

[David Stevenson](#)

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**Article (Accepted version)
(Refereed)**

Original citation:

Stevenson, David (2018) *The field artillery revolution and the European military balance, 1890-1914*. [International History Review](#). ISSN 0707-5332 (In Press)

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Available in LSE Research Online: May 2018

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The Field Artillery Revolution and the European Military Balance, 1890-1914

This article analyses the origins and Europe-wide impact of France's *Canon de 75mm Modèle 1897* (75mm model 1897 cannon). A beacon of Gallic engineering prowess, it has been considered the first modern field gun.¹ It became the standard field weapon not only of the French artillery but also of the 1917-18 American Expeditionary Force. In 1939 hundreds remained in service. Through a complex of changes – most notably a mechanism enabling the barrel to regain position after recoil while the carriage remained static – the 75mm fired much faster than its predecessors, and better protected its crew.² It impelled the other Powers to follow France's example, straining both their public finances and their manufacturing capacity, and disrupting the balance between the Continental armies. Developed and deployed in secret, it established French superiority over Germany for a decade. In the final pre-war years, however, France's lead eroded, and the 75mm's very success arguably became an impediment. Its history therefore illuminates the wider roles of technological innovation, domestic political pressures, and geopolitical rivalries in the pre-First World War land arms race, as well as the connections between that arms race and the breakdown of peace. Whereas in 1905 France's artillery advantage helped deter a German onslaught, by 1914 France's vulnerability helped encourage its neighbour to strike.

The 75mm built on decades of innovation. During the nineteenth century cone-nosed shells replaced spherical shot, artillery barrels were rifled (imparting a spin to increase range and accuracy), breech-loading replaced muzzle-loading, and steel replaced bronze. From the 1880s modern explosives supplanted gunpowder: both 'low' explosives as a propellant (driving the projectile from the barrel) and high explosives as the charge. Guns fired further, higher, and faster, without the smoke that had previously impeded visibility (though also assisted concealment). Yet simultaneously new and longer-range magazine rifles made gunners more vulnerable to sharpshooters. Moreover, the new explosives exacerbated recoil - the gun jolting backwards after firing and needing to be re-aimed - and 'jump' - if its wheels were locked, it bucked. Fortress, coastal, and warship guns were fitted with devices to counter recoil, but the equipment was heavy and cumbersome, and fitting it to mobile field artillery proved difficult.³ Absorbing recoil was everywhere acknowledged as the biggest obstacle to enhanced performance, but it was in France where the breakthrough to achieving it occurred.⁴

Much of the documentation on the 75mm was destroyed in 1940 by bombing.⁵ Nonetheless, the weapon's origins are traced in inter-war accounts. The gestation process centred on the War Ministry's workshops and testing grounds and was overseen by the ministry's Artillery Direction in conjunction with the President of the (advisory) Artillery Technical Committee and successive ministers.⁶ Since the Franco-Prussian War the standard French field artillery piece had been the de Bange 90mm 1877. Typically it recoiled by one to two metres and fired just one round every five minutes;⁷ moreover by the 1890s the de Banges were wearing out. Even so, the 75mm story began unexpectedly, when military intelligence alerted the Artillery Direction to a patent registered by a German engineer, Konrad Haussner. Haussner had worked on his design during his own time while employed by the Prussian state arsenal and then by Germany's biggest private arms firm, Krupp. His key insight, in a memorandum to his Krupp overseers, was that a longer recoil would facilitate hydraulic braking and push-back. His superiors doubted the practicability, and resented a young man trying to teach them their trade.⁸ Undeterred, Haussner protected his design by German and French patents. He

neglected, however, to pay the fees required to uphold the latter, which in January 1892 reached the French Artillery Director, General Charles Mathieu.⁹ They showed the Germans were working on the problem, and they adumbrated a solution.

The significance of the Haussner designs' contribution has been questioned; and they would be much amended.¹⁰ Still, they suggested a new approach when work on a short-recoil mechanism had reached an impasse.¹¹ Hence Mathieu consulted the Artillery Technical Committee and developed specifications for a recoil-absorbing 75mm gun. The committee's president approached the War Ministry's artillery workshop at Puteaux, whose director, Lieutenant-Colonel Joseph-Albert Deport, thought he could produce a workable device:¹² in May 1894 six of the resulting prototypes were ordered. Although they could already fire up to twenty-two rounds per minute without budging - more than satisfying the initial specification - the hydro-pneumatic brake was far from perfect and the piston fluid leaked. At this point Deport, disgruntled at receiving no promotion, left for a private arms firm and the project passed over to Captain Charles-Etienne Sainte-Claire Deville, soon assisted by Captain Emile Rimailho, both (like Deport) graduates of the army's elite engineering school, the *Ecole polytechnique*. They designed an entirely new brake (whose details they withheld even from the Artillery Committee)¹³ which formed the centrepiece of a complete new weapons system of guns, caissons, and shells.¹⁴ The authorities feared that premature approval might leave France inferior to the other Powers, who would copy the design.¹⁵ Nonetheless, in 1896 the Superior War Committee (*Comité Supérieure de Guerre* - CSG - a forum comprising the senior commanders and chaired by the Chief of the General Staff - CGS) endorsed the weapon. In 1897-8 it entered into mass production, before its eventual public disclosure on Bastille Day 1899.¹⁶

These security precautions were exceptional, and although other governments were aware before 1899 that a new weapon was coming, the details of the recoil-absorption mechanism remained concealed for years.¹⁷ While Deport and Sainte-Claire Deville developed model 75C, moreover, work continued on three others: 75A, 75B, and 75D. Mathieu and his successor Deloye considered C the most promising, but B a back-up. They hoped the Germans' intelligence would mistake the direction of French research and be diverted down a blind alley.¹⁸ It was when the 75C was entering its prototype phase and it was most vital to side-track the enemy that the General Staff officer Captain Alfred Dreyfus was falsely accused of betraying secrets.¹⁹ Actually the incriminating note, or *bordereau*, intercepted in the German Embassy in Paris and wrongly alleged to be in Dreyfus's handwriting, related to a different project that may also have been meant to distract the Germans, who remained ignorant of the 75mm until it was deployed.²⁰ In part for fear of pre-emptive attack, secrecy continued during manufacturing.²¹ This re-equipment was one of the biggest ever undertaken,²² and the Artillery Direction ordered the parts as soon as their designs were ready (without waiting for every component to be finalized),²³ and dispersed contracts between state and private establishments, again to aid deception.²⁴ While the development costs came from a clandestine fund, administered in the Finance Ministry with the acquiescence of the Chamber of Deputies Budget Commission, those for production came from an account approved purportedly to demolish the Paris fortifications, under an arrangement agreed by President Félix Faure with the Budget Commission and the Council of Ministers.²⁵ The legislature assigned the equivalent of 226 million francs, compared with the 300 million that the War Ministry thought necessary.²⁶ Nonetheless, France emerged with what most observers judged the best field gun in Europe.

The key to 'quick firing' was the recoil-absorption system that held the 75mm in place even when firing dozens of rounds. Its carriage supported a trough-shaped cradle, in which a

cylinder block contained the hydro-pneumatic braking system, the barrel sliding in guides within the cradle and being attached to a piston that formed part of the braking mechanism. After recoiling by over a metre the barrel returned smoothly into position.²⁷ However, the brake took on its full significance only alongside other innovations. A wheel lock provided anchorage. Behind the barrel a Nordenfeldt breech screw sealed and reopened the breech with a 120-degree turn that a gunner could execute in seconds. The shells were 'fixed' rounds, the projectile and its base with the propellant comprising a single unit like an enlarged rifle cartridge, while as the barrel repositioned it ejected the casing. As the barrel recoiled, the aiming sights remained steady, and the weapon was simple enough for an inexperienced crew to operate.²⁸ According to one commentator, it would douse the selected terrain and alter direction like a municipal water sprinkler.²⁹ Moreover, the gunners could continue working without needing to jump clear, being protected by a nickel-steel gunshield. The caissons, once rotated from their horizontal travelling position to the vertical for unloading, presented an armoured underside towards the enemy that enlarged the shielded zone. Finally, although the French had organized their de Bange field guns in batteries of six, they judged that a four-gun 75mm battery could match a six-gun German one, being more manoeuvrable and easier to supply. Four guns could be transported with more caissons than could six, and therefore each could fire more rounds.³⁰ Hence the French adopted four-gun batteries, though keeping twenty-three batteries per army corps, so that the guns per corps fell from 138 to 92. The General Staff warned that if Germany did not drop to four-gun batteries for its own quick-firer the issue must be reviewed.³¹

The new weapon's tactical mission had been identified by General Hippolyte Langlois, whom Sainte-Claire Deville consulted, and who had foreseen the use of quick-firing field guns.³² Langlois wanted to project deep cone-shaped showers of shrapnel over the enemy infantry: mobility and speed were crucial, for surprise and shock, and to pre-empt the opposing artillery.³³ This was actually a defensive concept, directed towards halting invaders in the open, and it matched the counterstroke approach of French strategic thinking. Until 1891 French planning for another war with Germany was purely defensive, but over the next two decades the General Staff increasingly envisaged the doctrine of a counter-offensive, though only after halting the initial enemy onslaught.³⁴ The 75mm was particularly designed, moreover, for indirect fire, that is 'fire by artillery ... at targets that cannot be seen from the weapon's own position'.³⁵ French gunners had pioneered indirect shooting guided by forward observers. Longer ranges facilitated it, and – though depending on the circumstances – smokeless powder left unconcealed weapons more visible. Both the 75mm's stability on firing and its novel sighting equipment suited the new tactic, its object being an intense and accurate surprise bombardment from a hidden position.³⁶

The Germans were wrong-footed. In the Franco-Prussian War Krupp's steel breech-loaders, positioned forward in dense masses, had overwhelmed their opponents.³⁷ Subsequently the C73, also a Krupp design, became the standard German field gun.³⁸ By the later 1880s, however, the C73s, like the de Banges, were outdated, while France's military renaissance and its 1891-4 alliance with Russia made Germany seem more exposed.⁴⁰ Yet whereas the Prusso-German Great General Staff (GGS) stressed firepower, the General Inspector of Artillery valued mobility, and the War Ministry fretted about the extra weight and fragility of a hydraulic brake.⁴¹ Nonetheless, in 1892 the Ministry asked Krupp to design a quick-firer.⁴² Meanwhile, Haussmann, who had ready another design, moved to the *Rheinische Metallwarenfabrik* (Rhenish Metalware Plant – Rheinmetall), a firm known to the army hitherto as a shell manufacturer. Although Rheinmetall's founder, Heinrich Ehrhardt, claimed

the credit for Haussner's efforts,⁴³ the latter continued working on his model and the firm took out a patent for a long-recoil quick-firing gun. The War Ministry's artillery testing commission (*Artillerie-Prüfungs-Kommission – APK*) found it interesting but not yet usable in war.⁴⁴ But Krupp too failed to develop a serviceable quick-firer, and concluded that recoil-absorption systems could not be applied successfully to field guns.⁴⁵ Instead the army settled on a non-quick-firing Krupp design, the 7.7cm FK (*Feldkanone – field cannon*) C96 (later FK 96).⁴⁶ The War Ministry argued retrospectively that when Emperor Wilhelm II approved the order the C73s were worn out, the French 75mm remained secret, and no viable German quick-firer was available.⁴⁷ Yet the 75mm would immediately outclass the FK 96, and the French delayed deployment of their gun until the Germans were committed to an inferior weapon that would cost them 140 million marks.⁴⁸ The FK 96 satisfied the War Ministry's concern for mobility (in what was planned to be an offensive campaign): it weighed 600 lbs less than the C73 and was also lighter than the 75mm. But although Krupp had built in a *Federsporn* (spring spike), the gun still jumped on firing and had to be re-laid. It delivered 5-9 rounds per minute, which was 2-3 times faster than the C73 but nothing like the 75mm. Its range was only one kilometre greater than the C73's, and it carried no shield.⁴⁹

