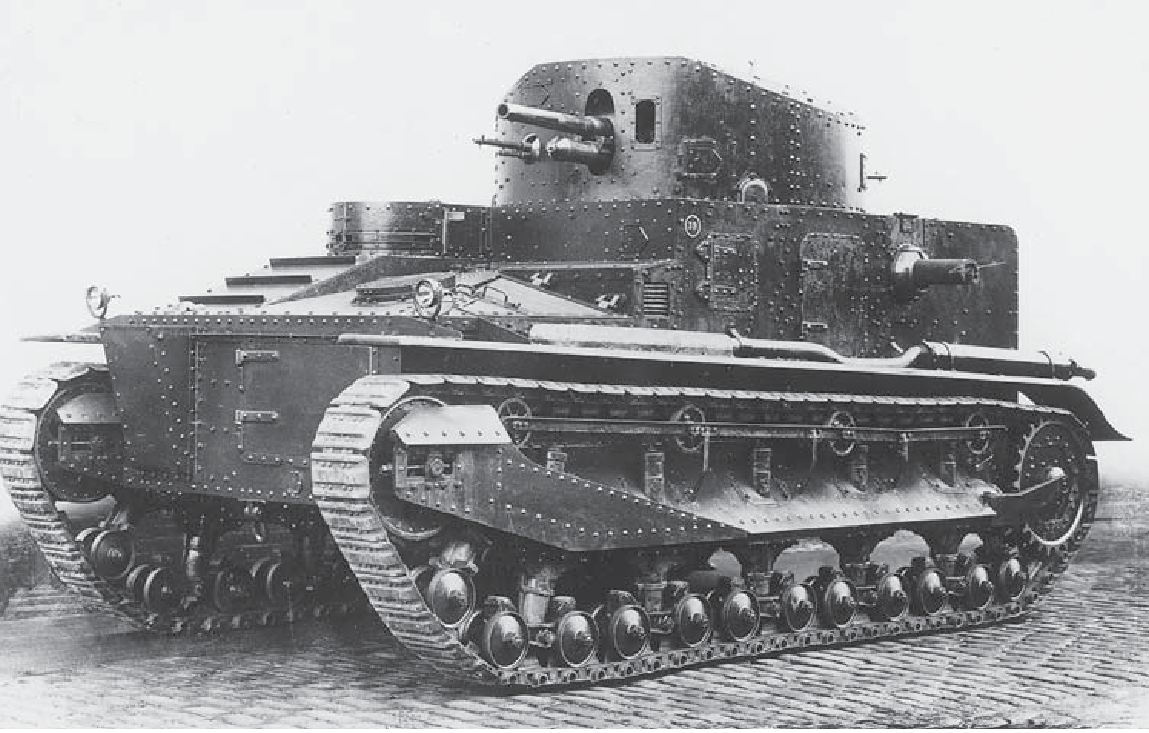




TOP • Belated products of the First World War: the US M1917 light tank, a copy of the Renault FT, and an Anglo-American Mark VIII, the last of the rhomboidal heavy tanks, both of which were retained by the US Army into the 1930s.

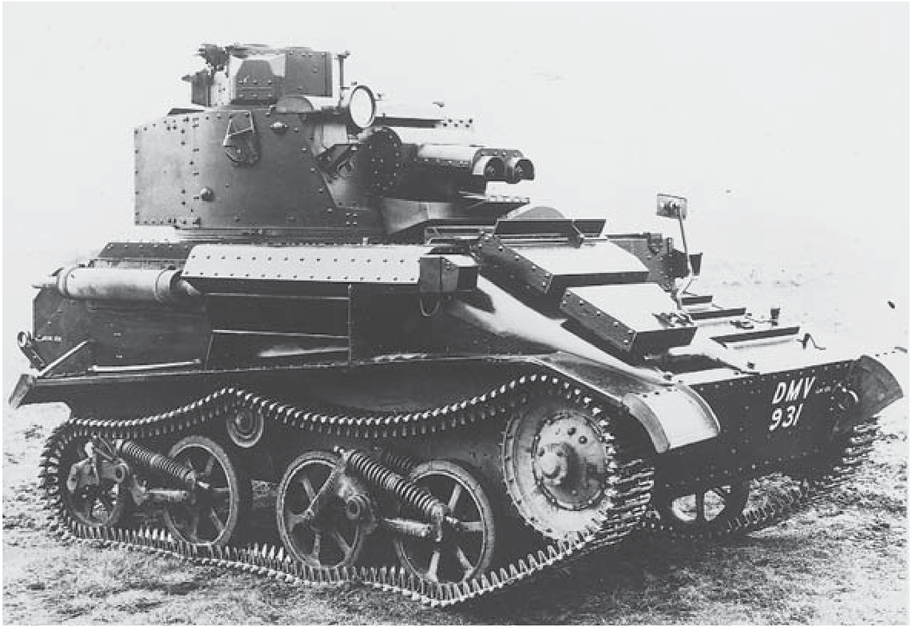
MIDDLE • The Experimental British Light Infantry Tank, which demonstrated the possibility of a considerable advance in the mobility of tanks by attaining a speed of 30mph in 1922.

BOTTOM • Two-man Light Tank Mark I (on the left), the three-turret A.6 or Sixteen Tonner (centre) and the five-turret A.1 Independent – outstanding examples of British tank development during the late 1920s. (The Tank Museum)



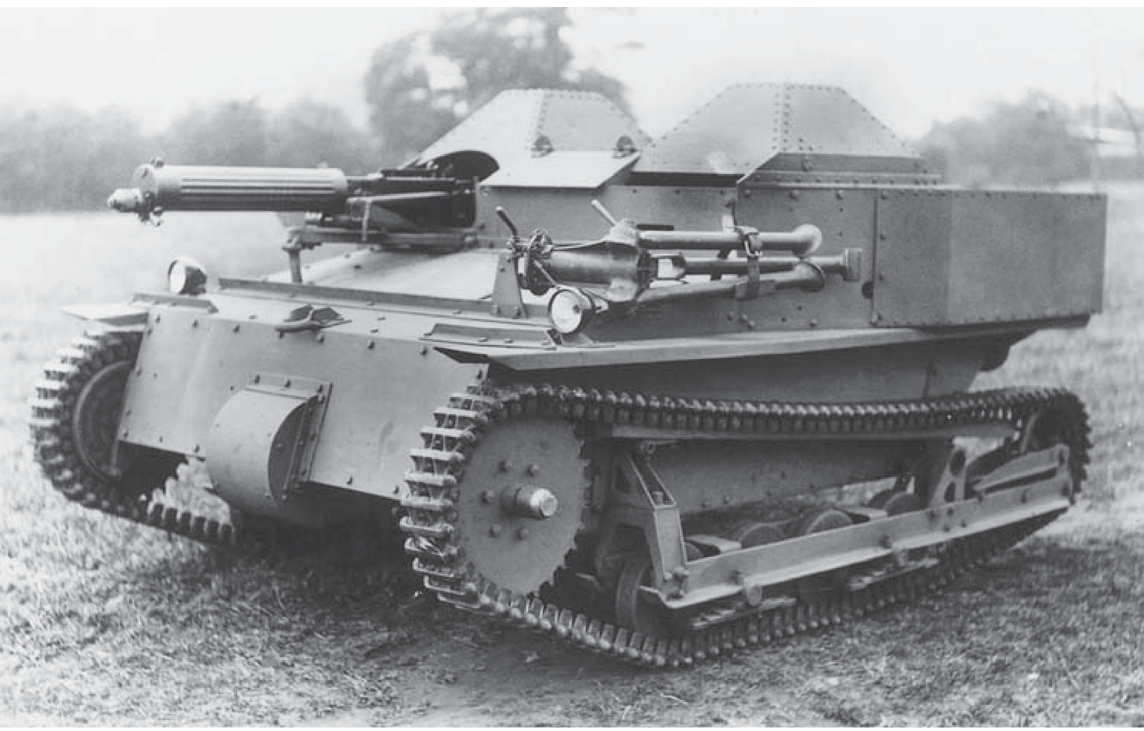
ABOVE • The Vickers Medium, the only tank produced in quantity during the 1920s and more mobile than its wartime predecessors, which made it arouse greater interest in tanks worldwide. (Vickers Armstrongs Ltd)

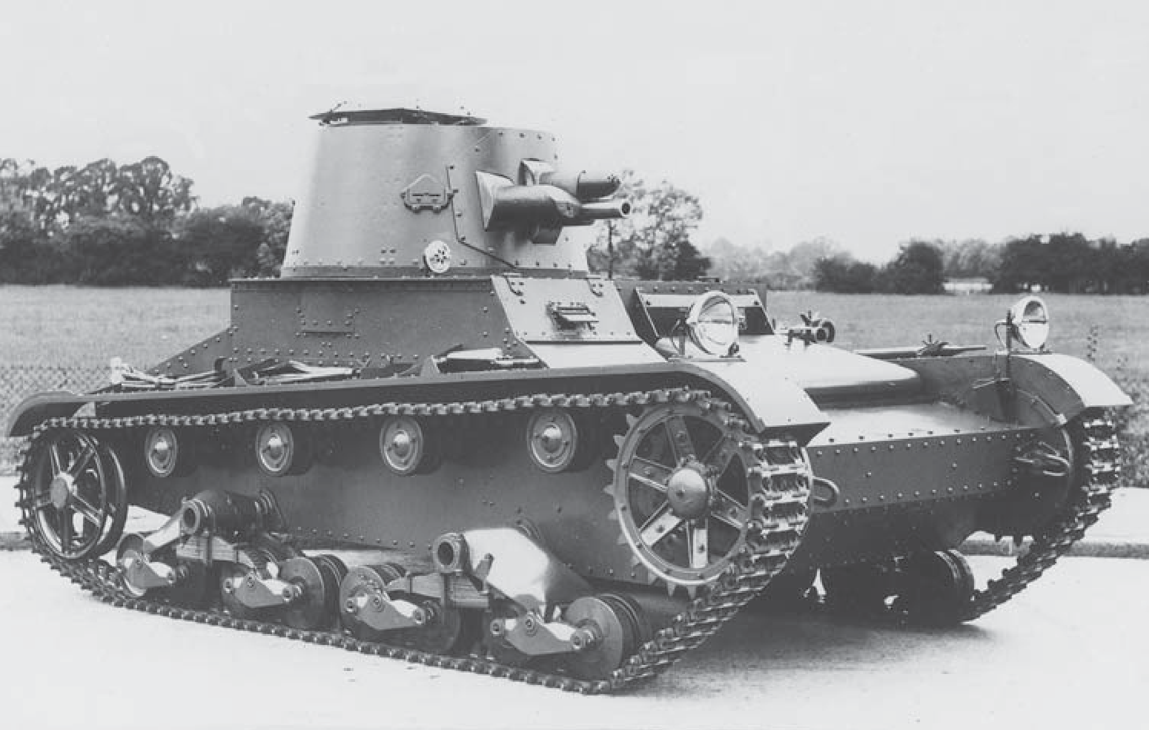
BELOW • The Matilda infantry tank, the most effective British tank in the early stages of the Second World War, due mainly to its thick armour. (Imperial War Museum, E 1416)



ABOVE • The Light Tank Mark VI, the principal British tank at the outbreak of the Second World War. (Imperial War Museum, MH 3582)

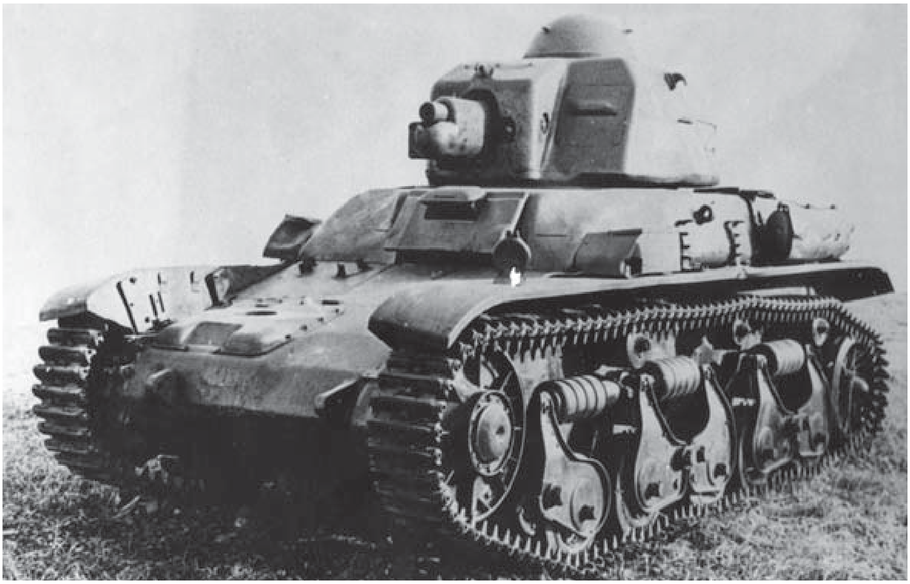
BELOW • The Carden Loyd Mark VI Machine Gun Carrier, which inspired the production in several countries of turretless 'tankettes' and very light two-man tanks. (Vickers Armstrongs Ltd)

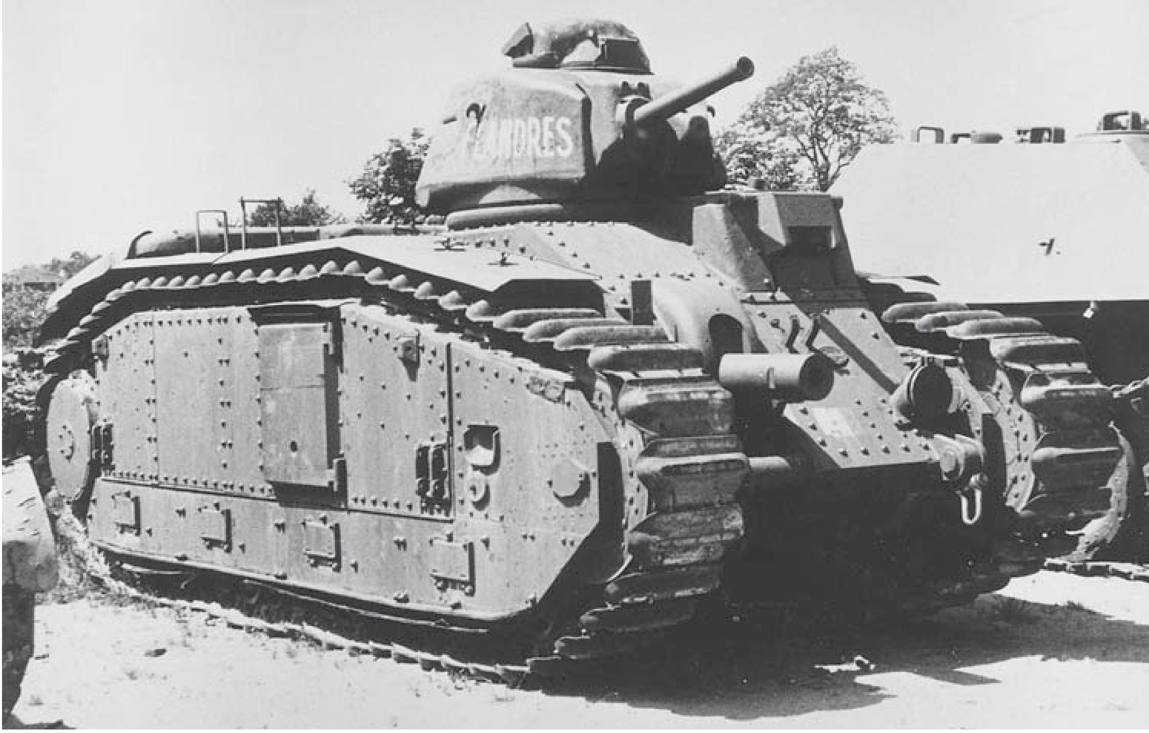




ABOVE • The Vickers Six Ton Tank, the forerunner of the light or medium tanks armed with cannon of 37 to 47mm that were typical of the late 1930s. (Vickers Armstrongs Ltd)

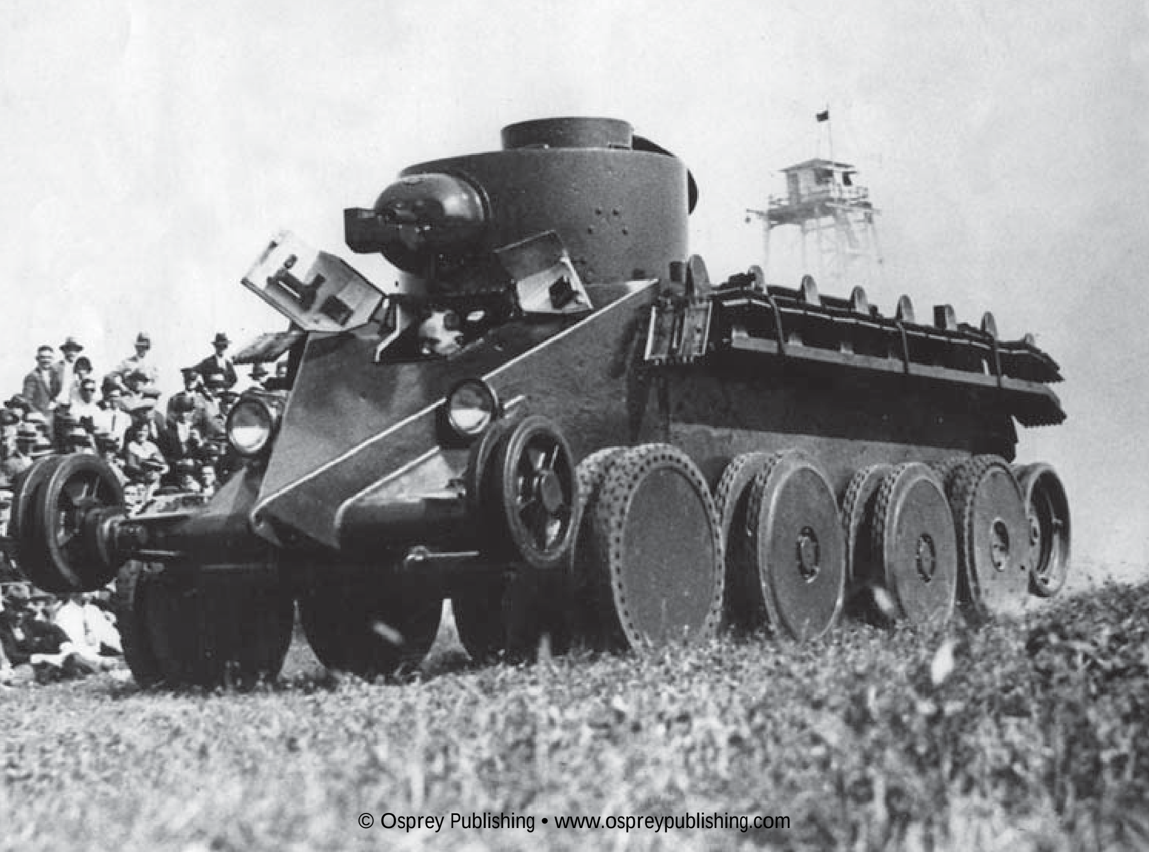
BELOW • The Renault R 35, a relatively well armoured but poorly armed light infantry tank that was the most numerous French tank in 1940.

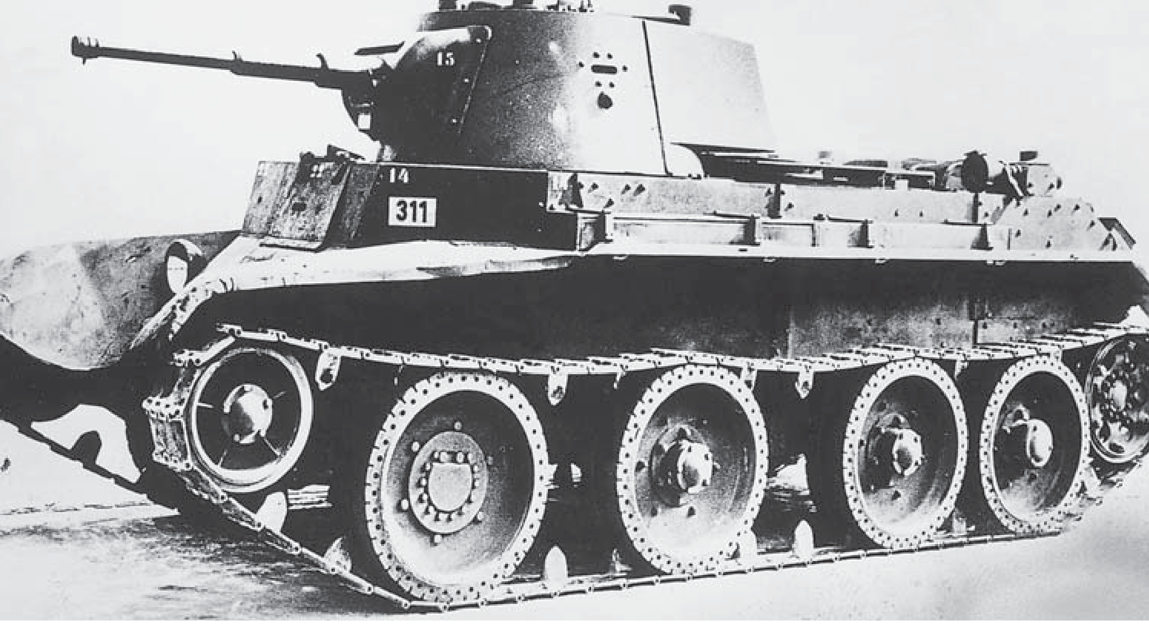




ABOVE • The French Char B1 bis, one of the most powerful tanks of its day but ill-suited to mobile operations.

BELOW • The US 'convertible' T3 Medium Tank designed by J. W. Christie, which could run on its road wheels after the removal of its tracks; on tracks it attained a maximum speed of 40mph.

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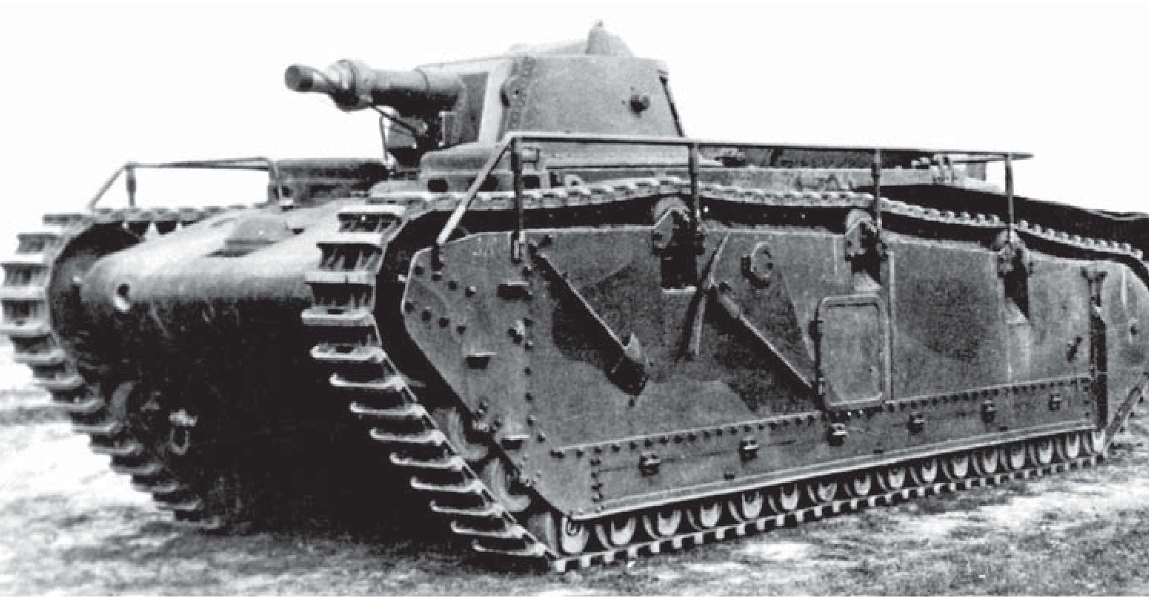
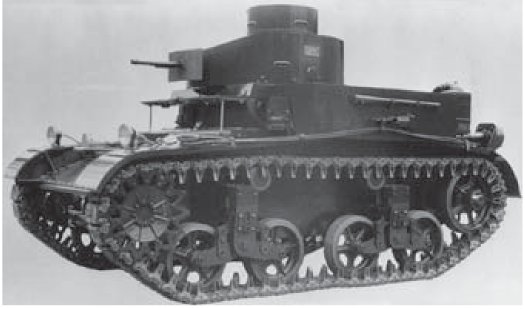


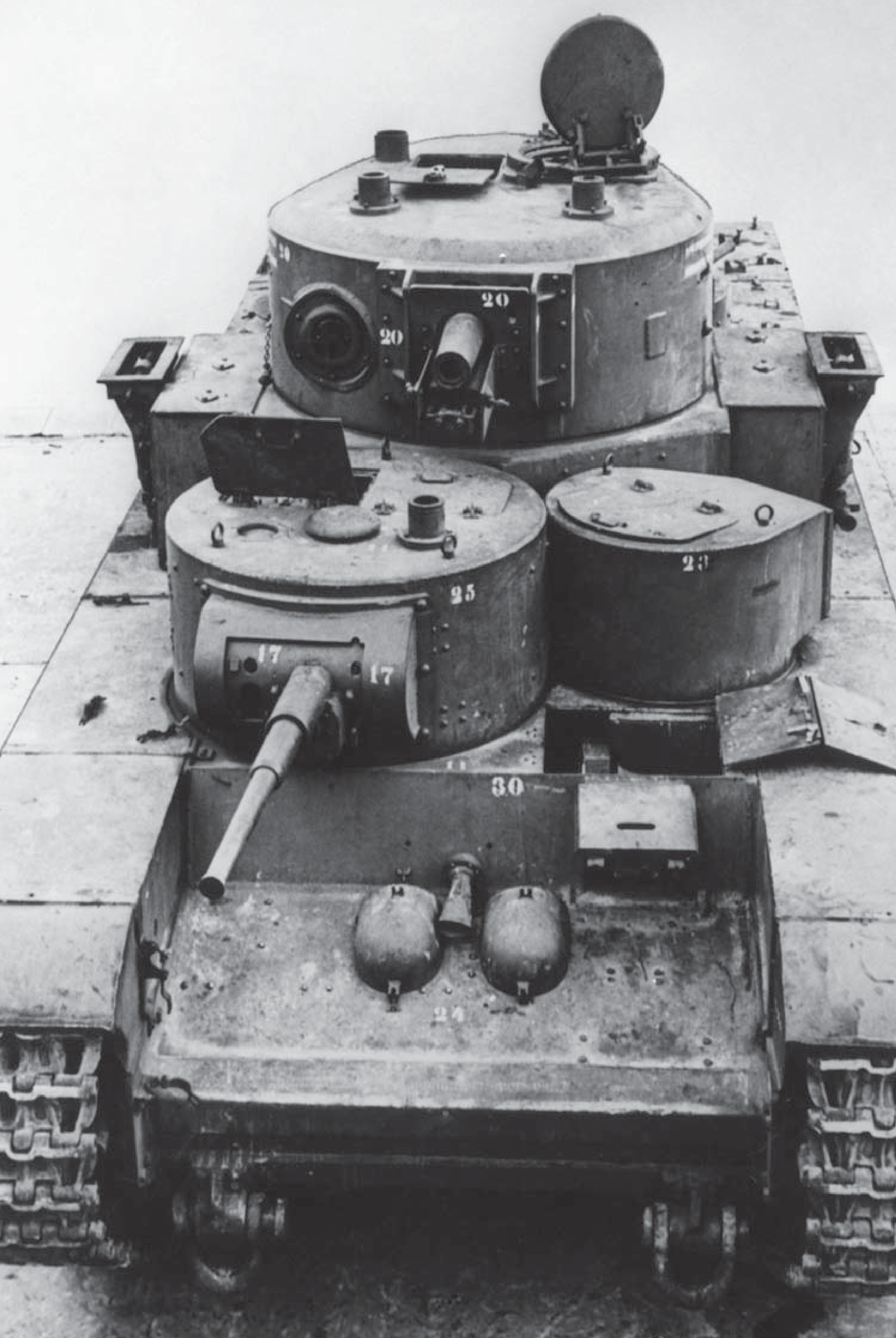
ABOVE LEFT• The Soviet BT-7, one of the series of the *bystrochodni* or fast tanks based on the medium tank developed by 1931 for the US Army by J. W. Christie.

ABOVE RIGHT • *Grosstraktor* secretly built by Rheinmetall, the first of the medium tanks with turret-mounted 75 or 76mm guns, which became the norm during the Second World War.

LEFT • The T-26, a Soviet copy of the Vickers Six Ton Tank, which became the most numerous tank in the world on the eve of the Second World War; in the background is an early twin turret version. (The Tank Museum)

BELOW • Progressive development of light tanks, like this M2A1, in the 1930s laid the foundations of the robust character of US tanks of the Second World War. (US Army)

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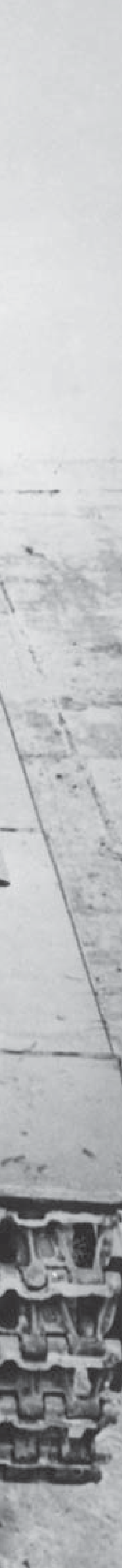
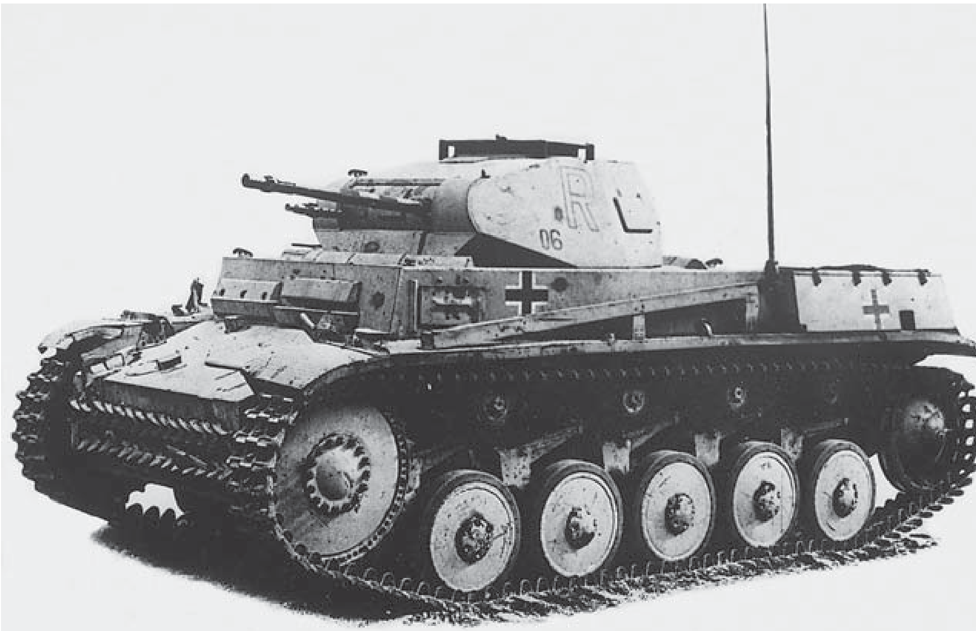
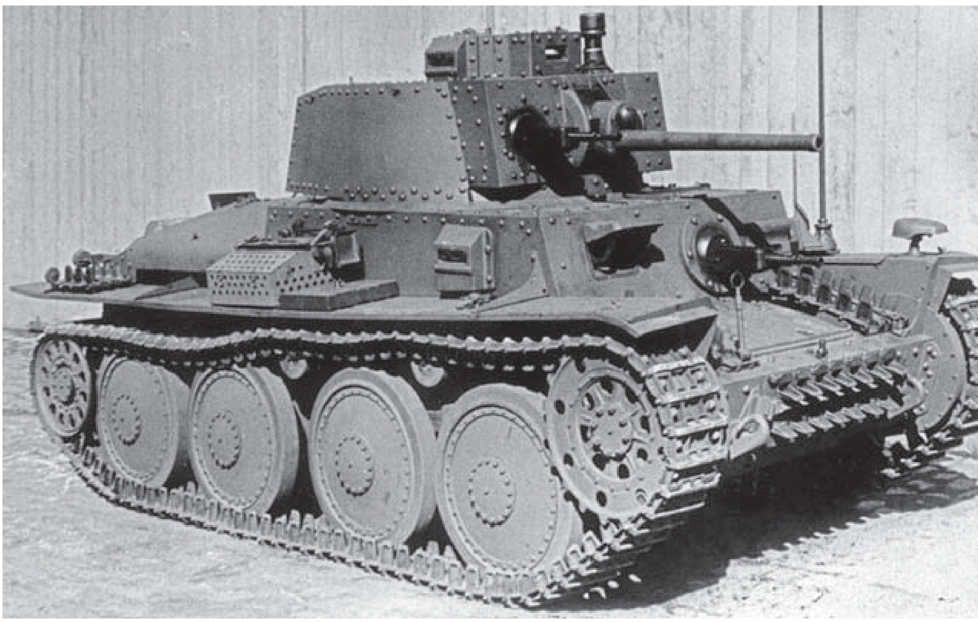


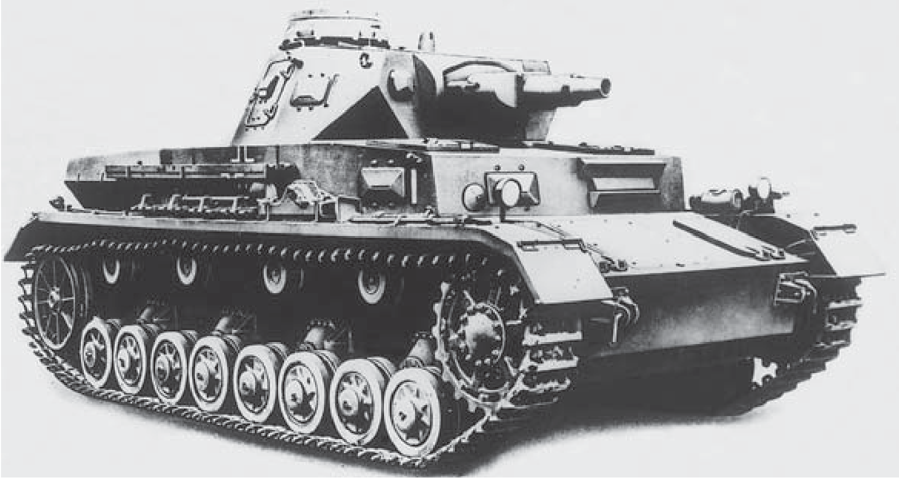


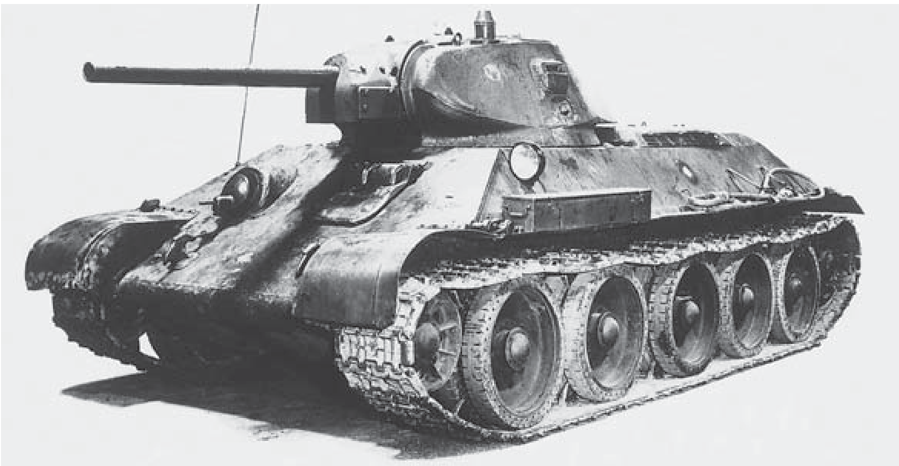


LEFT • T-35 heavy tank, the extreme example of Soviet tank development before the Second World War. (Topfoto)

TOP • A PzKpfw II light three-man tank armed with a 20mm cannon, which was the most numerous German tank during the 1940 campaign in France. (Imperial War Museum, MH 4134)

BOTTOM • Czech-produced light tank, which as PzKpfw 38(t) formed a significant part of the German tank strength during the first three years of the Second World War.

