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# Science and Technology (Great Britain and Ireland)

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**This article considers the challenges faced by Britain's armies, engineers, scientists and administrators as they sought to equip the country for total war. During the first half of the war, a lack of government coordination resulted in improvisation and the adoption of equipment and weapons that had not been fully optimised. Once the Ministry of Munitions was created, bottlenecks in ordnance and equipment supply eased, but a systematic approach to war-related scientific and technological innovation in Great Britain and Ireland did not truly begin until the Second World War.**

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## Introduction

[Great Britain's](#) armed forces underwent great change in their structure, employment and effectiveness during the war. The extent to which these changes were enabled by an institutionalised engagement with experts in the fields of [science and technology](#) is open to debate. At the beginning of the war the military relied on pre-existing technologies for success on the battlefield, improvising or

adopting new [weapons](#) not yet optimised for battle. As the war continued, however, the [government](#) found itself more involved in applying science and technology to the problems created by [total war](#).

## Technology on the Battlefield

“It is beyond any doubt that this war is a war of engineers and chemists quite as much as of soldiers”.<sup>[1]</sup>

The war witnessed the invention of important and eye-catching new technologies like the [tank](#), [chemical weapons](#) and [radio communications](#). Chemical warfare and the tank produced great psychological and tactical effects when they were first used, while radio communications had the potential to speed up the tempo of operations. However, the significance of these weapons needs to be put into context. 9 million men were [killed](#) during the war. Of these, 58 percent were by [artillery](#), 39 percent were by small arms and less than 3 percent were by chemical weapons.<sup>[2]</sup> The new weapons may have caught the imagination but they were far less important than the more established [armaments](#) that made up the mainstay of the [equipment](#) issued to the mass armies of the war.

As with other nations, this is reflected in British choices about technology, innovation and change. In Britain, more effort was put into improving familiar technologies invented before the war than into developing revolutionary new systems in direct response to battle. This tension between diverting scarce resources towards exploiting new systems and making use of existing technology can be seen in a number of ways. Take, for example, the automobile. The challenge of supplying vast armies on the [Western Front](#) offered ample opportunity for manufacturers to sell new load-carrying machines to help with [logistics](#). At the beginning of the war, 1,000 civilian lorries and 100 buses were requisitioned for use by the British army.<sup>[3]</sup> As the war progressed the army continued to make greater use of motor transport. If soldiers were to have enough bullets, blankets and bully beef, however, the General Staff had to make good use of mature technologies. Ships, trains and canal boats transported the vast bulk of supplies but [horses](#) took them from the railhead to the depot.<sup>[4]</sup> Before the war the army used 25,000 horses. Far from heralding a new revolution in automotive vehicles, by mid-1917 the army had expanded its use of horses to 591,000, a figure supplemented by a further 213,000 mules, 47,000 camels and 11,000 oxen.<sup>[5]</sup>

Analogous observations about using old technologies instead of developing new ones can be made for established weapons like small arms and artillery. The British army had shown some interest in automatic [rifles](#) prior to the start of the war. Investigations into their development had, however, foundered on the reality that the Short Magazine Lee-Enfield (SMLE) had only just been introduced and required significant work before equipping the army with it. To introduce another weapon with uncertain reliability and effects so soon after the introduction of the SMLE was considered premature.<sup>[6]</sup>

Similarly, while quick-firing artillery revolutionised gun laying and bombardment, it was the trench mortar that enabled tactical engagements along the frontline. In early December 1914, Major-General Henry Seymour Rawlinson (1864-1925) stated, “This trench warfare in which we are now engaged is causing a demand for all sorts of things which are not recognised by regulation.”<sup>[7]</sup> Lacking an understanding of how to frame a military requirement in engineering terms, early demands for the mortar tended to be couched in general language. Specifications were vague and made at a point when relationships between weapon designers, engineers and those fighting at the front were ill-defined and thus poorly institutionalised. At the same time, industrial capacity in Britain was having to readjust to the demands of wartime and the prospect of arming Kitchener Armies with equipment that had not been optimised for mass manufacturing.

This failure to properly embed the management of technology change into government, industry and the General Staff led to a great deal of improvisation by soldiers in the field. In 1914, for example, the army only had access to 4-inch mortars. Faced with poor supply but increased demand, the army started experimenting with all sorts of alternative weapons of uncertain efficiency. While soldiers fielded jam-pot and hairbrush grenades, catapults and spring guns were issued to units. Eventually field forces developed a 3.7-inch pipe gun. Supplemented by 2-inch, 1.57-inch and 3-inch pipe guns, and a number of light mortars, by May 1916, “seven different service types of trench mortar had been brought into existence.”<sup>[8]</sup>

On the one hand this might appear to demonstrate the speed at which the armed forces and industry could innovate. The reality, however, was that poor integration between technologists and the service arms created both tactical and logistical challenges that themselves fed back into operational planning. While these were eventually overcome through better staff planning and smarter dissemination of tactical technique,<sup>[9]</sup> if technology itself was to make a more effective contribution towards achieving victory, then matters of industrial production and the iteration of weapon design would have to be balanced more carefully. Too many varieties of equipment restricted interchangeability, hampered repair and logistics, and slowed down the tempo of operations. Fewer types of technology and greater manufacturing standardisation would make it easier to equip mass armies and facilitate transportation. If industrialists and engineers were to properly support tactical change, then a more effective approach to managing and institutionalising technology change was needed. Indeed, as the physicist Sir Joseph John Thomson (1856–1940) of Trinity College, University of Cambridge observed, “What was needed were permanent structures which made the ‘transition from the laboratory to the workshop or ship’ as short as possible.”<sup>[10]</sup>

## Technological Consequences of the War

Fielding mass armies inevitably meant adjusting Britain’s existing peacetime economy and scaling up production to satisfy the demands of the fighting front. Making both these adjustments at the same time created societal tension and manufacturing bottlenecks on the shop floor. After the first year, the British government began to realise that these dual challenges could not be resolved

without more direct state intervention. In many instances, private industry generated innovative responses to the increased demand. Without central organisation, however, supply chains could not be optimised to make use of the limited resources that otherwise needed to be imported.