Re-equipping the field artillery was a hugely costly undertaking that occurred only at intervals of several years. Adopting the FK 96 not merely condemned the Germans to what their War Ministry acknowledged was a period of inferiority,⁵⁰ but also impinged on the next armament cycle. Commentators condemned the gun as being a sitting target for the 75mm, the War Minister and GGS agreeing that the situation was 'extremely grave'.⁵¹ Once the 75mm had proved itself operationally during the European campaign in China against the Boxer Rising, Wilhelm II therefore insisted on a recoil-absorption system.⁵² Ehrhardt had resumed work on its quick-firers and Krupp also renewed its efforts, the APK commissioning both companies to develop a new model. The process still proved arduous, showing that the French had kept their secret and the Germans must find their own solution.⁵³ Moreover, money was tight. Under its 1898 and 1900 Navy Laws, Germany boosted expenditure on warships, and Karl von Einem (who became War Minister in 1903), had other priorities and was slow to concede that the 75mm was superior.⁵⁴ Hence the ministry sought an upgraded FK 96 rather than a completely new gun,⁵⁵ while the Reichstag Budget Commission refused finance for new barrels.⁵⁶ Eventually the state works at Spandau designed the ponderously entitled 77mm FK 96 n/A (Field cannon 96 *neuer Art – new type*). Approved in 1904, it incorporated the FK 96's barrel, wheels, and axle. Krupp reduced the calibre, but the recoil absorption system owed more to Ehrhardt.⁵⁷ The weapon had a bigger gunshield than the 75mm,⁵⁸ and a better aiming system. It met the APK's requirements for durability, as well as the GGS's for lightness and manoeuvrability, not only in Western Europe but also along the muddy tracks of the east.⁵⁹ Indeed, German commentators thought the 75mm had sacrificed mobility for firepower.⁶⁰ But the new gun fired a lighter shell than the 75mm, and because of the recycled barrel it had a kilometre shorter range, which might not matter in close-quarter encounters between fast moving armies, but in trench warfare would matter considerably. Its rate of fire was perhaps just half its French counterpart's.⁶¹ Given the French and German guns' contrasting missions (the French envisaging an initial strategic defensive, the Germans an opening attack), which of them prevailed would largely depend on the circumstances in which battle was joined.

Manufacturing and deploying the FK 96 n/A was another enormous undertaking that would cost some 300 million gold marks, but Einem began unobtrusively.⁶² Even the title – suggesting a mere modification to the FK 96 – obscured its significance.⁶³ However, in 1905-6 the process accelerated because of the opening instalment in a succession of European diplomatic confrontations, the First Moroccan Crisis. In fact neither Emperor Wilhelm nor

Chancellor Bernard von Bülow intended to use the episode to provoke a war,⁶⁴ and whereas Schlieffen saw an opportunity for a preventive strike westwards while Russia fought Japan, Helmuth von Moltke the Younger, who replaced Schlieffen during the crisis, was more circumspect.⁶⁵ Although Einem claimed in his memoirs to have advocated war, at the time he admitted to Wilhelm that the French artillery remained superior, and he wanted to postpone a showdown until the re-equipping was finished.⁶⁶ Military circles – and Wilhelm himself – saw ‘really considerable disadvantages’ in fighting while Germany’s guns were being replaced.⁶⁷ Speeding the re-equipping was the most significant military measure the Germans undertook during the crisis, but they concealed the acceleration as they intended it as a precaution rather than as a warning gesture to intimidate the French. Indeed, Einem advised Bülow that going still faster would mean persuading Krupp and Ehrhardt to suspend work on their export orders: a move so conspicuous that it might provoke war when Germany did not want it.⁶⁸ After the crisis ended in a compromise unfavourable to Germany, Einem still resisted further acceleration. When Bülow asked whether anything was needed to raise the army’s readiness, Einem did not mention the field guns.⁶⁹ He considered the re-equipping was now making ‘an excellent impression’ abroad and ‘thereby preserves peace’, but he did not want to cause ‘disquiet’ abroad or overstrain Reich finances.⁷⁰ Only by the end of 1908 was the task complete.⁷¹

Conversely, when the crisis started, in most respects other than the 75mm the French were unprepared. But subsequently they stepped up their readiness, while the Germans failed to reciprocate. Actually French intelligence had quickly detected their adversary’s re-equipping, and the French General Staff (*Etat-major de l’armée* – EMA) warned during the crisis that the new German gun was comparable to France’s and the situation ‘extremely serious’.⁷² The FK 96 n/A was not just a modification but a completely novel system: ‘willy nilly we are obliged to follow it along this road, or suffer material and especially moral inferiority’.⁷³ Other French experts believed the 75mm remained superior to the FK 96 n/A: faster, more accurate, and easier to use, and less conspicuous because possessing lower wheels, if admittedly less manoeuvrable.⁷⁴ But certainly France’s qualitative superiority had narrowed, which made its quantitative inferiority more pressing. The EMA had expected the Germans also to adopt four-gun batteries with fewer guns per corps,⁷⁵ but in fact Germany kept its six-gun batteries and soon had 144 field guns (plus additional howitzers) per corps against France’s 92.⁷⁶ Moreover, under General Schubert, a new Inspector-General of Field Artillery, the Germans increasingly practised indirect fire, acquiring better rangefinders, new telephones and cable, and observation towers.⁷⁷ In response the French enlarged the 75mm’s shield.⁷⁸ Under Schubert’s opposite number, General Percin, they shifted in their 1910 tactical regulations towards ‘neutralizing’ rather than destroying the German artillery, protecting their infantry by temporarily suppressing the enemy’s fire but economizing on munitions.⁷⁹

French anxiety spilled out into mainstream debate: both in the Paris press and in the legislature, where deputies became more willing to loosen the purse strings.⁸⁰ Most of the 75mm stock was still in good condition, though ageing.⁸¹ Four-gun batteries required more officers and gunners than did six-gun ones, however, and in autumn 1908, against the background of the Bosnian Annexation Crisis in the Balkans and of the Casablanca Deserters incident (a mini-crisis over Morocco), the War Minister General Brun introduced an artillery reinforcement bill that became law in July 1909.⁸² The EMA believed it urgent to redress France’s numerical inferiority:⁸³ which the measure would indeed do, but by creating additional batteries only on mobilization. Brun told the Chamber Army Commission that the 75mm and FK 96 n/A were roughly equivalent, and that France’s recent shortening of its conscription term meant less seasoned infantry who would need greater artillery backing.⁸⁴

Because France remained committed to the four-gun battery,⁸⁵ it could not in peacetime match Germany's 144 guns per corps, but by forming 159 new 75mm batteries it could raise the guns per corps from 92 to 120, and on mobilization to 144.⁸⁶ The law therefore very substantially augmented French firepower, and improved the crews' training and cohesion.⁸⁷ It cost 59 million francs initially and 14.5 million more each year,⁸⁸ but Moltke, impressed, believed France had the men and money to keep up the pace.⁸⁹ Indeed, he advised the law had restored French superiority.⁹⁰ In response the Germans similarly invested in FK 96 n/As, their total of six-gun batteries rising from 574 to 633 between 1905 and 1912-13.⁹¹ All the same, on the eve of war both French and German field gun numbers were reaching a plateau.

The 75mm's example generated pressures to follow suit not just in Germany but also across Europe.⁹² It is necessary first to consider France's principal ally, and Russia's abortive effort - through what became the First Hague Peace Conference - to avert a new round of escalation. In August 1898 a Russian circular to the Powers proposed a conference on arms limitation. It emerged from months of discussion in St Petersburg, after the War Minister, Aleksey Kuropatkin, briefed Tsar Nicholas II in February on the 75mm and FK 96. Adopting quick-firers, Kuropatkin estimated, would cost Russia 130 million roubles (when large sums were going on the navy and on a build-up in East Asia, and borrowing was increasingly difficult). It would cost Russia's rival, Austria-Hungary, 100 million. Hence Kuropatkin proposed a convention with Austria-Hungary to hold off artillery renewal for ten years. Nicholas was receptive, and urged an approach to the Foreign Minister, Mikhail Muraviev.⁹³ Russia's existing field guns, Kuropatkin told Muraviev, could fire one round per minute; but the FK 96 and the model Russia was currently working on fired six. Should one Power introduce such formidable weaponry, every other must strive 'feverishly' to copy it. In contrast, the present moment was favourable for Russia and Austria-Hungary to call a pause (thus the initiative heeded Russian interests) and to ban field guns that fired over three rounds per minute.⁹⁴

Kuropatkin's initiative was soon diluted.⁹⁵ Muraviev felt that Germany's re-equipment made for urgency. But he foresaw that a Russo-Austrian convention would disadvantage both Powers against others, and anyway that Austria-Hungary's ally Germany would resist such an arrangement. Besides, experience showed that it was almost impossible to check the spread of innovation, although it might be feasible to cap military personnel and budgets, which would be easier to monitor and could benefit Russia disproportionately because of its large standing army.⁹⁶ The Foreign Ministry also hoped, however, by highlighting Russia's peaceable intentions, to facilitate expansion in East Asia.⁹⁷ Hence the August circular was more self-interested and less specific than Kuropatkin had envisaged. Nicholas's 'chief object', said Muraviev, was to 'plant the germ that he desired to see fructify'.⁹⁸

Russia's calculated vagueness headed off a confrontation with its ally. No prior consultation took place with Paris: the Russians arguing that had the proposal emanated from the Franco-Russian bloc the Central Powers would have peremptorily rejected it. French journalists were bewildered, and French military circles downcast.⁹⁹ According to Kuropatkin, who made a damage limitation visit to Paris, the army chiefs, the War Minister, and President Faure feared that in order to avoid expenditure on quick-firers the Russians would deprive France of the 75mm, forfeiting an opportunity to reconquer Alsace-Lorraine. Kuropatkin reassured his hosts that Russia proposed not disarmament but arms limitation,¹⁰⁰ and on this basis the French agreed to attend the conference. But the Russians also gave assurances to Germany; and the agenda they circulated in January 1899 included restrictions on automatic rifles and on dropping high explosives from balloons, but not on quick-firing guns. Quick-firers figured

only briefly in the Hague conference's first commission, and Russia did not press the issue; while expenditure ceilings were soon abandoned as impractical.¹⁰¹ Although the German delegation gained notoriety for publicly opposing arms limitation, the Austro-Hungarians, British, Americans, and French privately felt likewise.¹⁰² Indeed the Russians themselves had now decided to acquire quick-firers. Their Finance Minister told the Germans that his country could afford rearmament;¹⁰³ Kuropatkin told the French that because at least for the first-line corps he could wait no longer, he would probably buy guns from abroad, although he wanted to order as much as possible from domestic industry.¹⁰⁴ Finally, Nicholas himself had been reading the celebrated work of Ivan Bloch, *The War of the Future*, and met its author, who who supported the thesis that warfare was becoming impossibly destructive by contending that since 1870 artillery had become twelve to fifteen times more powerful.¹⁰⁵ However, Nicholas's uncle, Grand Duke Alexei, believed experience showed that armaments were a guarantee of peace and Russia could afford the expenditure, Nicholas's mother and wife also favoured introducing the new weapons, and the tsar concurred that Russia must avoid giving the impression that in the competition for weaponry it could not hold its own.¹⁰⁶