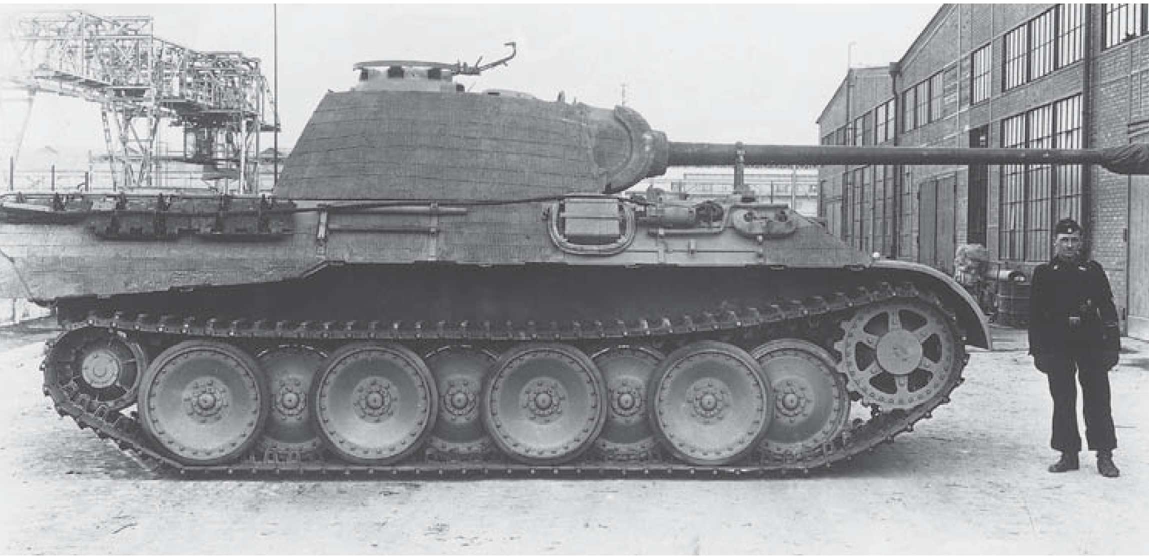




TOP • An early version of PzKpfw IV armed with a low-velocity 75mm gun, which was the most powerful German tank during the first part of the Second World War. (Imperial War Museum, MH 4227)

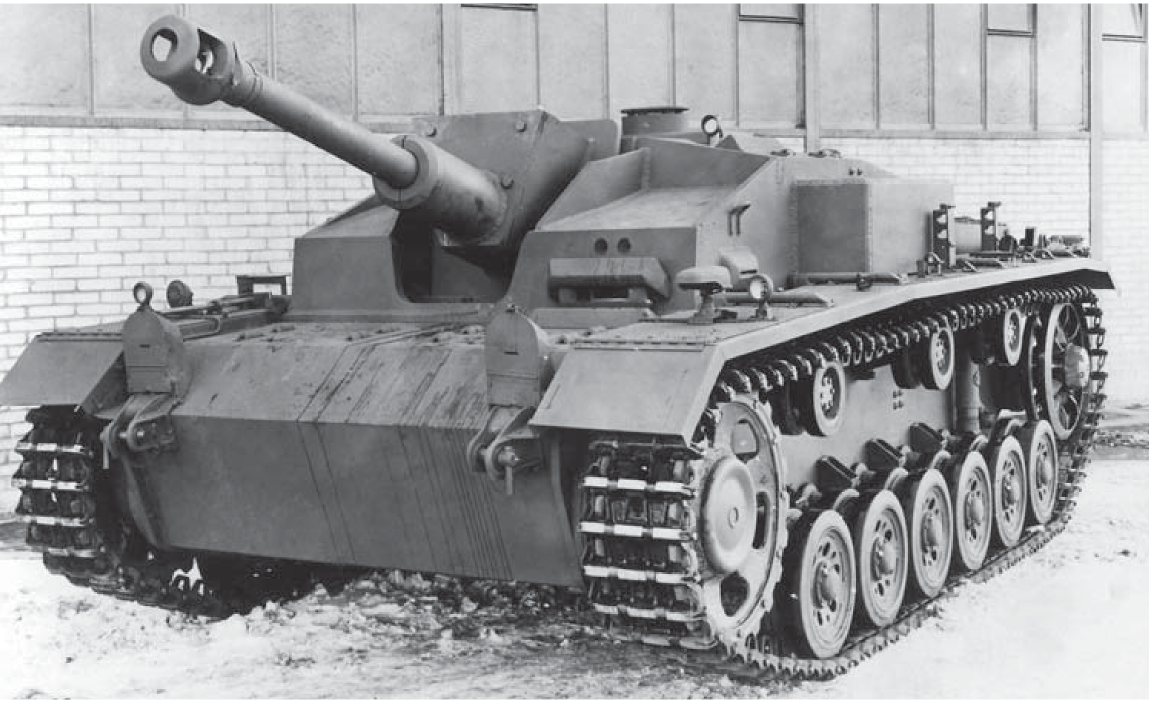
MIDDLE • The T-34, a tank of 26 to 31 tonnes armed with a medium-velocity 76mm gun that was the mainstay of the Soviet armoured forces during the war.

BOTTOM • The German Tiger I heavy tank, the first to be armed with a high-velocity gun of more than 75 or 76mm calibre, which made it the most powerful tank in 1943. (Tank Museum)



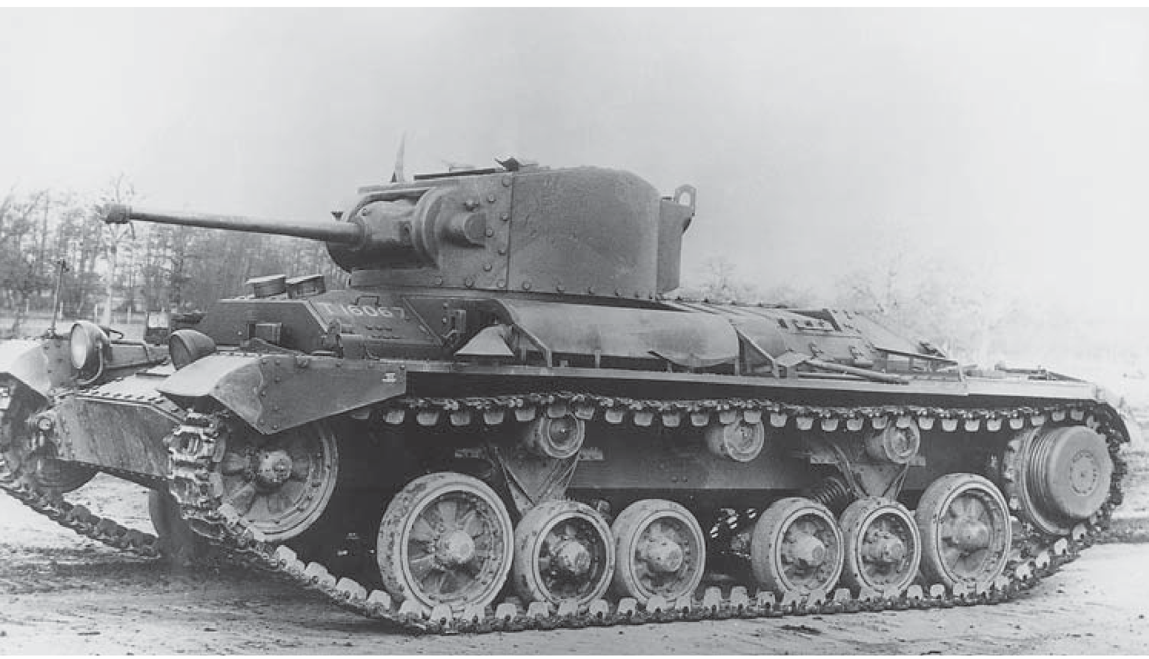
ABOVE • The German Panther, widely regarded as the best medium tank of the Second World War.

BELOW • The T-34-85, in essence the T-34 with a larger three-man turret and an 85mm gun that was produced in large numbers from the latter part of the war for the Soviet Army and the various post-war allies of the Soviet Union. (R. Fleming)



ABOVE • The *Sturmgeschutz* or assault gun, in effect a turretless tank armed with a 75mm gun that proved very effective as a mobile anti-tank weapon.

BELOW • The Valentine infantry tank, which was produced in greater numbers than any other British tank. (Vickers Armstrongs Ltd)



ABOVE • US-produced M3 medium tanks with the British-inspired Grant version on the left and the Lee version on the right, both armed with hull-mounted 75mm guns. (Imperial War Museum, E 14053)

BELOW • An early M4A1 version of the US Sherman medium tank armed with a medium-velocity 75mm gun. (US Army)

ABOVE • Tanks developed by the US Army in the 1950s: from the left, the M103 heavy tank, M48 and M47 medium tanks and the M41 light tank (US Army)

BELOW • A British Cromwell I cruiser tank armed with a 57mm gun. (Birmingham Railway Carriage & Wagon Co Ltd)

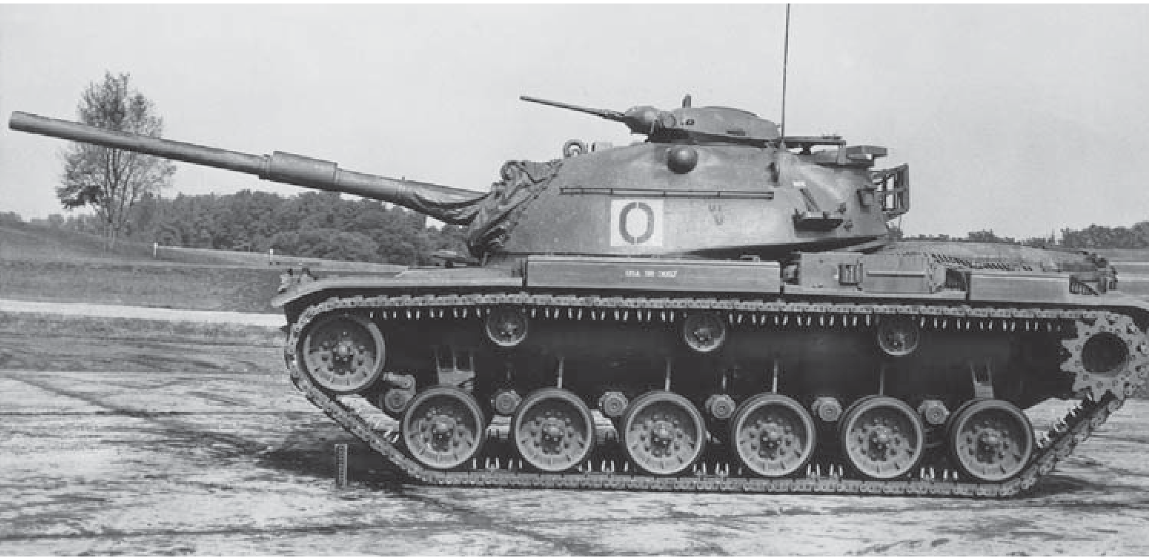
ABOVE • A late M4A3 version of the US Sherman medium tank armed with a 76mm gun that continued to be widely used for several years after the Second World War. (US Army)

ABOVE • The IS-3 (Stalin) heavy tank was first seen at the end of the Second World War. Here an IS-3 takes part in a Tank Day in the Czech Republic. (Public Domain)

ABOVE • The Soviet T-62 was more than a decade ahead of other tanks in being armed with a high-velocity, smooth bore gun firing APFSDS ammunition with arrow-like penetrators.

ABOVE • The T-54 and the very similar T-55 were the principal Soviet tanks from the 1950s onwards and the most numerous tanks ever built. (R. Fleming)

BELOW • The T-72, the most common of a series of Soviet tanks with three-man crews and automatically loaded smooth bore 125mm guns that was introduced in the 1970s. (R. Hilmes)



ABOVE • The M60A1, a 105mm gun-armed development of the M48 medium tank that was the principal tank of the US Army from the 1960s until the 1990s. (US Army)

BELOW • The US-German MBT-70, an advanced design incorporating an automatically loaded 152mm gun missile launcher and a three-man crew located in the turret, abandoned because of its cost. (US Army)

BELOW • The British Centurion in its final form armed with a 105mm rifled gun, which in the 1960s and 1970s became the Western world's standard tank weapon. (FVRDE, CCR)

BOTTOM • The Component Advanced Technology Test Bed, an experimental US vehicle with a 140mm gun and a turret bustle autoloader on a modified M1 tank chassis that began to be tested in 1985.

OPPOSITE TOP • The M1A1, the second version of the US Abrams tank armed with a 120mm smooth gun, which became the main battle tank of the US Army in 1991. (US Army)

OPPOSITE BOTTOM • The Tank Test Bed, an experimental US tank built in the 1980s on the M1 tank chassis with a 120mm gun in an unmanned turret remotely operated by a three-man crew located in the hull. (General Dynamics Land Systems)


GENERAL DYNAMICS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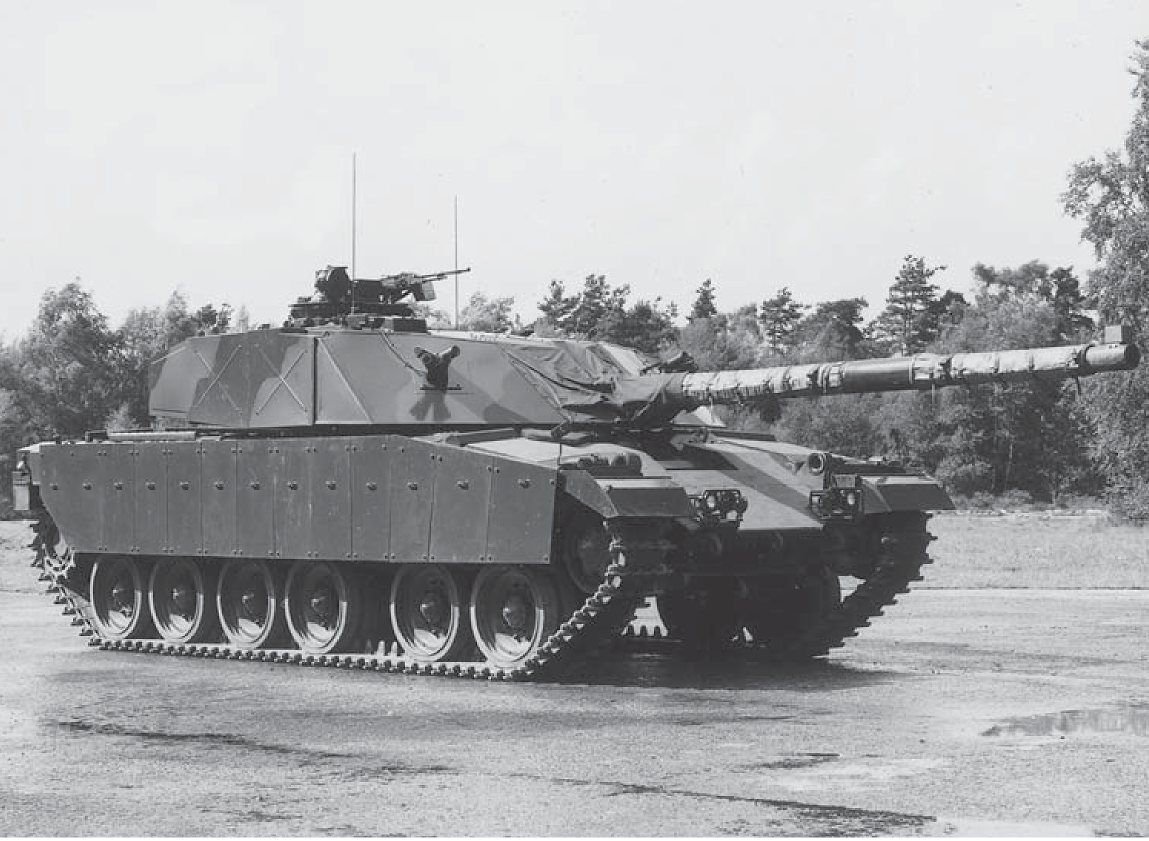


OPPOSITE TOP • The British Chieftain, the most heavily armed and armoured of the tanks deployed by NATO in Central Europe in the 1970s and 1980s. (FVRDE, CCR)

OPPOSITE BOTTOM • The Comres 75, an experimental vehicle built by the British Fighting Vehicles Research and Development Establishment in 1968 to explore the contemporary interest in tanks with guns mounted externally on pedestals. (FVRDE, CCR)

ABOVE • The FV 4211 experimental tank based on the Chieftain built in 1971 by FVRDE to demonstrate for the first time the potential effectiveness of the so-called 'Chobham armour' against shaped charge missiles and projectiles. (FVRDE, CCR)

BELOW • The Challenger I, a further development of the British Chieftain with enhanced protection incorporating explosive reactive armour, which was created for the invasion of Iraq in 2003 but was still armed with a rifled 120mm gun.

LEFT • French AMX 13 light tank of the early 1950s, the first to have a bustle autoloader for its gun. (French Army)

BELOW LEFT • The AMX 30, developed in the 1960s to meet a requirement for a European medium tank and armed with a 105mm gun firing special Obus G shaped charge anti-tank ammunition. (French Army)

ABOVE • The AMX Leclerc, the last of the third generation of post-Second World War tanks, manned by a crew of three and armed with an automatically loaded smooth bore 120mm gun. (GIAT Industries)

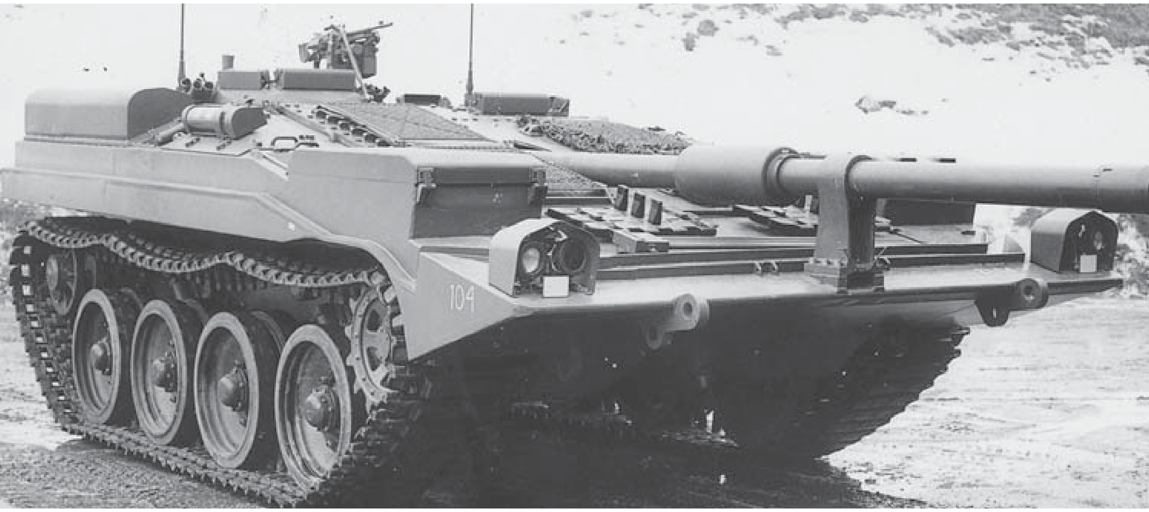
MAIN • The German Leopard 1, designed to the same requirement as the French AMX 30 but armed with the British 105mm L7 gun. It was highly regarded for its mobility. (Krauss-Maffei)

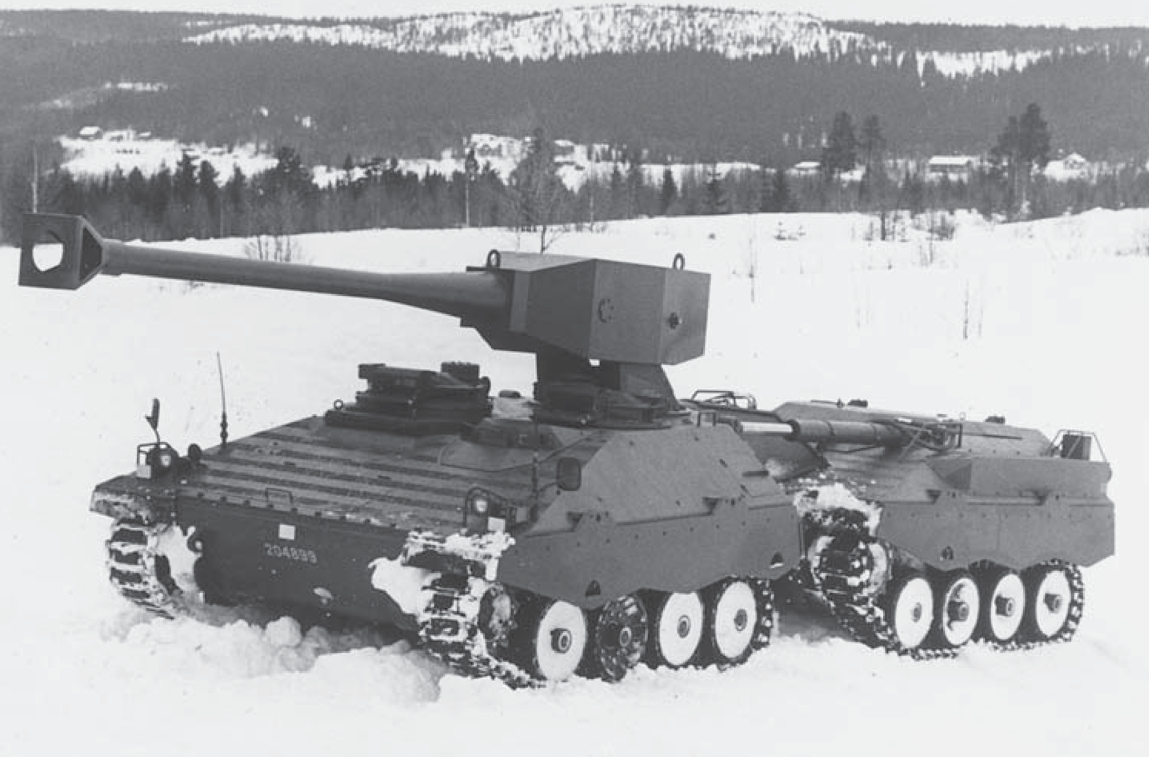
ABOVE • The experimental German VT 1-2 turretless tank with two 120mm guns that could fire salvoes to increase the probability of hitting a target. (Krupp-Maffei)

BELOW • The Leopard 2, a more heavily armoured follow-on to the Leopard 1, adopted by the German Army in 1979 and armed with the then new Rheinmetall 120mm smooth bore gun. It was subsequently also adopted by 14 other armies worldwide. (Krauss-Maffei)

ABOVE • The Swiss Pz.68, a rare example of a battle tank with a hull cast in one piece (Swiss Army).

BELOW • A turretless Swedish S-tank armed with an automatically loaded 105mm gun. It is the only tank ever built that could be fully operated by one man instead of its normal crew of three. (A. B. Bofors)





OPPOSITE TOP • The experimental Swedish UDES XX-20 articulated vehicle with a pedestal-mounted 120mm gun that offered superior performance in difficult terrain. (A. B. Bofors)

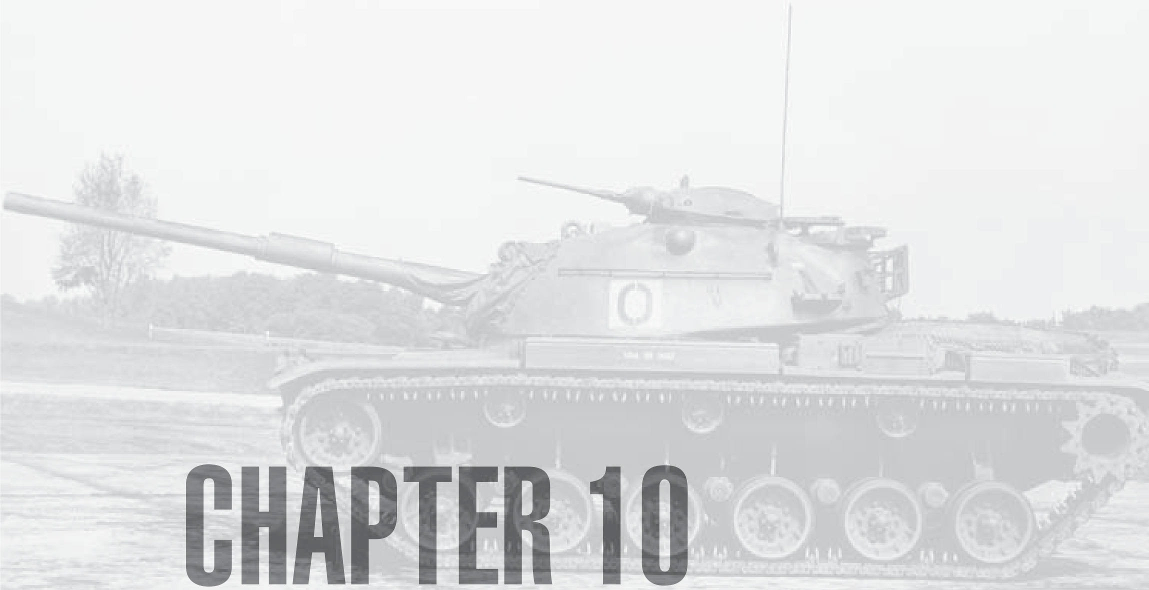
OPPOSITE BOTTOM • The Israeli Merkava, the only modern battle tank except for the Swedish S-tank with its engine at the front of the hull to increase crew protection against frontal attack. The version shown is Merkava Mark 3 Baz. (IMI)

ABOVE • A Merkava Mark 4 with radar detectors and counter-measure launchers of Rafael's 'Trophy' active protection system on each side of its turret.

BELOW • The Engesa Osorio 2, a very promising Brazilian attempt at an indigenous battle tank abandoned for financial reasons. (Engesa E.E.)

ABOVE • The K1A1, the second version of the South Korean K-1 tank designed in the United States but to a South Korean specification, and, like the second version of the US M1, re-armed with a 120mm Rheinmetall smooth bore gun. (Hyundai)

BELOW • Russian T-90 tanks paraded by the Indian Army in 2014. (Getty)



CHAPTER 10
On the Peripheries of Major Powers

Development of tanks and other armoured vehicles may have been dominated after the Second World War by the Soviet Union, the United States, Britain, France and Germany, but several other countries have also made significant if mostly intermittent contributions to it.

Switzerland

An early example of this was the development of tanks in Switzerland. It started virtually without the benefit of any earlier experience, as all the armoured vehicles the Swiss Army had before the war were four two-man light tanks purchased in Britain from Vickers Armstrongs and LTH light tanks, which were ordered from Czechoslovakia in 1936 and assembled in Switzerland as Pz.39 using Saurer diesel engines and 24mm Oerlikon guns. However, only 24 were built when the flow of components from Czechoslovakia stopped in 1939 after it came under German control.

Once the Second World War broke out, Switzerland's geopolitical position prevented it from procuring tanks from other countries. At the same time it was not in a position to produce them then on its own. It was only in 1942 that the first step was taken towards remedying the situation with the building by the Federal Construction Works (K+W) in Thun of a partially armoured self-propelled 75mm anti-tank gun called NK-I. A year later another step was taken with the construction of NK-II, a well-armoured 75mm assault gun. But by the time this prototype was built, the war in Europe was coming to a close and its development was discontinued. However, the Swiss Army recognized the need to provide itself with some armoured vehicles and in 1946 took advantage of an opportunity to purchase from Czechoslovakia 158 assault guns from a stock of Jagdpanzer 38(t) originally produced for the German Army. The last of them was delivered in 1952 and they were allocated as G 13 Panzerjager to three specially created tank destroyer battalions.[1]

G 13 was a 16-tonne low silhouette turretless vehicle armed with what was still a relatively potent 75mm L/48 gun, which in its German guise proved very effective in the later stages of the Second World War. In consequence it met the most urgent need of the Swiss Army for a counter to hostile tanks. The need to go further and to acquire battle tanks was not accepted until 1951, when the international situation had clearly deteriorated following the outbreak of the war in Korea. But battle tanks could not be procured from Britain or the United States, which were the only countries producing them at the time outside the Soviet bloc. The only opportunity left open to the Swiss Army was to go to France and to order 200 AMX 13s in 1951, which were beginning to be produced. It was actually the first of several armies to procure this light tank, which provided it with an armoured vehicle armed with a 75mm gun considerably more effective than that of the G 13.

Nevertheless, the need for more powerful tanks remained, and in 1955 it became possible to place an order in Britain for 100 Centurion tanks. This was followed a year later by a second order for 100 Centurions, all of which were delivered between 1956 and 1960, when 100 more were purchased from South Africa where the government of the day decided that they were no longer needed – a decision which the South African Army came to regret 20 years later when it had to fight the Marxist forces in Angola. On the other hand, this decision enabled the Swiss Army to build its fleet of Centurions to 300 tanks, which were later made more effective by being re-armed with the much more powerful 105mm L7 guns instead of their original 83.8mm 20-pounders.

Thanks to their armament, the Centurions met the Swiss Army's need for well-armed battle tanks, but in other respects they were not what it wanted. In particular, it wanted lighter tanks, of about 30 rather than 50 tonnes, and not wider than 3.06m, which would keep them within the Berne International Load Gauge and therefore allow them to be transported without restrictions by rail, as well as making them better able to operate along narrow roads and village streets. Such considerations reinforced the case for the development of an indigenous tank, which the Technical Section of the Swiss General Staff began to study as early as 1951. In addition to being better suited to Swiss conditions, an indigenous tank also had the attractions of making the Swiss Army independent of foreign sources and, although it was likely to cost more than an imported tank, most of the money would be spent on it within the country.

The characteristics of an indigenous tank were established in 1953 and the task of designing one was entrusted to K+W Thun, the principal Swiss ordnance establishment, which had produced and overhauled military equipment for more than one hundred years. In spite of being new to it, K+W Thun designed and produced a tank that was not only the first ever made in Switzerland but which was on a par with other contemporary tanks.

The first prototype completed in 1958 was armed with a version of a Swiss 90mm anti-tank gun, and so was a pre-production series of ten tanks that were designated Pz.58. However, the Swiss General Staff decided against the production of the Pz.58 and opted instead for a version of it armed with the British 105mm L7 gun. This gun was produced in Switzerland under licence and was the only major component of the Pz.61 that was not Swiss, except for the German Daimler Benz MB 837 V-8 diesel.

Production of 150 Pz.61s was ordered in 1961 and the first was delivered in 1964. It had a conventional configuration but its weight of 38 tonnes put it among the lightest of its generation of battle tanks. One of its unusual features was a hull cast in one piece, which until then had only been produced for the US M48 tank. The production of such a hull was a considerable achievement on the part of Swiss foundrymen and eliminated the need to import thick armour plate, which was not produced in Switzerland. Pz.61 also incorporated the second tank transmission ever to be produced with a progressive hydraulically controlled steering drive and a unique independent suspension with conical plate springs instead of coil springs or torsion bars.

Two years after the last Pz.61 was completed in 1966, the Swiss Army ordered a new version of it called Pz.68. Initially 170 were ordered but this was followed by two further orders for a total of 160 tanks, the last of which was delivered in 1979 when the Swiss tank fleet reached 780 tanks, all armed with the 105mm L7 gun.

However, Pz.68 proved troublesome, particularly where the various new features incorporated in it were concerned, and its procurement became the subject of controversy that led to it being investigated in 1979 by a committee of the Swiss Federal Council. In the course of the investigations the committee interviewed many people, including the writer, and concluded that the shortcomings of Pz.68 could be rectified. When this was done, it was decided that the fourth and final series of 60 tanks should be completed, but the committee endorsed the view that the Pz.68 was not fit to engage in duels with the latest of the contemporary battle tanks.[2]

The shortcomings of the Pz.68 had an important bearing on the next stage of the development of tanks in Switzerland, which was entrusted in 1978 to the Contraves company. The tank, called NKPz, which was designed by this company was no longer constrained by the 3.06m rail gauge width limitation that had handicapped Pz.61 and Pz.68, and its weight was allowed to rise to 50 tonnes. Moreover, it was provided with an unconventional configuration that was superior in several respects to that of other contemporary tanks. This included the location of the engine compartment at the front of the hull, a two-man turret and the best possible position for the ammunition in the rear of the hull from where it was fed automatically round-by-round to below the turret and then swung up into the breech of the 120mm smooth bore gun.[3]

For all that, the NKPz was never built. Bearing in mind the history of the Pz.68, Swiss authorities came to the conclusion that Switzerland lacked the infrastructure necessary for the successful development of a modern battle tank and that it would have to procure a proven foreign tank, which many Swiss Army officers favoured anyway.[4] This led to competitive trials of two German Leopard 2s and two US M1 tanks in 1981 and 1982, which resulted in the selection of the former, and in 1983 the Swiss Federal Council authorized the procurement of 380 of the German model.

The first 35 Leopard 2s came directly from Germany, but the remainder were built at K+W Thun, which had previously produced Pz.61s and Pz.68s, and the last of them, called Pz.87s in Switzerland, was delivered in 1993. Their production under licence in Switzerland accounted for much of their cost and ensured the retention in the country of production skills and facilities as well as saving foreign exchange.

While it preserved manufacturing skills, the adoption of the Leopard 2 put an end to the design of tanks in Switzerland, but did not prevent some other indigenous development. This included further improvements to some of the Pz.68s and the development for them of a much more effective composite armour, which was not, however, put into production. By 1988 K+W Thun had also developed a 120mm smooth bore compact tank gun with a smaller external diameter than all the earlier guns of its calibre so that it could be retrofitted if required in the relatively small turret of the Pz.68. In keeping with the developments in other countries, K+W Thun had also developed a 140mm smooth bore tank gun. This was installed in a Leopard 2, from which it was fired for the first time in 1989, and its APFSDS projectiles proved capable of penetrating about 1,000mm of steel armour. But, like that of the other 140mm guns, its development was not pursued beyond trials.

Further development was confined to modifications to Leopard 2s. Centurions and then Pz.61s and Pz.68s were disposed of by 2008 and the number of Leopard 2s maintained by the Swiss Army was reduced to 224.

Sweden

Unlike Switzerland, Sweden became involved with the development of tanks well before the Second World War, mainly as a result of the connections of some of its companies with German industry. Although it remained neutral, by the middle of the war Sweden built up its fleet to 436 tanks of 8.5 to 11 tonnes, all armed with 37mm Bofors guns mounted in two man turrets. They consisted of 216 tanks built by the Landsverk company and 220 Czech-designed TNH tanks built under licence as Strv m/41.

Czech built TNHs served the German Army well as PzKpfw 38(t)s in the 1940 campaign in France and in the early stages of the invasion of the Soviet Union. But in 1941 they began to lose their effectiveness, like other tanks of their kind. In consequence the Swedish Army decided that it needed a more powerful type of tank. The only way open to it of acquiring such a tank proved to be the adoption of one called Lago, which Landsverk had began to develop for Hungary.[5] This led to the Strv m/42, which was in effect a stretched version of the earlier Landsverk light tank but designed not to exceed 2.35m in width in order to meet the limitations of the Swedish transportation system. It weighed 22 tonnes and was armed with a short-barrelled 75mm gun mounted in a three-man turret, all of which made it comparable with the original version of the German PzKpfw IV.

The first Strv m/42 was produced in 1943 and the last in 1945, when 282 had been completed. They were the most powerful tanks the Swedish Army had at the end of the Second World War and they retained that position for several years after it. During this period the Swedish Army evaluated several wartime German vehicles, including the Tiger and the Panther, as well as US M4 Shermans, but did not take any steps towards acquiring new tanks until after the outbreak of the war in Korea in 1950 and the general revival of interest in tanks that followed. The initial steps took the form of negotiations with Britain about the purchase of Centurion tanks, which was agreed to in 1952 and led to the delivery a year later of the first of 80 Centurions armed with 83.8mm guns. More were ordered in 1954, bringing the total of Centurions to 240 tanks that were designated Strv 81.

Between 1952 and 1953 the Swedish Army also considered procuring the French AMX 13 light tank. One was brought to Sweden for trials and at one time the acquisition of 300 to 400 was considered, but in the end the idea of purchasing AMX 13 was rejected. Instead it was proposed in 1953 to retrofit the available but by then obsolete Strv m/42 with a new turret and a version of a pre-war 75mm Bofors anti-aircraft gun, which made it comparable in terms of gun power to AMX 13. The proposal was accepted and two prototypes were built in 1954, followed by a conversion of 225 Strv m/42s into Strv 74s, which remained in service until 1984.

In addition to this and the procurement of the Centurions, the Swedish Army began to study a heavy indigenous tank in the early 1950s. This came to be known as the KRV and consisted of a novel Bofors turret mounted on a chassis with a hull front like that of the Soviet IS-3. It was to be armed with a smooth bore 155mm gun firing fin-stabilized shaped charge projectiles that were automatically loaded from a magazine attached to the gun, so that they moved together like the gun and the magazine of the AMX 13. However, only two chassis were built by 1957 when the whole project was abandoned.[6] Instead the army ordered 110 additional Centurions in 1958, which were delivered during the following two years. This time they were armed with 105mm L7 guns, and by the mid-1960s Centurions received earlier were re-armed with this gun. As a result, by

1966 the Swedish Army had 350 tanks armed as well as any in the Western world except for the new British Chieftain.

In the meantime, the head of the tank design section of the Swedish Army ordnance, Sven Berge, put forward in 1956 the idea of a radically new type of turretless tank with a gun fixed in the hull and elevated and depressed by altering its pitch and traversed by turning the whole vehicle.[7] The idea of such a tank was inspired in part by AMX 13, which Berge studied when it was being considered by the Swedish Army and in particular by its relatively simple combination of a gun with an automatic loading system that resulted from the gun and the ammunition magazine being fixed in the upper part of the oscillating turret. In consequence, what Berge proposed was in principle putting the upper part of an oscillating turret directly on a tracked chassis.

As he told the writer, Berge was also impressed by the wartime record of the turretless German *Sturmgeschutz*, which not only enjoyed the advantage of a low silhouette but could be swung round rapidly if required to face a target. However, it was not evident that a vehicle could be turned sufficiently smoothly for tracking targets. This question was resolved by a series of tests with different vehicles that were carried out between 1957 and 1959, which led to the adoption of a two-stage steering system operating in a clutch-and-brake mode for rapid turns and as hydrostatically driven double differential for slower but smooth turns.

By 1959 the development of Berge's ideas had advanced sufficiently for an order to be given to Bofors for the construction of two prototypes, which were completed two years later. They were followed by the construction of ten pre-production vehicles and then by full scale production, from which the first tank was delivered in 1967 and the last in 1971, when a total of 290 had been completed.

The tank that was produced has been commonly known as the S-tank but was officially designated Strv 103. It was armed with a longer barrelled version of the 105mm L7 gun, which was fed automatically from a magazine containing 50 rounds and ideally situated in the rear of the hull. The front of the hull housed a unique power plant consisting of a diesel engine and a gas turbine. At the cost of some complication, this offered the potential advantage of the fuel economy of a moderately sized diesel that powered the tank by itself most of the time, and the small size of the gas turbine in relation to the additional power that it delivered but that was only required occasionally. The gas turbine also ensured starting under extreme cold weather conditions, and either engine could drive the tank by itself, which halved the common risk of the tank being immobilized by an engine failure. As in the case of the Swiss Pz.61 and Pz.68, the engines of the S-tank were the only major components that were imported, the diesels coming at first from Rolls-Royce in Britain and then from Detroit Diesel in the United States, while the gas turbines were originally of Boeing and then of Caterpillar origin.

The S-tank had a crew of three, two of whom sat abreast in the centre of the hull and were provided with identical sets of integrated steering, suspension and gun controls, which made either of them capable of fully operating the tank by himself: the first and still the only time that this could be done by one man in any tank. The S-tank also offered its crewmen a high degree of ballistic protection, not only because of its steeply sloped frontal armour but also because of the location of the engines and transmission in front of them.

However, there was also a major disadvantage to the S-tank, which was its inability to engage targets on the move unless they happened to be straight ahead of it. This was not a critical issue when tanks had to stop to fire accurately, because the S-tank could stop and fire as quickly as other tanks. But when further development of stabilized gun controls made tanks capable of firing accurately on the move, the S-tank became seriously handicapped by its inability to compete in this respect.

Nevertheless, the approach it represented was included in a comprehensive series of studies carried out by the Swedish Army of a possible lighter follow-on to the S-tank, which came to weigh 42.3 tonnes in its final version, having started at 37.7 tonnes. Studies of lighter vehicles began in 1972 and continued for about ten years. Like similar studies in Britain and Germany, they included the concepts of vehicles with a gun mounted externally on a pedestal instead of a turret, which was put to the test by installing a 105mm gun on a Marder infantry fighting vehicle borrowed from Germany. The studies led eventually to another very original vehicle, the 26-tonne UDES XX 20, which was built in 1982. This was an articulated vehicle with a front part containing a crew of three and a 120mm tank gun mounted on a pedestal, and a rear part containing the engine and the ammunition. The development of the UDES XX 20 by the Hagglunds company was encouraged by the success achieved by its Bv 206 articulated unarmoured all-terrain tracked carriers, 11,000 of which have been acquired by about 15 different countries. Like the latter, UDES XX 20 was inherently superior to conventional tracked vehicles in terms of its performance over soft ground and in crossing ditches and similar obstacles. But it was more complicated and more expensive to build. The 120mm gun was fired from it, but its development did not proceed beyond the tests of its prototype in 1984, when a system of loading its gun still had to be devised.[8]

Termination of the work on UDES XX 20 marked the end of attempts to develop well-armed but relatively light-tracked armoured fighting vehicles. Instead, the focus of attention in Sweden turned to the development of heavier vehicles, which would ultimately replace the Centurions and the S-tanks. Studies of possible alternatives included, once again, a tank with a pedestal mounted gun as well as a more conventional tank with a low profile turret. What was eventually adopted in 1991 and designated Strv 2000 was an original design with a cleft two-man turret mounting a 140mm gun that was to be provided only with APFSDS ammunition against enemy tanks side-by-side with a 40mm Bofors automatic gun for the engagement of all other targets. In these respects Strv 2000 differed from all other contemporary tanks, and it also differed from all but two of them in having its engine at the front of the hull. It was to have been well armoured and this would have made it weigh more than 50 tonnes.[9] However, its development did not advance beyond a full size mock-up because its cost was considered to be high and could be avoided by the adoption of a tank already produced elsewhere.

The alternative of adopting a foreign tank was pursued concurrently with the work on Strv 2000. It involved preliminary trials in 1989 and 1990 of a German Leopard 2A4 and a US M1A1, which were followed in 1992 to 1993 by the trials of an improved Leopard 2, an M1A2, and a French Leclerc, and in 1993 to 1994 a Russian T-80U. The trials led to the adoption of the Leopard and an agreement with its German manufacturers, the Krauss-Maffei-Wegmann company, for the partial production in Sweden of the Leopard 2S, which was a further improvement of the latest Leopard 2A5 incorporating considerably enhanced ballistic and mine protection that increased its weight to 62.5 tonnes. A total of 120 was ordered by the Swedish Army, the first 29 of which were built in Germany while the remainder were assembled in Sweden from Swedish and German components. They entered service in 1997 as Strv 122 and production of them was completed in 2002.[10]

In addition to the agreement for the production in Sweden of Strv 122, the Swedish Army also arranged in 1994 to lease 160 Leopard 2A4s from the German Army, which were designated Strv 121. As they and the Strv 122 came into service they replaced the Centurions and then the S-tanks, the last of which was retired in 2001. In 2006 Strv 121 was also phased out, leaving the Swedish Army with a small but highly effective fleet of tanks composed solely of Strv 122.

Israel

While Sweden as well as Switzerland gave up tanks they had developed in favour of tanks designed elsewhere, a very different course was pursued by Israel, which was forced by circumstances to use at first a mixture of such foreign tanks as it could acquire but eventually built a formidable force of indigenous tanks.

In fact, when the state of Israel was born in 1948, its tank force consisted of two Cromwell tanks spirited from the British forces as they were withdrawing from Palestine and ten Hotchkiss H.39 light tanks, which the German Army had captured in 1940 and the French Army recovered in 1945 and which the Israeli underground purchased from France in 1948. Within a year Israel managed to create, mainly by purchases from foreign scrapyards, a force of 30-odd obsolescent M4 Sherman tanks armed with their original 75mm guns. Some more were acquired later, but more effective tanks were not obtained until 1955 from France. They included 60 AMX 13 light tanks and 100 or so ex-French Army Shermans armed with 76mm guns, which were renamed M1 or Super Shermans. They were followed by Shermans that were re-armed in Israel with the same high-velocity 75mm gun as that mounted in the AMX 13. A company of these M50 Shermans was completed in time to be used in the 1956 Israeli offensive called Operation *Kadesh*, which preceded the ill-fated Anglo-French Suez Canal campaign and swept the Egyptian forces out of the Sinai. Israeli Defence Forces (IDF) lost 30 tanks in this operation but inflicted a loss of 150 tanks on the Egyptian Army, most of which were Soviet-built T-34-85.[11]

Although the AMX 13 and the Shermans re-armed with the latter's 75mm gun proved effective in 1956, they were no longer so 11 years later during the Six Day War, when the Egyptian Army had acquired from the Soviet Union the more heavily armoured T-54 tanks. The IDF therefore needed tanks with more powerful armament. To meet this need, the IDF developed yet another version of the Sherman tank called the M51, which was armed with a somewhat less powerful version of the 105mm gun developed for the new French AMX 30 battle tank that relied on the shaped charge Obus G for the defeat of enemy tanks. A total of 200 Shermans was converted into M51s and they began to come into use in 1960.

In 1960 the IDF took another and much more important step forward by purchasing from Britain 30 Centurion tanks, some of which were new and some had been used. They were still armed with the 83.8mm 20-pounders, but other Centurions purchased from Britain in 1962 were already armed with the 105mm L7 gun and those delivered earlier were re-armed with it. Thus by the outbreak of the Six Day War in 1967 the IDF had acquired a total of 385 Centurions and they became the most important part of its tank fleet.

The IDF had also ordered 150 US-built M48 tanks from Germany, where they had become surplus to its army's requirements, but because of Arab pressure only 40 were delivered. However, in 1965 the IDF received the first M48 tanks directly from the United States and by the outbreak of the war in 1967 it had 250 of them, all still armed with 90mm guns.

In consequence, when the IDF delivered their pre-emptive strike in 1967 against the Egyptian forces, their tank fleet consisted of several different types. Nevertheless, in spite of the tactical and logistics handicaps that the mix of tanks entailed, the IDF routed the Egyptian Army in four days and inflicted on it a loss of about 820 tanks out of the 935 it deployed. The tanks that the Egyptian Army lost included 373 T-54s and T-55s, many of which were taken into Israeli service, meaning that there were enough of them to equip one Israeli armoured brigade. The IDF also captured about 100 M48s that were used by the Jordanian forces and that were quickly integrated into their own M48 tank units.[12]

The riposte of Egypt and Syria came six years later when they launched a co-ordinated attack on Israel that resulted in the 1973 Yom Kippur War. The Egyptian and Syrian armies had been furnished since 1967 with large quantities of Soviet equipment and their tank strength had risen to an estimated total of 2,200 and 1,820 tanks respectively. Most of the tanks were T-54s and T-55s, but they also included a number of the relatively new T-62s armed with smooth bore 115mm guns instead of the 100mm rifled guns of the other Soviet tanks. Moreover, the Syrian Army was supported by contingents from Iraq and Jordan, which committed 450 tanks out of their total of 1,740 tanks.[13]

To oppose this potential total of almost 6,000 tanks, Israel had about 2,000. They included 540 M48s and M60A1s, the first 150 of the latter having been received from the United States in 1971. The rest were for the most part Centurions, but they also included captured T-54s and T-55s and still some M51s and even M50 Shermans armed with the obsolete 75mm guns. However, except for the last two, all the other tanks were now armed or re-armed with 105mm L7 guns or their US equivalent.

The war was waged on two fronts and on both the scale of tank battles was comparable to the biggest tank battles of the Second World War. On the northern or Golan Heights front the Syrian Army had concentrated three infantry divisions, each containing a tank brigade, backed by two armoured divisions that had an estimated total of as many as 1,260 tanks.[14] Facing them initially were two Israeli tank brigades with a total of 177 Centurions, these being considered more suitable for employment in the rocky terrain of the Golan Heights because of their rugged suspensions and all-steel tracks than the M48s and M60s, which were employed in the Sinai.

In spite of the numerical inferiority, the Israeli 7th Armoured Brigade successfully fought off repeated Syrian attacks against the northern sector of the Golan Heights in an epic defensive battle that left 260 Syrian tanks destroyed or abandoned in front of its positions on what came to be called the Valley of Tears.[15] The 7th Armoured Brigade also suffered heavy losses and was reduced to seven tanks by the time reinforcements arrived, when the Israeli forces began to counter-attack, which eventually brought them within artillery range of Damascus. All the fighting on the Golan plateau cost the Syrian Army a loss of 867 tanks and in total it is estimated to have lost 1,150.[16]

On the Sinai front, the successful assault crossing of the Suez Canal by the Egyptian forces was followed immediately by counter-attacks by the Israeli 252nd Division, which ran into Egyptian infantry equipped with an exceptionally large number of Soviet-made Sagger anti-tank guided missiles and failed, losing 165 of its 268 tanks. This immediately led to worldwide rumours that tanks were no longer effective and it took some time for these to be disproved by the evidence provided by the rest of the Yom Kippur War, in which many more tanks were destroyed by the guns of the opposing tanks than by guided missiles. This was shown to be the case on the Syrian front and was demonstrated on an even larger scale on the Sinai front when the Egyptian forces tried to break out of the bridgehead they established after the crossing of the Suez Canal. Their offensive carried out on either side of the Great Bitter Lake involved up to 1,000 tanks and precipitated the largest tank battle since the Second World War, in which the Egyptian tanks were defeated by the superior gunnery and manoeuvring skill of the defending Israeli tank units. The latter had about 750 tanks, of which they lost 20, while they managed to destroy 260 Egyptian tanks.[17] The total number of tanks lost by the IDF on both fronts is estimated to have been 840, but as they were left in control of most of the battlefield they might have recovered about 400 of the tanks that were put out of action.[18]

To make up for their losses, the IDF received more M48 and M60 tanks from the United States, which restored the size of their tank fleet to 2,000 or more. With their arrival the M48 and the M60 outnumbered the Centurions, which had been the principal tanks of the IDF and which continued to be used until 1992. While they were still in use the Centurions as well as the M60s were fitted with explosive reactive armour, with which they took part in the 1982 invasion of the Lebanon and which greatly improved their protection against RPG-7 rocket propelled grenades and other shaped charge anti-tank weapons. Subsequently, while the Centurions were being retired, the M60s were extensively modified by the addition of a considerable amount of passive armour to their turrets and hulls, increasing their weight by 6.5 to 7 tonnes, and in the up-armoured form they were designated Magach 7.

The modifications that the IDF made to the various tanks it acquired from Britain, the United States and elsewhere improved them considerably and they undoubtedly proved effective. Nevertheless, since the 1960s the IDF hankered after a modern tank of its own, to be sure of having one when it was needed and that it was up to date. This prompted the idea of producing a foreign-designed tank under licence in Israel, which coincided in 1966 with a proposal by the British Ministry of Defence for the joint development and co-production of the new British Chieftain tank. The proposal was eagerly accepted by the IDF and in 1967 two Chieftains were sent for trials in Israel.[19] The writer may have unwittingly contributed to this in a small way by lecturing in Tel Aviv on the Chieftain to an audience that included General I. Rabin, the IDF Chief of Staff, and other senior officers two years before the British offer!

Two more Chieftains were sent to Israel in 1968 to replace the original pair, but a year later, under pressure from Arab countries, the British government reneged on its agreement with Israel.[20] This confirmed the IDF in its belief that it could not depend on foreign sources for tanks, and within eight months of the Chieftains being returned to Britain a decision was taken to produce an indigenous tank in Israel.

The direction of the design and the development of the tank, which was called Merkava or Chariot, was entrusted to General Israel Tal, who led one of the three Israeli armoured thrusts in the Sinai in 1967 and who, as commander of the Armoured Corps, inspired it to achieve a high level of proficiency in long-range tank gunnery. Tal took the view that survivability should be the basic feature of the Merkava and in particular that it should offer a high level of protection for its two most vulnerable components, which are the crew and the ammunition. To this end, Tal departed from convention and had Merkava's engine and transmission located at the front of the hull so that they would contribute to the protection of the crew against the most common frontal direction of attacks. Only the Swedish S-tank also made use of the power pack to augment its frontal protection, but this was inseparable from its whole concept rather than a deliberate choice. Otherwise, Merkava was protected by spaced armour, which until the advent in Britain of Chobham armour represented the most advanced form of protection used in Western tanks, and by making as many as possible of the mechanical components contribute to it.[21]

The designers of the Merkava had little choice when they adopted the US-made AVDS-1790 diesel and CD-850 transmission, which were already well known in Israel not only because they were used in the M60 tanks but also because the IDF used them to re-power the Centurions. The choice of the main armament was also restricted, being confined to the Israeli version of the US 105mm M68 gun, derived from the British L7, which was already produced in Israel and was used by the IDF to re-arm most of its other tanks as well as being similar to guns widely used throughout the Western world.

The location of the engine and transmission at the front meant that the ammunition could be located at the rear of the hull, where it was least vulnerable. It also made possible the provision of a unique rear access door, which made entry and exit much easier and safer than in all other tanks. Moreover, the combination of the rear access door with removable ammunition racks made it possible to convert the rear of the hull into a compartment that could, among other things, accommodate six infantrymen.

This led to a lot of nonsense being written about Merkava being a novel type of tank-cum-infantry carrier. In fact, it was only expected to carry infantrymen or casualties in emergencies and could only do so when most of its 50 rounds of ammunition had been unloaded.

The first prototype of the Merkava began to be tested in December 1974, and five years later the first were delivered to the Israeli Armoured Corps.

This represented a remarkable achievement bearing in mind that Israel had no previously established tank manufacturing facilities and put to shame the time taken to produce new tanks in other countries where such facilities were well established.

Merkava received its baptism of fire during the 1982 Israeli invasion of the Lebanon, where it performed with credit. In particular, although the armour of some was inevitably pierced by anti-tank weapons, no crewman was burnt. This attested to the effectiveness of the measures taken against the common threat of tanks catching fire when hit, which included stowing the ammunition in a unique system of heat resistant containers. Merkava Mark 1 was followed in 1983 by the Mark 2, which was provided with even better, composite armour and a more efficient Israeli-produced automatic transmission, and in 1990 by the Mark 3, which was armed with an Israeli version of the 120mm smooth bore gun mounted in the German Leopard 2 and the US M1A1. Further development resulted in the appearance in 1992 of the Mark 3 Baz with a fire control system incorporating automatic target tracking, which put it ahead in this respect of other tanks except for the Japanese Type 90. Its inclusion increased very considerably the probability of hitting targets on the move, which was demonstrated to the writer when he was given an opportunity to fire from a Mark 3 Baz during a visit to the IDF Armour School and hit a target every time.[22]

In 2002 Israeli tank units began to receive Merkava Mark 4, which incorporated further major improvements, particularly in mobility and survivability. The former involved the replacement of the AVDS-1790 diesel, although its output had been gradually increased to 1,200hp, by the German 1,500hp MTU MT 883 diesel, which was not only more powerful but was the best available tank engine. The advances in survivability included the use of a combination of passive and reactive armour and reshaping of the turret, which made Merkava Mark 4 one of the best protected tanks in the world. In spite of this its weight had only risen to 65 tonnes, compared with 60 tonnes of the Mark 1 and 2. Moreover, from Mark 3 onwards much of the armour became modular, so that it could be easily changed to meet changing threats by taking advantage of advances in protection technology.

The need for further improvements was shown when a Merkava Mark 3 was destroyed in 2002 on the border of the Gaza Strip by a mine containing almost 100kg of explosive.[23] No tank could be expected to withstand the explosion of such a heavy mine, but to increase their protection against other mines Merkava Mark 4s were fitted with an additional thick steel belly plate, which proved so effective that at least one of them survived the blast of a mine containing 150kg of explosive during the 2006 war in the Lebanon with only one of its crew being killed.[24]

The 2006 war against the Hezbollah also brought out the threat of the new generation of anti-tank guided missiles and in particular of the Russian-made laser beam riding Kornet, which is claimed to be capable of penetrating 1,000 to 1,200mm of steel armour even when the latter is protected by explosive reactive armour. The missiles took their toll of the Merkavas, about 50 being hit, of which according to the IDF 14 were destroyed by missiles and six by mines. Fewer might have been lost if the IDF high command had employed tanks more decisively from the start, instead of adopting as the dominant tactic the use of stand-off fire power delivered mainly by aircraft, which was popular at the time in air force circles not only in Israel but also in the United States although it only delivered partial success.[25]

In response to the threat of missiles, the IDF accelerated the development of active protection systems on which the Israeli industry had been working since the mid-1990s. The initial outcome of this was a system called Trophy produced by the Rafael organization, which was adopted for use on the Merkava Mark 4 in 2009. In the following year, the Merkava Mark 4 fitted with the Trophy system was deployed with an IDF tank battalion, which made it the first tank to go into service with an active protection system since the introduction of the Soviet T-55AD of 1983.

By 2010, the number of the Merkavas available to the IDF is estimated to have reached a total of about 1,600 and they had almost completely replaced the M60 and Magach 7 that in the 1990s constituted the bulk of the IDF tank fleet, although some Magach 7 have been kept in the reserve.

Italy

Israeli armoured forces were not the only ones to start with second hand tanks, as the Italian armoured forces did the same when they were re-created after the Second World War, although they did so on a larger scale. The number of tanks they could have was restricted at first by the terms of the peace treaty imposed on Italy and in 1948 they had only 99 armoured vehicles. But by 1952 the peace treaty restrictions were lifted and Italy received tanks under the US military aid programmes, which raised the number of armoured vehicles in its possession to 521. At the same time, the Ariete and Centauro armoured divisions were re-created and were followed in 1953 by the formation of a third division, each of which had a nominal strength of 250 tanks. Most tanks were initially US M4 Shermans armed with their original 75mm guns, but some were armed with the 76mm 17-pounders when they came from British Army stocks. However, in 1953 the Ariete already had US M46 and the Centauro had M47 tanks.[26]

In 1958 Italy joined France and Germany in drawing up the requirements for what was intended to be a standard European tank, but while these led to the French AMX 30 and the German Leopard 1 tanks, it took no steps to implement them. Instead it acquired 100 M60A1 tanks from the United States and obtained a licence to build 200 more, which became the first tanks to be produced in Italy since the Second World War.

In the meantime pre-production Leopard 1 tanks had been built in Germany, and the Italian Army tested one of them in 1964. It took six more years for a decision to be taken to adopt the Leopard, but when it was finally taken an order was placed for 800. The first 200 were built in Germany and were delivered in 1971 and 1972. The remaining 600 were produced under licence in Italy, the first being completed in 1974 and the last in 1978.[27] Subsequently an order was placed for 120 more tanks, which by 1983 brought the Italian fleet of Leopard 1 tanks to be the second largest after Germany and made it comparable to the tank fleets of Britain and France. Leopard 1 became the mainstay of the Italian armoured forces during the 1980s and 1990s, displacing the M47s and then the M60A1s, and the last were only withdrawn from service in 2009.[28]

Having acquired considerable experience with the Leopard 1, the Italian Oto Melara and Iveco companies developed from its basis a more powerful tank called the Ariete, just as the German industry developed Leopard 2 from its basis. The requirement for the new tank was issued by the Italian Army in 1982 and two years later its specification was agreed with industry, which worked with commendable speed producing the first of six prototypes in 1986. But the first tank of the production order for 200 placed by the Italian Army was not completed until 1995, while the last was only delivered in 2002.

Ariete turned out to be a well-designed tank of 54 tonnes, comparable in general terms to the German Leopard 2A4. It had the same conventional configuration and was armed with a 120mm smooth bore gun similar to the Rheinmetall 120mm gun of the Leopard 2. It was powered by a 1,300hp Iveco (originally Fiat) diesel coupled to a German ZF transmission produced under licence. All this implies that although Italian armoured forces were reduced by 2009 to four tank regiments with 200 Ariete, they were well equipped.

Argentina

Like Italy after the Second World War, almost all Latin American countries have provided their armies with tanks originally built for other armies and previously used by them. An exception to this was Argentina, which produced, albeit in small numbers, Latin America's first indigenous tank.

The tank was the DL 43 Nahuel, or Tiger. Its development is believed to have begun in 1942 when Argentina was still maintaining diplomatic relations with Germany and was unable therefore to obtain tanks from the United States as Brazil did. Nevertheless, Nahuel resembled the contemporary US M4 Sherman medium tank. In particular it had a comparable weight of 35 tonnes and a similar armament of a medium-velocity 75mm L/30 gun, albeit of 1909 vintage, and it was powered by a French 450hp aircraft engine that was produced under licence in Argentina.

Nahuel began to be produced in 1944 but only 16 were completed, as with the ending of the Second World War and changes in the political situation Argentina was able to procure tanks from abroad. It took advantage of this by purchasing from Britain in 1946 ex-British Army M4 Shermans, which began to be delivered a year later. Most were armed with the original medium-velocity 75mm guns, but they included a number that had been re-armed with the 76mm 17-pounders and that became, for a number of years, Latin American's most potent tanks.

It was only in 1973 that the Argentinian Army issued a requirement for a tank to replace the Shermans. It was to be a medium tank of not more than 30 tonnes, to be compatible with Argentina's transportation infrastructure, and as well armed as most other contemporary Western tanks, which meant having a 105mm gun of L7 type. The German Thyssen Henschel company that responded was awarded a contract to design such a tank in 1974, and two years later delivered two prototypes of what came to be called Tanque Argentino Mediano or TAM.

The design of TAM was based on the chassis of the German Marder infantry fighting vehicle, and this as well as the 30-tonne limit placed on its weight meant that it was not heavily armoured. But in other respects it was a well-designed tank that compared favourably with other contemporary medium tanks. It began to be assembled in Argentina in 1979 in a purpose built factory, but its production was interrupted in 1983 by the repercussions of the Falklands or Malvinas War and was not resumed until 1994. It was therefore only a year later that the order for 230 was completed in full.

In contrast to at least four other Latin American countries Argentina has made no attempt to procure more powerful tanks. But in the 1960s, in an initial attempt to replace its Shermans, the Argentinian Army procured from France 58 AMX 13 light tanks and had 40 more of them produced at home. In 1981 it followed a similar policy and purchased from the Austrian Stey-Daimler-Puch company 118 SK 105 light tanks or tank destroyers, which consisted of an oscillating turret similar to that of the AMX 13 and were armed with a 105mm gun mounted on the chassis of a Saurer armoured infantry carrier.

Brazil

Brazil, Argentina's traditional rival, might have equipped its army with an indigenous tank, but like other Latin American countries it has relied instead on tanks produced elsewhere.

As an ally of the United States, Brazil received during the latter part of the Second World War 104 M3 Lee and 53 M4 Sherman medium tanks as well as about 200 M3 Stuart light tanks. The Shermans and the Stuarts continued to be used into the 1970s when the latter served as a model for the X1A2, which was armed with a 90mm medium-velocity gun made popular by the Panhard AML armoured cars and of which about 30 were built.

A more significant move towards modernizing the Brazilian tank fleet took place in 1960 with the arrival of the first of 386 ex-US Army M41 light tanks. They became the principal tanks of the Brazilian Army and some continued to be used into the 21st century after almost all were modified in the 1980s. The principal features of their modification were a replacement of the original petrol engine by a diesel and of their 76mm gun by a 90mm gun firing fin-stabilized shaped charge projectiles, which was either of the type manufactured in Brazil for the Engesa armoured cars or produced by boring out the original 76mm gun to 90mm.

The Bernardini company that modified the M41 tanks designed, around 1981, a very similar but heavier tank, the MB-3 Tamoyo. Three prototypes of it were built by 1988, but it was not adopted by the Brazilian Army. The same thing happened to Tamoyo III, which had a more powerful engine and was armed with a 105mm L7 type gun, only one prototype of which was built in 1987.

A much more serious proposition was represented by the Osorio medium tank designed on its own initiative by Engesa, a private engineering company that became involved with armoured vehicles when it took over the development of the Carro de Reconhecimento sobre Rodas or CRR, a wheeled reconnaissance vehicle that the Brazilian Army was trying to develop around 1970 to replace the obsolete Second World War US-built M8 6x6 armoured cars that it was still using.[29] The CRR evolved into Engesa's EE-9 Cascavel, a 6x6 armoured car armed at first with a 37mm gun and then fitted with a French turret with a 90mm gun similar to that of the Panhard AML, and eventually with an Engesa turret with a Belgian 90mm Cockerill gun produced under licence. Cascavel was designed and built in prototype form in 1970 at the same time as the EE-11 Urutu, a 6x6 amphibious personnel carrier which shared with it many components. The two vehicles began to be produced in 1974 and quickly proved very successful, being procured not only by the Brazilian Army but also by about 20 different countries in Latin America, Africa and the Middle East. By the time their production ceased, a total of 2,767 of the two vehicles had been built.

Emboldened by the success of its wheeled armoured vehicles and enticed by the prospect of orders from the Brazilian Army and even more from Saudi Arabia, Engesa decided in 1982 to develop a battle tank. Work on it started a year later and exactly one year after it began the first prototype of the tank, which was called Osorio, was rolled out. This was a remarkable achievement that showed the speed with which Engesa worked, untrammelled by the usual military bureaucracy, and which the writer witnessed as an adviser to it from 1972 onwards.

It is only fair to add that the record speed with which Engesa designed and built the first Osorio prototype was helped by the fortuitous existence on the international market of a number of suitable components. Thus its turret with a 105mm L7 gun came from Vickers Defence Systems in Britain and was very similar to that of the Vickers Valiant.[30] For financial reasons Osorio was powered by a German MWM industrial diesel of 1,000hp instead of a proven tank engine, but nevertheless this proved very successful. The German ZF transmission of the Osorio had already been developed for other tanks and its Dunlop hydropneumatic suspension was the unsuccessful contender for the suspension of the British Challenger tank. However, the hull still had to be designed and built by Engesa and all the many components that make up a modern tank had to be successfully integrated, which they were as was shown when the Osorio prototype was sent in 1985 to Saudi Arabia for preliminary trials and outperformed a British Challenger.

A second Osorio prototype was completed in 1986. It also had a Vickers turret but it was a further and much more sophisticated development of the Valiant's turret designed for Vickers' Mark 7 tank, and it mounted a French Giat 120mm smooth bore gun comparable to that of the German Leopard 2. In 1987 the second prototype took part in extensive competitive trials in Saudi Arabia in which it outperformed the Challenger as well as the French AMX 40 and proved at least as good as the US M1Al. This led Saudi authorities to indicate an interest in procuring 316 Osorios, but they did not follow it with an order. Instead, on the eve of the Iraqi invasion of Kuwait in 1990, the Saudi government decided to order 315 US M1A1 tanks, and Engesa, which had already exhausted its financial resources in developing the Osorio, became bankrupt.

In consequence, Brazil lost an opportunity of producing a modern tank of its own and a valuable industrial asset, which Engesa had come to represent. This was all the more regrettable in view of the fact that five years after Engesa filed for bankruptcy the Brazilian Army declared its intention to procure Leopard 1 tanks, which were similar to the first prototype of the Osorio and not as advanced as the second, although admittedly they were well proven and required no investment in production facilities.

Leopard 1s were originally ordered from Belgium and the first of 128 of them arrived in 1997, but 80 were then declared unfit for use. Subsequently 250 modernized Leopard 1A5s were ordered from Germany, with the first being handed over to the Brazilian Army in 2009. In addition, in 1997 the Brazilian Army received, somewhat against its wishes, the first of 91 M60A3 tanks from the United States, originally on lease but then converted into a donation.

All these acquisitions provided the Brazilian Army with a sizeable force of relatively modern tanks that were a very considerable advance on the M41 light tanks on which it had previously relied. They also put it ahead of

Argentina. However, both countries were overtaken by Chile, which has acquired the most modern and powerful tank force in Latin America.

Chile and Peru

Like Argentina and Brazil, Chile started after the Second World War with M4 Sherman tanks, having acquired 76 of them from the United States and elsewhere. It made little further progress until the 1960s, when it received 60 M41 light tanks from the United States, but during the following two decades it found it almost impossible to acquire other more powerful tanks because of the hostility to its government headed by General Pinochet. In fact, during this period Chile was only able to obtain 150 M51 and M50 Sherman tanks from Israel and about 20 AMX 30s from France. It was not until 1998, well after General Pinochet relinquished power, that Chile was able to order from the Netherlands 202 ex-Dutch Army Leopard 1 tanks. Eight years later it took an even greater step forward by ordering from Germany 140 of an upgraded version of the Leopard 2A4. The latter was comparable in several respects to the latest Leopard 2A6 and became Latin America's most powerful tank. With its entry into service Chile's Leopard 1 fleet was reduced to 120, with 30 being sold to Ecuador.