The Hague Conference thus confirmed the absence of support for renouncing quick-firers. Soon they spread to every major army: not to mention smaller ones. Few countries had the capacity and expertise to supply themselves, but by 1906 Krupp and Ehrhardt as well as the French companies Schneider, Saint-Chamond and Châtillon-Commentry all had export models available. They sold to the Low Countries and to Scandinavia as well as to the USA, which purchased from Ehrhardt.¹⁰⁷ Even Belgium, which had a large home-grown armaments industry, turned abroad. As late as 1908 Belgian field batteries still had pre-quick-firers resembling Germany's C73,¹⁰⁸ but they were replaced by Krupp 75mm models that in trials outperformed Saint-Chamond - not the sole occasion on which Germany's arms concerns equipped potential adversaries.¹⁰⁹ Similarly, in South-Eastern Europe Krupp supplied Turkey and Romania while Schneider supplied Bulgaria and Serbia.¹¹⁰ Serbia's conversion was particularly fraught, as its traditional armourer was Austria-Hungary, but after a dynastic coup in 1903 the Serbs loosened their ties with Vienna. A commission considered German, Austrian, and French models before opting for Schneider, a purchase facilitated by a Franco-German bank loan.¹¹¹ Although the order took years to execute, a neighbour that the Austrians found increasingly threatening no longer bought its field guns from them.

In the first phase of the quick-firing revolution, indeed, which centred on light field guns, Germany's partners, Italy and Austria-Hungary, adapted less successfully than did France's partners, Russia and Britain. The balance of advantage shifted not only against Germany and towards France but also against the Central Powers collectively and towards the emerging Triple Entente.

Britain's transition was smoothest. Re-equipment had been mooted before the 1899-1902 South African War, but if undertaken so early might have saddled the British with another pre-quick-firer and ensnared them in the same trap as the Germans.¹¹² Instead the precipitant was the Royal Artillery's poor performance on the veldt against Boer guns supplied by Schneider and Krupp. As a result, its equipment was completely replaced, the Ordnance QF 18-pounder and 13-pounder becoming the standard Royal Field Artillery and Royal Horse Artillery arms. In 1901 the Special Committee on Horse and Field Artillery Equipment was established with Cabinet approval. Also known as the Marshall Committee after its chair, Major-General George Marshall,¹¹³ it was asked to consider 'whether a system in which the gun recoils on a cradle, recoil being checked by hydraulic buffers and the gun returned to position by springs, is permissible or desirable'.¹¹⁴ It interviewed representatives from the biggest arms firms, Armstrong and Vickers, and from Woolwich Arsenal. The Vickers

spokesman insisted that twenty rounds per minute were attainable with a French-style long recoil: 'Provided the gun comes back after firing without throwing the sight out, there is no reason why the rate of fire should not be controlled by the rate of loading'.¹¹⁵ Although the French police prevented British observers from inspecting the 75mm close-up,¹¹⁶ its influence was once more evident. Similarly, when the committee's first report stressed lightness and mobility and seemed uncertain whether these were achievable with an apparatus that eliminated recoil, the Director-General of Ordnance, Sir Henry Brackenbury (who was well informed about Continental developments) pressed for clarification. Marshall replied that 'if a high rate of fire is obtainable only with a system of cradle and buffer, the committee is prepared to accept them despite the disadvantages'.¹¹⁷ This ruling set the course towards quick-firing, and the 18-pounder would discharge up to twenty rounds per minute, with a bigger calibre (83.8mm) than either the 75mm or the 96 n/A.¹¹⁸ The committee recommended an Armstrong barrel, a Vickers recoil-absorption system, and Woolwich sights and caissons. One member saw no need for an intermediate weapon between the 13-pounder and the heavy artillery, but Prime Minister Arthur Balfour judged the 18-pounder also necessary.¹¹⁹ All the same, the expense was daunting. Finally, under pressure from *The Times*, the War Office ordered the new guns, although initially re-equipping the Indian army. Once again the First Moroccan Crisis lent urgency, and the British Isles regained priority: the six home infantry divisions and one cavalry division being re-equipped by 1906.¹²⁰ This was the biggest such undertaking in the British army's history, costing over £4 million, and when as Secretary for War Richard Burdon Haldane reorganized the British Expeditionary Force, he doubled the batteries available on mobilization from forty-two to eighty-one.¹²¹

In Russia the impetus towards quick-firers came not just from fear that Austria-Hungary would adopt them but also from the mistaken supposition that Germany already had done. In summer 1898 the Russian War Ministry decided it must follow suit, which helps explain quick-firers' sidelining at The Hague. According to the ministry, 'Our artillery must no doubt follow the example of the artillery of the Western armies in order not to fall behind them in armament and effect of fire; but rearming the artillery will cause us great difficulty both because of significance of expenditure and because of limited production resources and consequent inability to fill orders for a large number of guns, carriages, and shells in any kind of short time period.'¹²² Given the urgency, approaches went to Krupp, Saint-Chamond, and Schneider, but the model adopted came from the largest Russian private arms firm, Putilov.¹²³ The French seem not to have disclosed the 75mm's secrets even to their ally, and Russia's 76mm M 1900 was steadied by a crude system of rubber rings along the trail.¹²⁴ Despite fearing its carriage was unstable, Kuropatkin still rushed into production.¹²⁵ In contrast, the gun's successor (also from Putilov), the 76mm M 1902, featured a hydraulic recoil-absorption system. If heavier than the German and Austrian field gun, it was lighter than France's 75mm, and longer-range than other quick-firers. Yet it frequently broke down and the brake was inefficient, so the weapon still moved on firing and delivered only ten rounds per minute.¹²⁶ Its designers economized on nickel in the barrel, whose rifling wore down quickly, and at night the muzzle flash betrayed the location. These defects exposed the limitations of Russian engineering, and German commentators considered the M 1902 barely serviceable.¹²⁷ Moreover, distribution was exceedingly slow. At the time of Russia's humiliation in the 1908-9 Bosnian Crisis the M 1902 guns still lacked shields and panoramic sights.¹²⁸ Only after the establishment in 1911 of an inquiry commission was the re-equipment process finished.¹²⁹

The Russians, like the Germans therefore transferred in two stages, and found the adjustment difficult. Even so, by 1914 they had accomplished it, whereas Austria-Hungary had done so only very inadequately, and Italy's transition remained incomplete. Although Italy also had a

sizeable armaments industry, much of it was foreign owned. By 1898 the army recognized a pressing need to update its 75B and 87B Krupp-model guns.¹³⁰ However, the War Ministry opened bids for a replacement that lacked a recoil-absorption mechanism, the ministry experts fearing such a device would be too fragile and being so briefed by the Krupp representative (who concealed that his company had failed to perfect one).¹³¹ Hence another Krupp design, the 75A, not a quick-firer, was chosen to replace the 75B. Sixty million lire were earmarked for another weapon that proved obsolete once France unveiled the 75mm. Even after this experience, a special commission on 87B replacement preferred a further Krupp model to a War Ministry one, and the minister signed the contracts, presenting parliament with a *fait accompli*.¹³² Although the order was not to be completed until 1910-13, criticism of the new Krupp gun began at once, spiced by corruption allegations and prompting yet a further investigation.¹³³ To succeed to the 75A the Italians therefore settled on a new design by Colonel Deport, the father of France's 75mm, to be manufactured by an Italian consortium.¹³⁴ The technology was extremely innovative – a split trail enabled the barrel to be angled higher - but Italian steel proved defective and the consortium failed to deliver on time.¹³⁵ Even when Italy joined the war in 1915 its re-equipment was barely complete.¹³⁶

Austria-Hungary was little better situated. Traditionally its guns came from the state-run Vienna Arsenal, which private concerns - especially Skoda – were overtaking in expertise. Major-General Franz von Uchatius had invented a 'steel-bronze' material for the gun barrels, which partly for financial reasons the Austrians used instead of nickel steel. By the 1890s they too needed to replace their stock, but the War Ministry's Technical Military Committee favoured not acting precipitately but instead fitting a tail spur to the existing weapon. The resulting M 75/96 lacked a recoil brake or shield. In 1906 Schlieffen warned his Austrian counterpart that the gun was outdated, and Wilhelm II reiterated the message.¹³⁷ After prolonged negotiations, the Austrians purchased the rights to the Ehrhardt design, and built the FK M5, which resembled Germany's FK 96 n/A. Skoda manufactured the carriage, which possessed a recoil-absorption mechanism; but the steel-bronze barrels were heavy and liable to warp, and the gun still lagged in range and rate of fire, while shortages of funds and of personnel delayed its introduction.¹³⁸ Admittedly, one of Austria-Hungary's major actions during the Bosnian Annexation Crisis was to speed up the re-equipping.¹³⁹ After 1909 the army had a reasonably up-to-date field gun, but this was the only quick-firing weapon in service and its numbers remained few. On the eve of war, infantry divisions in the Austro-Hungarian common army typically possessed forty-two field guns, against fifty-four in their German counterparts. In the Landwehr and Honvéd divisions controlled by the governments of the Dual Monarchy's Austrian and Hungarian halves, the guns per division numbered twenty-four. The reasons were political as well as financial: the Landwehr and the Honvéd were considered potential vehicles for separatism. Yet the upshot was that Austria-Hungary's army remained relatively 'the most undergunned ... in Europe'.¹⁴⁰

Quick-firing, however, was applicable not just to light field guns. Given that by 1908 the latter had largely been converted, the major subsequent development was the extension of the new technology to curved-trajectory and to heavy artillery. Through this process the Germans substantially retrieved their position, only as 1914 approached to find it once again in danger.

Rather than diversifying France's artillery portfolio, the 1909 law had intensified French reliance on the 75mm. Heavier weapons, the Paris War Ministry feared, would complicate supply, and delay the field army or lag behind it. But in other armies heavy guns were becoming field weapons, in the second stage of the quick-firing revolution. Technically the

second stage differed little from the first, although commonly the braking devices were duplicated, one being placed on either side of the barrel. Weapons firing at higher angles had less space for recoil without the barrel hitting the ground, and heavier shells needed more propellant and caused greater wear.¹⁴¹ Nonetheless, from the turn of the century these challenges were surmounted.