Chile's Pacific coast neighbour, Peru, has been the only other Latin American country with a sizeable force of tanks as a result of purchasing in the mid-1970s 300 T-55 tanks from the Soviet Union. By the turn of the century these tanks had become obsolescent, and in 2009 the Peruvian government turned to China for new tanks. In consequence five MBT 2000 tanks were sent by China to Peru for evaluation, but the possibility of purchasing them collapsed as a result of objections from the Ukraine to their export because they were powered by engines that it produced.

Australia and South Africa

Elsewhere in the Southern hemisphere, Australia made a brave attempt to produce a medium tank during the Second World War. Its development was hampered by a lack of suitable components, such as engines, which resulted in it having to be powered by a combination of three Cadillac car engines. In spite of the difficulties, about 69 were built as the Australian cruiser tank Sentinel and proved mechanically successful, but none was used in battle.[31] After the war the Australian Army used British-built Centurion tanks, which were replaced in the 1980s by 90 German-built Leopard 1 tanks and these were succeeded in turn by 59 US M1A1s.

Apart from the Australian Sentinel, the Argentinian Nahuel and the Brazilian Osorio, the only indigenous battle tank designed in the Southern hemisphere has been a South African vehicle called the Tank Test Bed. Its development was preceded by a somewhat fitful use of armoured vehicles by the South African Army, which for many years before the Second World War had the only two tanks in the whole of Southern Africa. During the war South Africa concentrated on the production of armoured cars, of which it built no fewer than 5,746, using chassis imported from the United States, for its own and other forces of the British Empire. It also mustered an armoured division that fought in Europe as part of the British Eighth Army.

When the war ended, South Africa retained three regiments of M4 Shermans, which were reinforced in 1953 by the purchase from Britain of 200 Centurions. The latter were regarded as part of the strategic reserve of the British Commonwealth, but when South Africa left the Commonwealth its government saw no further need for tanks and sold 100 of the Centurions to Switzerland.

Instead of tanks, the South African Army concentrated for a time on armoured cars and in particular on the light, 4x4 Panhard AMLs of 4.8 to 5.5 tonnes, which were armed either with 60mm mortars or 90mm guns capable of firing fin-stabilized shaped charge anti-tank projectiles. The first 100 were ordered directly from France in 1961 and 500 more were assembled in South Africa, where they were subsequently produced in a modified form as Eland armoured cars. Production of the Elands continued until 1986, by which time a total of 1,300 vehicles had been built.

Elands were still the only armoured vehicles being produced in South Africa when the writer visited their factory in 1974, and a year later they were successfully used when the South African forces intervened for the first time in the Angolan Civil War in what was called Operation *Savannah*.[32] In later operations, Elands were combined with South African-produced six-wheeled infantry fighting vehicles called Ratels, which began to be developed in 1968 and entered service in 1977. Ratels eventually became the principal armoured vehicles of the South African forces, and when their production ended in 1987 more than 1,200 had been built.

Some of the Ratels were armed with the same 90mm gun as the Elands, and in that form proved capable of destroying T-54 or T-55 tanks operated by the Cuban-backed Angolan Marxist forces by outmanoeuvring them in the dense vegetation of southern Angola, which lessened the disparity between them by reducing the range of engagements. However, in the end the Soviet-supplied tanks used by the Angolan forces, which by late 1985 were estimated to number about 350 T-55s and 150 T-34-85s, had to be countered with tanks.[33] In consequence, in 1987 the South African Army deployed tanks in Angola. They amounted to only a squadron of 16 and in the following year the number of South African tanks in Angola rose to no more than two squadrons. But they proved more than a match for the Angolan T-55, and as a deterrent to further offensive action by the latter contributed to the cessation of hostilities in 1988.

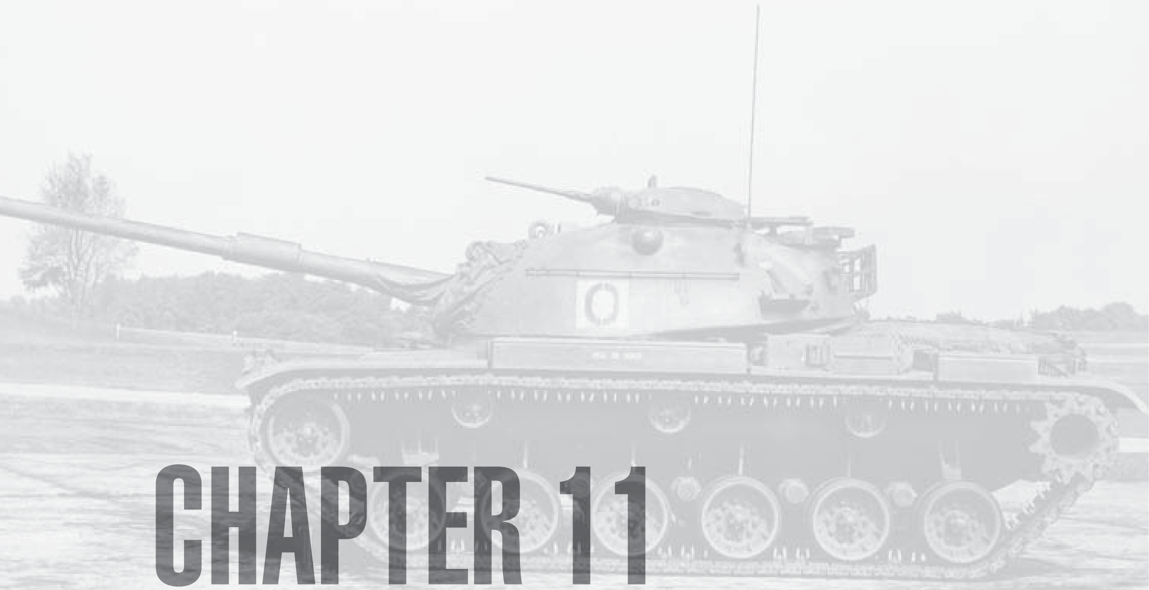
The tanks were Olifants 1A, which were much modified British Centurions. The South African Army made an initial attempt in 1972 to improve some of the Centurions it was left with after the sales of one half of its original fleet to Switzerland by retrofitting them with the engines and transmissions of US M48 tanks. This was followed in 1974 by further modifications and the eventual transformation of the Centurions into Olifants, which began to be implemented in 1983. During this period South Africa managed to rebuild its stock by the purchase of a number of them, in various states of repair, from Jordan and India, despite the embargo on the sale of military equipment to South Africa imposed by the United Nations in 1976. As a result the South African Army acquired enough Centurions to transform them into more than 200 Olifants.

In spite of the embargo, Olifant 1A, which was accepted by the South African Armoured Corps in 1985, was powered by the same diesel engine and had the same transmission as the US M60 tanks and was armed with a South African version of the 105mm L7 gun instead of its original 83.8mm 20-pounder. In all these respects it closely resembled the Centurions modified a decade earlier by the Israeli forces and, on a much smaller scale, proved as successful. Olifant 1A was followed by the 1B version (also known as the Olifant 2), which incorporated major improvements in armour protection as well as a more powerful version of the V-12 diesel engine, a more effective transmission, a double floor for better protection against mines and, somewhat unnecessarily, a torsion bar suspension instead of the original rugged coil spring suspension of the Centurions.[34]

Although the Olifants proved an effective counter to the T-54s and T-55s, the use by the Angolan Marxist forces of Soviet tanks, which were encountered as early as 1981, raised the prospect of South African forces having to fight more modern and more powerful tanks, such as the T-72. This led to a decision in 1983 to develop a modern indigenous tank, but before it could be implemented the war in Angola came to an end in 1988–89. As a result of this, development was restricted to the construction of a single prototype thatwas called the Tank Technology Demonstrator, or TTD, which was unveiled in 1993.

TTD had a conventional configuration and outwardly resembled the German Leopard 2A4. It was initially armed with a 105mm L7 gun but was designed to mount instead a South African developed GT6 120mm smooth bore gun, which could, if required, be fitted with a 140mm smooth bore barrel. It was well armoured, which was reflected in its combat loaded weight of 58.3 tonnes, but in spite of this it was relatively agile due to it being powered by a 1,200hp V-8 diesel.[35]

In general, TTD compared favourably with other contemporary battle tanks and represented a considerable achievement, particularly as it was the first tank ever to be designed in Africa and as its development was handicapped by the sanctions imposed at the time on South Africa.



CHAPTER 11
Asia Catches Up

The Imperial Japanese Army showed some interest in tanks at the end of the First World War, but little use was made of them in the Far East until the early 1930s, when the Japanese Army began to employ tanks in China. Their use by the Japanese Army grew during the Second World War when they were widely deployed albeit in small numbers, particularly by comparison with the increasingly large scale use of them by the US forces during their 'island hopping' operations in the Pacific. Tanks were also used, although on a much smaller scale, by the British forces in Burma and by the Australian forces in the South West Pacific, and they were used finally by the Red Army, which assembled as many 5,556 tanks and assault guns in August 1945 for the offensive against the Japanese forces in Manchuria.[1]

However, none of the tanks used in the Far East was produced there until well after the Second World War, except for those built in Japan. Their post-war production began, with Soviet aid, in the 1950s in China, and at about the same time their development was resumed in Japan, where it was interrupted by the country's surrender in 1945. In the 1960s production of tanks also began, with British assistance, in India, where it was then continued in co-operation with the Soviet Union, and in the 1980s it also started in South Korea, while Pakistan began at the time to co-produce tanks with China.

In spite of the relatively late start, by about 2000 Japan, South Korea and China had caught up with tanks produced in Europe and the United States and in some respects had surpassed them, while India was producing the latest Russian tanks and Pakistan was building the most modern Chinese designs. The progress made by all these countries stood in marked contrast with the neglect of the development of new tanks in Europe and the United States at the end of the 20th century.

Japan

The initial Japanese interest in tanks manifested itself in the purchase in 1918 from Britain of a Mark IV heavy tank, and a year later of 3 or 6 British Medium A tanks and 10 to 13 French Renault FTs. Their acquisition did not arouse any great interest in tanks on the part of the Japanese Army, but its attitude changed radically in 1923 with the appearance in Britain of the Vickers Medium tanks, which were much faster than the wartime British and French tanks it had acquired. As a result the Japanese Army formed its first tank unit in 1925 and considered equipping itself with tanks acquired from abroad. However, the only tanks available for purchase were the Renault FTs, which the Japanese already considered outdated. This led the technical headquarters of the army to propose the development of an indigenous tank, which was approved in spite of justifiable scepticism.

The task of designing the tank was entrusted in 1925 to a group of army engineers led by Captain (later Lieutenant General) Tomio Hara, who, in spite of having no prior experience of tank design and nothing to go by except the few obsolete British and French tanks, completed his task in 1927, only 21 months after he embarked on it. The tank was built at the Osaka Arsenal and in 1927 was successfully demonstrated at the Fuji training ground.[2]

Japan's first tank had an original configuration with three turrets, which consisted of a central two-man turret mounting a low-velocity 57mm gun and two one-man machine gun turrets, one of which was at the front of the hull and the other at the rear behind the engine compartment. The location of a turret at the rear of the hull might have been inspired by the French 2C heavy tank, which had such a turret and which might also have influenced the adoption of a similarly located turret for the Krupp and Rheinmetall *Grosstraktoren* designed in Germany at about the same time as the first Japanese tank.

In spite of its successful debut and a road speed of 12.5mph, which was more than twice that of the Renault FT, the first Japanese tank was not adopted because it weighed 18 tonnes and was therefore considered too heavy. It was later developed through the Type 91 into the Type 95 heavy tank, which still had three turrets, but only a few of which were built.[3]

In the meantime the army headquarters issued a requirement for a tank of 10 tonnes for close infantry support. Drawing on the experience gained with the first tank, the new tank was quickly designed, with a prototype being completed in 1929, and it was adopted as the Type 89 medium tank. It had a single two-man turret with the same low-powered 57mm gun as the first tank, and it was relatively fast, being capable of a road speed of 17mph. In its original form it was powered by a gasoline engine, but this was replaced in the Type 89B by a specially developed six-cylinder air-cooled diesel. The development of this type of engine began in 1932 and was driven by its lower fuel consumption as well as its greater tolerance of poor quality fuels, while the adoption of air cooling eliminated the risk of freezing up present with water-cooled engines, particularly at the very low ambient temperatures encountered in Manchuria where Japanese tanks were expected to operate. The engine was successfully developed by Mitsubishi and in 1936 was adopted for use, placing Japan in the forefront of the use of diesels in tanks.

The case for the use of diesels was reinforced by an accidental fire that damaged a gasoline engined Vickers Mark C purchased from Britain in 1927 for comparative trials. The damage was repaired but, as he told the writer many years after the event, the consequent delay gave Captain Hara more time to complete his development work and be therefore in a better position to compete with the Vickers tank. In any event, Vickers Mark C did not, contrary to widespread belief, become the basis of the Type 89 medium tank, which differed from it in several respects.[4]

Having been accepted, Type 89 became the first Japanese tank to be produced in quantity, with the first 12 being built in 1931 and the last in 1939, by which time a total of 404 was completed.[5] Type 89 was also the first Japanese tank to be used in action, during the so-called 'Shanghai incident' of 1932, and was the principal Japanese tank when the war with China began in 1937.

The Type 89 medium tank was used in the fighting in China to support the infantry and was considered to have performed successfully in that role, albeit against an enemy who had few anti-tank weapons. But it was completely outgunned by Soviet BT tanks armed with high-velocity 45mm guns when it came up against them in 1939 at Khalkin-gol on the Manchurian border in what is known in Japan as the Nomonhan Incident. A more modern Type 97 medium tank was already being produced and a few were used at Khalkin-gol. However, although it was well in advance of the Type 89 from the automotive point of view, it was still armed with the same low-velocity 57mm gun as the latter. This gun may have been adequate against the Chinese infantry, but it was well behind the armament of the tanks that were coming into use in the late 1930s.

The development of Type 97 was accompanied by the first Japanese attempt to advance beyond the use of tanks to support the infantry in, at most, battalion-size units to their employment in a self-contained combined arms mechanized brigade, which was created in 1934 under the influence of the contemporary mechanized warfare experiments in Britain. However, after the outbreak of the war with China the brigade was broken up and its tanks were dispersed to support infantry formations. It was only in 1942 that the Japanese Army concentrated most of its tanks in three armoured divisions, each of which consisted of infantry and four tank regiments as well as other units.[6]

The principal tank of the armoured divisions was the 15-tonne Type 97 medium tank. It was originally designed in response to a requirement for a tank more mobile than the Type 89, which meant having a 170hp V-12 air-cooled diesel and a much better coil suspension. In most respects it was up to the contemporary standards of tank design, but it was only after the Nomonhan Incident that it was realized that Type 97 also needed better armament than the 57mm gun with which 1,162 of the original version were built between 1938 and 1942. From then on about 1,000 were produced with a newly developed high-velocity 47mm gun, which also armed 170 very similar Type 1 medium tanks built in 1943 and 1944. The only better-armed Japanese tank to come into service was the Type 3 medium tank. This followed Type 1 and was armed with a medium-velocity 75mm gun similar to that of the US M4 Sherman tank. However, its production did not commence until 1944, and only 166 were completed by the end of the war.

In 1943 work also began on a larger 30-tonne version of Type 97, the Type 4, which was armed with a derivative of a 75mm anti-aircraft gun and had armour up to 75mm thick. But by the time the war ended only two had been completed, while the construction of the even heavier Type 5 was confined to a single prototype.

The Japanese Army was evidently slow to recognize the need for well-armed medium tanks and it was hampered by the limited capacity of the Japanese tank industry, which at its peak produced only about 500 medium tanks per year. Moreover, in 1944 production of tanks declined and in 1945 fell further as a result of the devastation wrought by American bombing raids. How bad the situation had become towards the end of the war is shown by the employment of General Hara, the leading Japanese tank designer, as an inspector in an aircraft factory because a shortage of armour plate severely restricted the production of tanks.[7]

In addition to medium tanks the Japanese also developed light tanks and tankettes. The most numerous and most widely used of them was the Type 95 light tank, a 7.4 tonner with a one-man turret mounting a medium-velocity 37mm gun. It was originally designed in response to demands for a more mobile tank than the Type 89 medium model, but became a part of most tank units irrespective of their role, and 2,375 were produced between 1936 and 1943.

The tankettes were a peculiar and much publicized product of the Japanese tank development. They were very small two-man armoured vehicles with a turret mounting a machine gun, which in their original Type 94 form weighed only 3.4 tonnes. Their design, like that of almost all other contemporary ultra-light armoured vehicles, was inspired by the Carden Loyd Mark VI, some of which were purchased from Britain, but their role resembled that of another Carden Loyd derivative, the French Renault UE *chenilette*, as it was to be that of armed tractors towing trailers with supplies for front line troops under fire. But as they were allocated by companies to infantry divisions that had no other armoured vehicles they were often used as tanks, particularly during the war in China. Because they were inexpensive as well as useful they were produced in quantity, 843 Type 94s being built between 1935 and 1940, and they were followed by the improved Type 97 armed with a 37mm gun instead of a machine gun, 616 of which were built between 1937 and 1944.

In spite of their indifferent armament and thin armour, Japanese tanks contributed to the successes of the Japanese forces in the early stages of the war in East Asia. Their most notable action took place in 1942 during the drive by the Japanese Army down the Malay Peninsula, when a mixed detachment of 15 Type 97 medium and Type 95 light tanks broke through the British defences along the Slim River and by their action opened the road to Singapore. Although three armoured divisions were created in 1942, tanks were generally dispersed over the vast area of the Japanese Army's operations and were used and destroyed piecemeal, even when the 2nd Tank Division was deployed in 1944 against the US forces on Luzon in the Philippines. However, on the eve of the surrender in 1945 the Japanese Army still had several battalion-size tank regiments for the defence of the Home Islands. It also had 1,215 tanks in Manchuria. But they were, at best, comparable to the BT tanks of the 1930s (some of which the Red Army was still using in the Far East) and were completely outclassed by the more modern tanks such as the T-34-85, which formed much of the total of 5,556 Soviet tanks.[8]

After the surrender of Japan in 1945, the short-sighted conditions imposed on it by the United States resulted in its complete disarmament. This involved the destruction of the entire fleet of Japanese armoured vehicles and put an end to their further development. But seven years later, when the war in Korea made obvious the need for Japan to contribute to the resistance to Soviet aggression in the Far East, Japan was allowed to begin re-creating its army, initially under the guise of a National Safety Force and subsequently of a Ground Self-Defence Force (GSDF). The latter was at first provided with US M24 light and M4A3E8 medium tanks and then with 130 US M41 light tanks. But none of them was either modern or powerful enough to meet the need of the GSDF for a battle tank. It could have procured M47 or M48 medium tanks from the United States but they were rejected for a number of reasons, which included having been designed to suit the stature of American crewmen rather than the smaller stature of their Japanese counterparts, as well as the relatively heavy weight and high cost of the American tanks. In consequence a decision was taken in 1954 to produce an indigenous tank, which was designated Type 61.

In spite of the destruction of the tank manufacturing facilities as part of the post-1945 disarmament, a prototype of Type 61 was built in 1956 and production of it began in 1961, to continue until 1975 when a total of 560 had been completed. Type 61 was as light as any of the contemporary battle tanks, weighing 36 tonnes, which made it compatible with the load-carrying capacity of the Japanese rail and road networks. In some respects it represented a revival of the best feature of the earlier Japanese tanks, which was the use of an air-cooled diesel, its 570hp engine being similar to the engine of the Type 97 medium tank originally developed between 1930 and 1936. It also continued, less wisely, the use of front sprocket drive, which was a feature of German and US as well as Japanese tanks until the end of the Second World War when it was abandoned in favour of rear sprocket drive. In fact, Type 61 was the last rear-engined battle tank with a front sprocket drive and the associated transmission shafts running fore and aft and taking up valuable space within the hull. In other respects, Type 61 departed from the earlier Japanese practice and followed the example of US tanks in having a torsion bar suspension and a 90mm gun similar to that of the US M47 and M48 medium tanks.

Soon after Type 61 began to be produced, studies were started in 1963 of a successor to it, which was adopted as Type 74. A prototype of it was built in 1968 and was followed seven years later by the commencement of its production, which continued until 1989, by which time 893 had been completed. Type 74 was a considerable advance on Type 61 and was comparable to the German Leopard 1 and French AMX 30, which preceded it by a few years. In particular it was in the same weight category, as it weighed 38 tonnes, and was armed with the same 105mm L7 gun as the Leopard. In some other respects it was in advance of them. This included an adjustable hydropneumatic suspension and all-electric gun elevation and traverse controls instead of the less safe electro-hydraulic controls of the other tanks and of Type 61. It was also fitted with a laser rangefinder while the other tanks still relied on the less accurate optical rangefinders.[9]

Type 74 was also powered by a unique type of tank engine – an air-cooled two-stroke uniflow diesel. This type of engine was developed during the war by Mitsubishi for high speed torpedo boats, and was highly regarded because of its high specific output. Its development started in 1939 as a research project originally unconnected with tanks, and it was only several years later that a V-10 version of 720hp was produced for the Type 74.[10]

Type 74 brought Japanese tank development up to the standard of tanks produced in Europe and the United States. Its successor improved on this, as it was not only up to the standard of the latter but was superior to them in some respects. Development of this, the third Japanese post-war tank, began in 1976 when the production of Type 74 had only just started, and resulted in the construction of two prototypes in 1980. They were followed by a somewhat protracted development period, during which four more prototypes were built, but in 1990 the new tank was eventually adopted as the Type 90.

However, even then Type 90 was ahead of the French Leclerc battle tank in having an automatic loading system with a turret bustle magazine containing ammunition for its 120mm L/44 smooth bore gun produced under licence from Rheinmetall. In fact, Type 90 was the first battle tank with an automatic loading system, except for the Swedish S-tank and the Soviet tanks from T-64 onwards, and was consequently manned by a crew of three. It was also ahead of other tanks in having a sophisticated fire control system capable of automatically tracking targets, which was already in use when the writer visited the GSDF Fuji Tank School in 1990, shortly after Type 90 was accepted for service. By 2008 341 Type 90s had been produced and in the meantime all Type 61s were taken out of service.

It was originally hoped that Type 90 would not be much heavier than Type 74, but it turned out to weigh 50 tonnes due largely to its armour of a modular spaced multi-layered composite type incorporating ceramics. In spite of this Type 90 is agile, as it has a power-to-weight ratio of 30hp per tonne thanks to its 1,500hp V-10 engine. The engine is basically the same as that of the Type 74 tank, but is much more highly supercharged and is liquid instead of air cooled in order to control the temperature of the hot spots that exist in high output two-stroke diesels. As a result it produces twice the power of the Type 74's engine from the same swept volume of 21.5 litres

However, the weight of the Type 90 tank has proved to be a problem because it exceeds what is allowed by Japanese road regulations and restricts its ability to deploy anywhere in Japan. This and its high cost led to design studies of a new tank that would be lighter and more compact. These studies started just after Type 90 began to be produced but, in the absence of an immediate threat, development of the new tank did not commence until 2002 and the first prototype was only completed in 2007.

The new tank, designated Type 10, is basically a scaled down version of the Type 90. It has the same general configuration, which includes a two-man turret mounting a 120mm smooth bore gun automatically loaded from a 14-round magazine in the turret bustle. It also has a similar hydropneumatic suspension, but, in contrast to the Type 90, it is powered by a liquid-cooled four-troke V-8 diesel of 1,200hp. Its weight varies from 44 to 48 tonnes with the amount of removable modular armour that is fitted, and this in turn depends on the anticipated threat and the transportation requirements. In addition to ceramics, its armour incorporates the latest development in tank armour, which is high strength nano-crystal steel. Type 10 is also fitted with an advanced command and control system, which is a further development of that installed in the Type 90 and which enables it to share battlefield information with other tanks.

The first of 13 Type 10 tanks were produced in 2011 and have provided GSDF with one of the most advanced tanks to be developed so far.

South Korea

By the beginning of the 21st century, South Korea had reached much the same level of tank technology as Japan in spite of starting very much later and not having any previous experience of tank development. In fact it was only in the late 1980s that South Korea produced its first tank. Prior to this its army relied entirely on the United States for its tanks, which were at first M4A3E8 Shermans and then M47 and M48 medium tanks.

Faced with the renewed threat of aggression by North Korea, South Korea's president decided in the 1970s that his country needed more powerful tanks and, unable at the time to procure M60A1 tanks from the United States, began to consider the possibility of producing an indigenous tank. But as South Korea lacked the necessary knowledge and experience, his authorities decided very sensibly that the tank would have to be produced to a foreign design. This led to discussions with the German Krauss-Maffei-Wegmann company, which submitted alternative designs of 30- and 45-tonnes tanks based on its Leopard 1. However, neither was accepted. The Joint US Military Assistance Group-Korea (JUSMAG-K) and the US Defense Advanced Research Projects Agency (DARPA) then stepped in and brought in four US companies, which were awarded contracts for the preliminary design of a tank to Korean military requirements. At the same time they set up an independent team to evaluate the competing proposals, which the writer was invited to join.

By mid-1978 the proposals were whittled down to two, which were also rejected after further analysis either because of some questionable design features or because of doubts about their designers' engineering resources. In consequence a new contract was awarded in 1980 to Chrysler Defense, who were the only one of the four original competitors to have the necessary engineering resources but who were eliminated in the first round of the competition because they came up with nothing better than a slightly modified version of the US M60 tank that they had been producing for several years. However, at the second attempt they tried harder and came up with a new design that in several respects was superior to the M1 tank that they had just designed for the US Army.

The tank designed by Chrysler was originally known as the Republic of Korea Indigenous Tank, or ROKIT, which superficially resembled the US M1 but differed from the latter in some important respects. In particular, it had a fire control system designed in the United States for the German Leopard 2 tank, which was the most advanced at the time but which Chrysler could not afford to incorporate in the US M1 because so much of the money available for it was being spent on its AGT-1500 gas turbine. ROKIT also had an adjustable hydropneumatic-cum-torsion bar suspension, which resulted in it having a lower silhouette and at the same time greater depression for its gun – a feature highly desirable in Korea's mountainous terrain – because the whole tank could be tilted to achieve it.

The gun was a US M68 version of the 105mm L7 on which the Korean authorities insisted following the example of the US Army. It armed the original version of the US M1 and was adequate at the time, but the Korean authorities were persuaded that the diameter of ROKIT's turret should be large enough to accommodate a 120mm gun, which it was bound to have at a later stage because of the general trend in tank armament. The Korean authorities also had a preference for the air-cooled V-12 Teledyne diesel because they were familiar with similar engines used in their US-made tanks. But the writer argued that the German MTU MB 871 V-8 liquid-cooled diesel of 1200hp, which had become available because of the collapse of the Anglo-German-Italian 155mm self-propelled gun programme for which it was developed, was more suitable for ROKIT, and it was finally adopted for it.

The design of ROKIT was completed in essence by the end of 1980 and after three reviews and an examination of a full scale mock-up the writer co-authored in 1981 a report for the Korean Ministry of National Defense, which recommended that the design proposed by Chrysler should be accepted as the basis of further development of ROKIT.[11] Further development did in fact follow and a prototype was completed in 1983.[12] There was some doubt about the US State Department agreeing to the use of the US version of the British Chobham armour, but this was eventually approved and production was launched in 1984 at a plant at Changwon, from which the first tank was delivered a year later. The first batch of 210 tanks was completed in 1987 and was followed by a second batch of 325 tanks, which by then were called K-1 or Type 88.

In its production form K-1 weighed 41 tonnes, which was more than the Korean Army originally specified but was still less than the 54.5 tonnes of the US M1. In 1997 K-1 was followed by K1A1, which as expected was armed with a 120mm smooth bore gun – a US version of the Rheinmetall L/44. At the same time, the weight of K1A1 rose to 53 tonnes compared with 57 tonnes of the corresponding M1A1. By 2010 the total number of K1 and K1A1 tanks produced by the Rotem company of the Hyundai Motor Group was reported to have reached 1,511 units.

The successful production of the K-1 led the Korean Agency for Defense Development to embark in 1995 on the design of an even more advanced and truly indigenous tank. Its design was settled by about 2004 and three years later Rotem completed the first three prototypes, with a production of 397 being planned to follow. The new tank was called K2 or Black Panther and was armed with the latest longer barrelled L/55 development of the 120mm Rheinmetall gun. The gun was fed automatically from a 16-round magazine in the turret bustle and, as a result, the crew of K2 consists of three instead of the four men of its predecessors. Other features of K2 include a fire control system incorporating automatic target tracking, the latest MTU MT 883 diesel of 1,500hp, a hydropneumatic instead of a hybrid suspension and an active protection system. In its basic configuration K2 weighs 55 tonnes, but with additional armour its weight rises to 60 tonnes.

Unlike Japan, whose constitution imposed on it after the Second World War does not allow it to export military equipment, the Republic of Korea is free of such restrictions. One consequence of this has been an agreement with Turkey for the transfer to it of Korean tank technology for its incorporation in the Turkish Altay tank. How much of it is incorporated in it remains to be seen, but in view of the lack of previous experience in tank development on the part of the Turkish industry, the closer it adheres to the Korean models the more successful it is likely to be.

China

Tanks arrived in China only a few years later than in Japan, but their subsequent use was intermittent and on a small scale. The first were the ubiquitous Renault FTs, some of which were ordered by a Chinese warlord for his forces in Manchuria. Ten are believed to have arrived in 1924 and their number is reputed to have risen later to 36, but they were all lost when the Japanese invaded Manchuria in 1931.[13]

The National Army of the Republic of China procured some Vickers Carden Loyd light tanks from Britain in the early 1930s, and in the mid-1930s created three tank battalions equipped with a mixture of tanks that included about 20 Vickers Six Ton Tanks, a similar number of Italian L 3/35 tankettes and 10 German PzKpfw I light tanks. However, most were lost in the early stages of the Sino-Japanese war, which started in 1937. In the following year the Nationalist forces were able to procure 80-odd T-26 tanks from the Soviet Union, but most of them were also lost soon afterwards in battle and there were no further Chinese tank actions of any consequence during the Second World War.

After the war Soviet authorities handed over to the Communist winners of the Chinese Civil War captured Japanese Type 97 medium tanks, which are said to have numbered 300, and they became the principal tanks of the People's Liberation Army, or PLA, until 1950 when the war in Korea broke out. As China entered that conflict it received the first batch of Soviet tanks, which consisted of 30 T-34-85 medium and two IS-2 heavy tanks. Subsequently the number of T-34-85s grew considerably, reaching 1,837 according to some accounts. Both types of tanks were paraded annually in Beijing until 1959, when T-34-85 began to be replaced by Chinese-built Type 59 as the principal tank of the PLA.

Type 59 was the outcome of the Sino-Soviet Treaty of Friendship of 1950, under which the Soviet Union agreed to help build a tank factory in China. The factory was completed in 1956 and two years later assembled its first tank from parts produced by the Soviet factories. In 1960 the factory produced the first tank made of Chinese manufactured components. Type 59 was then built in quantity, and by the time its production came to an end in the 1980s it is believed to have reached 10,000 tanks.

Type 59 was actually a Soviet T-54A medium tank in Chinese guise. Like its Soviet model, it was a 36.5-tonne tank with a crew of four and a main armament of a 100mm rifled gun. When it began to enter service in numbers in the 1960s, it compared well with other contemporary tanks and met the immediate needs of the PLA. However, other armies were developing new tanks, and not to be left behind the PLA initiated in 1967 the development of a second generation Chinese tank. But its development foundered three years later in the turmoil of Mao's Cultural Revolution. As a result, no new tanks were produced for several years and the PLA had to continue using Type 59 as its only battle tank, which was evident when the present writer visited the PLA's Armour School near Beijing in 1979.

When China began to recover from the chaos of the Cultural Revolution, the requirement for a second generation tank was revived and from 1979 onwards led to the construction of a series of different prototypes. But no decision was taken which of the alternative tanks to adopt until 1984, when the one chosen eventually became the third generation tank. In the meantime further development of Type 59 led to Type 80, which was adopted in 1981 as the second generation tank.

The developments that led to the Type 80 included in the first instance the Type 69, which was not very different from the Type 59 and like the latter was widely exported to countries in Africa, Asia and the Middle East. An experimental version of it was armed with a 120mm gun, but this was not adopted. Instead the PLA followed the Israeli example of re-arming Soviet-built T-54 and T-55 tanks captured from the Arab armies with a version of the British 105mm L7 rifled gun. Thus the 105mm gun was mounted in the Type 79 and then other Chinese tanks instead of their Soviet-designed 100mm guns. One of them was the Type 80, which in addition to the 105mm gun incorporated several improvements on the Type 59, including a new suspension with six instead of five road wheels on each side, a more powerful 730hp engine and a fire control system with a laser rangefinder. Type 85, which followed in 1988, was originally also armed with a 105mm L7 type gun, and its turret was welded instead of being cast like the turrets that its predecessors inherited from the Soviet T-54. What is more, its Type-85-III version was armed with a more powerful 125mm smooth bore gun and was provided with a carousel-type autoloader like the Soviet T-72, which made it in these respects the forerunner of the third generation of Chinese tanks.

Development of the third generation of tanks became a major PLA programme in 1980, which involved the award of a contract in 1989 to the China North Industries Corporation, or NORINCO, and the construction a year later of the first of several prototypes. These were subjected to extensive tests and troop trials until 1998, when the outcome was accepted for small scale production as Type 98. The general configuration of this tank deliberately followed that of the Russian T-72 but it was heavier, weighing 51.8 tonnes, partly because its hull was larger, and was distinguished by the driver's station being in the centre of it instead of the left hand side, as in Type 85-III and the earlier Chinese tanks. The hull was in fact almost one metre longer due to the traditional longitudinal location of the engine instead of the transverse location in the Russian and earlier Chinese tanks. The engine itself was a copy of the German MTU MB 871, a V-8 diesel of 1,200hp similar to the engine of the Korean K-1 tank.

Like the T-72, the Type 98 was armed with a 125mm smooth bore gun, which was provided with a 22-round carousel-type autoloader under the turret. The gun has been claimed to fire APFSDS projectiles with a muzzle velocity of up to 1780m/s and a muzzle energy nearly 45 per cent greater than that of its Russian counterpart. The Type 98 has also been provided with Chinese copies of the Russian 9M119 tube-launched laser beam riding missiles, which have flight velocities of up to 800m/s and shaped charge warheads capable of penetrating 700mm of armour. Type 98 is protected over its front by multi-layered composite spaced armour, and to increase its survivability it has been fitted with an infrared jammer system, similar to the Russian Shtora, against anti-tank guided missiles.[14]

Some Type 98 tanks have also had mounted on their turret roof a high powered laser to dazzle and damage the sights of hostile weapon systems, with the attendant risk of injuring the eyesight of enemy gunners. Type 98 has also had developed for it an active protection system with radar to detect and track approaching threats and counter-missiles to destroy or disable them 1.5 to 4m from the tank.

All this shows that the Type 98 is comparable to the latest tanks developed elsewhere, and in more general terms demonstrates that Chinese tank technology is well advanced. In terms of firepower, the Type 98 is even claimed to be superior to other tanks, and the protection of its latest Type 99 version has been improved further, making the pointed front of its turret look like that of the latest German Leopard 2A6.