Germany equipped itself not only with the FK 96 n/A but also with quick-firing light field howitzers and heavy field cannon. Schlieffen gave encouragement, as he wanted greater mobile firepower for a westward offensive,¹⁴² and Russia's siege of Plevna in 1877-78 had shown that against entrenched infantry flat-trajectory bombardments achieved little. Though meant to plug this gap, the 1898 105mm field howitzer was controversial: critics found it too short-range, and it lacked a shield. Wilhelm ordered its upgrading and it received a recoil brake, the resulting 10.5cm FH 98/09 being deployed from 1908 for use against enemy artillery protected by gunshields as well as against dug-in infantry.¹⁴³ Adopting it meant abandoning plans for unified training and shell supply across the field artillery, and financial constraints limited its numbers.¹⁴⁴ Still, by 1914 whereas the field artillery of a French army corps still entirely comprised 75mms, that of a German corps was about one fifth field howitzers. On the eve of war, the peacetime German army had 3,786 field guns in 642 batteries; on mobilization, 6,326 in 1,069 batteries, of which 5,076 were FK 96 n/A and 1,230 were FH 98/09.¹⁴⁵ Schlieffen's planning also necessitated greater focus on the heavy artillery: not just siege artillery against steel and concrete fortresses but also heavy cannon and howitzers that could (if necessary by being temporarily dismantled) be horse-drawn. In 1896 the Heavy Field Artillery (*Schwere Artillerie des Feldheeres*) was created to incorporate the mobile heavy-gun battalions,¹⁴⁶ and the German army's first quick-firer was actually a heavy field howitzer, the *schwere Feldhaubitze 02*. Other heavy quick-firers followed, including the 10cm *Kanone 04* and a 21cm howitzer in 1910, in this weapons branch Krupp taking the lead.¹⁴⁷ Having deployed the FK 96 n/A, ministers now concentrated on the heavy guns.

Other armies lagged. In 1914 Belgium still lacked modern heavy artillery. Austria-Hungary had a handful of Skoda 30.5cm siege mortars; otherwise its heavy quick-firers were only prototypes.¹⁴⁸ An Italian law of 1910 provided for a heavy field artillery but in 1914 just half the heavy field howitzers (again supplied by Krupp) were ready, and none of the heavy field cannon,¹⁴⁹ while a light field howitzer remained at the planning stage.¹⁵⁰ It was true that France's Entente partners made more progress. The British Expeditionary Force's artillery resembled the German mixed pattern. It complemented the 18-pounder field gun with an efficient quick-firer, the 1908 4.5" light howitzer. Partly due to South African experience, it also had some mobile heavy guns.¹⁵¹ German observers were impressed, although the BEF remained small.¹⁵² In contrast the Russians occupied a half-way house between Germany's and Britain's mixed portfolios and France's reliance on the 75mm. Among the lessons of the Russo-Japanese War was that more heavy weapons were needed.¹⁵³ But after the defeat the tsarist army budget was squeezed, and rolling out the M 1902 light field gun was the priority, German observers judging Russia's heavy artillery wholly outdated.¹⁵⁴ In 1913 they still thought Russia's artillery backwardness offset its greater numbers of cavalry and infantry.¹⁵⁵ After 1909, however, as the tsarist economy recovered and planners turned to rearmament, Germany rather than France served as the model. This meant field howitzers and heavy field artillery, though neither of Russian design.¹⁵⁶ A Krupp-model field howitzer was adopted for manufacture by the Obukhov and Putilov works,¹⁵⁷ and by 1914 probably most Russian army corps had such equipment, German business again assisting a potential adversary. For the heavier weapons, however, Russia went to its ally, ordering one hundred and twenty 120mm heavy field guns from Schneider.¹⁵⁸ In a review of tsarist war readiness in February 1914 the GGS warned that further increases in light field howitzers and heavy field artillery were

impending.¹⁵⁹ Indeed the artillery was at the heart of Russia's 'Great Programme' of army expansion that became law in July 1914. The programme followed an agreement with the French to build strategic railways to the western border, and it complemented the adoption of an offensive war plan, Schedule No. 19A.¹⁶⁰ War Minister Vladimir Sukhomlinov sought stronger and more mobile backing for the infantry advance by doubling the heavy artillery and raising each army corps' quick-firing field guns up to parity with Germany. For these purposes he would recruit some 89,000 additional personnel.¹⁶¹

On the eve of war Russia planned to reinforce its artillery both quantitatively and qualitatively. France planned likewise, and the GGS was well informed about both countries.¹⁶² But whereas the timing of the innovation cycle had favoured France with the 75mm, a decade later circumstances were less propitious. Down to 1905, in the opinion of many French and even German observers, France possessed artillery superiority over Germany.¹⁶³ Thereafter, however, historians have detected a relaxation of French effort while Germany deployed the FK 96 n/A and FH 98/09, with heavy quick-firers closely following.¹⁶⁴ It is true the French introduced the 1904 155mm Rimailho, whose designer, Captain Rimailho, had assisted Sainte-Claire Deville in perfecting the 75mm. The Rimailho's quick-firing mechanism resembled that of the 75mm, and it was meant to be an equally mobile but more powerful weapon that could target entrenchments.¹⁶⁵ Unfortunately the Rimailho proved disappointingly short-range, and few were built. It was difficult to supply, and unpopular with its crews.¹⁶⁶ The GGS thought it too heavy and ballistically poor.¹⁶⁷ Yet it remained France's only quick-firing heavy gun, even though soon after the 1909 law debate resumed over whether deploying more 75mms sufficed against Germany's re-emerging advantage.¹⁶⁸

Matters came to a head after the Second Moroccan (Agadir) Crisis in 1911, when France and Germany seemed on the brink of war. The French Premier during the crisis, Joseph Caillaux, regarded artillery inferiority as one reason to seek compromise,¹⁶⁹ and both War Minister Adolphe Messimy and Messimy's successor, Alexandre Millerand, lent new energy to military preparation, as did Joseph Joffre, newly appointed as CGS. At a sombre CSG meeting at the height of the tension, members were briefed that the FK 96 n/A was comparable to the 75mm and outnumbered it; that the Germans were catching up in indirect fire, and their light field howitzers and heavy artillery could silence the French field guns. With Messimy's backing General Augustin Dubail urged that France too needed a light field howitzer and heavy field artillery, not only for defensive operations but also to advance across the border.¹⁷⁰ France's changing artillery requirements, indeed, were linked to a more aggressive military strategy: by 1911-12 the EMA sensed that the strategic balance was moving against the Central Powers and it might be possible to launch a Franco-Russian offensive without first absorbing a German blow.¹⁷¹ Still, the CSG was supportive, and established an implementation commission under General Lamothe.¹⁷² In the more senior *Conseil supérieur de la défense nationale* (Superior Committee for National Defence - CSDN - attended by French politicians) Messimy reiterated that France needed both a field howitzer and heavy field artillery, seconding fortress guns for the latter purpose as an interim measure.¹⁷³ The army was improving its supply networks, and France like Germany was introducing tractors to pull heavy guns. Under Millerand, the War Ministry began commissioning.¹⁷⁴

Yet even after a report by one of France's foremost artillery experts, General Frédéric-Georges Herr, underlined heavy guns' importance in the 1912-13 Balkan Wars, urgency was lacking.¹⁷⁵ Millerand's successor reduced an order for two hundred and twenty 105mm Schneider long-range heavy cannon to one for thirty-six, which would become operational

only from September 1914.¹⁷⁶ In addition the legislature cancelled the field howitzer in favour of the *plaquette Malandrin*, a disc fitted to the 75mm's shells to curve their trajectory. It was expected to cost 500,000 francs for a few weeks' work, whereas developing the field howitzer would cost 80 million over several years. This new loss of momentum was therefore partly due to resource deficiencies, the War Ministry in 1913 being preoccupied with securing extra manpower by lengthening military service from two to three years. Legislation for a big equipment credit was authorized by the parliamentary finance commission in March 1913 but passed only in July 1914. It released 755 million francs, of which 404 million would go on artillery, but like Russia's Great Programme it came too late.¹⁷⁷ Moreover, the state arsenals had been run down since building the 75mm and had lost key personnel to private industry, whereas firms like Schneider could be slow and expensive suppliers.¹⁷⁸ Yet even given the constraints placed on the War Ministry, progress was disappointing: suggesting to the Germans that the French were uncertain about how best to proceed.

German observers acknowledged French fears that heavy ordnance would reduce manoeuvrability. Whereas German planners expected big guns to support an advance, many French officers still considered heavy weapons an encumbrance.¹⁷⁹ The President of the Technical Committee still judged the 75mm at least the equal of any other light field gun in the world.¹⁸⁰ The French General Staff advised that as the 75mm fired heavier shells than the FK 96 n/A a light field howitzer was unnecessary (although in fact the *plaquette Malandrin* would prove in wartime to be worse than useless, causing projectiles to fall short on France's own troops).¹⁸¹ Hence the EMA prepared a more offensive strategy (shortly to be embodied in France's Plan XVII), while acknowledging that little had been done to broaden the artillery portfolio;¹⁸² the 75mm remained the best gun of its type and could defeat Germany's FK 96 n/A and light field howitzers. It should remain France's principal weapon, rather than being supplementary.¹⁸⁴ Joffre later blamed the delay in modernization on parsimony in the legislature and perfectionism in the War Ministry's technical services, against which he carried less authority than did Schlieffen and Moltke. Yet in January 1914 he himself submitted what he later acknowledged to be a misleadingly reassuring assessment: 'a mobile artillery, knowing how to utilize the terrain, will rarely have need of a long-range cannon to place itself a good distance from the enemy'.¹⁸⁵ The upshot was that when on 1 April the French army created its first regiments of heavy field artillery (at the same time as Plan XVII took effect), their equipment comprised Rimailhos, seconded fortress artillery, and nineteenth-century pre-quick-firers.¹⁸⁶ The objective remained to neutralize the German guns rather than destroy them,¹⁸⁷ and the 1913 regulations discouraged massive application of artillery and stressed economy with munitions.¹⁸⁸ The gunners were not to prepare infantry attacks through preliminary bombardments, but to support them once underway:¹⁸⁹ a doctrine soon invalidated by bitter experience and revised in the war's second month.¹⁹⁰

On 5-6 July 1914 Germany's leaders secretly promised support to Austria-Hungary for an attack on Serbia in response to the assassinations at Sarajevo of the Archduke Franz Ferdinand and Sophie, Duchess of Hohenberg. Wilhelm II and Chancellor Theobald von Bethmann Hollweg acknowledged the risk of a general European conflict. But whereas Germany had passed (and largely implemented) two major army laws in 1912 and 1913, France and Russia's new programmes would take full effect only by 1917-18. In fact the evolving balance in quick-firing artillery encapsulated that in land armaments as a whole. Krupp's head, Gustav Krupp von Bohlen und Halbach, reassured Wilhelm that the potential enemy artilleries were neither good nor complete, whereas Germany's had 'never been better'; field artillery officers felt more confident than in years about their equipment and tactics.¹⁹¹ Although Moltke was absent during the first phase of decisionmaking, and asserted himself more vigorously only after returning to Berlin in late July, by then the Germans had

received an exceptional piece of corroborating intelligence. On 13 July Charles Humbert addressed the French Senate, decrying France's artillery unpreparedness.¹⁹² The next day Major Klüber, Germany's military attaché, met Colonel Dupont, the head of the EMA's Second Bureau (intelligence), who spoke remarkably freely on matters he assumed the Germans knew about anyway. Germany, said Dupont, had gained an enormous advantage in heavy field ordnance - the Rimmails were useless and France's other heavy guns outdated or not yet in service - while the 75mm had once been pathbreaking but now was the oldest of its type and inferior to the FK 96 n/A. Klüber reported his surprise at how far France had dropped behind in manufacturing heavy guns, and that whereas Humbert had denied the 75mm was outmatched, Dupont accepted it was.¹⁹³ On 31 July, the day the German Government decided on general mobilization, Moltke gave three reasons for judging the conjuncture favourable. Germany's rifle outmatched France's, and because France had just called up two new conscript cohorts much of its army was untrained; but his first point was Germany's lead in artillery. France and Russia lacked howitzers and could not hit protected infantry, and for the foreseeable future the position would never be more favourable.¹⁹⁴ The GGS supported the civilian leaders in risking war, and when that war became likely the artillery situation gave little ground for holding back.