NORINCO have shown that Type 98 could be more compact and lighter and yet remain well armoured by developing in collaboration with Pakistan a very similar tank, which it has marketed as MBT 2000 and which is called Al Khalid in Pakistan. This tank has a significantly shorter hull because it is powered by the exceptionally compact Ukrainian 6TD-2 two-stroke diesel instead of the more conventional power pack of Type 98, and consequently weighs 46 instead of 51.8 tonnes.

Pakistan

The collaboration between Pakistan and China exemplified by the Al Khalid had its origin in Pakistan's need for tanks, which it was unable to satisfy itself. When Pakistan came into existence after the partition of British India in 1947, it inherited six armoured regiments from the British Indian Army and some of the US-built M4 medium and M3 light tanks that the British Army had used in Burma and that were in varying states of repair. It was only after the signing of the Mutual Defence Assistance Agreement with the United States in 1954 that Pakistan began to create an effective armoured force. As a result of this agreement, Pakistan received from the United States 230 M47, 202 M48 and 200 M4A3E8 medium tanks. By then it had become involved in the Second Kashmir War with India in 1965 and formed two armoured divisions.

However, although they outnumbered the Indian armoured forces and had more modern equipment, the Pakistani armoured formations were outfought by their opponents, losing about 200 tanks in what have been described as the largest scale tank engagements since the Second World War. Shortly afterwards, Pakistan also lost its existing source of supply of tanks because of the US embargo on military aid imposed as a result of Pakistan's nuclear weapons programme. This made Pakistan turn for assistance to China, and it received from it 80 Type 59 tanks in 1965 and 1966. Further deliveries followed, and eventually Pakistan acquired 1,200 Type 59 tanks, which it prefers to call T-59.

To maintain the effectiveness of its tank fleet, between 1971 and 1979 Pakistan built with Chinese help a Heavy Rebuild Factory, which expanded into the Heavy Industries Taxila. By 1994 this industrial facility had not only rebuilt all the T-59s but upgraded many of them into T-59Ms by re-arming them with 105mm L7 type guns. It also began to co-produce with Chinese factories the very similar T-69, which was also armed with the 105mm L7 gun.[15] In 1990 Pakistan embarked on another and more ambitious programme by signing an agreement with the Chinese NORINCO organization to develop jointly and co-produce a more modern and more powerful tank than those it had. The tank was called Al Khalid and turned out to be similar to the MBT 2000 that NORINCO offered for export, which meant that its general configuration was very similar to that of the Russian T-72 and in particular that it was armed with a 125mm gun fed by an autoloader. But before this stage was reached, different British and German engines and French and German transmissions were tried in a number of prototypes. A decision was finally made to use the Ukrainian 6TD-2 engine of 1,200hp and its associated transmission. Partly because of all the trials, development of Al Khalid was slow and the first 15 pre-production tanks were not delivered until 2001.

In the meantime, the acquisition by India of T-72 tanks from the Russian Federation, which began in 1978 with the purchase of 500 units, spurred Pakistan to co-produce with China T-85 tanks armed with 125mm guns as an interim measure. These were in fact Chinese-designed Type 85 III tanks, and the first of 300 of them were put into service in 1993. To increase the capabilities of its tank forces, in 1996 Pakistan also ordered from the Ukraine 320 T-80UD tanks, which were also armed with 125mm guns. The first 35 were delivered in 1997 and the order was completed in 2002. A further increase in the gun power of the Pakistani tank forces was achieved at relatively low cost by a programme launched in 1990 to rebuild part of the T-59 fleet, re-arming 300 with 125mm guns but without the carousel autoloaders. As a result, the rebuilt tanks, which were called Al Zarrar, retained four-man crews but in addition to the guns acquired several systems developed originally for Al Khalid. The first batch of 80 of them was delivered to the Pakistani Army in 2004.

India

India's development of its armoured forces was driven to a large extent by its rivalry with Pakistan and in particular by the growth of the latter's tank strength, which was motivated in turn by the build up of the Indian tank forces. The latter started with tanks inherited after the partition of India in 1947 from the British forces, which consisted principally of US-built M3 and M4 medium tanks. Four years later the Indian Army acquired 200 M4 Shermans from US surplus stocks, but did not procure more tanks until 1955, when it ordered the first of 220 Centurions. All were delivered in 1957 and thanks to their 83.8mm 20-pounder guns served the Indian Army well, proving superior during the Second Kashmir War of 1965 to the US-built M47 tanks used by the Pakistani Army in spite of the latter's more sophisticated fire control systems.

In spite of their performance, the Indian Army did not extend the effectiveness of the Centurions by retrofitting them with 105mm L7 guns and more modern power packs, as the Israeli and then South African forces had done. Instead it turned to more modern but in some respects less capable tanks.

The first of them was the Vijayanta, a 38-tonne tank armed with a 105mm L7 gun, which was designed in Britain by Vickers and was adopted in 1961 by India, where it was subsequently produced in a factory specially built for the purpose at Avadi near Madras. The first tank was completed there in 1965, but it was preceded by the prototypes and 90 tanks built in Britain. Moreover, tanks produced at Avadi were initially assembled from components made in Britain. But eventually almost all of them were made in India, and by the time their production was terminated in the 1980s the Indian Army had received a total of 2,277 Vijayantas.

The second tank that the Indian Army acquired during the 1960s was the Russian T-54. The procurement of this tank was a response to the growing collaboration between Pakistan and China, with which India fought a war in 1962, and the support that Pakistan was receiving from the United States. In the first instance the Indian Army ordered 300 T-54s in 1964 and they were followed by orders for 225 T-55s in 1968 and 650 in 1971. Thus, by 1974 the Indian Army had taken delivery of 1,175 T-54s and T-55s and it employed them into the 1990s, by which time some of the T-55s were being upgraded by being re-armed with 105mm L7 guns and fitted with new fire control systems.[16]

Having met its immediate needs by producing the Vijayanta and acquiring the T-54 and T-55, the Indian Army decided in 1974 to develop a more advanced indigenous tank. The task of developing it was assigned to the Combat Vehicle Research and Development Establishment at Avadi, which unfortunately had no previous experience of developing a battle tank. Moreover, its task was made more difficult by the expectation that the tank be made entirely of Indian components, which meant that they all had to be developed from scratch with all the attendant problems that this entailed.

One of the major components was the engine, which at first was to be a 1,500hp gas turbine, although India had no experience of this type of tank engine that was only being developed at the time in the United States and the Soviet Union. Not surprisingly, the intention of using a gas turbine was soon abandoned, only to be replaced by the idea of using another novel and almost equally questionable type of engine, namely a V-12 air-cooled variable compression ratio diesel similar to that used at the time in the unsuccessful General Motors prototype of the US M1 tank, of which it was the least successful feature. At first it failed to produce more than 500hp and problems encountered with it led inevitably to the adoption of another already proven engine, which was an upgraded version of the MTU MB 838 diesel used in the German Leopard 1 tanks.

The propensity to ignore general trends also manifested itself in the decision to develop a 120mm rifled gun at a time when the leading countries, led by the Soviet Union, were beginning to abandon rifled tank guns in favour of smooth bore guns. The decision to adopt a rifled gun left the Indian Army with a unique ammunition system that deprived it of the possibility of developing ammunition in collaboration with friendly countries, and in an emergency would have prevented it from obtaining ammunition from abroad.

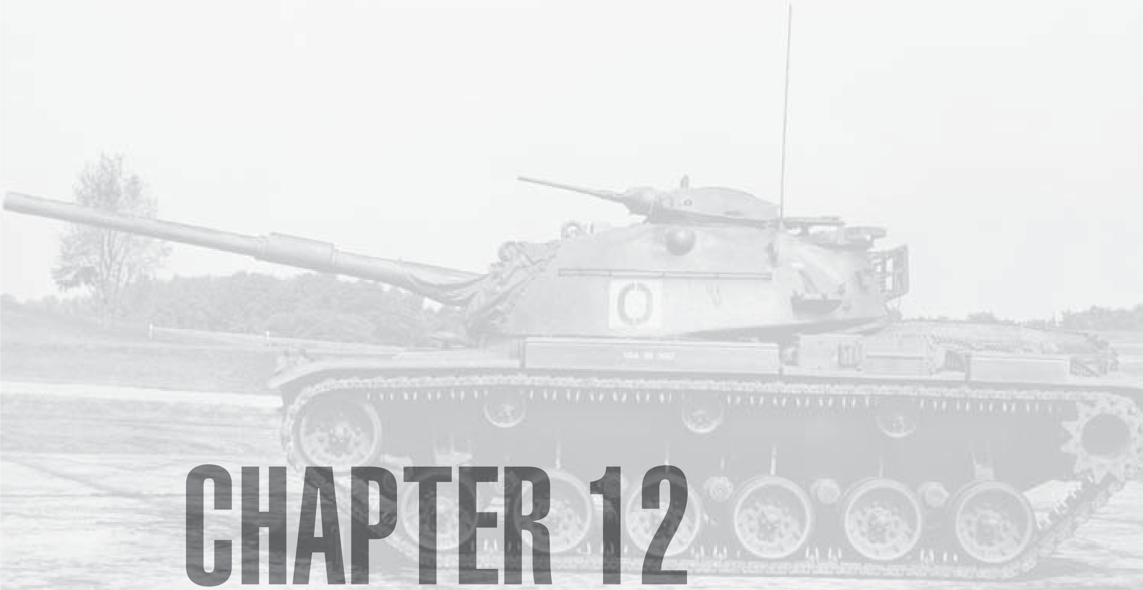
The first prototype of what came to be called the Arjun was unveiled in 1985, but changes to the requirements delayed the completion of six pre-production tanks until 1993. It then took seven more years for production of 124 tanks to be ordered, the first of which was delivered to the Indian Army in 2004. This meant that 30 years had passed from the issue of the original requirement to the production of the first tank – something of a record in the annals of tank development!

In the meantime, while the development of the Arjun was getting under way, the Indian Army decided to procure some more tanks from the Soviet Union. This time they were T-72Ms, which were armed with 125mm smooth bore guns that were more powerful than any the India Army already had. They also incorporated several other advanced features, including a carousel-type automatic loading system that reduced their crews to three men, and much more effective composite armour. The first five hundred were ordered directly from the Soviet Union in 1978, only six years after similar tanks began to be produced for the Soviet Army, and an agreement was reached for the production of the T-72 at Avadi, where ultimately about 1,400 were built as the Ajeya.

During the course of their production, some of the Ajeyas were upgraded by being retrofitted with explosive reactive armour and a fire control system incorporating thermal imaging. However, the Indian Army came to demand much more than upgraded Ajeyas when Pakistan began to acquire T-80UD tanks from the Ukraine. To counter them, it ordered from the Soviet Union 310 T-90Ss, which were in effect T-72BM powered by 840 instead of 780hp engines. Subsequently a licence agreement was reached for the production of

1,000 T-72Ss in India, initially from kits sent from Russia and then entirely locally. In 2007 a third contract was signed for the supply of 347 T-72Ss, which were to be assembled from kits at Avadi.

In spite of ordering 1,657 T-90Ss, the Indian Army did not give up the Arjun but continued testing and developing it. It may therefore order an improved and somewhat lighter Arjun Mark 2 at some future date.



CHAPTER 12
Epilogue

Tanks have come a long way in the hundred years of their existence. Starting as little more than a thin-walled steel box on tracks, they have evolved into highly sophisticated vehicles armed with powerful guns and protected by heavy armour.

However, the development of tanks has not always run smoothly. In fact, on several occasions there were doubts about their viability. These usually accompanied the appearance of new anti-tank weapons, which awoke people to the fact that tanks were vulnerable. This happened during the 1930s when armies began to acquire medium calibre anti-tank guns. It happened again at the end of the Second World War when hand-held light infantry anti-tank weapons, such as the bazooka and the *Panzerfaust*, appeared, and again at the time of the 1973 Yom Kippur War when anti-tank guided missiles were first extensively used. But the conclusion drawn from the ability of anti-tank weapons to defeat tank armour that it would lead to the demise of tanks was in error, because tanks were never invulnerable. Moreover, armour protection was not their only or even principal attribute.

Ultimately, the principal characteristic of tanks has been their ability to make the weapons mounted in them more mobile and therefore more effective. This made them play a decisive role in the land battles of the Second

World War and the basis of its offensive operations. However, tanks also played an effective role in defensive operations during that conflict and since, as they did during the Yom Kippur War.

Tanks were also an important element of the defensive strategy pursued by NATO during the four decades of the Cold War, when they made a major contribution to the deterrence to aggression in Central Europe. The subsequent collapse of the Soviet Union in 1991 and the consequent easing of political tension greatly diminished the importance attached to tanks in Western Europe, where there was no longer an immediate need for them. As a result, the size of the Western European tank fleet was reduced to a fraction of what it had been. Thus, major Western European armies, such as those of Germany, France, Britain and Italy, were left with no more than about 200 tanks each, while the armies of the Netherlands and Belgium suffered the indignity of having all their tanks sold off. What is more, in Britain, the country where the very first tanks were built, the government allowed the ability to develop and to produce more tanks to wither.

But elsewhere tanks have continued to be viewed as a major element of military strength. In particular, the army of the Russian Federation has maintained a fleet of 2,000 to 3,000 modern tanks backed by a reserve of several thousand older vehicles and has been developing a new tank, about 2,000 of which are expected to be produced. Turkey, which maintains a fleet of 1,500 tanks, is also developing a new tank called Altay.

Several other countries, particularly in the Middle East and North Africa, have also maintained sizeable tank fleets to deter aggression and to safeguard the integrity of their frontiers. They include Israel, which operates a considerable number of Merkavas, and Egypt, which holds 1,130 US M1 tanks as well as older tanks. Only the United States has a greater number of M1 tanks, still possessing about 6,000 of them. Other countries using M1 tanks include Saudi Arabia and Kuwait as well as Morocco, which is reported to have 200 in addition to 150 Chinese tanks of the latest MBT 2000 type.

Farther east, India and Pakistan maintain relatively large tank fleets to assure mutual deterrence to aggression, the tanks being mainly of Russian origin in the case of India and of Chinese origin in the case of Pakistan. China's co-operation with Pakistan is an offshoot of a large scale development and production programme that has provided its army with about 2,500 tanks similar to the latest Russian tanks as well as several thousand older types. The Republic of Korea started later, but has produced tanks comparable to or even better in some respects than the US M1 tanks and has deployed them behind its frontier with North Korea as part of the deterrence to aggression by the latter. Japan has not been exposed to an immediate threat of invasion, but, nevertheless, has provided its Ground Self Defence Force with a succession of indigenous tanks, the latest of which are as advanced as any developed elsewhere.

The latest Japanese Type 10 differs in several respects from the earlier types of tanks, whose general configuration dates back to the end of the Second World War. In particular, earlier types have manually loaded guns and consequently four-man crews. This applies to tanks such as the widely used German Leopard 2, the US M1 and the British Challenger, and even to some tanks still being built, such as the Indian Arjun and the Turkish Altay. However, in the 1960s the Soviet Army began to adopt tanks with automatically loaded guns, which reduced their crews to three men and made them more compact and therefore potentially lighter in relation to their armour. Since then all Soviet, Russian and, more recently, Chinese tanks have had automatically loaded guns, which are now being operated even in countries like Bangladesh. Automatic loading of guns and three-man crews were also adopted in the Japanese Type 90 and the French Leclerc, but only in 1990. Since then this has also been adopted in the Japanese Type 10 and the new South Korean K2.

Development of automatic loading systems opened the possibility, which has still to be exploited, of mounting guns in unmanned remotely controlled turrets and relocating crews in the hull where they could be less vulnerable. Another possibility arising from it has been a further reduction in the size of the crew to two men, which in fact was already explored in the 1990s in the United States and in Germany but was not pursued beyond a mock-up in the former and a test bed vehicle in the latter.

Automatic loading of tank guns could not have been avoided if the calibre of the guns had risen further to 140mm, because of the size and weight of their ammunition. Guns of this calibre began to be developed in several countries in the 1980s but were abandoned in the following decade because existing guns of 120 or 125mm were considered to be adequately powerful for the defeat of enemy tanks, in spite of the advances in armour protection.

Development of the protection of tanks has taken it well beyond the use of solid steel armour, on which they relied for the first 50 years of their existence but which reached its limit when the thickness of armour could not be increased further without causing unacceptable increases in the weight of tanks. The search for alternatives led to multi-layered arrays of steel and non-metallic materials and to reactive armours, including explosive reactive armour, which proved significantly more effective against threats facing tanks than steel. Other research led to the development of active protection systems, which electronically detect attacking missiles and destroy or disable them before they strike their target. The first of such systems was adopted by the Soviet Army in 1983 but no other followed it until 2007, when the Israeli Defence Force decided to install one on some of its Merkava tanks.

All the advances in the protection of tanks have considerably increased their ability to survive a range of threats. But, as before, none has made tanks invulnerable. Nevertheless, they remain potent as mobile protected weapon platforms that make heavy direct fire weapons mounted in them more effective. In consequence, whatever their shape or form, tanks continue to be an important component of armies and a significant element of military strength.

Appendices

Appendix I: Growth of Gun Power

No matter how dissimilar tanks developed in different countries might be, the evolution of their principal components has followed to a large extent a common course.

The most important of these components has been their armament, which enables tanks to perform their basic functions of destroying or suppressing enemy personnel or weapons. The performance of these functions has generally involved machine guns as anti-personnel weapons and guns capable of destroying other tanks, as well as dug-in machine guns and other weapon emplacements.

The actual armament of the original tanks consisted of weapons designed for other purposes that happened to exist at the time. In the case of the original British tanks, the main armament consisted of 57mm 6-pounder guns that were furnished by the Royal Navy as the army lacked suitable weapons. Subsequently, similar guns were produced specifically for tanks but with barrels shortened from 40 to 23 calibres to make them protrude less from the sides of the tanks. The first French tanks were armed with standard 75mm field guns, which were the mainstay of the French artillery, or short-barrelled guns of the same calibre. In addition to their guns, all tanks also had two to four machine guns. However, once tanks began to be produced, 'female' versions of British tanks were armed only with six machine guns to defend tanks against an imagined onrush of enemy infantrymen! In all cases the machine guns were standard rifle calibre infantry weapons.

Machine guns were also the only armament of one version of the Renault FT light tank that came into use towards the end of the First World War, the other version being armed with a 37mm short-barrelled infantry cannon. The example of the machine gun version of the Renault was followed after the war when machine guns became the only armament of most tanks, and in particular of the light two-man tanks that were widely used for several years, from the Vickers Carden Loyd light tank of 1926 to the German PzKpfw I of 1940.

To maximize their machine gun fire power, the larger tanks built during the 1920s and early 1930s were provided with small machine gun turrets in addition to their main gun turret. The extreme example of this was the British A.1 Independent, which had as many as four machine gun turrets clustered about its main turret. The only plausible justification of them was that they provided all-round protection against enemy infantry, which might have implied a survival of the notion that led to the wartime 'female' tanks. In any case, although the concept of a five turret tank aroused a great deal of interest at the time, it led to only one other tank of this kind being built, the Soviet T-35. However, other tanks were built with an additional machine gun turret, oddly located at the rear of the hull behind the engine compartment. The first of them was the French 2C heavy tank built immediately after the war, which was followed in the 1920s, and probably inspired in this respect, the German *Grosstraktoren* and the first Japanese tank.

Multi-turreted tanks attracted little further interest except in Britain, where machine guns were regarded as the principal tank weapon and where the Independent was followed by a series of tanks with two additional machine gun turrets at the front of the hull. They ranged from the A.6 or Sixteen Tonner of 1928 to the experimental A.14 and A.16 heavy cruisers of 1938. The additional machine gun turrets may have increased the volume of suppressive fire that could be delivered over the front of a tank, but they did not in general justify the weight and the complication that they involved. They were therefore abandoned at the beginning of the Second World War, but one additional machine gun turret was still incorporated in the original version of the Crusader cruiser tank ordered in 1939.

Apart from those mounted alongside the main armament and usually called 'coaxial', the use of machine guns was confined for several years on many tanks to one mounted in the front of the hull and operated by a gunner sitting alongside the driver. This arrangement was pioneered by the British A7E2 medium tank built in 1929, and became almost universal during the Second World War. Tanks that incorporated it included all the German tanks from PzKpfw III to Tiger II and Soviet T-34s, as well as US M4 Shermans and M3 and M5 Stuart light tanks, and British tanks from Churchill infantry tanks to the Comet cruiser tanks. They also included Italian M 13/40 and Japanese Type 97 medium tanks.

However, even before the Second World War some of the more advanced tank designs, such as that of the British Matilda infantry tank, dispensed with the hull machine gun and the gunner who went with it, which reduced the average crew from five to four men. A general change to this was led by the British Centurion and the Soviet T-44, both of which came into use in 1945, as well as the Soviet IS-2. From then onwards the use of machine guns was confined in almost all newly built tanks to one per tank mounted alongside the main armament, until an additional machine gun was mounted on top of the turret. This began to be practised initially for anti-aircraft defence, particularly during the latter part of the Second World War on US tanks, but was not generally adopted for the very good reason that the tank commander, who had to operate the machine gun, had to expose himself out of the turret to do it and was also drawn away from his principal function of commanding the tank. However, the objection to externally mounted machine guns was party removed later when they could be operated from within tank turrets.

Long before this stage was reached, it was realized that there was a need for more powerful automatic weapons than the rifle calibre machine guns that were the only armament of almost all the early light tanks. The German Army was the first to do so and shortly before the end of the First World War initiated the development of a heavy dual purpose anti-tank and anti-aircraft *T.u.F.* ('Tank und Flieger' or 'Tank and Aircraft') machine gun of 13mm calibre, instead of the usual 0.303in. or 7.92mm. The defeat of Germany prevented this gun being produced, but after the war it was followed by the development in the United States of a somewhat similar 0.50in. heavy machine gun for fighter aircraft.[1] By 1931 the use of this '50 calibre' machine gun was extended to US light tanks, and it was the most powerful weapon of the US T4 medium tank built in 1935.[2] A 0.5in. version of the Vickers machine gun was also developed in Britain towards the end of the First World War for use in fighter aircraft, and in 1929 it was mounted in the experimental A4 E10 version of the A4 light tank. Five years later it became the main armament of British light tanks from the Mark V to Mark VI B, which formed the great majority of British tanks on the outbreak of the Second World War.

The 0.5in. machine guns fired bullets with much the same velocity as that of rifle bullets, but they were heavier and therefore had five or six times as much kinetic energy, or ‘punch’. They were therefore able to penetrate about 20mm of armour at 200 metres, which made them reasonably effective against contemporary light tanks when they were introduced. But by 1940 their performance was no longer adequate, except against very lightly armoured vehicles, and they ceased to be used as the main armament even of light tanks.

The need for larger calibre automatic weapons was foreseen in Germany even before the First World War came to an end. At first they were intended for aircraft, and as they could not be developed in Germany because of the restrictions imposed on it by the Versailles Treaty, their development was undertaken in Switzerland. The resulting 20mm automatic cannon were offered for use not only in aircraft but also as anti-aircraft and anti-tank weapons. One of the companies involved in this was Solothurn, which was taken over by the Rheinmetall company, and the latter subsequently produced a 20mm cannon for the German Army. Other 20mm automatic cannon were also produced in Denmark by Madsen and in Italy by Breda, and they armed a number of light tanks and armoured cars built during the 1930s. But the only noteworthy use of 20mm cannon was that of the Rheinmetall-produced 2cm KwK 30 used as the main armament of the PzKpfw II, which was the most numerous German tank used during the 1940 campaign in France.

When the PzKpfw II began to be produced in 1937, other tanks of its weight of less than 10 tonnes were already being armed with larger calibre cannon, albeit manually loaded, which could perforate thicker armour than the 20mm cannon. The first to be armed with such a medium calibre cannon was the Vickers Light Tank built in 1923, which was followed by the highly influential Vickers Mediums. However, these tanks were most likely armed with 47mm cannon because Vickers happened to have naval cannon of this calibre rather than as the result of an established military requirement.

Development of medium calibre guns specifically for tanks and as anti-tank guns was began in Germany by Rheinmetall in 1924. The 37mm calibre chosen for the guns by Rheinmetall was the same as that of the cannon of the Renault FT, but the gun was 45 instead of 21 calibres long and fired armour-piercing projectiles with a muzzle velocity of 760 instead of 388m/s, as a result of which it could pierce armour more than twice as thick. By 1930 the 37mm Rheinmetall gun was mounted in the secretly built *Leichttraktoren* and in 1932 it was adopted by the Red Army for the first of its series of BT tanks, the BT 2.[3] In the mid-1930s the US Army also acquired a licence to produce the Rheinmetall gun, and it was adopted in 1938 for the M2 medium tank.[4] In Germany the 37mm gun was adopted for a light tank that began to be developed in 1934 and evolved into the PzKpfw III.[5] In the mid-1930s a 37mm gun with very similar characteristics was also developed in Sweden by Bofors, which then armed some Swedish and Polish tanks.

In view of all this, the 37mm Rheinmetall gun could be regarded as the typical armament of the 'light/medium' tanks of the 1930s. However, towards the end of the decade it began to be superseded by similar guns of larger calibre. This process started in 1933 with the Soviet BT-5, which was armed with a 45mm gun, and two years later the T-26 was also armed with a gun of this calibre.[6] In 1936 British tanks began to be armed with a 40mm gun 50 calibres long, which could perforate thicker armour than the 37mm Rheinmetall gun, and at about the same time the French Somua S 35 tank was armed with a 47mm gun, which could also perforate somewhat thicker armour, as did the Soviet 45mm gun. The German Army only began to redress the balance in 1941 by arming the PzKpfw III with a 50mm gun 42 calibres long and in 1942 arming it with another 50mm gun 60 calibres long. The latter could perforate thicker armour than all the others, as it fired heavier projectiles and with a higher velocity. In fact, it could perforate 68mm of armour at 500m. Apart from the Italian, Czech and Japanese 47mm guns, the only other medium calibre tank gun was a new British 57mm 6-pounder, which was mounted in 1942 in Churchill infantry tanks and Crusader III cruiser tanks and which could perforate armour 40 per cent thicker than the German 50mm L/60.

However, by 1942 it was beginning to be generally recognized that tanks should be able not only to defeat the armour of the opposing tanks but also deliver effective high explosive fire against enemy anti-tank guns and other targets. To be able to do this, they had to be armed with guns of not less than 75mm.

As already mentioned, the first French tanks were in fact armed with 75mm guns and after the First World War the French Army embarked on the development of a tank armed with a 75mm gun, which was to be its principal tank. By 1930 this led to the Char B. As in the wartime Schneider and St Chamond tanks, the 75mm gun of the Char B was mounted in the hull and in such a way that it could only be aimed in traverse by turning the whole tank and therefore required the driver to act also as a gunner.[7] Such an arrangement might have worked in direct assaults on enemy positions, but it was not suited to the mobile manoeuvre warfare in which Char B became involved in 1940.

In contrast, the British Army did not adopt a 75mm gun for any of its tanks until the latter part of the Second World War. As mentioned in Chapter 5, as late as 1937 British General Staff saw no need for tank guns of more than 40mm. Larger calibre weapons were in fact mounted in British tanks but they were either 3.7in. (95mm) or 3in. (76.2mm) howitzers, which replaced the medium calibre guns in some of them. Tanks armed with the howitzers were called Close Support Tanks and their capabilities were confined almost entirely to firing smoke shells to create smoke screens, which were considered essential.[8]

The German Army avoided such extravagant over specialization when it began secretly to develop medium tanks in the 1920s and adopted a 75mm gun for the *Grosstraktoren.* The 75mm gun was only 24 calibres long and fired armour-piercing projectiles with a velocity of only 400m/s, but it could still defeat thicker armour than the contemporary 37mm tank guns. What is more, unlike the latter, it also fired very effective high explosive projectiles. It was consequently adopted as the main armament of the PzKpfw IV, which became the most powerful German tank during the first three years of the Second World War. Its nature was not always recognized at the time, and because of its short-barrelled gun it was often wrongly equated with the British Close Support Tanks, although the latter had none of its capabilities.[9]

The Russians followed the German example when they began to develop their T-28 medium and T-35 heavy tanks in 1932 and armed them with 76mm guns. The prototype of T-28 was still armed with a 45mm gun, which made it comparable in this respect to the British A.6 Sixteen Tonner, but when it went into production it was armed, like the T-35, with a 76mm gun, albeit only 16.5 calibres long. But in 1938 this was superseded by a gun 26 calibres long, which fired projectiles with a higher velocity of 555m/s instead of 381m/s and therefore was capable of defeating thicker armour. Yet another increase in barrel length and projectile velocity took place in 1940 when a 76mm gun 30.5 calibres long was installed in the KV-1 heavy tank and then in the T-34 medium tank. Finally, from 1941 onwards, the KV-1 and T-34 were armed with a 76mm gun 41.5 calibres long that fired projectiles with a velocity of 625m/s.

In contrast to the progressive development of 76mm guns by the Red Army, no successor to the 75mm L/24 gun of the PzKpfw IV was produced in Germany until after the invasion of the Soviet Union in 1941, when German forces came up unexpectedly against the new and, for their time, heavily armoured Soviet tanks. An outcome of this was the 75mm L/43 tank gun, which had a muzzle velocity of 740m/s and proved superior to the Soviet 76mm as well as US 75mm tank guns when it appeared in 1942 as the new armament of the PzKpfw IV. But, good as it was, the 75mm L/43 gun did not represent the peak of the development of 75mm tank guns. That distinction belonged to the 75mm L/70 gun, which was also developed in response to the appearance in 1941 of the new Soviet tanks but was mounted in the Panther medium tank and fired projectiles at 925m/s, which enabled it to perforate 126mm of armour at a range of 1,000m.

A 76mm 17-pounder gun with performance characteristics very similar to those of the 75mm L/70 was developed in Britain at about the same time. But there was no British tank in which to mount it, apart from the rather clumsy Challenger employed on a limited scale in 1944. However, it was found that the 17-pounders could be mounted in M4 Sherman tanks in place of their 75mm guns and most of them were successfully used in that way, the re-armed tanks being called Fireflies. Other tanks used by the British Army in 1944, such as the Cromwells, were still armed with lower performance 75mm guns similar to those of the US Shermans, which were only 37 calibres long and fired projectiles with a velocity of 619m/s.

The muzzle velocity of Panther's 75mm L/70 gun approached the limit of what could be done with conventional full calibre armour-piercing projectiles before the law of diminishing returns set in, that is before disproportionate amounts of propellant had to be used to further increase projectile velocity. When that limit was reached, the only practical way of increasing the kinetic energy and therefore the armour-piercing capability of conventional projectiles was to make them heavier and therefore of larger calibre. The move to larger calibres had in fact started before the muzzle velocity limit was reached, driven by the increases in the armour of the opposing tanks and aided by the existence of guns suitable for conversion into tank guns. The guns in question were anti-aircraft guns.

The first of these guns was the German 88mm L/56, which had proved very effective against ground targets as well as aircraft from the Spanish Civil War onwards and which was adopted in 1941, just prior to the German invasion of the Soviet Union, for the Tiger I heavy tank. The Red Army followed the German lead and in 1943 armed its KV and T-34 tanks with an 85mm gun 51.5 calibres long, which was also an adaptation of an anti-aircraft gun. Similarly, in 1944 the US Army adopted a modified 90mm 52.5 calibres long anti-aircraft gun for its M26 Pershing tank.

By 1944 the German Army had followed Tiger I with Tiger II, which was armed with a new and more powerful 88mm gun. This gun had a longer 71 calibres barrel and fired 10.2kg armour-piercing projectiles with a velocity of 1,000m/s, which was higher than that of projectiles fired from other contemporary tank guns. However, its projectiles did not have as much kinetic energy as those fired by the Red Army's counter to the Tigers, which was the IS-2 heavy tank. The latter was armed with a 122mm gun, which was an adaptation of a field artillery piece and fired projectiles at 781m/s, but they weighed 25kg, as a result of which they had a muzzle energy of as much as 10.1 mega joules (MJ), compared with 5.1 MJ of the projectiles fired by Tiger II. But, because the projectiles were of a larger calibre, their energy was spread over a greater area of a target they hit and consequently they penetrated less armour. In fact, at a range of 1,000m the 122mm gun of IS-2 penetrated 147mm of armour, whereas the 88mm L/71 penetrated 190mm.[10, 11]

A marginally higher level of kinetic energy of 10.2 MJ was attained in 1945 by projectiles fired from the 128mm L/55 gun of the German Jagdtiger heavy tank destroyer. Only 77 were built before the war in Europe ended, but they foreshadowed the calibre and the kinetic energy of tank guns adopted several years later, although using other types of ammunition.[12]

Some of the new types of ammunition had already appeared during the war. One of them was called Armour Piercing Composite Rigid, or APCR. Its projectiles consisted of a sub-calibre penetrator of tungsten carbide, which is harder and more dense than steel, in a light alloy carrier or sabot. The penetrator absorbed most of the energy imparted to the projectile by the gun and concentrated it on a smaller area of the target, which resulted in it perforating thicker armour than conventional projectiles of the same calibre.

APCR projectiles were also lighter than the latter, so they had higher muzzle velocities. But because of their lighter weight they lost velocity more rapidly with distance, which resulted in their armour penetration becoming less than that of conventional armour-piercing projectiles at longer ranges.

APCR ammunition was first provided in 1940 for the 37mm gun of PzKpfw III and then for other German tank guns, but its use was restricted by shortages of tungsten. Towards the end of the war, APCR ammunition was also produced in the United States for the 76mm guns of the Sherman tanks re-armed with them and for the 90mm guns of the M26 Pershing.

Another type of ammunition to make its debut during the Second World War was Armour Piercing Discarding Sabot, or APDS. This began to be developed in France on the eve of the war by the Brandt armament company, and when France was defeated in 1940 the work on it was transferred to Britain, where it was successfully completed at the Fort Halstead research establishment. Like APCR, it consisted of sub-calibre tungsten carbide penetrators in light alloy sabots, but the latter were discarded at the muzzle so that the penetrators flew to their targets by themselves and, as they suffered less aerodynamic drag, their armour penetration decreased far less with range. APDS ammunition was originally produced for the 57mm guns mounted in Churchill tanks as well as 6-pounder anti-tank guns, and then for the 76mm 17-pounder guns mounted in the A.30 Challenger and in the re-armed Sherman tanks of the British Army, all of which took part in the 1944 Normandy campaign. The APDS projectiles of the 17-pounder had a marginally higher muzzle velocity of 1,200m/s than that of the APCR projectiles of the German 88mm L/71 and could penetrate 187mm of armour at 1,000m.

The third of the new types of ammunition to appear during the Second World War was called High Explosive Anti-Tank, or HEAT, and, more precisely, shaped charge ammunition. Unlike the others it did not rely for defeating armour on the kinetic energy of the projectiles, but on the impact of a very high-velocity small diameter copper jet formed by the collapse of a copper-lined conical cavity in the nose of a high explosive projectile. This type of ammunition was first provided in 1941 for the 75mm L/24 gun of the PzKpfw IV, and it could only perforate 80mm of armour because the projectiles were spun like all others by the rifling of the gun, which interfered with the formation of the copper jet. However, the performance of the 75mm shaped charge projectiles was at least superior to that of the standard armour-piercing projectiles fired from the short-barrelled 75mm L/24 gun, and they were used with some success against Soviet tanks. But shaped charge ammunition did not come into its own until several years later, when its projectiles were no longer spun but were stabilized by fins.