This does not mean that the conflict was premeditated; and here it is necessary to consider ammunition.¹⁹⁵ Shells were the real artillery weapon, the cannons' and howitzers' function being to deliver them. Light field artillery shells generally carried either high explosive or shrapnel charges, the latter set with time fuses and conveying 250-300 lead balls that burst over advancing opponents with horrific effect. Although the British 18-pounder had only shrapnel munitions, other armies had stocks of both with shrapnel more numerous, the proportion of high explosive growing apace as evidence accumulated that against dug-in troops shrapnel was ineffective.¹⁹⁶ The Russo-Japanese War underlined this lesson, as well as suggesting that artillery would engage via indirect fire at longer ranges than had been expected, while consuming larger quantities of shells.¹⁹⁷ To simplify supply, the Germans introduced a 'universal shell' for the FK 96 n/A that could be adjusted for either mission, though consequently delivered less high explosive and fewer shrapnel balls than did its single-function 75mm counterparts.¹⁹⁸ Nonetheless, the Berlin War Ministry wanted the new projectile, in part because it could not predict what shrapnel/HE ratio would be needed.¹⁹⁹

Over munitions, France and Germany staged an arms race within an arms race. It had been known from the start that quick-firers would rapidly exhaust supplies. The British Army Council estimated that an 18-pounder battery could fire 3,600-5,400 rounds hourly, and no horse-drawn supply system could sustain this rate of expenditure beyond a couple of hours. Regulations warned against wasting munitions, and the Army Council allocated to each gun 500 rounds in the field, though by 1914 it had doubled that allowance.²⁰⁰ On the Continent the munitions race began after the First Moroccan Crisis, the French in 1906-11 spending 62 million francs on shells.²⁰¹ By May 1909 stocks were some 800 rounds per gun, but still deemed quite inadequate, Premier Georges Clemenceau fearing a re-run of 1870.²⁰² Targets were raised to 1,200 by 1911.²⁰³ After the Agadir Crisis Messimy told the CSDN that France had reached 1,280 but the goal should now be 1,500, and Joffre agreed that for his offensive strategy more was needed, reflecting that 'Quick-firing artillery is a great consumer of munitions'.²⁰⁴ He also wanted 1,500, but the War Ministry technical services claimed to hold precise intelligence that France had 50% more rounds per corps than did Germany and progress could therefore be slowed.²⁰⁵ In fact in August 1914 France possessed 1,390 rounds per 75mm, of which 1,190 were ready to fire. Yet French planners envisaged that by Day

Five the daily output of new 75mm shells would total a mere 13,600, and they made little preparation to draw in private industry.²⁰⁶ Indeed, contracts signed in 1906 for firms to retain the equipment needed for shell manufacture had lapsed, so the army would depend entirely on an inadequately equipped state sector.²⁰⁷

Germany had better prepared to manufacture ammunition during hostilities, but French intelligence was right that it had fewer rounds immediately available. The Berlin War Ministry acknowledged that quick-firers and indirect shooting had heightened consumption, and in 1909-14 it raised the shells assigned per FK 96 n/A from 676 to 987.²⁰⁸ Even so, the Germans knew the French had overtaken them.²⁰⁹ In 1912 the War Ministry (mirroring Messimy) raised the peacetime target to 1,200, whereas Moltke (mirroring Joffre) preferred 1,500. The War Ministry said the munitions' limited shelf life ruled out storing more, as did lack of finance: moreover, Russo-Japanese and Balkan War experience suggested 1,200 would bridge the gap until new production materialized. It anticipated 'a certain munitions tightness'. Actually when war broke out, each field gun and howitzer had about 1,000 rounds.²¹⁰ In April 1914 Moltke warned that France was spending huge sums, and pressed again for faster accumulation: after 30-40 days he expected most stocks to have gone. The ministry agreed to accelerate output, but only in the 1915 budgetary cycle: on 18 June 1914 it asked Bethmann Hollweg for twenty million marks on the grounds that due to French and Russian expenditure, 'the fastest increase in the munitions reserve is an unavoidable demand'.²¹¹ For Germany as well as France the urgency therefore heightened, but the War Ministry commented retrospectively that it was planning to raise the reserve to 1,200 by 1917 and this (as well as the failure to stockpile saltpetre for explosives) undermined any allegation that Germany had pre-scheduled hostilities for summer 1914.²¹²

The First World War became quintessentially a gunners' conflict. By one reckoning, whereas in 1870-1 the two sides had deployed one gun per 350 soldiers, in 1914 they deployed one per 200 and in 1916-18 one per 60.²¹³ The French army estimated artillery caused 67% of all its casualties; the German army attributed to it 75% of its Western Front losses in 1917.²¹⁴ Yet the campaigning to an extent confirmed both sides' prognostications. In August 1914, in the forested hills of Lorraine and the Ardennes, Germany's field howitzers adapted better than the 75mms and inflicted terrible damage. But by the Battle of the Marne in September Germany's heavy artillery had outrun its supplies, and on flatter terrain France's 75mms proved their worth.²¹⁵ Some fired 1,000 rounds per day, and French commentators thought them critical in averting defeat.²¹⁶ Almost half the 75mms were destroyed, worn out, or captured in the first fifteen months of conflict.²¹⁷ After the Marne, however, Joffre drastically rationed munitions expenditure, and even reintroduced de Bange pre-quick-firers, although Germany's guns also ran short.²¹⁸ The FK 96 n/A's mobility helped the Germans conquer territory in west and east, but in the trenches proved less advantageous.²¹⁹ Indeed in 1916 Germany introduced a heavier replacement, though reinstating the FK 96 n/A for the more open campaigning of 1918.²²⁰ Also in 1916, concealed 75mm batteries firing indirectly helped to save Verdun, but once the Germans had overrun northern France and Belgium the Allies' imperative was to dislodge them. For this purpose the French and British needed heavy and curved-trajectory guns (primarily delivering high-explosive), which took years to deploy in adequate numbers with plentiful munitions and experienced crews. On the opening morning of the Battle of the Somme, on 1 July 1916, Britain's devastating losses were due to inability to silence the opposing artillery, as much as to the enemy machine guns.²²¹ By 1918, in contrast, the French army had acquired almost as many heavy field pieces as it had 75mms,²²² and Britain's transition was similar. Still the light field gun took on new roles,

protecting the infantry with creeping barrages and drenching enemy gunpits with gas shells. Throughout the conflict what the French troops christened *Mademoiselle soixante-quinze* ('Miss Seventy-Five') remained indispensable. The 75mms fired some 200 million projectiles: today as trophies for collectors, thousands of those shells remain interred.²²³

Theoretical approaches to the arms race phenomenon centre on technological dynamism, on pressures from domestic 'military-industrial complexes', and on escalatory 'action-reaction' spirals of inter-state tension.²²⁴ In its culminating phase in 1910-14, the pre-war European land arms race was primarily a competition for manpower and for military readiness rather than for new technology.²²⁵ But during the preceding decade quick-firing had transformed the European artilleries, and to re-equip the armies with quick-firers and their ammunition necessitated unprecedented resort to private enterprise. Moreover, firms such as Krupp and Schneider became the vehicles by which the recoil-absorption system was disseminated to the Low Countries, to the Balkans, and outside Europe. French officials allowed Deport and Schneider to supply a putative enemy – Italy – and Krupp equipped potential German antagonists such as Belgium and Russia, the Berlin War Ministry accepting that exports were needed to maintain manufacturing capacity.²²⁶ Like HMS *Dreadnought*, however, although drawing on private industry the 75mm and its counterparts resulted from a command technology, developed by state rather than commercial initiative. Moreover, government financial stringency played a countervailing role throughout the story: in France, for example, with the decision for the *plaquette Malandrin*, and in Germany where the FK 96 n/A suffered from using recycled C96 barrels and the drive to increase shell stocks faltered. Indeed in general France had the edge in finance and Germany in manufacturing, although the French artillery service was a prestigious arm with a reputation for intellectual distinction, and in the early stages the *polytechniciens* outmatched their Krupp and Ehrhardt rivals.²²⁷ More generally, the artillery race's fiscal and industrial demands widened the gap between the leaders – France, Germany, Britain – and the also-rans.

Domestic considerations notwithstanding, the quick-firing revolution's biggest implications were for the European military balance. That balance was never simply a Franco-German one, and Russia in particular carried weight. All the same, whereas in 1897-1905 artillery innovation favoured France and helped deter armed conflict, after 1906 Germany first regained the advantage but then again feared losing it. The French brought in the 75mm at a critical point, prolonging their qualitative advantage. Their secrecy paid off, and they made a leap that other armies resolved as soon as possible to emulate. Russia's effort to forestall the process through the Hague Peace Conference was too tardy. The French understood, however, that the new technology would spread and that their advantage might be transient. Yet unlike the British with the *Dreadnought* they failed to consolidate and extend their lead,²²⁸ and in the second phase of the quick-firing revolution the advantage passed to Germany, which applied the new technology to howitzers and heavy field weapons. The Germans hedged their bets rather than staking all on the light field gun, and gave more thought to wartime shell production, anticipating more contingencies and better preparing for the conflict that actually occurred. They did so partly because their equipment matched better with their longstanding offensive war plans, whereas the French switched belatedly from a counter-stroke strategy to one of precipitate all-out attack. Having first expanded 75mm provision in order to maintain the numerical balance with the FK 96 n/A, the French resolved in principle to build howitzers and heavy field weapons but then failed to do so. In fact the development cycle for a new generation of French quick-firing heavy guns was not particularly slow, but the Germans still pre-empted it. Indeed, the artillery record confirms the indications that by 1914 Germany's leaders perceived a fast receding opportunity for victory, although the evidence from munitions stockpiling does not suggest that they

premeditated hostilities. Nonetheless, the quick-firing revolution's influence was pervasive. To incorporate its story is essential to a fuller understanding not only of the conduct of the First World War but also of its outbreak.

¹ Cf. *The Encyclopaedia Britannica*, 11th edn, (Cambridge: Cambridge University Press, 1910), ii, 689-90; David Herrmann, *The Arming of Europe and the Making of the First World War* (Princeton: Princeton University Press, 1996), 17; Ian Hogg, *A History of Artillery* (London: Hamlyn, 1974), 97; Bruce Gudmundsson, *On Artillery* (Westport, Conn.: Praeger, 1993), 17.

² 'A Q.F. or quick-firing gun is one of which the carriage does not recoil on firing', H. Bethell, *Modern Artillery in the Field* (London: MacMillan, 1911), 3.

³ John Headlam, *The History of the Royal Artillery from the Indian Mutiny to the Great War*, ii (Woolwich, 1937), 13; Gudmundsson, *Artillery*, 6. Field artillery (guns light enough to be drawn with their ammunition caissons by six horses and therefore to give the infantry close support), consisted predominantly of flat-trajectory long-barrelled pieces. The horse artillery were equipped with lighter weapons so as to keep pace with the cavalry. Mortars were curved-trajectory guns, stubbier and shorter-barrelled; howitzers an intermediate category.

⁴ On the pre-1914 land armaments race in general, see Herrmann, *Arming*, David Stevenson, *Armaments and the Coming of War: Europe, 1904-1914* (Oxford: Oxford University Press, 1996), and William McNeill, *The Pursuit of Power: Technology, Armed Force and Society since A.D. 1000* (Oxford: Oxford University Press, 1983). None of these works discuss the quick-firing revolution as a separate theme or in the detail attempted here.

⁵ M. de Lombarès, 'Le "75"', *Revue historique des armées*, i (1975), 80; Emile Rimailho, *Artillerie de campagne* (Paris: Gauthier-Villars, 1924), 25.

⁶ J. Challéat, *L'Artillerie de terre en France pendant un siècle: histoire technique (1816-1919)*, ii (Paris: Lavauzelle, 1935), 356.

⁷ Jean Doise and Maurice Vaisse, *Diplomatie et outil militaire, 1871-1969* (Paris: Imprimerie nationale, 1987), 50, 88-9.

⁸ Konrad Haussner, *Das Feldgeschütz mit langem Rohrrücklauf* (Munich: Oldenbourg, 1926), 18-31.

⁹ Rimailho, *Artillerie*, 24.

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- ¹⁰ Ibid, pp. 24, 405; Lombarès, ‘Le “75”’, 96.
- ¹¹ Ibid, p. 86; Challéat, *L’Artillerie*, 338.
- ¹² Lombarès, ‘Le “75”’, 92.
- ¹³ Challéat, *L’Artillerie*, 349.
- ¹⁴ Rimailho, *Artillerie*, 44, 57.
- ¹⁵ Challéat, *L’Artillerie*, 349.
- ¹⁶ Patrick Mercier, *Des Canons et des hommes: une histoire de l’artillerie française* (Lavauzelle, 2011), 84.
- ¹⁷ Cf. H. Rohne, *Studie über die Schnellfeuergeschütze in Rohrrücklauflette* (Berlin: Mittler & Sohn, 1901), 22.
- ¹⁸ Challéat, *L’Artillerie*, 364; Lombarès, ‘Le “75”’, 105.
- ¹⁹ Doise and Vaisse, *Diplomatie*, 103-4.
- ²⁰ Ibid, p. 105; Jean Doise, *Un Secret bien gardé: histoire militaire de l’Affaire Dreyfus* (Paris: Seuil, 1994), 11-12, 21; Lombarès, ‘Le “75”’, 84.
- ²¹ Rimailho, *Artillerie*, 64.
- ²² 829 batteries were built, each of four guns and twelve caissons, plus 100 training batteries, each of four guns and six caissons, 3ème Direction to War Minister, 9 Oct. 1900 [Vincennes, France], S[ervice] H[historique de la] D[éfense] 7.N.16.
- ²³ Challéat, *L’Artillerie*, 356.
- ²⁴ Lombarès, ‘Le “75”’, 102; E. Egg, et al, *Kanonen: Illustrierte Geschichte der Artillerie* (Manfred Pawlak Herrsching, n.d.), 166, [Freiburg-im-Breisgau, Germany], B[undes-]A[rchiv]-M[ilitär]A[rchiv], K.IV.C15.
- ²⁵ Rimailho, *Artillerie*, 58, 63; Lombarès, ‘Le “75”’, 102-4.
- ²⁶ Report to War Minister, 9 Oct. 1900, SHD 7.N.16.
- ²⁷ For a non-technical description, Ian Hogg, *The Guns, 1914-18* (London: Butler and Tanner, 1971), 12-14.
- ²⁸ Rohne, *Schnellfeuergeschütze*, 13; Egg, *Kanonen*, 166-7.
- ²⁹ Haussner, *Feldgeschütz*, 11.
- ³⁰ Gudmundsson, *Artillery*, 22; Dennis Showalter, ‘Prussia, Technology, and War: Artillery from 1815-1914’, in Ronald Haycock and Keith Neilson, eds, *Men, Machines, and War* (Waterloo, Ont.: Wilfred Laurier University Press., 1988), 13.
- ³¹ CSG, 30 Jan. 1904, SHD 1.N.19; EMA to Minister, 30 Jan. 1905, SHD 7.N.103; Challéat, *L’Artillerie*, 364.
- ³² Notably in his *L’Artillerie de campagne en liaison avec les autres armes* (Paris, 1892).

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- ³³ Rimalho, *Artillerie*, 33, 38-40, 45-7; R. Ripperger, 'The Development of the French Artillery for the Offensive, 1890-1914', *Journal of Military History*, cix (1995), 600-3.
- ³⁴ Robert Doughty, 'France', in Richard Hamilton and Holger Herwig, eds, *War Planning 1914* (Cambridge: Cambridge University Press, 2010), 153-4.
- ³⁵ C. Bellamy, 'The Russian Artillery and the Origins of Indirect Fire, Part I', *The Army Quarterly and Defence Journal*, cxix (1982), 211; cf. Shelford Bidwell and Dominic Graham, *Fire-Power: British Army Weapons and Theories of War, 1904-1945* (Boston: Allen & Unwin, 1985), 9; Hogg, *History of Artillery*, 111.
- ³⁶ Showalter, 'Prussia', 138; Gudmundsson, *Artillery*, 21; Rimalho, *Artillerie*, 36-7; Herrmann, *Arming*, 18; Lombarès, 'Le "75"', 94.
- ³⁷ Showalter, 'Prussia', 125-6; Gudmundsson, *Artillery*, 1-2.
- ³⁸ Showalter, 'Prussia', 131-4; Reichsarchiv, *Der Weltkrieg, 1914-1918. Kriegsrüstung und Kriegswirtschaft*, i (Berlin, 1936), 237.
- ⁴⁰ Ibid, p. 233; Eric Brose, *The Kaiser's Army: the Politics of Military Technology in Germany during the Machine Age, 1870-1918* (Oxford: Oxford University Press, 2001), 44-7.
- ⁴¹ Ibid, pp. 67; Reichsarchiv, *Weltkrieg*, i, 234.
- ⁴² Oberstleutnant Denecke, *Geschichte der Königlich-Preussischen Artillerie-Prüfungskommission* (Berlin, 1909), p. 101; Erich Schoen, *Geschichte des Deutschen Feuerwerkswesens der Armee und Marine mit Einschluß des Zeugwesens* (Berlin: Bernhard Paul, 1936), 397.
- ⁴³ Haussner, *Feldgeschütz 101*; Heinrich Ehrhardt, *Erinnerungen eines 89-jährigen Mannes und Erfindern* (Zella-Mehlis, 1928), 41.
- ⁴⁴ Ibid., 58-70; Denecke, *Prüfungskommission*, 105; R. Wille, *Ehrhardt-Geschütze* (Berlin: Eisenschmidt, 1908), 16ff.
- ⁴⁵ Volker Mollin, *Auf dem Weg zur 'Materialschlacht': Vorgeschichte und Funktionieren des Artillerie-Industrie Komplexes im Deutschen Kaiserreich* (Pfaffenweiler: Centaurus, 1968), 249-50.; Röhne, *Schnellfeuergeschütze*, 7.
- ⁴⁶ Denecke, *Prüfungskommission*, 101-5; Alfred Muther, *Das Gerät des leichten Artillerie vor, in und nach dem Weltkrieg* (Berlin: Bernard & Graefe, 1923), 13.
- ⁴⁷ Karl von Einem, *Erinnerungen eines Soldaten, 1853-1933* (Leipzig: Koehler, 1937), 84-5; Mar Köhler, *Der Aufstieg der Artillerie bis zum Grossen Krieg* (Munich: Barbara, 1938), 134.

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- ⁴⁸ Rimmelho, *Artillerie*, 59; Haussner, *Feldgeschütz*, 71, 121; William Manchester, *The Arms of Krupp, 1587-1968* (London: Michael Joseph, 1969), 254; cf. Mollin, 'Materialschlacht', 271. Pre-1914 exchange rates: £1 = 25.221 lire = 20.429 marks = 9.45 roubles = 25.22 francs = 24.02 Austro-Hungarian crowns.
- ⁴⁹ Brose, *Kaiser's Army*, 65; cf. Reichsarchiv, *Weltkrieg*, i, 234-5.
- ⁵⁰ Ibid, Anlagen, 69; Wandel to Heeringen, 21 Feb. 1912, BA-MA PH 2/87.
- ⁵¹ Brose, *Kaiser's Army*, 98; Reichsarchiv, *Weltkrieg*, i, Anlagen, 77.
- ⁵² Lombarès, 'Le "75"', 110-11; Doise, *Secret*, 98.
- ⁵³ Muther, *Gerät*, 224; Haussner, *Feldgeschütz*, 71.
- ⁵⁴ Einem, *Erinnerungen*, 65-6; Brose, *Kaiser's Army*, 130.
- ⁵⁵ Brose, *Kaiser's Army*, 97-8; Denecke, *Prüfungskommission*, 106; Reichsarchiv, *Weltkrieg*, i, 235; ibid, Anlagen, 84; Einem, *Erinnerungen*, 65.
- ⁵⁶ Reichsarchiv, *Weltkrieg*, i, Anlagen, 87; V. Mollin, 'Materialschlacht', 271.
- ⁵⁷ Reichsarchiv, *Weltkrieg*, i, 235-6; Einem, *Erinnerungen*, 85-6; Herbert Jäger, *German Artillery of World War One* (Marlborough: Crowood, 2001), 17; Denecke, *Prüfungskommission*, 106-7; Muther, *Gerät*, 19-20; Einem in Budget Commission, 12 Mar. 1909, B[ayerisches]H[auptstaatsarchiv;] A[bteilung]K[riegsarchiv], MKr. 5582.
- ⁵⁸ Wilhelm feared shields would weaken the army's offensive spirit, but Einem won him round: Einem, *Erinnerungen*, 86-7. Similarly the President of France's Artillery Technical Committee considered shields 'contrary to the French character', Rimmelho, *Artillerie*, 37.
- ⁵⁹ Reichsarchiv, *Weltkrieg*, i, 236.
- ⁶⁰ W. Heydenreich, *Das Moderne Feldgeschütz* (Leipzig: Göschen, 1906), ii, 17, 131.
- ⁶¹ Doise and Vaisse, *Diplomatie*, 146; Doise, *Secret*, 98.
- ⁶² Bernd Schulte, *Die Deutsche Armee 1900-1914. Zwischen Beharren und Verändern* (Düsseldorf: Droste, 1977), 384.
- ⁶³ Jäger, *German Artillery*, 17.
- ⁶⁴ A. Moritz, *Das Problem des Präventivkrieges in der deutschen Politik während der ersten Marokkokrise* (Frankfurt-am-Main, 1974), 280-3.
- ⁶⁵ Ibid, 212-26.