In the immediate post-war period, the US Army continued to arm its medium tanks with 90mm guns that fired full calibre armour-piercing projectiles as their primary anti-tank ammunition. But this was complemented by fin-stabilized HEAT ammunition when slipping driving bands were developed and minimized the spinning of the HEAT projectiles by the rifling of the guns. The French Army adopted an ingenious alternative to minimizing the rotation of shaped charges by mounting them on ball bearings within the spinning projectile body. This approach was incorporated in the Obus G or Gessner projectile, which was adopted as the only anti-tank ammunition of the 105mm gun developed in the 1950s for the AMX 30 tank. Obus G was less effective in relation to its calibre than fin-stabilized 105mm HEAT projectiles because of the smaller diameter of its shaped charge, but it could still perforate 360mm of armour, which was considerably more than conventional armour-piercing projectiles did.

The perforation capabilities of shaped charge projectiles led to them being regarded not only by the French but also by the US Army as the most effective type of anti-tank ammunition. The high opinion of shaped charges contributed to the recommendation made in 1957 by the US Army ARCOV (Armament for Future Tanks and Similar Combat Vehicles) committee that future tanks should be armed with guided missiles, which would depend of course on shaped charge warheads for defeating armour. This led to the development of the Shillelagh missile system and its installation in the M60A2 battle tank as well as the M551 Sheridan light tank. The missile was fired from a 152mm gun launcher, which could also fire more conventional ammunition except for high-velocity armour-piercing projectiles as it was only 17.5 calibres long. It was only in 1967 that the 152mm gun launcher was developed, largely in response to German demands in the context of the US-German MT-70 programme, into the XM152 version, which was 30.5 calibres long and could fire high-velocity projectiles. However, the XM152 gun launcher was abandoned in 1971 together with the MBT-70 tank in which it was to be mounted. The same fate befell the short-barrelled version, in spite of the Shillelagh missile being able to perforate as much as 690mm of armour, which was more than enough to defeat any contemporary tank.

A somewhat similar system consisting of the ACRA guided missile and a 142mm gun launcher was developed at about the same time in France. It was mounted in a modified version of the AMX 30 tank but was not developed beyond the prototype stage. Only the Soviet Army continued the development of gun launched guided missiles, which it started in 1962 or 1963 and which resulted in a whole series of missiles – mostly laser beam-riders – that were fired from guns ranging from the 100mm gun of the T-55 to the 125mm gun of the T-90.

In contrast, the British Army did not develop any projectiles or gun launched missiles with shaped charge warheads, largely because of doubts about their lethality. Instead it concentrated for more than a decade after the Second World War on the development of a series of guns firing APDS ammunition. The first of them was the 83.8mm 20-pounder, which was introduced in 1948 on the Centurion tanks. It fired APDS projectiles with a muzzle velocity of 1,465m/s, which was higher than that of any type of tank gun produced until then and which greatly increased their armour penetration. Then, as the thickness of tank armour continued to increase, the demand grew for guns with even greater armour piercing capability, and in response to it the 20-pounder was developed into the 105mm L7 gun, initially by boring out from 83.8 to 105mm! As already indicated in Chapter 9, the armour-piercing capability of the 105mm L7 with its APDS ammunition was such that it became almost the Western world's standard tank gun. Its performance is illustrated by its ability to perforate a shot line thickness of 240mm of armour inclined at 60° and at a range of 1,830m.

The performance of the 105mm L7 gun was such that it made redundant the Conqueror heavy tank, which the British Army developed during the 1950s, because it approached that of the latter's 120mm gun. The Conqueror also fired APDS, but instead of the complementary high explosive ammunition that was usual at the time it fired a novel type called High Explosive Squash Head or HESH. The projectiles of this ammunition were filled with a plastic explosive that was squashed on impact against the armour before it exploded, causing spalling of lethal metal scabs from its inner surface. The British Army regarded HESH more highly than shaped charge ammunition and provided no other anti-armour ammunition for light armoured vehicles, such as the Scorpion light tank. HESH was also going to be the only anti-tank ammunition fired by the FV 215 heavy tank, which began to be developed in 1950 and which was going to be armed with a

183mm gun. The tank did not advance beyond a full size wooden mock-up, but the 183mm gun, which was the world's largest calibre tank gun ever made, was built and successfully test fired from a Centurion chassis.[13]

Although APDS outperformed the original armour-piercing ammunition, it was itself outperformed in time by Armour Piercing, Fin Stabilized, Discarding Sabot or APFSDS ammunition. This resembled APDS but its penetrators were much longer and of smaller diameter, which meant that their kinetic energy was concentrated on a smaller area of the target and as a result they penetrated more of the armour. However, because their length to diameter ratio was more than about 5, they could not be spin stabilized like other projectiles but had to be stabilized by means of fins. In consequence they were fired from smooth bore guns, although they could also be fired from rifled guns with the aid of slipping driving bands.

The development of fin-stabilized projectiles began in Germany during the Second World War, but it was only taken up in earnest in the 1950s in the United States and in the Soviet Union. In the United States a decision was taken in 1954 to build 90 and 105mm smooth bore guns, but neither was successfully developed. They were followed by a very promising smooth bore 120mm Delta gun, but this was abandoned around 1961 after the US Army decided to arm its tanks with guided missiles instead of high-velocity guns.

The Soviet Army was more persistent. It started to develop smooth bore guns by 1958 and adopted one of 115mm calibre, mounting it in the T-62 tank that went into production in 1962. The APFSDS projectiles fired by the T-62 looked like a scaled down version of the Peenemunde Arrow Projectiles that were being developed in Germany during the Second World War for long range artillery.[14] Their penetrators were only of steel, but they were fired with a muzzle velocity of 1,615m/s and were capable of penetrating 240mm of armour at 1,900m, which made them as good in this respect as the contemporary 105mm APDS projectiles.

The next Soviet tank was at first also armed with a smooth bore 115mm gun, but its improved T-64A version, which succeeded it in 1964, was armed with a new 125mm smooth bore gun. Similar guns subsequently armed other Soviet tanks, from the T-72 of 1973 to the T-90 of 1990. During this period, the effectiveness of these guns was gradually increased by the provision of improved APFSDS ammunition with tungsten alloy or depleted uranium penetrators and saddle or spool type sabots similar to those adopted by the Western armies.

In contrast, no smooth bore gun was adopted by the US Army until 1981. But in the meantime it made considerable progress in the development of APFSDS ammunition fired from rifled guns, thanks to the use of slipping driving bands. This began with the APFSDS fired from the 152mm gun launcher of the ill-fated MBT-70 and came to fruition with the M735 APFSDS developed for the US M68 version of the 105mm L7 gun, which put new life into that widely used gun and led to its adoption for the US M1 tank.

While Germany was still participating in the MBT-70 programme, work began there on a fall-back solution, and this led in 1971 to the building of experimental tanks armed with newly developed 105 and 120mm smooth bore guns. The tank with the 120mm gun was eventually adopted as the Leopard 2, which was accepted for production in 1977 and the first of which was handed over to the German Army two years later. After it was adopted for the Leopard 2, the 120mm L/44 gun developed by Rheinmetall was also adopted for the US M1A1 and then for the Italian Ariete, the Israeli Merkava, the Japanese Type 90 and the South Korean K1A1, spreading its use around the world. With the subsequent acquisition by several other countries of the Leopard 2 from German and other surplus stocks, the use of the 120mm L/44 gun spread even further and it became the standard tank gun of the Western World, just as the 105mm L7 had been. The British Ministry of Defence continued for a time to champion the use of rifled guns and APDS, but in the end it had to accept the superiority of APFSDS and procured it in the mid-1980s. However, it failed to replace the rifled gun of the Challenger by a smooth bore gun, relying on slipping driving bands for firing fin-stabilized APFSDS.

The effectiveness of the 120mm L/44 gun and of its clones has been increased over the years by the development of APFSDS ammunition with progressively longer penetrators able to penetrate more armour because penetrations at their impact velocities was roughly equal to the length of the penetrator.[15] In fact, the length to diameter ratio of the penetrators increased over the years from about 10:1 to 32:1. The armour-piercing capabilities of the Rheinmetall gun were also raised by increasing the length of its barrel from 44 to 55 calibres, which was accompanied by an increase in the muzzle velocity from 1,650 to 1,750m/s and in the muzzle energy of the APFSDS projectiles from 9.8 to 12.5 MJ.

The progressive increases in the calibre of tank guns to 120 or 125mm raised the weight of their ammunition to a level at which it was difficult to manhandle. For example, a round of the traditional armour-piercing ammunition fired by the 120mm gun of the US M103 heavy tank weighed 48.8kg, which called for two loaders to handle it, increasing the crew of the turret from three to four men and consequently increasing the size of the turret. The Red Army avoided a similar problem when it armed the IS-2 with a 122mm gun by the use of ammunition with separate projectiles and propellant charges. This halved the load that had to be handled, but reduced the speed with which the gun could be re-loaded and therefore the rate of fire. The British Army also opted for separated ammunition when it developed the Conqueror heavy tank and then the Chieftain and Challenger, in which the handling of the ammunition was made easier by the lighter weight of the APDS or APFSDS projectiles and the propellant being in bags instead of the traditional brass cases. In Germany Rheinmetall followed the lead established in the United States by the 120mm Delta gun and developed one-piece ammunition with combustible cartridge cases instead of the traditional, heavy brass cases. This reduced the weight of a 120mm APFSDS round to a manageable 18 or 19kg and that of the complementary HEAT/Multi-purpose ammunition to 24kg.

The alternative to the manual loading of tank guns has been the use of powered automatic loading systems. This eliminated the restriction on the weight of the ammunition imposed by human strength, but in most cases has been adopted mainly to facilitate firing on the move and to reduce the size of tanks by eliminating the human loader.

Development of automatic loading systems began soon after the Second World War when the AMX 50 heavy tank was built in France with one located in the turret bustle of its oscillating turret, which lent itself particularly well to it. The AMX 50 was not developed beyond prototypes, but a bustle-mounted automatic loading system was installed in the oscillating turret of the AMX 13 light tank that was produced and widely used from 1950 onwards. AMX 13 also inspired the construction in the United States of experimental tanks with automatic loading systems, and a bustle-mounted automatic loading system was also incorporated in the US-German MBT-70. However, except for the AMX 13 and the Swedish S-tank, automatic loading systems did not begin to come into use until they were incorporated in Soviet tanks, starting in the 1960s with the T-64 and following with the T-72, T-80 and T-90 and similar Chinese tanks. All their automatic loading systems have been of the carousel type mounted under the turret. In contrast, when automatic loading systems were eventually adopted elsewhere, they were all mounted in the turret bustles. The first of them was mounted in the Japanese Type 90, which was followed by the French Leclerc and then by the South Korean K-2 and the Japanese Type 10.

A general use of automatic loading systems would have followed if the studies begun in 1982 had led to the adoption of 140mm guns as successors of the 120mm guns because their ammunition was far too large and too heavy to handle, a typical round weighing 38kg and being 1.5m long overall.[16] Guns of 140mm were the subject of an agreement reached in 1988 between Britain, France, Germany and the United States about an interoperable tank gun, or Future Tank Main Armament (FTMA), and prototypes of such a gun were built and fired by 1992. The muzzle energy of their APFSDS projectile reached 23 MJ, or almost twice the muzzle energy of the most powerful of the projectiles of the 120mm guns, but as the Soviet threat receded the development of the FTMA was abandoned. What its performance might have been is indicated by a 140mm smooth bore gun that was built in Switzerland and that in 1999 perforated 1,000mm of armour firing APFSDS projectiles with a 900mm long penetrator.[17]

The problem of handling the increasingly heavy and large charges of solid propellant that accompanied the increases in the calibre of tank guns was thought at one time to be avoidable by the use of liquid propellants that could be piped directly from their containers into the gun. At the same time, the greater density of the liquid propellants and the relative freedom of the shape and location of their containers appeared to offer significant reductions in the internal volume of tanks and therefore in their size.

The development of liquid propellant, or LP, guns started in the late 1940s in the United States, following the lead taken in Germany during the Second World War in the application of liquid propellants to rocket propulsion. It led to an experimental 90mm LP gun that was tested in 1951, but the results obtained with it and other LP guns of up to 120mm calibre showed that their interior ballistics were inconsistent and that liquid propulsion offered no advantage in performance over solid propellants. Moreover, the propellants used in the early LP guns were highly corrosive and toxic and therefore required special handling. It is not surprising therefore that after another catastrophic explosion in the mid-1960s work on LP guns in the United States came to an end.

A similar fate overtook the work on LP guns in Britain. Started in 1952, it led a year later to the construction of an experimental gun based on the contemporary 83.8mm tank gun. This gun used red fuming nitric acid, which was highly corrosive, as part of its propellant mix, and which alone should have dispelled contemporary ideas about LP guns arming future tanks. Nevertheless, further work was carried out using 76mm LP guns and in a fit of remarkable optimism the use of an LP gun was included in the studies that led to the design of the Chieftain tank. But, as in the United States, LP guns failed to come up to expectations and work on them in Britain was terminated in 1957.[18]

There was little further interest in LP guns until the early 1970s, when it revived in the United States as the result of the development by the US Navy of a new liquid monopropellant for torpedoes, which in addition to a relatively high density exhibited low toxicity, low flammability and low susceptibility to detonation. An attempt was made during the mid-1970s to exploit the properties of this new monopropellant in a bulk-loaded high-velocity 75mm LP gun, which formed part of the US High Mobility Agility Program. But this initiative again ran up against the inconsistent ballistics inherent in bulk-loaded LP guns and ended with another catastrophic explosion. Attention then turned to the use of the new monopropellant in LP guns with regenerative injection during the combustion cycle, on which General Electric began to work in the United States in 1973.[19] By 1977 this work had progressed to the stage of an experimental 105mm LP gun, and ten years later studies began of the use of LP guns with regenerative injection in tanks. However, these studies were abandoned in 1991 because the US Army came to the conclusion that liquid propellants might be more appropriate to artillery guns than to tanks. In consequence an order was issued for the development of a 155mm LP howitzer, which was duly built and test fired. However, interior ballistics were again a problem and work on LP guns in the United States was terminated in 1996.

The revival of work in the 1970s in the United States on LP guns resulted in renewed interest in them in Britain in 1981. This led in 1987 to the setting up of a research programme aimed at exploring the possible use of LP guns in tanks. However, before the programme got very far interest in Britain in LP guns switched from tanks to artillery and in 1995 all the work on them was abandoned.

Well before the work on LP guns in the United States and in Britain came to an end, it was overshadowed by the emergence of another potential alternative to solid propellant guns, namely electromagnetic or EM guns. These offered the possibility of much higher projectile velocities, which made them particularly attractive as tank armament because this implied greater armour penetration for a given calibre of gun as well as greater probability of hitting moving targets.

EM guns had been proposed before this, but their development only began after some physics experiments carried out around 1970 at the Australian National University where 3g pellets were accelerated to about 6,000m/s, or almost four times the muzzle velocity of contemporary tank guns. In 1978 this prompted a group of US Army physicists to propose an EM launcher research programme, which was accepted and led to work at several US facilities.[20] One of them was the Westinghouse Research and Development Center, which in 1983 used a laboratory EM launcher to accelerate a 317gm projectile to 4,200m/s, while five years later Maxwell Laboratories in California used a capacitor-powered 90mm EM launcher to accelerate a 1.08kg projectile to 3,400m/s. This meant that the energy imparted to the projectile by the 90mm EM laboratory launcher had reached 6.2 MJ, and this brought it to the level of the muzzle energy of tank gun projectiles.

The progress made with laboratory EM guns led in 1987 to a design study carried out by FMC Corporation for the US Defense Advanced Research Projects Agency (DARPA) of a tank armed with a 15 MJ EM gun, which concluded that a prototype of such a tank was 'achievable by 1991'.[21] A similar conclusion was reached a year later by another DARPA-sponsored study, which recommended a 'tank destroyer' armed with a 11 MJ EM gun and expected its components to be demonstrated by 1992. A contemporary NATO study also opined that tanks armed with EM guns would begin to be produced and come into service in 2000.

Similar optimism existed in Britain, where the Royal Armament Research and Development Establishment (RARDE) proposed in 1987 the construction of a technology demonstrator consisting of an EM gun mounted on a Chieftain tank. What actually happened was the construction at the University of Texas of a self-contained 90mm EM laboratory gun mounted on a skid so that it could be taken to a range for firing trials. In 1993 another 90mm EM laboratory launcher was installed at the UK-US electromagnetic launch facility built at Kirkcudbright in Scotland. Tests carried out with the 90mm EM laboratory guns established that realistic APFSDS projectiles could be launched at up to 2,340m/s.[22] But the 'skid gun' proved to weigh 25 tonnes, which showed that EM guns were far too heavy as well as being far too large to be mounted in tanks.

However, such evidence did not deter US and UK military planners from considering arming future tanks with EM guns in the late 1990s. In the case of the United States, the tank in question was the Future Combat System, or FCS, which was to come into service in 2012; in the case of the UK, it was the Mobile Direct Fire Equipment Requirement, or MODIFIER, which was to be introduced in 2020. But before these ideas were shown to be unrealistic, the development of FCS and of MODIFIER was abandoned in favour of lighter armoured vehicles, which were heralded by the transformation policy adopted by the US Army in 1999 and which were even less capable of accommodating EM guns. Research work on EM guns continued, but interest in their possible application shifted to warships, in which weight and space were far less restricted, and the prospects of their use in tanks remained remote.

In contrast, the prospects of arming tanks with another type of electric gun, the electro thermal-chemical or ETC gun, were brighter from the start because only part of the energy it used to launch projectiles was electrical, the rest coming from the chemical reaction of a solid or liquid propellant. In consequence, the ETC guns did not require electrical equipment as large and as heavy as the EM guns.

Development of ETC guns was pioneered by GT Devices, a small US company that started firing 20mm ETC guns in 1985 and was subsequently taken over by General Dynamics Land Systems (GDLS). In 1985 FMC Corporation also started work on what it called Combustion Augmented Plasma Guns, in which originally most of the projectile propulsion energy was expected to be electrical but which were in effect ETC guns. The early work on ETC guns was so promising that by the end of 1989 a competitive trial was arranged between 120mm tank guns converted by GDLS and FMC into ETC guns, which were intended to demonstrate that an ETC gun could arm the next version of the US M1 tank. The trial was clearly premature, and proved so disappointing that it led to an equally rash view that ETC guns were less promising than EM guns. This view was reached, among others, by the US Army Science Board, which recommended in 1990 that development funds be diverted from ETC to EM guns.[23] Similar views were held in Britain, where RARDE had already shown little enthusiasm for ETC guns.

However, the US Army continued to support research into ETC guns and ordered a 9 MJ 120mm ETC laboratory gun from FMC, which was installed in 1991 and from which projectiles were fired at up to 2,500m/s. Work on ETC guns was also pursued in Germany, where it started in 1987, and resulted in the construction by Rheinmetall of a 105mm ETC gun thatby 1995 fired projectiles at up to 2,400m/s. This was followed by the design of a 120mm ETC gun that began to be used for firing trials in 1999, and by collaboration with France, where another 120mm ETC gun was built by GIAT and started firing trials in 2003.

Since 1986, work on ETC guns has also been pursued in Israel at the Soreq Nuclear Research Centre, which pioneered the use of solid propellants as the source of the chemical part of the projectile propulsion energy instead of the liquid or slurry propellants used originally by FMC and GDLS. Soreq's lead was followed by others, and since the early 1990s the development of ETC guns has concentrated on the solid propellant form of them, becoming focused during the 1990s on guns of 120mm calibre.

The object of the development of the solid propellant 120mm ETC guns that was pursued in the United States, Germany and elsewhere became that of making them a potential alternative to 140mm solid propellant guns that were being developed for the defeat of future enemy tanks. In the course of this development, the use of a 120mm ETC gun was considered in the early stages of the US Future Combat Systems programme and in 2004 United Defense LP (originally FMC and now BAE Systems) successfully fired a 120mm ETC gun from a light tank developed from a much modified M8 Armored Gun System. An ETC gun was also included in the plans for a new family of armoured vehicles that were drawn up in Germany in the late 1990s, and by 2002 Rheinmetall demonstrated a 120mm ETC capable of generating 30 per cent more muzzle energy than the 120mm solid propellant gun on which it was based.[24]

However, even though 120mm ETC guns were considered capable of firing projectiles with a muzzle energy of 15 MJ, their performance still fell short of that of 140mm solid propellant guns, which could fire projectiles with an energy of 18 to 23 MJ and at the same time enjoyed the advantages of being based on well proven technology.

Appendix II: The Quest for Greater Protection

Over the years tanks have faced a number of weapons that have posed an increasingly severe threat to them and have consequently called for progressive increases in the thickness of their armour and for the development of other forms of protection.

To start with, the armour of tanks was very modest, the maximum thickness of that of the original British tanks being only 12mm.[1] This was sufficient to resist ordinary rifle bullets but not thick enough to provide protection against steel-cored ammunition fired by machine guns. The armour was of naval origin, as there was virtually no other at the time than that produced for navies.[2] It was a nickel chrome steel alloy, plates of which were heat treated to provide them with a high degree of hardness for the defeat of bullets.[3] From the latter part of the First World War to the early 1930s, tank armour was generally face hardened by carburizing to make it better able to resist penetration. Such armour was too hard to be machined or drilled after heat treatment so that any machining had to be done before the latter, and it could only be assembled by being bolted or riveted on to angle-iron frames, which became a feature of the early tanks.

Although it had its ballistic advantages, face hardened armour was difficult to produce and its use was abandoned in the 1930s in favour of homogeneous machineable quality armour. However, this did not bring to an end the assembly of armour by riveting or bolting, which continued to be used well into the Second World War, particularly in Britain, Italy and Japan. Elsewhere homogeneous armour was by then already assembled directly by electric arc welding. The change from riveting to welding began in 1934 or 1935 when modified versions of the Soviet BT and T-26 tanks started to be produced using welding technology acquired from Germany, where welding was also used as soon as tanks began to be produced in 1934.[4] Other countries followed six or seven years later.

By the mid-1930s an alternative had been developed to the fabrication of tank turrets and hulls from armour plates, which involved casting them. The use of castings was pioneered in France, where cast turrets were already produced during the First World War for some of the Renault FT light tanks and where one-man cast turrets were adopted during the 1930s for most light and all medium and heavy tanks. Larger three-man cast turrets were subsequently adopted for British, Soviet and US tanks, starting in 1939 with the British Matilda infantry tank. Castings were also used for the production of parts of hulls, starting in the 1930s with the French R 35 light tank. During the Second World War the whole of the upper part of the M4A1 version of the US Sherman medium tank was cast in one piece, and in the 1950s the entire hulls of the US M48 and M103 tanks were cast, as were the hulls of the Swiss Pz.61 and Pz.68 tanks. In general, the ballistic properties of cast armour were slightly lower than those of rolled plates, but casting lent itself better to the production of complex shapes, as a result of which most turrets came to be cast.

The beginning of the use of castings coincided with and contributed to a general increase in the thickness of tank armour. Although some of the armour of the Renault FT was already 22mm thick and that of the multi-turreted Independent was 25mm thick, the armour of most other tanks was for many years thinner.[5] In fact, the armour of the influential Vickers Medium Mark I was only 6mm thick, and the maximum thickness of armour of most other tanks was 14 or 15mm, which included the original versions of the British cruiser tanks and of the German PzKpfw III and IV. But in the early stages of the Second World War, the maximum thickness rose to at least 30mm in the case of the more mobile tanks and 75 or 78mm in the case of the British Matilda and the Soviet KV-1 heavy tank. It then continued to increase further, reaching by the end of the war 100mm in the case of the German Panther and 120 and 180mm respectively in the case of the Soviet IS-2 and German Tiger II heavy tanks.

Some thicker armour was incorporated in tanks designed after the Second World War, bringing it up to a maximum of 200mm. However, such armour was confined to the front of tank turrets. When inclined at 60º or more from the vertical it had a horizontal shot line thickness of about 400mm, which implied an areal density of more than 3 tonnes per square metre of the area of the tank normal to the direction of attack. Significant increases in the thickness of armour were not practicable because of the consequent increases in the weight of tanks and hence a reduction in their mobility.

Moreover, increasing the thickness of homogeneous steel armour became less profitable as a result of the development of shaped charge weapons, against which it was less effective than against the armour-piercing projectiles of high-velocity guns.

This was brought out particularly clearly by the *Panzerfaust* anti-tank grenades with shaped charges that were used by the German infantry in the closing stages of the Second World War and that could penetrate up to 200mm of steel armour. The threat to tanks of shaped charge weapons was maintained after the war by rocket propelled anti-tank grenade launchers, like the US 3.5in. M20 'bazooka', which could penetrate 280mm of armour. But it did not emerge in full until the appearance of anti-tank guided missiles, which began to be developed in Germany towards the end of the war.[6] Their development was continued after the war in France and in the first instance resulted in the SS-10 guided missile, which had a warhead with a diameter of 165mm and could penetrate 400mm of armour. The SS-10 came into service with the French Army in 1953, but it was first used in action by the Israeli forces during the 1956 Sinai campaign.

The penetration capability of the SS-10's successor, the SS-11 that was adopted by several countries, rose to 600mm, which was clearly more than any practicable thickness of steel armour. There was a need therefore to develop alternative ways of protecting tanks against shaped charge weapons. The search for the alternatives began in 1952 in the United States, where it was found that glass could be twice as effective in relation to its weight as steel armour in resisting the penetration of shaped charge jets. This led to the development of 'siliceous armour', which consisted of fused silica glass encased in steel that was successfully trialed as part of the US T95 tank programme. In 1958 it was subsequently proposed to incorporate it in the M60 tank, which was then being developed, but it was not adopted.[7]

A somewhat similar solution to the problem was pursued in the Soviet Union when the T-64 tank began to be developed in 1962, which was provided with frontal hull armour consisting of two thick layers of a glass fibre composite sandwiched between steel plates. A similar type of composite armour with a high glass content was subsequently adopted in the T-72 and other Soviet tanks.[8]

On the other hand, siliceous armour was no longer considered in the United States when the M1 tank began to be developed in 1972. Instead, what was initially considered in its design were arrays of spaced plates of steel and aluminium, which were expected to defeat shaped charge jets by eroding them in stages instead of defeating them by the properties of the armour materials. As it happens, arrays of metallic plates were not adopted for the US M1, but were retrofitted to Soviet T-55 tanks.[9]

As it proceeded with the development of the M1 tank, the US Army became aware of and decided to adopt a new type of armour developed in Britain called Chobham armour, as already described in Chapter 9.[10]

Chobham armour was developed at the Fighting Vehicles Research and Development Establishment of the British Ministry of Defence by G. N. Harvey and J. P. Downey from the basis of a research programme initiated in 1963, and was successfully incorporated for the first time in a Chieftain-based experimental tank designated FV 4211, which was built in 1971. It proved to be more than twice as effective against shaped charges as steel armour in relation to its weight, and when its existence became known it did much to restore the faith in tanks, which had been shaken by the grossly exaggerated claims about the vulnerability of tanks to anti-tank guided missiles that arose out of the 1973 Arab-Israeli War. The nature of Chobham armour has been kept secret by the British Ministry of Defence, although it has been succeeded by another type of armour called Dorchester, and in spite of it being obviously some form of spaced armour incorporating non-metallic materials as well as steel.

However, there is no secret about armour developed against shaped charges, which consists of an array of spaced sandwiches of steel plates with a rubber interlayer. When a sandwich is struck obliquely by a shaped charge jet the rubber expands, causing the plates to bulge and to move apart, interfering thereby with the jet, and if there are enough of the sandwiches arranged behind each other, ultimately breaking it up. Because of the way in which the sandwich plates deform, this type of armour is often referred to as 'bulging armour', and was described as early as 1973 in a patent applied for by M. Held.[11] It has been incorporated subsequently in tanks such as the Soviet T-72M, which began to be produced around 1980 and which contained an array of 20 spaced steel and rubber sandwiches in each of two cavities in the front of its cast turret.[12]

Some of the armours devised for protection against shaped charges incorporate layers of ceramics, such as aluminium oxide and silicon carbide. Ceramics first came into use as armour materials in the late 1960s in panels made to protect US helicopter pilots against bullets during the war in Vietnam. By the early 1970s ceramics were also recognized as being twice as effective in relation to their weight as steel against shaped charge jets.[13] In consequence, they have been incorporated since then in a number of armour systems to erode the jets or the long-rod penetrators of APFSDS projectiles and to absorb their kinetic energy.

Ceramics have also been used to enhance the protection of light tanks and other light armoured vehicles against rifle and heavy machine gun bullets. In this case, their function has been to shatter the bullets by virtue of their greater hardness, and they have been used in the form of relatively thin tiles assembled into panels mounted on the outside of the basic metallic armour of the vehicles. Early examples of this were the Canadian M113 and the Swedish Pbv 302 armoured carriers that were deployed in support of the peace-keeping operations in Bosnia in the mid-1990s.

The ballistic protection of some light armoured vehicles has also been increased by the addition of a type of armour originally introduced in 1943 on German tanks and assault guns to increase the protection of their sides against Russian 14.5mm anti-tank rifles. It consisted of thin steel plates mounted some distance in front of the vehicles' armour, which offered little resistance to the attacking bullets but tipped them so that as they struck the armour yawed and therefore hit less effectively. The use of this type of 'tipping' armour was revived in 1970 when it was adopted in the United States for a derivative of the M113 armoured carrier called the Armored Infantry Fighting Vehicle that was produced for the Dutch, Belgian and Eqyptian armies and was also produced in Turkey, as well as South Korea.[14]

The spaced-off tipping type of armour was developed further in Israel by the Rafael organization, who replaced the thin homogeneous steel plates by high hardness steel plates perforated by holes somewhat smaller than the diameter of the attacking bullets, which reduced their weight to one half of that of the equivalent solid plates and increased their ability to tip the attacking bullets. Called TOGA, the perforated plate armour was introduced on Israeli operated M113 carriers around 1985 and has been used since on other armoured vehicles, including some light tanks.

However, from the 1980s onwards the most common method of increasing the ballistic protection of light armoured vehicles has been to bolt on plates of high-hardness steel on to their steel or aluminium hulls, or of titanium on to aluminium hulls. An example of this has been the M2A2 version of the US Bradley Infantry Fighting Vehicle, which around 1986 had its original tipping armour consisting of two spaced 6mm steel plates replaced by a single 32mm thick appliqué armour plate.[15]

A very different type of armour appeared on Israeli M60 and Centurion tanks during the 1982 Israeli invasion of the Lebanon. This was explosive reactive armour, or ERA, which was devised by M. Held from the basis of the studies he carried out in 1969 in Israel on behalf of the Messerschmitt-Bolkow-Blohm missile company on the effects of shaped charge hits on the tanks disabled two years earlier during the Six Day Arab-Israeli War. Held patented his ideas in 1970 and they were subsequently put into effect in Israel by the Rafael organization in the form of the Blazer explosive reactive armour.[16]

In essence, ERA consists of sandwiches of two steel plates with an explosive interlayer, which is set off when a sandwich is penetrated by a shaped charge jet and which, when the plates are at an angle to the jet, drives the plates apart into its path, disturbing or disrupting it. Originally the plates were only 2 or 3mm thick, but when the sandwiches incorporating them were at an angle to the jet, as they had to be, they could still reduce its penetration of armour by as much as 70 per cent.

The appearance of ERA on Israeli tanks was followed by its large scale installation on Soviet tanks, starting in 1983 with T-64BV, as already described in Chapter 9. Having decided to use ERA, the Soviet Army took the lead in developing a heavy version of it with sandwich plates of 15mm or greater thickness, which were effective not only against shaped charge jets but also against the long-rod penetrators of APFSDS projectiles. The Soviet Army also took the lead in the development of tandem ERA consisting of pairs of sandwiches separated by an air gap, which was considerably more effective than the original type of ERA against single shaped charges. Tandem ERA could also defeat warheads with tandem shaped charges that incorporated a precursor charge designed to clear any single ERA sandwich out of the way of the main charge. An example of such tandem ERA described in a Russian journal incorporated an outer light ERA sandwich followed by a layer of a damping material and a sandwich of heavy ERA.[17] This, together with a tank's steel armour, was claimed to be capable of defeating the tandem warhead of the US AGM-114F Hellfire guided missile, which has a diameter of 178mm and is thought to be capable of penetrating up to about 1,500mm of armour.

What emerged out of all the development of armour was a trend towards the use of multi-layered protection systems combining several different types of armour. Thus the outer layer of armour might consist of very steeply sloped thin high-hardness steel, which would fracture penetrators striking it or at least throw them to some degree off their trajectory. Examples of this are the sharply pointed noses of the turrets of several tanks modified during the 1990s, including the German Leopard 2A5 and the Chinese Type 99. The nose armour might be followed by tandem ERA to break up long-rod penetrators or disrupt shaped charge jets, and then by the tank's main armour, which could incorporate ceramics and which would absorb the kinetic energy of penetrator fragments or of jet particles. The effectiveness of some tanks' frontal armour that has been developed has been estimated to be equivalent to as much as 900mm of steel armour against kinetic energy projectiles and to well over 1,000mm of armour against shaped charges.

After its successful introduction on tanks, the use of ERA was extended to lighter armoured vehicles. This initially created problems because lighter vehicles did not, unlike tanks, have armour thick enough to absorb the front part of a shaped charge jet, which inevitably passes through an ERA sandwich before it is set off, and because the flying rear plate of a sandwich could damage thin armour. To overcome these problems, Rafael developed a hybrid ERA by backing an explosive sandwich with an elastomer and another steel plate.[18] This reduced the impact of the ERA on the host vehicle and provided additional resistance to bullets.

The use of ERA on armoured vehicles other than tanks was already being considered in the 1980s but it was not generally implemented until the following decade, partly because there was no urgent requirement for it and partly because of concern about the collateral damage that it could cause. Thus when the second generation of the US M2 Bradley infantry fighting vehicle was being developed in the 1980s, only a part of the fleet was fitted for, but not with, ERA. However, after the US forces invaded Iraq in 2003 hybrid ERA became standard on the Bradleys and it was also fitted to some of the Israeli M113 carriers. Subsequently the British Ministry of Defence was persuaded to have it fitted also to the Bulldog, the modernized version of the FV 432 armoured carrier, and the Warrior infantry fighting vehicle.

Hybrid ERA provided a badly needed response to the extensive use in Iraq of RPG-7 rocket propelled anti-tank grenades by the *fedayeen* or militants. The situation that had arisen in Iraq in 2003 also revived the use by the US Army of another form of protection against RPG-7 grenades, which was simpler and cheaper than ERA but which was only partially effective against them. It consisted of horizontal steel slats set apart at less than the diameter of the RPG-7 grenades so that one side or the other of a grenade's nose would hit a slat as it flew between the slats and would be crushed, thereby short-circuiting its fuse and preventing detonation of the grenade. However, some grenades are bound to hit the edges of the slats with their nose impact fuse and thus to detonate. The probability of this happening is such that slat armour is only effective at most against about 60 per cent of the hits.