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- ⁶⁶ Einem, *Erinnerungen*, 111-12; Moritz, *Präventivkriege*, 90; Schulte, *Deutsche Armee*, 386; H. Raulff, *Zwischen Machtpolitik und Imperialismus: die Deutsche Frankreichpolitik, 1904/06* (Düsseldorf, 1976), 132; Brose, *Kaiser's Army*, 130.
- ⁶⁷ Moritz, *Präventivkriege*, 90; Gebattel reports, 22 Dec. 1905, 30 Mar. 1906, [Munich, Germany,] MKr. 42.
- ⁶⁸ Einem to Bülow, 9 Jan. 1906, [Berlin, Germany, P[olitisches] A[rchiv] des [Auswärtigen] A[mtes] R.794.
- ⁶⁹ Einem to Moltke, 18 June 1906, *ibid.*
- ⁷⁰ Einem to Bavarian War Minister, 8 Oct., Burkhard report, 9 Dec. 1906, BHAK, MKr 5580.
- ⁷¹ Reichsarchiv, *Weltkrieg*, i, 236.
- ⁷² *Documents diplomatiques français (1871-1914)* (Paris: Imprimerie nationale, 41 vols, 1929-59), 2ème série, vi, 540-43, Pendézec note, 26 May 1905.
- ⁷³ SHD 7.N.103, Pendézec/Villemejeane note, 8 June; Villemejeane note, 30 Sept. 1905.
- ⁷⁴ Ripperger, 'Development', 606; General Gascoign, *L'Evolution de l'artillerie pendant la guerre* (Paris: Flammarion, 1920), 22; cf. Doise and Vaïsse, *Diplomatie*, 140ff.
- ⁷⁵ CSG, 30 Jan. 1904, SHD 1.N.9.
- ⁷⁶ De Laguiche report, 24 June 1908, SHD 7.N.1108; cf. Heeringen in Budget Commission, 9 Feb. 1911, BHAK MKr.1133; Gebattel report, 4 Apr. 1911, BHAK MKr.42.
- ⁷⁷ Brose, *Kaiser's Army*, 145-9, Dieter Storz, *Kriegsbild und Rüstung vor 1914. Europäische Landstreitkräfte vor dem Ersten Weltkrieg* (Herford: Mittler & Sohn, 1992), 190-2; Schubert memorandum, 10 Feb. 1910, BHAK MKr. 981.
- ⁷⁸ GGS report on French army in 1911 (Feb. 1912), BHAK MKr 991.
- ⁷⁹ Moltke memorandum, 20 Jan. 1910; GGS memorandum, 7 Apr. 1911, BHAK MKr. 991.
- ⁸⁰ Mutius reports, 1 Jan., 7 June 1906, PAAA R.6748.
- ⁸¹ Artillery Technical Committee note, 29 Feb. 1909, SHD 7.N.16.
- ⁸² CSG, 12 Oct. 1908, SHD 1.N.10.
- ⁸³ EMA, 'Augmentation de l'artillerie', Oct. 1908, SHD 7.N.105; cf. de Lamothe in Chamber Army Commission, 2 June 1908 [France,] A[rchives] N[ationales] C7341.
- ⁸⁴ Brun in Army Commission (n.d), SHD 7.N.49.
- ⁸⁵ EMA note July 1909, SHD 7.N.49; Lebon and Piquart in Sous-commission des cadres, 6, 23 Nov. 1908, AN C7341.
- ⁸⁶ GGS report, 5 Dec. 1909, BHAK Generalstab 162.

⁸⁷ Gascouin, *L'Evolution*, 43.

⁸⁸ Note for Minister, 14 Dec. 1908, SHD 7.N.49. 144 in peacetime would have cost much more: EMA note on the bill (n.d.), *ibid.*

⁸⁹ Moltke report, received 23 Feb. 1908, PAAA R.995.

⁹⁰ Moltke to Bethmann, 2 Dec. 1911, PAAA R.789.

⁹¹ Ludwig Rüdiger von Collenberg, *Die Deutsche Armee von 1871 bis 1914* (Berlin: Mittler & Sohn, 1927), 123; cf. Prussian to Bavarian War Minister, 2 June 1910, BHAK MKr.1132.

⁹² Reichsarchiv, *Weltkrieg*, i, 235.

⁹³ 'Zur Komödie der Ersten Haager Abrüstungskonferenz. Aus dem Tagebuch des russischen Kriegsminister Kuropatkin', *Berliner Monatshefte*, xii (1934), 323-4; Calvin Davis, *The United States and the First Hague Peace Conference* (Ithaca, NY: Cornell University Press, 1962), 44-5; Jost Dülffer, *Regeln gegen den Krieg? Die Haager Friedenskonferenzen von 1899 und 1907 in den internationalen Politik* (Frankfurt-am-Main: Ullstein, 1978), 22ff.

⁹⁴ 'Zur Vorbereitung der ersten Haager Abrüstungskonferenz. Neue russische Dokumente', *Berliner Monatshefte*, xi (1933), 681-4.

⁹⁵ Dülffer, *Regeln*, pp. 23ff; *Documents diplomatiques français*, 1ère série, xiv, 526.

⁹⁶ 'Zur Vorbereitung', 684-9.

⁹⁷ T. Ford, 'The Genesis of the First Hague Peace Conference', *Political Science Quarterly*, li (1936), 363-9; *GP*, xv, doc. 4251; [Kew, United Kingdom National Archives, F[oreign] O[ffice Records] 65/1555, Scott to Salisbury, 1 Sept. 1898.

⁹⁸ FO 65/1555 Scott to Salisbury, 1 Sept. 1898.

⁹⁹ George Gooch and Harold Temperley, eds, *British Documents on the Origins of the War, 1898-1914* (London: His Majesty's Stationery Office, 11 vols, London, 1926-38), i, doc. 262.

¹⁰⁰ 'Hinter der Kulissen der ersten Haager Abrüstungskonferenz: aus neuen Russischen Dokumenten', *Berliner Monatshefte*, xi (1933), 573-9; *Documents diplomatiques français*, 1ère série, xiv, doc. 317.

¹⁰¹ Davis, *Peace Conference*, 11-15.

¹⁰² According to the British Prime Minister, the destructiveness of armaments had 'acted no doubt as a serious deterrent from war', Gooch and Temperley, *British Documents*, i, doc. 269.

¹⁰³ *GP*, xv, doc. 4251.

¹⁰⁴ *Documents diplomatiques français*, 1ère série, xiv, doc. 422.

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- ¹⁰⁵ Dülffer, *Regeln*, 30-2; I. S. Bloch, *Is War Now Impossible?* (English abridgement, Aldershot, 1991), 8.
- ¹⁰⁶ D. Morrill, 'Nicholas II and the Call for the First Hague Conference', *Journal of Modern History*, xlvi (1974), 305-9; *Berliner Monatshefte*, 'Zur Komödie', 327.
- ¹⁰⁷ Hogg, *History of Artillery*, 100.
- ¹⁰⁸ GGS report, Jan. 1908, BHAK Generalstab 223.
- ¹⁰⁹ GGS report, 5 Dec. 1909, BHAK Generalstab 162; GGS annual report for 1911, BHAK Generalstab 576.
- ¹¹⁰ The Schneider 75mm should not be confused with the 75mm M 1897. It was lighter and had a different braking mechanism, Rimalho, *Artillerie*, 104; Challéat, *L'Artillerie*, 513, 522.
- ¹¹¹ Muther, *Gerät*, 231; R. Poidevin, 'Les intérêts financiers français et allemands en Serbie de 1895 à 1914', *Revue historique*, clxxxii (1964), 57-8; Austrian reports in Österreichischen Staatsarchiv, Kriegsarchiv, Generalstab 1906 (25-8).
- ¹¹² Headlam, *Royal Artillery*, ii, 87.
- ¹¹³ *Ibid*, 71.
- ¹¹⁴ [Kew, United Kingdom National Archives] SUPP 6/543, Marshall Committee reports, p. 3. I am indebted to Dr Andrew Breer for this reference.
- ¹¹⁵ *Ibid*, 23.
- ¹¹⁶ Headlam, *Royal Artillery*, 13.
- ¹¹⁷ SUPP 6/543, p. 17.
- ¹¹⁸ Martin Farndale, *History of the Royal Regiment of Artillery: Western Front, 1914-18* (Woolwich, 1986), 1.
- ¹¹⁹ Hogg, *The Guns*, 19.
- ¹²⁰ Headlam, *Royal Artillery*, 77-8; Herrmann, *Arming*, 56.
- ¹²¹ *Ibid*, 87. National Library of Scotland, Haldane MSS 5919, Haldane memorandum, April 1916, 111.
- ¹²² Bruce Menning, *Bayonets before Bullets: the Imperial Russian Army, 1861-1914* (Bloomington/Indianapolis: Indiana University Press, 1992), 106.
- ¹²³ *Ibid*; Evgenii Barsukov, *Russkaya Artilleriya v Mirovuyu voiny*, i, (Moscow, 1938), 29.
- ¹²⁴ Denecke, *Prüfungskommission*, 234; Hogg, *The Guns*, 27.
- ¹²⁵ The French military attaché advised against this while the Russians continued to order from Krupp, *Documents diplomatiques français*, 1ère série, xiv, doc. 422.
- ¹²⁶ Barsukov, *Russkaya Artilleriya*, 31.

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- ¹²⁷ Denecke, *Prüfungskommission*, 237. The French attaché agreed: de Laguiche report, 27 Nov. 1913, SHD 7.N. 1478. The Russian CGS admitted the Putilov was inferior to the 75mm: de Laguiche report, 9 Feb. 1914, SHD 7.N.1535.
- ¹²⁸ Moltke report, 23 Feb. 1908, PAAA R.995; GGS reports, 1 Dec. 1907; 29 Nov. 1908, 3 Dec. 1908, BHAK Generalstab 489.
- ¹²⁹ Vadimir Sukhomlinov, *Erinnerungen* (Berlin, 1924), 339.
- ¹³⁰ John Gooch, *Army, State, and Society in Italy, 1870-1915* (Basingstoke: MacMillan, 1989), 112; F. de Chaurand de Saint Eustache, *Come l'esercito italiano entrò in guerra* (Milan: Mondadori, 1929), 106.
- ¹³¹ *Ibid*, 106-7.
- ¹³² GGS annual reports for 1907 and 1908-9, BHAK Generalstab 204.
- ¹³³ Jullian reports, 24 Oct. 1907, 5 July 1908, SHD 7.N.1369.
- ¹³⁴ Archives diplomatiques, Paris, Nouvelle série, Italie 44, Jullian report, 6 June 1908; de Gondrecourt reports, 1 Mar., 28/30 Apr., 15 May 1912, SHD 7.N.1370.
- ¹³⁵ Herrmann, *Arming*, p. 138; de Gondrecourt reports, 19 May, 25 June, 22 Dec. 5 Feb, 21 June 1913, SHD 7.N.1370; GGS reports on Italy, 1912 and 1913, BHAK Generalstab 196.
- ¹³⁶ Luigi Cadorna, *La Guerra alla Fronte italiana* (Milan: Treves, 1921), 8-16.
- ¹³⁷ Gunther Rothenberg, *The Army of Francis Joseph* (West Lafayette, Ind.: Purdue University Press, 1976), 126-7.
- ¹³⁸ GGS reports, 1 Apr., 5 Dec. 1909, BHAK Generalstab 204.
- ¹³⁹ Franz Conrad von Hötzendorff, *Aus Meiner Dienstzeit, 1906-1918*, i (Vienna, 1929), 127; GGS annual report, 5 Dec. 1909, BHAK Generalstab 204.
- ¹⁴⁰ Hew Strachan, *The First World War: i. To Arms* (Oxford: Oxford University Press, 2001), 285.
- ¹⁴¹ Hogg, *History of Artillery*, 108-9; Bethell, *Modern Artillery*, 40.
- ¹⁴² For the same reason the Germans developed more mobile and powerful siege artillery, notably the 42cm Krupp mortars used in 1914 against the Belgian fortresses. These weapons fall outside this article's remit.
- ¹⁴³ Reichsarchiv, *Weltkrieg*, i, 259; Denecke, *Prüfungskommission*, 115.
- ¹⁴⁴ Reichsarchiv, *Weltkrieg*, i, 239-40.
- ¹⁴⁵ *Das Ehrenbuch der Deutschen Feldartillerie* (Berlin: Tradition Wilhelm Kolk, n.d.), 35.
- ¹⁴⁶ *Ibid*, 243ff.
- ¹⁴⁷ Storz, *Kriegsbild*, 187.