A form of slat or the very similar bar armour was first used in the 1960s by the US Navy on the gun boats that it operated in the Mekong delta during the Vietnam War.[19] It was also used by the Soviet Army in Afghanistan in the 1980s and in Chechnya in 1995 on T-62 tanks, and it was also fitted to the turrets of some Chinese-built Type 69 tanks used by the Iraqi Army in 1991 during the First Gulf War. The US Army developed bar armour for its M113 carriers as early as 1966 but did not start using it until 2003, immediately after the invasion of Iraq, when it came up against the widespread use of RPG-7 by the Iraqi *fedayeen*.[20] Slat armour then began to be used widely not only by the US Army but also by others, including the British Army. Nevertheless, in 2005 the British Ministry of Defence still considered slat armour as something new and regarded a contemporary article about it as revealing secrets.[21]

Slat armour originally fitted by the US Army to its Stryker eight-wheeled armoured carriers weighed 2,231kg, or about as much as a suite of hybrid ERA, which constituted an undesirable increase in their weight. It was consequently followed by the development of several lighter alternatives, including L-Rod armour developed by BAE Systems in which steel slats were replaced by bars of high strength aluminium and which had half the weight of the original type. An even lighter version was developed in Switzerland by RUAG using a diamond-patterned mesh of very high strength steel wire, and still lower weights have been achieved with fibre net systems, such as RPGNets developed in the United States or Tarian developed in Britain, which squash the noses of the grenades that become enmeshed in them.

The quest for ballistic protection that would be more effective in relation to its weight than steel led several years earlier to the use of aluminium armour. This began to be developed in the United States around 1956 and three years later the US Army ordered the production of the M113 armoured carrier, which became the first aluminium armoured vehicle to be produced in quantity and subsequently the most numerous tracked armoured vehicle to be built outside the Soviet Union. Britain, France, Italy and South Korea followed the example of the United States and produced aluminium armoured infantry fighting vehicles, like the US M2 Bradley, of up to 20 and eventually 30 tonnes. On the other hand, Germany, Sweden and Singapore built similar vehicles of steel armour. In spite of the lower density of aluminium armour, there has been little to choose between vehicles with the two kinds of armour so far as their weight is concerned, but those of aluminium armour have been somewhat easier to manufacture and are structurally stiffer because their walls have to be thicker for a similar level of ballistic protection.

The structural stiffness of aluminium armour hulls makes them particularly attractive where most of the ballistic protection comes from other materials, such as high-hardness steel or ceramic tiles, which are structurally parasitic. This was also the case with the Chobham armour of FV 4211, which was designed with a hull of aluminium armour, relying on the Chobham armour packs for most of the ballistic performance. But the combination of Chobham armour with aluminium armour was not considered entirely satisfactory and it was adopted for the hull of only one other tank, the 43-tonne Vickers Valiant designed for export by Vickers Defence Systems in 1977 but not developed beyond the prototype stage.[22] Some light tanks, such as the US M551 Sheridan and the British Alvis Scorpion, have also had hulls of aluminium armour, but the levels of protection they were expected to provide were very much lower than that of FV 4211 and Vickers Valiant.

Interest in the possible alternatives to steel extended at one time beyond aluminium armour even to composite materials made of resin bonded glass fibres. The latter began to be considered by the US Army Materials Technology Laboratory in 1976 and attracted the interest of the US Marine Corps, which in 1983 ordered two M113-type armoured carriers to be made with composite hulls. When one of them was tested, it was adjudged to be superior to the standard aluminium hulled carriers, which encouraged the US Army to order a composite armour analogue of the larger 22-tonne aluminium armoured Bradley infantry fighting vehicle. This was completed by FMC Corporation in 1989, when the writer was able to examine its construction.[23]

The hull of what became known as the Composite Infantry Fighting Vehicle or CIFV was made of high strength aerospace quality S-2 glass fibres bonded by a thermosetting polyester resin. The laminate that made up its walls contained as much as 68 per cent of glass by weight and was superior ballistically to the aluminium armour of the M113 carriers. CIFV was fitted with the standard turret as well as the engine, transmission and suspension of the Bradley and successfully completed a 6,000 mile automotive test programme, which encouraged further work in the United States on composite hulled armoured vehicles.

One sequel to it was the construction in 1993 of a Heavy Composite Hull, or HCH, which resembled that of the US M1 tank. It was intended to be part of a 45-tonne composite hulled, US tank, but the latter was never built. However, another and more realistic project launched by the US Army in 1993 led to the construction of the Composite Armored Vehicle Advanced Technology Demonstrator or CAV-ATD, a 20-tonne vehicle that might have served as a model for an armoured reconnaissance vehicle but that had no direct follow-up after it was rolled out in 1997.

The incentive to develop composite vehicles was the hope that they would be significantly lighter than conventional vehicles with metallic hulls, and savings in weight of up to 33 per cent were claimed. But, even if this were true, it only applied to hulls, which in general account for only one third of the total weight of an armoured vehicle. In consequence, the overall saving in weight would be only of the order of 10 per cent, and this would hardly justify the adoption of composite armoured vehicles, bearing in mind the problems associated with their production and their considerably higher cost.

Nevertheless, interest in composite armoured vehicles extended beyond the United States. In fact, a study of a composite hull for the Scorpion light tank was carried out in Britain for the Fighting Vehicles Research and Development Establishment as early as the 1960s.[24] Nothing came of it, but in 1993 the Defence Research Agency, which succeeded FVRDE, embarked on the development of a composite hulled vehicle of about 22 tonnes to demonstrate the possibility of basing a future reconnaissance vehicle on it. It was called the Advanced Composite Armoured Vehicle Platform or ACAVP, and was completed in 2000, after which it successfully passed extensive automotive trials but, like the US CAV-ATD, it had no successor.

The only composite armoured vehicle to go into production and service has been the CAV 100, which consists of a resin bonded glass fibre body mounted on the chassis of the 3.5-tonne 4x4 Land Rover light truck. More than one thousand CAV 100s were built by Courtaulds Aerospace from 1992 onwards, mainly for use by the British Army in Northern Ireland where it acquired the name ‘Snatch’ because of its use in grabbing rioters. Its composite body provided some protection against small arms, but it proved entirely inadequate, with fatal consequences, when the British Army mistakenly deployed it in the mid-2000s in Iraq and then in Afghanistan, where it was exposed to improvised mines and anti-tank grenades.

The only other large scale and far more effective use of glass fibre composites has been as the intermediate component of the glacis armour of Soviet tanks from the T-64 onwards, which has been mentioned previously. Because of their high glass content, glass fibre composites made a very effective contribution in this case to the frontal protection of tanks against shaped charge weapons.

An entirely different form of protection, particularly against weapons with shaped charge warheads, came to be represented by active protection systems. There are several different types of them, but they all consist of three basic components. One of them is a threat detection system, usually based on millimetre wave radar. Another component is a 'kill' system consisting of counter-missiles with blast or fragmentation warheads or of focused blast modules. The third component is a computer-based control system that processes information about the threat and activates the countermeasures.

An active protection system called a Dash-Dot Device, which incorporated radar for threat detection and linear shaped charges as countermeasures, was proposed as early as 1955 in the United States at the Picatinny Arsenal.[25] However, actual development of active protection systems did not become evident until the 1980s.[26] In fact, in 1983 after six years of development the Soviet Army completed the installation of the Drozd active protection system on a T-55AD tank.[27] This pioneer Soviet system consisted of a radar module and a cluster of four launchers of 107mm rockets with fragmentation warheads on each side of a tank's turret, which formed the countermeasures. Between them they covered a frontal arc of 80º, which would have been sufficient for protection during frontal attacks in open terrain. As it is, some tanks fitted with the Drozd system were employed towards the end of the 1979–89 Soviet occupation of Afghanistan, where according to the system's developers they defeated 80 per cent of anti-tank grenade attacks.

Elsewhere, during the 1970s and 1980s, attention was focused on simpler 'soft kill' protection systems, which were not designed to damage or destroy threat missiles but merely to make them miss their targets. The basic component of such systems were infrared jammers, which interfered with the guidance of anti-tank missiles with semi-automatic command-to-line-of-sight or SACLOS guidance that were perceived at the time to be a major threat to tanks. A 'soft kill' defence system based on infrared jammers was deployed on French AMX 30 B2 tanks during the 1991 Gulf War, and at about the same time another such system called Shtora appeared on Russian tanks.

The latter also incorporated a laser warning receiver that could trigger smoke grenade launchers to produce smoke screens that would blind laser designated missiles with semi-active guidance.

Further development of the 'soft kill' systems exemplified by the MUSS system produced in Germany involved the addition of a missile warning receiver capable of detecting the ultra-violet emissions of missiles' rocket plumes and consequently of alerting the infrared jammers, which would otherwise have to be switched on continuously when missile attacks were expected and thereby could reveal the tank's position.

Although 'soft kill' active protection systems can prevent some anti-tank missiles from hitting their targets, they are ineffective against others, and in particular against unguided anti-tank rockets, which became the principal threat to tanks by the time Russian forces moved into Chechnya in 1995 and US forces moved into Iraq in 2003, when the scene of operations shifted to urban environments. In consequence the focus of attention began to turn from soft to hard kill active protection systems, which were potentially capable of defeating a much wider range of threats.

An early object of the renewed interest in hard kill active protection systems was the Russian Arena system, which appeared in 1993.[28] In addition to radar, Arena was based on the use of fragmentation cassettes launched from a collar-like mounting around the turret of a tank as its kill mechanism so that, unlike Drozd, it provided almost all-round protection and it produced far less risk of collateral damage. However, although it aroused a great deal of interest when it appeared on a T-80 tank, it did not advance beyond experimental installations.

It was only 27 years after the appearance of the Russian Drozd that another hard kill active protection system came into use. This was Trophy, which began to be developed in Israel by Rafael around 1995 and which fired at the threat missiles a beam of small explosively formed penetrators from one of two automatically reloadable launchers mounted at the sides of a tank's turret. The development of Trophy was accelerated by the 2006 war in the Lebanon, where Israeli forces came up against the powerful Russian-made Kornet (9M133) anti-tank guided missiles acquired by Hezbollah through Syria. In consequence, 100 Trophy systems were ordered in 2007 for installation on Merkava Mark 4s, and a battalion of them was subsequently deployed along the frontier with Gaza, where in March 2011 for the first time Trophy automatically destroyed an anti-tank rocket fired at a Merkava by Palestinian militants.

Several other hard kill systems have been developed since the 1990s, including AWISS developed in Germany by EADS, Iron Fist developed by the Israel military industries and LEDS 150 developed in South Africa by Saab Avitronics. Although they differ from each other in several respects, all these systems have been designed to defeat attacking missiles at some distance from the defended vehicle by launching counter-missiles with fragmentation or blast warheads at them from rapidly traversable two to six tube launchers, which ensured all-round protection.

Hard kill active protection systems have also been developed that do not launch counter-missiles but fire directly at the attacking missiles from the defended vehicles. The Israeli Trophy belongs to this category of active protection systems, but most of them incorporate counter-measures that are distributed around a vehicle and defeat threats close to it by blast. This minimizes the risk of collateral damage, but because of the very short distance at which the threat is attacked requires the system to have a very short reaction time. The principal example of this kind of system is AMAP developed in Germany by IBD Deisenroth Engineering; others include the Iron Curtain developed in the United States by Artis and Zaslon developed in the Ukraine.

In addition to the threat posed by various missiles as well as other anti-tank weapons, tanks have also had to be protected against anti-tank mines. The latter emerged as a threat almost as soon as tanks came into use during the First World War, when in 1918 the German Army began to use mines improvised from artillery shells.[29] However, there was little interest in anti-tank mines for some time after the First World War and there was no significant use of them again until the Spanish Civil War of the 1930s. They were also employed by the Finnish Army during the 1939–40 war between Finland and the Soviet Union, but it was only in 1942 that they began to be used extensively by the German Army in North Africa and by the German and Soviet armies in Russia.

The use of mines resulted in as much as 18 per cent of the Allied tank casualties in North Africa and 23 per cent of the casualties in Western Europe in 1944–45. However, much of the damage was confined to the running gear of tanks and was repairable, particularly when tanks had externally mounted suspension units. Moreover, mines were laid to create minefields to restrict the freedom of manoeuvre of armoured formations rather than to destroy tanks. In consequence, considerable effort was devoted during the latter part of the Second World War and for some time afterwards to the development of devices such as flail tanks for the clearing of paths through minefields instead of improving the mine resistance of individual tanks.

The situation changed in the second half of the 20th century when mines became the principal weapons of the insurgents, terrorists and others involved in the various asymmetric wars of that period. The change was brought out by the war in Vietnam, in which as many as 69 per cent of the US armoured vehicle casualties were caused by mines. However, in contrast to the Second World War where the armoured vehicles concerned were mainly tanks, in Vietnam most of the vehicles were lighter and less robust. Moreover, the Vietnamese forces were short of anti-tank weapons other than mines.

The war in Vietnam had little impact on the design of tanks, although it led to the installation of additional steel belly plates in some of the lighter vehicles, such as the US M551 Sheridan light tank.[30] The 1979–89 war in Afghanistan in which a number of Soviet tanks were destroyed by mines laid by the *mujahedin* produced greater repercussions, at least so far as Soviet tanks were concerned. In particular, it led to a number of modifications to them that were later widely adopted elsewhere. Thus to reduce the risk of the driver's seat being hit by a belly plate bulging under the impact of a mine explosion, T-62 tanks were fitted with an additional outer spaced-off belly plate under the front part of the hull, although this seriously reduced the ground clearance. Then in T-72 and other tanks the risk of the bulging belly plate hitting the driver's seat was reduced without affecting the ground clearance by suspending the seat from the roof of the hull instead of keeping it fixed as usual to the floor, which disconnected them and lifted the seat well off the floor and the belly plate.

Like the war in Afghanistan, the 1964–79 war in Rhodesia (now Zimbabwe) also involved extensive use of mines but not of tanks.[31] However, it led to the development of a new category of mine resistant wheeled armoured vehicles that were developed further with great success in South Africa.[32] They included the 4x4 Buffel, 3,500 of which were built and which reduced dramatically the number of casualties caused by terrorist mines, and its successor, the Casspir. Like the Buffel, the 4x4 Casspir had a hull with a blast deflecting V-bottom and, in spite of its relatively light weight of 11 tonnes, was claimed to be able to survive the explosion of three stacked anti-tank mines, or 21kg, of TNT under one of its wheels or of 14kg of TNT under its hull. Since it was first built in 1981, about 2,500 Casspirs have been produced and they were used as armoured personnel carriers in counter-insurgency operations in South West Africa (now Namibia) and elsewhere, with casualties occurring in them due to mine explosions only when they encountered a penetrator mine.

A few South African Mamba mine resistant vehicles derived from the Casspir were procured by the British Army in 1995 for the contemporary peace-keeping operations in Bosnia that came up against widespread use of mines, including Yugoslav TMRP-6 penetrator mines. At about the same time the Krauss-Maffei company began to develop in Germany the 4x4 Dingo mine resistant vehicle, which was to be produced later in quantity.[33] However, mines were still not a major concern to US and other NATO forces, and the design of their tanks that dated from the Cold War was focused on protection against horizontal attack by tank guns and anti-tank weapons and not against mines. US and British forces were therefore unprepared for the extensive use of improvised mines by the Iraqi insurgents that followed the invasion and occupation of Iraq in 2003.[34]

Prior to these events, the usual threat to tanks was considered to consist of industrially produced blast mines with contact fuses that exploded when a tank's track ran over them,, or less frequentls with tilt rod or magnetic influence fuses that would set off mines not only under tracks but also, and more dangerously, under the bellies of tanks. Worldwide studies carried out in the United States and Germany established that the most common of the industrially produced anti-tank mines contained 7 to 8kg of explosive and the highest level of mine threat specified by NATO was the explosion, of 10kg of TNT under the hull of a vehicle.[35]

However, many of the blast mines improvised by the Iraqi insurgents weighed more that this. In fact, one of them that wrecked a US M1A2 tank in October 2003 is believed to have contained more than 100kg of explosive. A year earlier, an Israeli Merkava Mark 3 was similarly wrecked on the border of Gaza by a mine containing almost 100kg of explosive detonated by remote control by Palestinian militants, as already mentioned in Chapter 10. Evidently even well-armoured tanks cannot withstand such large mines, but their resistance can be improved, as has been shown by Merkava Mark 4, which has been provided, among others, with a thick additional belly plate of special steel and one of which even survived the explosion of a 150kg mine laid by the Hezbollah during the 2006 war in the Lebanon with the loss of only one crew member.[36] What is more, very heavy mines are not easy to plant and although many mines laid by the insurgents have weighed more than 10 kg they have not, in general, weighed much more than about 20kg, which is about as much as an insurgent could carry any distance.

In addition to improvised blast mines, tanks and other armoured vehicles need to have their protection improved against the use of improvised penetrator mines, which was foreshadowed by the appearance of such mines in Southern Africa and Bosnia. Penetrator mines consist of explosive charges with shallow copper-lined cavities that resemble shaped charges but instead of copper jets shoot copper slugs with velocities of up to 2,000m/s, which may be compared to kinetic energy projectiles. Their armour-piercing capability is less than that of the shaped charges of the same size, but it does not fall off as rapidly with distance as that of the latter, which makes them particularly effective as remotely controlled off route mines, and in this role they were used extensively by the Iraqi insurgents.

Appendix III: Different Aspects of Mobility

Mobility is commonly described as one of the major attributes of tanks, but in relation to them it has at least three different connotations.

One of them is strategic mobility, which implies the ability of tanks to be moved over considerable distances by ship, by rail or by road transport to the zone of operations. Such movement has become increasingly difficult as the weight of tanks has increased, and so the latter has had an adverse effect on the strategic mobility of tanks. Strategic mobility has also been hampered by the dimensions of tanks and in particular by their width, which beyond a certain limit can prevent them from being transported by rail without special arrangements. Thus, to avoid this, tanks designed in Britain before the Second World War were less than 2.67m wide to keep them within loading gauge of British railways. On the other hand, the broader gauge of Russian railways allowed Soviet tanks to be 3.32m wide for unrestrained rail movement, which provided greater latitude in their design.

Width restrictions also apply to movement by air, but what has been far more important in this context is the weight of tanks, which has prevented their strategic deployment by the available aircraft. After General Shinseki launched his plan in 1999 to transform the US Army into a strategically more mobile force, it was expected that the Future Combat Systems' vehicles that were to take the place of tanks would be light enough to be deployed by

Lockheed C-130 Hercules aircraft. This meant that they would weigh not more than about 17.5 tonnes. But within a few years of the inception of the FCS programme the realities of combat operations in Iraq led to the inevitable conclusion that, to achieve an adequate level of survivability, the FCS vehicles would have to be better armoured and consequently would weigh well over 20 tonnes, as already mentioned in Chapter 9. They could not, therefore, be transported in C-130 aircraft, which were the only ones available in quantity.

Much heavier tanks have been flown, of course, in aircraft but only in small numbers. An example of this is the 60-odd tonnes Leopard 2 tanks of the Canadian and Danish forces, a few of which were transported, one by one, in 2009 to Afghanistan in Russian-built Antonov 124 aircraft.

Another aspect of the mobility of tanks is their ability to move under their own power, on and off the roads, in the zone of operations but out of contact with the enemy. This, known as the operational mobility of tanks, is related to a large extent to the power of tanks' engines in relation to their weight, which governs the average speed with which they can move from one area to another. However, the average speed over longer distances also depends to some extent on how often tanks have to stop for refuelling and for maintenance.

Whatever their other characteristics, the operational mobility of tanks has been inferior to that of the corresponding wheeled armoured vehicles whenever operations take place mainly along roads or over relatively dry, hard ground. This has led to attempts to develop 'wheeled tanks', but the resulting vehicles have been generally inferior to tanks, mainly because they have had to be lighter for comparable performance off the roads, particularly over soft wet ground, and therefore have been less well protected.

In addition to being an important component of operational mobility, speed is also an important ingredient of the tactical or battlefield mobility of tanks, which is their ability to operate in imminent or actual contact with the enemy. Under such circumstances, tanks need to minimize their exposure to enemy weapons and therefore to move rapidly over different types of terrain, which requires them to exert a sufficiently low ground pressure in the case of soft soils and to have a resilient suspension in the case of hard, rough ground.

Tanks that are fast and agile can also outmanoeuvre enemy forces. All this leads to a strong case for providing tanks with the highest possible power-to-weight ratio. However, in practice the maximum has been of the order of 25 to 30hp per tonne. That of some experimental vehicles has been higher than this but, whatever benefits it offered, it did not justify the cost of achieving it.

Moreover, the automotive characteristics of tanks are not the only constituent of the tactical mobility of tanks. An important contribution is provided by armour protection, which allows tanks to disregard the threat of some weapons, such as small arms, and therefore to move about more freely. In this respect tanks differ significantly from unarmoured weapon platforms, which may have greater operational mobility but have inferior tactical mobility because they can be immobilized by the fire of machine guns and other light weapons that populate the battlefield. Unfortunately, these facts have been frequently disregarded by the mounting of troops in unarmoured vehicles, such as Humvees, Land Rovers and other light trucks.

On the other hand, because of its impact on the weight of tanks, the provision of armour protection has been in conflict with the achievement of a high level of automotive performance. Striking a balance between the two has been difficult to achieve, and in many cases has led to military requirements being deliberately biased in favour of one or the other. For example, greater importance was attached to protection than to mobility in the case of the French light infantry tanks of the 1930s, while the reverse applied to the British cruiser tanks of the same period. Since then several attempts have been made to develop tanks that were significantly more mobile than their predecessors, but in general they have been overtaken by demands for more armour protection, which adversely affected their automotive mobility.

Increasingly powerful engines

The starting point of the development of the mobility of tanks was the construction in 1916 of the British Mark I heavy tank, which was powered by the only suitable engine available for it at the time, namely a six-cylinder water-cooled petrol engine of 105hp originally produced by the Daimler company for a large-wheeled tractor. This engine provided the Mark I with a power-to-weight ratio of only 3.7hp per tonne and a maximum speed of 3.7mph on hard level ground.

It was soon realized that tanks needed more powerful engines and to meet their need a special six-cylinder 150hp engine was designed by H. R. Ricardo and produced for the Mark V and other British tanks.[1] It proved generally satisfactory but it was not powerful enough for the last and heaviest of the rhomboidal tanks, the Anglo-American Mark VIII, which weighed 37 tonnes compared with 29 or 28 of the Mark V. The problem was solved by the adoption of the V-12 Liberty aero engine, which began to be produced at the time in the United States and which developed 300hp. As a result the maximum road speed of the Mark VIII went up to 7mph, which made it about as fast as any tank produced by the end of the First World War.

The adoption of the Liberty engine for the Mark VIII pioneered the use in tanks of aircraft engines and at the same time of engines with a V-12 cylinder configuration, which was to be a feature of the larger tank engines, even when engines of this kind were no longer produced for aircraft. For several years the Liberty engine was also the most powerful engine available for use in tanks and as such provided the basis for the record speed of 42.5mph attained in 1928 in the United States by J. W. Christie with one of his experimental tanks.[2] Christie's example was followed by the Red Army, which adopted the Liberty engine, uprated to 400hp, to power the early models of the BT series of fast tanks and then had it produced in the Soviet Union as the M5 tank engine. One consequence was that the BT-2 tank had a power-to-weight ratio of as much as 35hp per tonne and a maximum speed on tracks of 32.5mph. Nevertheless, an even more powerful engine, the M17, with a capacity of 45.8 instead of the 27 litres of the Liberty engine, was installed in the BT-7, although throttled down to 400hp. However, the same engine was rated at 500hp when it powered the T-28 medium and T-35 heavy tanks and at 680hp when it powered some of the contemporary Soviet aircraft. The M17 was actually a licence-built copy of the German BMW VI, a V-12 water-cooled aircraft engine, a six-cylinder BMW IV forerunner of which powered some of the secretly built German *Grosstraktoren.*

In the meantime, the British Army opted for tanks powered by engines built again specially for them. The first was a V-8 of 90hp, which was produced by the Armstrong Siddeley company soon after it started building other air-cooled engines for aircraft and which was installed in the Vickers Medium Mark I in 1923. A V-12 air-cooled engine of 370hp was subsequently adopted for the A.1 Independent heavy tank, and V-8 air-cooled engines of 180hp were then installed in the experimental Sixteen Tonners and the Mark III medium tanks of the 1928–34 period. A four-cylinder air-cooled engine of 87hp was also produced by Armstrong Siddeley for the widely used Vickers Armstrongs Six Ton Tank and was copied for the Soviet T-26 tank.

Air-cooled engines were considered to offer several advantages compared with water-cooled engines, including the absence of leaks and the elimination of the risks of the coolant boiling or freezing.[3] In consequence they were adopted not only for British but also for American and Japanese tanks.

The use of air-cooled engines in US tanks started with the experimental installation between 1929 and 1931 of six-cylinder Franklin engines in seven US copies of the Renault FT. The results obtained were considered encouraging but the US Army had no money at the time to develop air-cooled, or indeed other, engines specially for tanks. In consequence, it turned to the only air-cooled engines of sufficient power that were available at the time and could be used in tanks, which were radial aircraft engines. The configuration of these engines was far from ideal from the tank point of view, mainly because of their height, but the US Army had no choice and, in spite of their adverse effect on the silhouette of tanks, used them from the early 1930s until the end of the Second World War.

The first model to be powered by an aircraft radial air-cooled engine was an experimental light tank built in 1931 for the US cavalry, which had to resort to the subterfuge of calling it a 'combat car' because a Congressional edict made the development of tanks a prerogative of the infantry. The engine installed in it was a seven-cylinder Continental of 156hp, but subsequently the more powerful 250hp Continental R-670 engine was used, from the M1 combat car of 1934 to the M3A3 light tank of 1943. Following their use in light tanks, air-cooled radial engines were also adopted for medium tanks, starting with the M2 of 1939 that was powered by a nine-cylinder Wright engine of 350hp. The same engine but developing 400hp also powered the early versions of the M3 and M4 Sherman medium tanks produced during the Second World War. But there were not enough of them as the production of tanks increased, and to make up for the shortage some of the medium tanks were powered by adaptations of General Motors truck diesels and even of Chrysler car engines. As they were not powerful enough individually, the General Motors diesels were used in twin engine installations that took up more room and required more maintenance but were, nevertheless, used successfully in M3A3, M3A5 and M4A2 medium tanks. Undeterred by the complexity of combining more engines, the US Army adopted as many as five six-cylinder Chrysler car engines assembled in a star configuration to power its M3A4 and M4A4 medium tanks, but was glad to be able to pass most of them to allied armies.

The twin General Motors diesels and the multi-bank Chrysler engines were followed by a V-8 version of a V-12 water-cooled engine designed originally by the Ford Motor Company for aircraft, which became available for tanks and was adopted in 1943 for the M4A3 medium tank. The latter became the most popular model of the M4 tank family and one that continued to be used for two decades after the war. The engine provided the final M4A3E8 model of the series with a power-to-weight ratio of 15.3hp per tonne, which was as high as that of any of the M3 and M4 medium tanks and compensated for the increases in weight that took place during the course of their development and made them weigh in the end 33.65 tonnes.

The 500hp Ford GAA engine also powered the M26 Pershing medium tank which was built towards the end of the Second World War and which was in some respects the forerunner of the post-war US tanks. However, when the US Army embarked in 1943 on the development of engines specifically for tanks it decided to return to air cooling. The new engines were not, of course, radial, but their development and production were entrusted to the same company as that which had earlier produced most of the air-cooled engines for tanks, namely the Continental Motors Corporation. The most important of the new engines was AV-1790, a V-12 with a displacement of 29.36 litres that developed 810hp and that began to be produced in 1949 for the M46 medium tank.

Several years earlier the British Army came up against the same problem as that which made the US Army power its tanks by modified aircraft engines, namely a lack of money for the procurement of special tank engines. This made it abandon the use of the air-cooled Armstrong Siddeley engines. In anticipation of this, the Royal Ordnance Factory at Woolwich started to develop in 1928 the A.7 medium tank as an alternative to the A.6 Sixteen Tonner and powered the third prototype of it, built in 1934, by two six-cylinder water-cooled AEC bus diesels that had a combined output of 280hp. The combination of the two engines proved successful and met the need for more power than could be provided by single available engines. In consequence it was adopted in 1937 for the A.12 Matilda infantry tank, which the British Army used successfully in the early stages of the Second World War.

Another consequence of the lack in Britain of adequately powerful engines was a revival in 1937 by the Nuffield organization of the production of the Liberty engine of the First World War. The Nuffield Liberty engine, which developed 340hp, provided some of the early cruiser tanks with 23 or

24hp per tonne, and this together with their Christie-type suspensions enabled them to move at up to 30mph. However, the engine proved troublesome, particularly in the heavier Crusader cruiser tanks, although it still provided them with 17 to 18hp per tonne. There was by then an alternative in the form of the horizontally opposed 12-cylinder engine that was specially designed for the Crusader's contemporary, the Covenanter cruiser tank. The engine was designed by the Meadows company, which had produced engines for almost all the British light tanks since the 1920s, but its output of 280hp was lower than that of the Nuffield Liberty engine and its cooling system was unsatisfactory. This and their other shortcomings resulted in all the Covenanters being considered unfit for use in battle.

No sufficiently powerful and reliable engine was produced for British tanks until a decision was taken to use a derated unsupercharged version of the V-12 Rolls-Royce Merlin engine that successfully powered the Hurricane and Spitfire fighters of the Royal Air Force as well as some of its bombers. The use of this engine, called Meteor, was proposed in 1941 and was put into effect a year later in a new cruiser tank called Centaur, which was originally powered by a Nuffield Liberty engine but which was renamed Cromwell when powered by the Rolls-Royce engine. Although it had the same displacement of 27 litres as the Nuffield Liberty engine, the Meteor produced 600hp, which provided the 27.5-tonne Cromwell with 21.8hp per tonne and enabled it to reach a speed of 38mph, in spite of being twice as heavy as the original cruiser tanks.

Having successfully powered the Cromwell, the Meteor also powered its successors, the 33-tonne Comet and then the Centurion, which came to weigh 51.8 tonnes. It was also developed in the early 1950s to produce 810hp in the 65-tonne Conqueror heavy tank after being fitted with petrol injection.

Unlike their British and US counterparts, German tanks used during the Second World War were not powered by adaptations of aircraft or commercial automotive engines but by engines specially designed for them. Moreover, except for the original PzKpfw I Model A, their engines were of one make, being produced by the Maybach company. They were all water-cooled petrol engines with six-cylinders in line in the case of light tank engines and with a V-12 configuration in the case of engines that powered what were the principal German tanks until the middle of the Second World War, that is PzKpfw III and IV.

Although it had not made engines for aircraft since the First World War, the Maybach company built engines for airships until the early 1930s, and the V-12 engines that it produced for the PzKpfw III and IV were comparable to contemporary aircraft engines. The HL 108 TR engines that originally powered both tanks had a capacity of 10.8 litres and produced 230hp, which resulted in a power-to-weight ratio of 15.5 and 12.6hp per tonne respectively. The capacity and the output of the engines were increased to compensate for the increases in the weight of the two tanks when they were fitted with more powerful guns and thicker armour, but in spite of this the power-to-weight ratio went down to 11.5hp per tonne. However, this did not prevent them playing a very effective role in mobile operations.

A more powerful engine was clearly needed for the 57-tonne Tiger heavy tank, and another V-12 Maybach engine, the HL 210, was produced for it. It developed 650hp, but this was considered insufficient, and so after the production of the first 250 tanks the engine's cylinders were bored out to increase its capacity from 21.33 to 23.88 litres and its output to 700hp. The modified HL 230 engine was also adopted for the Panther medium tank, which in its original form weighed 43 tonnes and therefore had a power-to-weight ratio of 16.3hp per tonne. This was higher that that of any German tank except for the light PzKpfw II. Nevertheless, a more powerful version of the HL 230 was being developed for the Panther as well as the Tiger II heavy tank, which needed it as it weighed 68 tonnes. The resulting HL 234 engine was for the first time provided with petrol injection instead of using a carburettor, and this increased its output from 700 to 900hp.

Development of the HL 234 engine did not advance beyond its installation in a Tiger II test bed because of the defeat of Germany in 1945 and its occupation by the Allied armies. However, the Maybach company was located in the zone controlled by the French Army, which very sensibly allowed some of its development work to continue, as well as adopting the HL 230 engine for its ARL 44 *chars de transition.* The outcome of this was another engine with petrol injection, the HL 295, which had a capacity of 29.5 litres and which developed 1,000hp. But, for all its advanced characteristics, only about ten engines of HL 295 type were built, being used in the AMX 50 family of heavy tanks that the French Army was developing in the early 1950s.[4]

Maybach's pioneering use of petrol injection was followed by its use in an uprated version of the Meteor engine developed for the British Conqueror heavy tank and in the AVI-1790 engine adopted around 1954 for the US medium tanks. These engines represented the ultimate form of tank petrol engines. No others were built for medium or heavy tanks and eventually even for light tanks, their place being taken by diesel engines that offered lower fuel consumption and less risk of catching fire.

Diesel engines

Interest in the use of diesel engines to power tanks arose soon after the first steps were taken to develop them for airships and aircraft. This attracted the attention of some officers in the British War Office, primarily because of the advantage they offered of longer operating range. In consequence, in 1926 the Ricardo research organization was asked to design a four-cylinder sleeve-valve diesel engine of 90hp, which meant that it was to be of the same power as the air-cooled petrol engines used at the time in the Vickers medium tanks. It was successfully tested a year later in one of them and was followed by the construction of at least four more similar engines and of a larger six-cylinder engine of 180hp, which was tested in 1933 in one of the A.6 Sixteen Tonner tanks.[5] However, the Ricardo diesels were not developed further for lack of money, and the use of diesels in British tanks was reduced to the adaptation of bus engines in the A7E3 experimental medium tank and then in the A.12 Matilda infantry tank, as mentioned earlier in this chapter. After this no British-built tank was diesel powered until well after the Second World War, except for the Valentine infantry tanks designed by Vickers Armstrongs, all but the first of which used commercial AEC or General Motors diesels.

In the meantime, the British lead in the development of diesel engines for tanks was followed in several other countries. They included Japan, where development began in 1932 of an air-cooled diesel for the Type 89B tank and where subsequently all other tanks were diesel powered. They also included Poland, where the 7TP derivative of the Vickers Six Ton Tank began to be produced in 1935 with the Swiss Saurer diesel, and Switzerland where a Saurer diesel was also installed in the LTH light tanks imported from Czechoslovakia. By 1938 the French Army also ordered 100 FCM 36 light tanks powered by Berliet-Ricardo diesels, although all its other tanks were powered by petrol engines. In 1936 the US Army tested a Guiberson nine-cylinder radial diesel in an M1 light tank, and this led to its use in M1A1 and M3 light tanks produced during the early part of the Second World War.

All this was overshadowed by the development of a diesel engine for tanks in the Soviet Union. It began in 1931 and was originally intended to produce a V-12 water-cooled engine to power aircraft as well as tanks, as the M17 petrol engine had done. The idea of using it in aircraft was gradually abandoned, but it retained to its advantage the characteristics of an aero engine and in particular light weight. Its characteristics also led to claims that it was a copy of contemporary French or Italian aircraft engines, but in spite of some similarities there has been no convincing evidence of this.

With what was either remarkable foresight or merely a continuation of the power levels already attained by the engines of the T-28 and T-35 tanks, the diesel engine was specified to produce 500hp, which met the needs of Soviet tanks for many years. However, before its definitive V-2 form was reached in 1937, it had to be re-designed, which involved, among other things, an increase in its capacity to 38.8 litres.

While it was still being developed, the V-2 engine was installed in the last tank of the BT series, the BT-7M, and in 1939 it was put into production for the T-34 medium tank rated at 500hp and for the KV heavy tank rated at 600hp. It then powered all the medium and heavy tanks and the assault guns based on them that were produced for the Red Army during the Second World War. Towards the end of that conflict it was modified so that it could be mounted transversely in the T-44 medium tank, which made it take up less of the hull length than the conventional longitudinal engine installations. Surprisingly, this had not been done before, except for the Italian Fiat 3000 and the L.3 tankettes. But, in view of the advantages of it, all the subsequent versions of the V-2 engine were mounted transversely, starting with the V-54 of the T-54 tanks. The output of the engine was increased to 580hp of the V-55 version, which powered the early models of the T-55 and T-60 tanks and finally produced 620hp. A further increase in power to 780hp was achieved in the V-46 version, which was fitted with a mechanically driven supercharger and powered the early models of the T-72 tank, while its later models were powered by the V-84 engine developing 840hp. The output of the engine was increased further to 1,000hp in the V-92S2 version, which was fitted with a single turbo-charger and was installed in the T-90 tanks, and still further to 1,200hp in the V-99 version, which was fitted with two turbo-chargers. All this more than made up for the increases in the weight of Soviet and then Russian medium tanks that took place over the years, as it resulted in a power-to-weight ratio of 25.8hp per tonne of T-90S compared with 18.9hp per tonne of the original T-34.

Thus, by a judicious initial choice of a sound conventional design and its progressive development, the Red Army and its successors were able, to a large extent, to meet most of their needs with a single type of tank engine over a period of 70-odd years and gained thereby considerable economic and operational advantages. Admittedly, in the middle of that period the Soviet Army threw away the advantages of a single type of medium tank engine by developing two others, but in the end the army reverted to the wiser policy of using a single type of engine.

By comparison, other armies dissipated their resources by successively developing different types of engines. One reason for this was changes in the policy concerning the availability of fuels. In particular, the US National Petroleum Board decided during the Second World War that military vehicles should use spark ignition petrol engines because petrol was considered to be more readily available than diesel fuel. Similar views were held after the war within NATO. As a result, engines developed for tanks towards the end of the war and in its aftermath were all petrol engines, and production of petrol-engined tanks, such as the US M48 and British Centurion, did not cease until 1959.

However, in 1957 NATO adopted a policy that tanks should be powered by what were called 'multi-fuel engines'. This in practice meant diesel engines, as the latter could be adapted to run on a range of fuels, including petrol as well as diesel oil. The change in attitude began to manifest itself in 1954 when work began in the United States on converting the standard AVI-1790 tank petrol engine into a turbo-charged diesel. The resulting AVDS-1790 diesel produced 750hp compared with 810hp of its petrol-fuelled forerunner, but when installed in the M60 tank it increased its range on roads to approximately 300 miles, compared with 160 miles of the similar but petrol-engined M48A2.[6] Similar improvements in the operating range were achieved by all the other diesel-engined tanks designed during the 1950s, such as the German Leopard 1, French AMX 30 and Swiss Pz.61.

The British Chieftain tank, which was designed at about the same time, was also diesel powered, but its Leyland L.60 engine was not of a well proven four-stroke type like the others but of the opposed-piston two-stroke type, which was adopted because of its perceived ability to operate on a wide range of fuels.[7] In fact, the more conventional engines proved equally capable of using different fuels while the opposed-piston engine had peculiar development problems that took time to resolve, particularly by a company that had no previous experience of its type, and which delayed the attainment of the specified output of 700hp.

A different attempt to improve on conventional diesel engines was made in the United States. It involved the use of variable compression ratio pistons devised by the British Internal Combustion Engine Research Association that offered the prospect of much higher specific output. They were first used in the AVDS -1100 diesel that was being developed for the US T95 tank and enabled its output to be raised from 550 to 700hp and eventually in the AVCR-1100 form to as much as 1,475hp. At that power level it was adopted for the US version of MBT-70, but its capacity was increased from 18.3 to 22.3 litres and it was designated AVCR-1360. When MBT-70 was abandoned AVCR-1360 was adopted by General Motors for their entry into the competition for the US M1 tank, but it proved difficult to achieve consistently good combustion with it, which manifested itself in clouds of black exhaust smoke, and its specific fuel consumption was not as good as that of other diesels. This and the other characteristics of the AVCR-1360 engine handicapped the General Motors prototype of the M1 tank, and when it failed to win the competition in 1976 interest in the variable compression ratio type of engine vanished.

Eight years later, when the US Army showed renewed interest in diesels, it funded the development of another unconventional tank engine as part of the competitive Advanced Integrated Propulsion System, or AIPS, programme. What emerged out of it was another departure from standard diesel engine practice, the Cummins XAV-28, a 27.56 litre V-12 with a high temperature lubricant acting also as the coolant. The engine was to produce 1,450hp but failed to come up to expectations, and in mid-1990 Cummins terminated its involvement with it.

Another departure from established diesel engine practice, which was also aimed at a high specific output, was adopted in France in the 1970s. It involved the use of the Hyperbar high pressure turbo-charging system in which the turbo-charger was driven not only by the exhaust gases but also by additional energy supplied by a gas turbine type combustion chamber. When applied to the V8X-1500 engine, this approach raised its output to 1,500hp in spite of its displacement being only 16.47 litres. It also resulted in a much more rapid engine response that led to high vehicle acceleration, but it complicated the engine installation, made it expensive to produce and resulted in a relatively high specific fuel consumption. Moreover, although its displacement was much smaller than that of conventional diesels of the same power, the space occupied by its whole system within a tank hull was not very different from that of the best of them. In consequence, its use was confined to the Leclerc tanks produced for the French Army. Other Leclerc tanks, produced for the United Arab Emirates, were powered by more conventional MTU diesels.

The most radical departure from the prevailing diesel engine practice was contemplated by the British Army, which in the 1960s funded the development of a rotary diesel by the Motor Car Division of Rolls-Royce. Its development was prompted by the excitement created in the motoring world by the appearance in Germany in 1958 of the Wankel rotary car engine.[8] In the unique two-stage twin rotor form devised by Rolls-Royce, the rotary diesel was expected to be lighter than conventional, piston-type diesels and more efficient than automotive gas turbines. However, it turned out to suffer from a number of problems inherent in its configuration and would have required, at best, considerable further development.[9] In consequence, the British Army abandoned supporting its development in 1974 and finally opted for a conventional water-cooled four-stroke V-12 diesel that was part of a family of engines developed, initially on its own initiative, by the Diesel Engine Division of Rolls-Royce.

The most consistent and successful development of diesel engines for tanks was that pursued in Germany where, over a period of 60 years, all the engines have been of the same conventional four-troke water-cooled type with a 90° V cylinder configuration. They have been progressively improved, mechanically and thermodynamically, resulting in three generations of them. Their development was preceded by that of the MB 507 diesel of 850hp, which Mercedes Benz proposed as early as 1942 as an alternative to the Maybach petrol engine of the Panther tank but which was not adopted.[10] It was only ten years later that Mercedes Benz were able to resume the development of diesel engines for tanks. This led to the first of a new generation of Mercedes Benz diesels, the MB 837, a 630hp V-8 that was adopted for the Swiss Pz.61 tank. The same engine then powered the prototype of the German Leopard 1 tank but was quickly succeeded by its more powerful MB 838 development, a V-10 of 830hp that provided Leopard 1 with a power-to-weight ratio of about 20hp per tonne and made it the most agile tank of the period.

The second generation of Mercedes Benz diesels began to be developed in 1965, initially to provide the US-German MBT-70 with 30hp per tonne.

This requirement was met by MB 873 which was designed on much the same lines as MB 838 but was more compact and had two turbo-chargers instead of the two mechanically driven superchargers. When the MBT-70 programme collapsed, MB 873 was developed further for Leopard 2, retaining the 1,500hp rating but having its capacity increased from 39.8 to 47.6 litres in order to increase its torque and consequently the acceleration of the tank.[11] In the meantime, the production of Mercedes Benz tank diesels was taken over by Motoren und Turbinen Union, or MTU, which incorporated the high performance diesel divisions of Mercedes Benz and Maybach.

A year after coming into existence in 1969, MTU embarked on its own initiative on the development of the third generation of tank diesels in anticipation of a demand for more compact engines.[12] The outcome of this was the MT 883 engine, which appeared in 1979. It was another V-12, although with a smaller capacity of 25.1 litres than the MB 873, but nevertheless with a maximum output of 1,500hp. Moreover, when it was mounted transversely in a tank, following the example of Russian tanks, the Euro Power Pack based on it had a total volume of 4.5m^3 compared with 7m^3 of the power pack of Leopard 2 with its longitudinally mounted MB 873 engine. It also took up 1m less of hull length.

As a result of its characteristics, the MT 883 was mounted in the export versions of the French Leclerc, the US M1 and the British Challenger 2 as a superior alternative to their standard engines. It has also been adopted as the best available engine for newly designed tanks, such as the Israeli Merkava Mark 4, the South Korean K-2 and the Turkish Altay.

With the possible exception of the Mitsubishi engines of the Japanese Type 74 and Type 90 tanks, the only diesels that have successfully departed from the prevailing four-stroke type appear to have been the two-stroke engines designed in the Ukraine by the Kharkov Engine Building Design Bureau. These water-cooled turbo-charged engines with horizontally opposed pistons have been only 581mm high and are unique in being connected on either side to a transmission gearbox, which when they are mounted transversely results in exceptionally compact power packs. They are also unique in dispensing with cooling fans, using instead exhaust driven ejectors to suck cooling air through the radiators.

Engines of this kind were originally installed in the Soviet T-64 tanks in the form of the five-cylinder 5TDF engine of 700hp, which was followed in the final models of the T-64 series by the six-cylinder 6TD engine of

1,000hp. The 6TD was also mounted in some of the Soviet T-80U instead of their gas turbines because of the high fuel consumption of the latter, the re-engined tanks being designated T-80UD. After the collapse of the Soviet Union the T-80UD was developed in the Ukraine into the T-84, which was powered by 1,200hp 6TD-2. At about the same time 320 T-80UDs were sold to Pakistan, and subsequently the 6TD-2 engine was adopted for the Al Khalid tank and for the very similar MBT 2000 marketed by the Chinese North Industries Corporation, which sold 44 to Bangladesh. The 6TD engine has also been adopted for the 200 T-72 tanks that are to be modernized in the Ukraine for Ethiopia.

Gas turbines

By the time diesels became generally accepted as tank engines, a potential alternative emerged to them in the form of automotive gas turbines. Study of their application to tanks began in 1944 in Germany, which already had established a lead in the development of gas turbine powered aircraft, including building the world's first, a Heinkel He 178, which flew in 1939. German work on gas turbines for tanks had not advanced beyond preliminary designs of a 1,000hp engine when it was brought to an end by the defeat of Germany in the Second World War.[13] However, it was taken up in Britain, where a contract was awarded within seven months of the end of the Second World War to the Parsons company for the design study of a 1,000hp gas turbine for tanks. This was followed by the construction of an engine of 655hp, which was installed in 1954 in a Conqueror heavy tank chassis, and then of a second engine, rated at 910hp. However, neither advanced beyond trials because their fuel consumption was unacceptably high, as might have been expected.[14] In retrospect it is somewhat difficult to understand why the development of gas turbines for tanks was taken up so readily in Britain, except for the contemporary euphoria engendered by the world lead in the development of gas turbines for aircraft that Britain enjoyed for a time after the war.

The exploratory work in Germany on gas turbines for tanks might also have led to them being considered in 1949 in the Soviet Union, as already mentioned in Chapter 9. But little of consequence happened there until 1963, when experiments began with a helicopter gas turbine installed in a tank chassis. This was followed in 1967 by a decision to develop a 1,000hp gas turbine, which was accepted in 1976 for use in the T-80 tank in spite of its high production cost and high fuel consumption. The T-80 continued to be produced until the collapse of the Soviet Union, after which only a few more were built. It was then offered for export, but only a small number was procured by Cyprus and South Korea, and by mid-1990 the Russian Army decided to abandon it and to concentrate on further development of the diesel-powered T-72, the T-90.

Development of gas turbines for tanks began in the United States, as in the Soviet Union, with tests of an engine built for other purposes. This took place in 1961 when a Solar Saturn gas turbine was mounted in one of the T95 medium tanks that was then being developed.[15] Shortly afterwards the US Army funded the competitive development of a 600hp gas turbine by the Solar Aircraft and Ford Motor Companies. But the engines built by them failed to establish an overall advantage over diesels and were abandoned without being tested in a tank. In spite of this, the US Army placed another contract in 1965, this time with the Lycoming Division of Avco Corporation, for what came to be known as the Army Ground Turbine of 1,500hp, or AGT-1500. It began to be tested in 1967 and was originally considered for MBT-70, but after the demise of the latter it was adopted in 1973 by Chrysler Defense in its XM1 prototype, which was accepted by the US Army to become its M1 tank in 1976 – the same year as that in which the Soviet Army accepted the GTD-1000T gas turbine for its T-80 tank!

When AGT-1500 began to be tested, it was claimed that its minimum specific fuel consumption was as low as that of diesel engines. But when the M1 powered by it came to be used, its overall fuel consumption proved to be twice that of diesel-powered tanks. This exacerbated the problem of supplying US tanks powered by it with fuel, which was brought out by the large quantities of it that had to be delivered to M1 tank units in Kuwait in 1990 and Iraq in 2003. AGT-1500 was also relatively expensive, which handicapped the Chrysler designers of the M1 tank who, like their General Motors competitors, had to work within an overall cost target for the tank of $500,000 in 1972, and consequently had to keep down the cost of other components.

During the 1980s, an attempt was made to show that gas turbines could be as fuel efficient as diesels using a Garrett GT-601 engine originally designed for commercial truck operation that was tested in several tanks, including the US M48, British Chieftain and French AMX 30. Their overall fuel consumption was estimated to be only 10 per cent higher than that of their diesel-powered counterparts. However, because of its more robust design and bulky heat recuperator, the GT-601 was twice as large and heavy in relation to its power as the AGT-1500 and did not enjoy any advantage over diesels in terms of weight and volume.

Undeterred, the US Army funded the development of yet another gas turbine as part of its Advanced Integrated Propulsion System programme, which included the award of a contract in 1984 to General Electric and Textron Lycoming for the LV 100, a 1,360hp gas turbine. Two were built by 1991 and one of them was installed in a tank test bed with an electric transmission built as part of the Armored Systems Modernization Program. The latter was abandoned around 1994 when international tension abated, but interest in gas turbines continued and in 2000 General Electric and Honeywell were awarded a contract for the LV 100-S engine, which was intended for the Crusader 155mm self-propelled howitzer and as a replacement of the AGT-1500 in the M1 tanks. However, development of the Crusader was terminated in 2002, having been overtaken by the US Army's transformation programme, and so was that of the LV 100-5 gas turbine.

Although they were adopted for only three tanks – the US M1, the Soviet T-80 and the Swedish S-tank – the use of gas turbines constituted a significant divergence from the well-established automotive engineering practice. But it did not represent the most radical departure. This would have been the use of a nuclear reactor to power a tank, which was proposed, in all seriousness, at a conference held in 1955 at the US Army Ordnance Tank Automotive Command.[16] It was estimated that the proposed nuclear powered tank would weigh 50 tonnes, or about as much as a conventional contemporary tank, but this appears to have grossly underestimated the weight of the shielding that would have been required to protect the crew from radiation.[17]

Transmissions and steering

Whatever their engines, tanks, like other vehicles, need transmissions to vary the engines' torque. In most cases, this requirement has been met by providing tanks with multi-speed gearboxes that have in general terms followed contemporary automotive engineering practice. Thus, over the years, tank transmissions have advanced from incorporating sliding gears to automatically controlled epicyclic or planetary gear trains, augmented since the Second World War by hydrokinetic torque converters.

Tanks also require a system of altering the relative speed of their tracks by which they are steered. The earliest method of achieving this appears to have been incorporated in 1904 in the United States in a Holt half-track steam traction engine.[18] It amounted to disengaging the drive to one track and then applying a brake to it, which made the vehicle swing around it. Such 'clutch-and-brake' steering was used in the first French tanks built in 1916 and as one stage of the steering in the first British tanks up to the Mark IV of 1917. It was subsequently used by most light tanks built during the 1920s and 1930s and by heavy tanks such as the A.1 Independent and even the Soviet T-35. It proved adequate for steering the former but was not suitable for the latter. In consequence, as their weight grew, no British tanks were produced with it after the Valentine.

Another steering system somewhat similar to but more gradual than the 'clutch-and-brake' steering that has been used successfully in heavy as well as light tanks has been based on inserting a multi-speed gearbox, usually of the epicyclic type, in the drive of each track: changing gear in one or the other of them produced the desired difference in the speed of the tracks. The first geared steering system of this kind was designed in 1918 for the Anglo-American Mark VIII heavy tank, and other experimental geared steering systems were tried in a number of British tanks during the 1930s. But none was adopted until they were incorporated in the Covenanter and Crusader cruiser tanks designed at the beginning of the Second World War, in which they proved eminently successful. In the meantime a geared steering system was designed in 1925 for the first Japanese tank and similar systems were subsequently adopted in all tanks made in Japan. A geared steering system was also adopted in Czechoslovakia for the LTH light tank that was used extensively by the German forces as PzKpfw 38(t), and proved very successful mechanically. A geared steering system was also produced for the German Panther medium tank, but it differed from all the others in being more elaborate.[19]

Soviet tanks, including the T-34-85, continued to rely on clutch-and-brake steering well into the Second World War, in spite of it being one of their weak points. However, in 1943 a geared steering system with two-speed epicyclic gearboxes was developed for the KV-13 experimental heavy tank that led to the IS or Stalin tanks, and they became the first Soviet tanks to go into service with such a system.[20] After the war a similar system was used on a large scale in T-54, T-55 and T-62 tanks, and was then succeeded by a more elaborate version that incorporated epicyclic gearboxes with as many as seven speeds. This provided several turning radii under power and therefore more gradual control of tanks' manoeuvres. Such a system was first installed in the

T-64 and was then adopted for the T-72 and T-90 as well as Ukrainian tanks and the Chinese Type 98.

From the beginning there was also an alternative to geared steering in the form of differential steering. The simplest and earliest embodiment of it consisted of an ordinary truck differential interposed in the drive of the tracks and fitted with a brake on each of the half-shafts coming out of it. Steering based on it was used in the first successful fully tracked tractor built by Richard Hornsby in 1905 and ten years later was incorporated in the first British tanks, although they were generally steered by clutch-and-brake methods. Braked differential steering was evidently simple, but it is also very inefficient, and its use after the First World War was confined to very light vehicles such as the Carden Loyd tankettes of the 1920s and the Bren Gun Carriers that were produced on a large scale during the Second World War.

The inefficiency of the braked differential steering is avoided in the closely related controlled differential steering systems, which contain supplementary gears that allow the speed of the half-shafts to be reduced instead of bringing them to rest. However, controlled differential systems provide only one minimum radius of turn, and this has to be a compromise between a large radius of turn required at high speeds and tight turns at low speeds. Nevertheless, it has been widely used since it was developed in the United States during the First World War by the Cleveland Tractor Company, after whose trademark it is sometimes called a Cletrac Differential. It was used in almost all French light tanks built since the mid-1920s until 1940 and in the secretly built German *Grosstraktoren*, but not in later German tanks. It was also used in all US light and medium tanks from 1932 until the end of the Second World War. Since then it has been used in the French AMX 13 light tanks and a number of armoured personnel carriers, but in only one more medium tank, the Japanese Type 61.

Much more sophisticated double differential steering systems began to be developed in France as early as 1921. In them one differential was driven through the gearbox while another was driven directly by the engine, and their outputs were then combined, which resulted in a different minimum radius of turn for each gear in the gearbox – the lower the gear the smaller the radius, as is generally required. They also offered the possibility of making the drive from the engine through a hydrostatic pump and motor and thereby achieving infinitely variable control of steering. This was exploited in the design of the French Char B to make it possible for its driver to aim the tank's hull-mounted 75mm gun by turning the tank while at the same time driving it.

A double differential system with a simpler direct mechanical steering drive was adopted ten years later for the French S-35 Somua medium tank, and during the Second World War a more refined version of the double differential system was produced in Germany for the Tiger tank. At about the same time a triple differential system, functionally very similar to the double differential, was developed in Britain for the Churchill infantry tank and was subsequently adopted for the Cromwell cruiser tank. It then continued to be used in the Comet, Centurion, Conqueror and Chieftain tanks, although the TN 12 transmission of the last was very different from those of the earlier tanks in having epicyclic gear trains instead of crash gears. But transmissions with triple diffential systems did not lend themselves to the use of progressive hydrostatic steering controls and were therefore succeeded in the Challenger by one with a double differential system that did.

A general use of transmissions with double differential steering systems and hydrostatic steering drives began in the 1950s with the Swiss Pz.61, which was followed by the German Leopard 2 with a Renk transmission, the US M1 with an Allison transmission and the French Leclerc with a SESM transmission. However, other contemporary tanks have used double differential steering systems with mechanical steering drives, including the Italian C-1 Ariete and the South Korean K-1.

An entirely different approach to the problem of engine torque multiplication and steering existed from the start in the form of electric transmissions. The simplest of them consisted of a DC generator coupled to a tank's engine and a DC motor to drive each track. Such a system was first adopted in 1916 for the French St Chamond tank and had the advantage that it could be put together readily from existing electrical motors and generators. It also made the control of track speeds and hence steering easy. However, it was relatively heavy and inefficient. In consequence, its use between the two world wars was confined to the ten French 2C heavy tanks.

There was relatively little interest in electric transmissions during the Second World War, their use being confined at first to the two prototypes of the British TOG heavy tanks built between 1940 and 1941, which weighed 63.5 and 80 tonnes respectively and were in effect unsuccessful throw-backs to the First World War. A much more successful electric transmission was developed in the United States between 1943 and 1944 for the T23 medium tank, but although 252 of the latter were built none went into service. The only armoured vehicle with an electric transmission to be used during the Second World War was the Ferdinand heavy 65-tonne 88mm self-propelled anti-tank gun. This was based on the unsuccessful prototypes of medium and heavy tanks designed by F. Porshe between 1940 and 1942, and 90 were built and used by the German Army during the latter part of the war. The only other armoured vehicles built by then with an electric transmission were the two prototypes of the 182-tonne Maus heavy tank, which were built between 1943 and 1944.

No other armoured vehicle was fitted with an electric transmission until the 1960s, when the Atelier de Constructions Electriques de Charleroi, or ACEC, installed one in Belgium in a US-built M24 light tank and later in its Cobra armoured carrier. At about the same time FMC Corporation installed another electric transmission in one of the US M113 armoured carriers that it was producing. The ACEC transmission represented a significant advance as it used an alternator with a rectifier instead of a DC generator, while FMC not only did this but also used induction motors, which were not only lighter than the DC motors but were brushless.[21]

This was followed in the 1980s by a general upsurge of interest in electric transmissions, which led during the following decade to the construction of several experimental armoured vehicles fitted with them in the United States, Germany and France. Their transmissions took advantage of the contemporary development of rare earth permanent magnet alternators and motors, which made them more compact. However, in terms of the total weight and cost as well as the cooling requirements of their power electronics they were not competitive with hydro-mechanical transmissions. This was demonstrated by the most advanced and powerful of them developed as a possible tank transmission and installed in 1994 in the 50-tonne Automotive Test Rig, which was an offshoot of the US Army's abortive Armored Systems Modernization Program.[22]

However, interest in electric transmissions persisted, encouraged by the emergence in the 1980s of the concept of the 'all-electric tank', which was envisaged to combine an electric transmission with an electromagnetic gun system and electric armour. The combination failed to materialize, but the use of electric transmissions was taken further to form part of hybrid drive systems, in which they would operate alongside battery power packs storing electrical energy that could be drawn upon to meet peak power requirements and thereby make possible the use of smaller engines sufficient for most of the time or enable 'silent running' for short distances on battery power.

At first hybrid electric drives, or HEDs, were severely handicapped by the bulk and weight of their energy storage, which was based on conventional lead-acid batteries, but this was largely overcome by the development of lithium ion and other batteries with higher energy densities.

Except for the added complication of the hybrid drives, the electric transmissions referred to have been of the classic two line kind, with two parallel circuits carrying current from an engine-driven generator to two separate motors, each driving one track. This means that the only connection between the engine and the motor attached to it and the track driving motors consisted of cables, which made for greater flexibility in the relative positioning of them within vehicle hulls and has been a major advantage of electric transmission in the case of some types of armoured vehicles. But there is also a problem with the two line systems when it comes to steering, which to be efficient requires the transfer of the power regenerated at one track to the other track. The regenerated power can be considerably greater than that required for vehicle propulsion, and to cope with it the motors and generators have to be correspondingly large. However, their size can be kept down by mechanically and more efficiently transferring the regenerated power by a cross-shaft connecting the track final drives. The resulting electromechanical transmissions, or EMTs, which can have a single propulsion motor and a single steering motor, retain most of the advantages of the two line systems but are more complex and less adaptable to vehicles not specifically designed to use them.

The advantages of EMTs began to attract attention in the 1980s, but the first was only demonstrated in 2005 in Sweden, where it was designed by Hagglunds for the tracked variant of the SEP multi-role armoured vehicle. Another EMT designated E-X-Drive developed in Britain by QinetiQ might have been used in the manned combat vehicles of the US Future Combat Systems programme, but this was not adopted.[23]

Suspensions and tracks

Whatever their type, transmissions determine how effectively tanks' engine power is used to maximize their automotive performance, including speed. But the latter can be severely restricted by the vibrations set up by the rough ground when tanks move over it. The severity of the vibrations can be reduced by the resilience of the suspensions on which tanks' road wheels are mounted and which therefore governs the maximum speed of tanks in some circumstances.

As it happens, the first British tanks ran on rollers mounted rigidly in their hulls, which was only acceptable at the low speeds for which the early tanks were designed. But the first French tank, the Schneider, already had rollers mounted on sub-frames sprung by coil springs. During the 1920s and 1930s most tanks had suspensions based on pairs of rollers or road wheels mounted in tandem on balance beams sprung by leaf or coil springs. Suspensions of this kind worked mainly by 'walking beam' action, which was reasonably effective at low speeds but did not respond quickly enough to ground irregularities at higher speeds.

Such slow speed suspensions were therefore abandoned during the Second World War, and since then almost all tanks have had their road wheels sprung independently. This was pioneered in the United States by J. W. Christie, who first demonstrated a vehicle with road wheels independently sprung by long coil springs in 1928 and obtained with it a considerable increase in speed. His example was followed on a large scale a few years later by the Soviet BT tanks and then by the British cruiser tanks and Soviet T-34 tanks.

Independent coil spring suspensions were eventually abandoned in favour of suspensions based on torsion bars, which could absorb more energy in relation to their weight and did not take up any hull width. Torsion bar suspensions were first incorporated in 1938 in some of the German PzKpfw II light tanks, and their use became widespread by the end of the Second World War, by which time they had been adopted in the German Tiger and Panther as well as PzKpfw III tanks and Soviet KV and IS heavy tanks. Torsion bar suspensions were then adopted for almost all tanks built after the war, but in the 1960s they began to be superseded in turn by independent suspensions with hydropneumatic spring units, which offered superior, progressive spring action. If linked by suitable controls, they can also be used to vary the pitch of the hulls and their height off the ground. Such adjustable hydropneumatic suspensions were originally adopted in the 1960s for the Swedish S-tank and the Japanese Type 74, while simpler non-adjustable suspensions were adopted for the British Challenger and other tanks.[24]

While the speed with which tanks can move over rough ground is related to the resilience of their suspensions as well as engine power, their ability to move over soft muddy ground depends to a large extent on how their tracks spread their weight over it, or in other words on their ground pressure. The latter is commonly considered in terms of the nominal ground pressure, or NGP, which is the weight of a tank divided by the area of its tracks in contact with the ground. NGP does not represent the actual pressure exerted by tanks on the ground, but it was a reasonable approximation to it in the case of the early British tanks, which ran on a number of small rigidly mounted rollers and tracks with flat-plate links. In any case, it was accepted as an important characteristic of tanks and was quoted as such as early as 1917.[25] Moreover, a low NGP value became the object of some of the earliest tank designs.[26] There was no knowledge at first of what it should be, and in the circumstances it was assumed that it should be similar to the pressure exerted by a soldier's boots, so that tanks could move over the same ground as infantrymen.[27] This led to the view in the 1920s that NGP should be about $50kN/m^2$ and the most numerous tank of the period, the Renault FT, had in fact an NGP of $58kN/m^2$.

However, little attention appears to have been given for some time in military requirements to ground pressure, and the NGP of some tanks was allowed to rise in the 1930s to more than $100kN/m^2$, although this could have been avoided by the use of wider tracks. It was only during the Second World War, in particular as a result of the difficult terrain conditions encountered on the Russian Front, that the importance of ground pressure was generally recognized.

Although NGP is only an approximation to the pressure exerted by tanks on the ground, it has been a reasonable indicator of their relative ability to move over soft ground. But this is true only if their running gear is similar and in particular if they have the same number and size of road wheels and similar tracks. Otherwise, NGP fails to provide a correct indication of the soft soil capabilities because it does not take into account the fact that tanks' tracks are flexible and that ground pressure varies consequently along their length, with peaks occurring under the centres of the road wheels. It is the peak values and not the average of the ground pressure that govern sinkage and therefore soft ground performance. The importance of the maximums of the pressure under the tracks was recognized in Britain in the 1970s, and an empirical equation for calculating their average value, or Mean Maxim Pressure (MMP), was devised by D. Rowland working at the Fighting Vehicles Research and Development Establishment.[28] MMP based on this equation has been used since in British armoured vehicle specifications, providing them with a superior alternative to NGP. It has also helped to explain a number of apparent anomalies resulting from the use of NGP. One of them involved the British Matilda infantry tanks, which had a higher NGP of 112kN/m^2 than any other tank of the Second World War and yet operated successfully in many parts of the world, which could be explained by their MMP being lower than that of many other tanks.[29]

Although it provided a far better indication of the relative soft soil capabilities of tanks than NGP, MMP applied to only one particular and not especially difficult type of soil. To assess the performance of tanks over different types of soil, there had to be some measure of the soil properties. This requirement has been commonly met by measuring the resistance of soils to penetration by a simple instrument called a cone penetrometer, which could be described as a scientific descendant of the walking sticks used by British tank commanders during the First World War to probe the ground in order to decide whether tanks could move over it or not.

The cone penetrometer began to be used for military purposes towards the end of the Second World War by the US Army Corps of Engineers, and in spite of its shortcomings it has remained the only instrument widely used for assessing the trafficability of soils, that is their ability to support the movement of vehicles over them. It has also been used to determine the inverse, that is the cone index or the measure of the resistance to soil to penetration, of the weakest soil that a particular vehicle can traverse. This, called the Vehicle Cone Index or VCI, has been determined by experiment and has also been correlated with what has been called the vehicle's Mobility Index, but the latter consists of a questionable collection of vehicle parameters and arbitrary factors. Nevertheless, the Mobility Index has been incorporated in the NATO Reference Mobility Model or NRMM that has been used to predict the capabilities of vehicles.[30]

A more rational method of determining the cone index of the weakest soil that a vehicle can traverse was developed in the 1980s by E. B. Maclaurin working at the Defence Evaluation and Research Agency of the British Ministry of Defence. It is based on traction tests and provides the cone index of the soil on which a particular vehicle can no longer generate any traction. This has come to be called the Vehicle Limiting Cone Index or VLCI, and can be predicted from a relationship established between vehicles' principal parameters and the results of the traction tests.[31]

Useful as it might be, the use of cone penetrometers gives little insight into the physical phenomena involved in the operation of vehicles on soft deformable soils. Two aspects of it have been identified, one of them being the compaction of the soil and the consequent formation of ruts causing resistance to motion, which was recognized in Germany as early as 1913 by R. Bernstein.[32] The other aspect of it, which was identified in Britain in the 1940s by E. W. E. Micklethwaite, is the generation of thrust, or tractive effort, which is related to the shear strength of soils.[33] This was followed in the 1950s by M. G. Bekker, who proposed a semi-empirical method of predicting the performance of vehicles using the compression and shear strengths of soil measured simultaneously by a device named Bevameter after him. Bekker's approach has only been followed to a limited extent and has as yet had little application to armoured vehicles.[34] However, versions of the Bevameter have been developed for the characterization of lunar soil.

In addition to leading the work on soil-vehicle mechanics, Bekker was also responsible for some of the upsurge of interest in the United States during the 1950s in articulated vehicles.[35] The idea of articulated tracked armoured vehicles was not new, as indicated in Chapter 2, but no successful prototype of one was built until the 1980s in spite of the potential advantages of its kind. The principal advantage is that the total length on the ground of the tracks of articulated vehicles can be significantly greater than that of conventional tracked vehicles because the latter are restricted to about twice the distance between track centres, for otherwise they are unsteerable. In consequence the area of their tracks in contact with the ground is greater and their ground pressure is correspondingly lower. The steering of vehicles by turning the two halves of them relative to each other also imposes lower stresses on the ground than the skid steering of conventional tracked vehicles and thereby reduces the risk of stalling. Articulated vehicles are also better able to negotiate vertical obstacles.

As a result, the performance of articulated vehicles is superior to that of conventional tracked vehicles when the terrain is difficult and in particular when it is very muddy, marshy or covered with deep snow. On the other hand they are more complicated and expensive to produce, less manoeuvrable and difficult to shape well ballistically. Nevertheless, Bekker advocated their development prompted by his studies of vehicle operation off roads, starting in Canada in the 1940s and continuing in the 1950s in the United States, where he became chief of the Land Locomotion Laboratory set up at the time at the US Army Ordnance Tank Automotive Command.[36] He was apparently listened to, for when the writer visited the Command in 1961 he found it full of scale models of various articulated vehicles that were a reflection of the number of design studies of them. However, no articulated tracked armoured vehicle was built. All that happened so far as armoured vehicles were concerned was the design of an eight-wheeled articulated armoured vehicle unsuccessfully produced by the Tank Automotive Command to meet a contemporary US Army requirement for an Armored Reconnaissance/Airborne Assault Vehicle, which eventually led to the M551 Sheridan light tank. The design was taken up by the Lockheed company, where it was developed into the XM 808 8x8 'Twister', but the development of this eight wheeled articulated vehicle did not advance beyond the three prototypes that had been built by 1970.[37]

No prototype of an armoured articulated tracked vehicle was built until the Swedish UDES XX-20 was completed in 1982. As described in Chapter 10, the performance of this prototype was superior in several respects to that of conventional tracked vehicles, but its gun system was difficult to integrate with its two-part chassis and its development was terminated in 1984. The only other articulated tracked armoured vehicles to be built since have been the lightly armoured versions of the Swedish Hagglunds Bv 206 articulated carriers and, more recently, the Warthog versions of the Bionix articulated carrier built in Singapore for the British Army.

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Front cover: Russian tanks, 1938. (Topfoto)
Back cover: Mark I in 1916 (IWM, Q 2486); Matilda infantry tank (IWM, E1416); British Chieftain tank (FVRDE, CCR)

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