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- ¹⁴⁸ Christian Ortner, *Die k.u.k Armee und ihr letzter Krieg* (Vienna: Carl Gerold's Sohn, 2013), 180; Rothenberg, *Army of Francis Joseph*, 174.
- ¹⁴⁹ Saint Eustache, *l'esercito italiano*, 113-14; Herrmann, *Arming*, 138; Cadorna, *La Guerra*, 9.
- ¹⁵⁰ Gooch, *Army, State, and Society*, 121; Muther, *Gerät*, 241.
- ¹⁵¹ Headlam, *Royal Artillery*, ii, xii; Gudmundsson, *Artillery*, 33, 81-2; Hogg, *The Guns*, 22.
- ¹⁵² Moltke report, 16 Feb. 1912, BHAK MKr.1002.
- ¹⁵³ GGS annual report, 12 Jan. 1906, BHAK Generalstab 489.
- ¹⁵⁴ Herrmann, *Arming*, 118.
- ¹⁵⁵ GGS Memorandum, 14 June 1913, BHAK MKr 998.
- ¹⁵⁶ GGS memorandum on Russian heavy artillery, Mar. 1909, BHAK Generalstab 208.
- ¹⁵⁷ Ibid.
- ¹⁵⁸ GGS annual report, 12 Feb. 1912, BHAK Generalstab 489.
- ¹⁵⁹ 'Die Kriegsbereitschaft Rußlands', Feb. 1914, BHAK Generalstab 925.
- ¹⁶⁰ Bruce Menning, 'War Planning and Initial Operations in the Russian Context', in Hamilton and Herwig, eds, *War Planning 1914*, 115-26.
- ¹⁶¹ [Kew, United Kingdom National Archives, W[ar] O[ffice Records] 106/1039, Knox to Buchanan, 19 Mar. 1914; de Laguiche reports, 24 Mar. 1913, SHD 7.N.1478; 19 Mar. 1913 and 9 Feb. 1914, SHD 7.N.1535.
- ¹⁶² GGS annual report, 2 Feb. 1912, BHAK Generalstab 489; Report on Russian war preparedness, 26 Feb. 1914, BHAK Generalstab 925; Moltke report on France and Russia, 26 Feb. 1914, BHAK MKr.991.
- ¹⁶³ J. Joffre, *Mémoires du Maréchal Joffre (1910-1917)* (Paris: Plon, 1932), i, 60; Wandel memorandum, 21 Feb. 1912, BA-MA PH 2/87.
- ¹⁶⁴ Doise, *Secret*, 98; F. Crouzet, 'Recherches sur la production d'armements en France (1815-1913)', *Revue historique*, dix (1974), 57-8, 83-4, shows a peak of French expenditure on land military equipment in 1898-1900 that was not matched again.
- ¹⁶⁵ Rimailho, *Artillerie*, 69ff; Challéat, *L'Artillerie*, 487-93; Joffre, *Mémoires*, i, 61.
- ¹⁶⁶ EMA note, 2 Sept. 1905, SHD 7.N.103.
- ¹⁶⁷ Moltke to Wenninger, 29 Nov. 1912, BHAK MKr.991.
- ¹⁶⁸ Douglas Porch, *The March to the Marne: the French Army, 1871-1914* (Cambridge: Cambridge University Press, 1981), 233.
- ¹⁶⁹ Herrmann, *Arming*, 151.

¹⁷⁰ CSG, 19 July 1911, SHD 1.N.10, cf. Robert Doughty, *Pyrrhic Victory: French Strategy and Operations in the Great War* (Cambridge, MA: Harvard University Press, 2005), 30; Porch, *Marne*, 235.

¹⁷¹ Stevenson, *Armaments and the Coming of War*, 220.

¹⁷² EMA note, 28 Nov. 1911, SHD 7.N.108.

¹⁷³ CSDN, 9 Jan. 1912, SHD 2.N.1.

¹⁷⁴ Joffre, *Mémoires*, i, 64; Mercier, *Canons*, 85.

¹⁷⁵ Storz, *Kriegsbild*, 260-2. Herr examined particularly the Bulgarian bombardment of the Turkish lines at Chatalja.

¹⁷⁶ Doise and Vaïsse, *Diplomatie*, 168.

¹⁷⁷ Porch, *March*, 238-9.

¹⁷⁸ *Ibid.*, 214-15.

¹⁷⁹ GGS report, 10 Dec. 1910, BHAK Generalstab 489; Ripperger, 'Development', 106; cf. Rimailho, *Artillerie*, 73.

¹⁸⁰ Bernard note, 6 Oct. 1910, SHD 7.N.107.

¹⁸¹ EMA brief for CSG, Sept. 1913, SHA 1.N.11; *Ehrenbuch der Deutschen Feldartillerie*, 40; Rimailho, *Artillerie*, 109; M. de Lombarès, et al, *Histoire de l'artillerie française* (Paris/Limoges: Lavauzelle, 1984), 243.

¹⁸² EMA, 'Plan XVII: Bases du Plan', 2 May 1913, SHD 1.N.11.

¹⁸⁴ EMA notes, 11 Apr. 1913, Jan. 1914, SHD 7.N.50.

¹⁸⁵ Doughty, *Pyrrhic Victory*, 34.

¹⁸⁶ CSG, 15 Oct. 1913, SHD 1.N.11; War Ministry on heavy artillery, October 1913, SHD 7.N.112; Doise and Vaïsse, *Diplomatie*, 169; Gascoûin, *L'Evolution*, 26; Doughty, *Pyrrhic Victory*, 89.

¹⁸⁷ Bidwell and Graham, *Fire-Power*, 14.

¹⁸⁸ Doughty, *Pyrrhic Victory*, 27-8.

¹⁸⁹ Mercier, *Des Canons*, 87.

¹⁹⁰ *Ibid.*, 91; cf. Gascoûin, *L'Evolution*, 51.

¹⁹¹ Manchester, *Krupp*, 318; Storz, *Kriegsbild*, 189-190.

¹⁹² Moltke memorandum, 31 July 1914, BHAK MKr. 991; Georges Bonnefous, *Histoire politique de la Troisième République*, ii (Paris: Presses universitaires de France, 1967), 17-18.

¹⁹³ Klüber report, 16 July 1914, PAAA R.6756.

¹⁹⁴ Geheime Staatsarchiv, Munich: Berlin Embassy, 1087, Lerchenfeld despatch, 31 July 1914.

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- ¹⁹⁵ See generally Strachan, *To Arms*, 993-1005.
- ¹⁹⁶ E.g. Gascouin, *L'Evolution*, 37-9.
- ¹⁹⁷ Storz, *Kriegsbild*, 153-4.
- ¹⁹⁸ Wandel memorandum, 25 Nov. 1911, BA-MA PH2/87; Doise and Vaïsse. *Diplomatie*, 146.
- ¹⁹⁹ Heeringen to Bethmann, 16 Sept. 1911, BHAK MKr. 5585.
- ²⁰⁰ David French, *British Economic and Strategic Planning, 1905-1915* (London: Allen & Unwin, 1982), 40.
- ²⁰¹ Joffre, *Mémoires*, i, 75.
- ²⁰² CSG, 15 May, 9 June 1909, SHD 1.N.10.
- ²⁰³ War Ministry note, 15 July 1909, SHD 7.N.49.
- ²⁰⁴ CSDN, 9 Jan. 1912, SHD 2.N.1; Joffre, *Mémoires*, i, 75-6.
- ²⁰⁵ Cf. Bru note, 18 May 1910, SHD 7.N. 107.
- ²⁰⁶ Joffre, *Mémoires*, 76-7.
- ²⁰⁷ War Ministry note, 28 Nov. 1912, AN Millerand MSS 470/AP.10.
- ²⁰⁸ Heeringen to Bethmann, 23 May 1911, BHAK MKr. 5585; War Ministry memorandum, 20 Nov. 1914, BA-MA PH 2/97.
- ²⁰⁹ Memorandum on munitions reserves, 20 May 1911, BHAK Generalstab 164.
- ²¹⁰ War Ministry Memorandum, 20 Nov. 1914, BA-MA PH/2/97.
- ²¹¹ Moltke to War Ministry, 7 Apr. 1914; Falkenhayn to Bethmann, 15 June 1914, BA-MA PH 2/97.
- ²¹² Wuther memorandum, n.d, BA-MA PH 2/97.
- ²¹³ Jäger, *German Artillery*, 217.
- ²¹⁴ *Ibid*, 218.
- ²¹⁵ Porch, *March*, 233; Brose, *Kaiser's Army*, 225.
- ²¹⁶ Gascouin, *L'Evolution*, 18; Haussner, *Feldgeschütz*, 121.
- ²¹⁷ Hogg, *History of Artillery*, 111. Britain and Russia also increased their stocks: French, *Planning*, 41; Moulin report, 15 June 1905, SHD 7.N.1477; Janin report, 17 Mar. 1911, SHD 7.N.1485.
- ²¹⁸ Cf. Strachan, *To Arms*, i, 996.
- ²¹⁹ Muther, *Gerät*, 20, 29.
- ²²⁰ *Ehrenbuch der Deutschen Feldartillerie*, 39.
- ²²¹ Tim Travers, *The Killing Ground: the British Army, the Western Front, and the Emergence of Modern Warfare, 1900-1918* (London: Allen & Unwin, 1987), 159ff.

²²² Doughty, *Pyrrhic Victory*, 118.

²²³ For a survey, Paul Strong and Sanders Marble, *Artillery in the Great War* (Barnsley: Pen & Sword, 2013).

²²⁴ Cf. Barry Buzan and Eric Herring, *The Arms Dynamic in World Politics* (Boulder, CO: Lynne Rienner, 1998), 81-2.

²²⁵ Stevenson, *Armaments*, 412.

²²⁶ War Ministry testimony to Reichstag investigation of arms sales, 8-10 Jan. 1914, Hauptstaatsarchiv Stuttgart: Abteilung Militärarchiv M.1/6, Bd. 299.

²²⁷ Gudmundsson, *Artillery*, 22.

²²⁸ Cf. M. Seligmann, 'The Anglo-German Naval Race, 1898-1914', in Thomas Mahnken, Joseph Maiolo, and David Stevenson, eds, *Arms Races in International Politics: from the Nineteenth to the Twenty-First Century* (Oxford: Oxford University Press, 2016), 21-40.