Prior to the formation of the Ministry of Munitions in 1915, the state's inability to satisfy demand led to a flood of inventions from the general public, many of whom were frustrated by the news of terrible slaughter on the Western Front. Notable among these inventors was Sir Arthur Conan Doyle (1859–1930), the author of the Sherlock Holmes detective series, who made the case for new body armours.<sup>[11]</sup> The quantity of suggestions being made by the public required the War Office, the Admiralty and, after it came into existence, the Ministry of Munitions to more formally establish their own individual Scientific Advisory Boards to consider these suggestions.<sup>[12]</sup>

In the early years of the war, however, technological innovation was made harder by organisational boundaries that inhibited innovation and perpetuated inefficiencies in mass production. In the summer of 1915, the Ministry of Munitions had been given the responsibility for fielding new ordnance. At the same time, the Ordnance Board, the Research Department at Woolwich, the proving grounds at Shoeburyness and those officers under the Director of Artillery were formally part of the War Office. This put these functions at administrative odds with those in the Ministry of Munitions and slowed down the process of researching, designing and testing new equipment types. Only once these bureaucratic hurdles were resolved in November 1915 and these departments of the War Office were transferred to the Ministry of Munitions could the process of innovation in equipment be clarified and properly institutionalised.<sup>[13]</sup>

Designing a process for receiving and evaluating new or improved versions of existing technologies was one thing. A more fundamental concern, however, was the need to produce enough ordnance to satisfy battlefield demand. In this respect, the crunch point for the British government came in 1915. In what became known as the “[shell crisis](#),” it became abundantly clear that traditional approaches to manufacturing cordite propellant would not be sufficient to meet any expanded shell production that otherwise might be engineered. A number of chemists, both from the Royal Gunpowder Manufactory at Waltham Abbey as well as academics and private individuals, rose to the challenge and developed alternative solvents that could be artificially manufactured.<sup>[14]</sup>

Even as the chemists overcame one of the bottlenecks in shell production, further innovation in the process of manufacturing was needed if supply was to keep up with demand. Here, and under the auspices of the Ministry of Supply, innovation on the shop floor assembly line started to help overcome challenges further down the supply chain. At Chilwell in Nottinghamshire, for example, Viscount Godfrey Chetwynd (1863–1936) took a completely novel approach to filling shells. As a former steelwork's manager, Chetwynd had no experience of working with explosives and was happy to apply whatever industrial techniques might make sense to facilitate mass production. The result was an innovative use of coal-crushing, stone-pulverising, sugar-drying, paint-making and sugar-sifting machinery, which used porcelain rollers usually associated with flour mills to grind TNT

and prepare propellants to fill shells. Over time the Chilwell factory filled 19 million shells, 25,000 sea mines and 2,500 aerial bombs. Unhappily, it was also the scene of the worst accidental explosion of the war when in 1918, 134 people were killed. This terrible accident aside, by the end of the war there were around 200 of these new National Factories, some of which were extremely large.<sup>[15]</sup> The factory at Gretna Green, for instance, was the largest cordite factory in the Empire, covering 9,000 acres (3,642.3 hectares), stretching for seven miles and employing nearly 20,000 people. Gretna had a maximum production of 1,000 tons (1,016 tonnes) of cordite a week and, due to economies of scale, was able to produce the propellant at a price that was around 25 percent lower than before the war.<sup>[16]</sup>

Developing standard processes for ordnance sub-components facilitated mass production. When changes in overall design were required, however, the knock-on effect in terms of workforce management could further disrupt supply. In 1903, the army had adopted the Short Magazine Lee-Enfield rifle, known as the Mark III. This weapon catered to the specialist requirements of a professional army and included long-range dial sites, so soldiers could fire to ranges of over 2,700 yards, and a wind gauge, so adjustments could be made to rear sights in windy conditions. By 1916, however, such extravagances were recognised as unnecessary in trench warfare and as a result a number of swivel lugs, butt markings, slots and the magazine cut-off were discarded.<sup>[17]</sup>

Unfortunately, these sorts of changes were not always well received by those working in the factory. The official history of the Ministry of Munitions notes, for example, that constant changes in design seriously affected the factories' output and gave rise to difficulty with employees. Occasionally these workers became discontented on account of constant variations in the details of their work. When conditions frequently fluctuated it was difficult to retain labour. In those parts of the country with a large number of factories, competition for labour was high. This gave unskilled and mobile workers the upper edge when it came to pay bargaining.<sup>[18]</sup>

<b>Producer</b>	<b>1914 (Aug- Dec)</b>	<b>1915</b>	<b>1916</b>	<b>1917</b>	<b>1918</b>	<b>Total</b>
Great Britain: Enfield	51,476	271,856	418,283	640,113	626,330	2,008,158
Birmingham Small Arms Co.	56,416	275,927	435,212	468,547	345,752	1,581,854
London Small Arms Co.	12,101	65,678	99,433	97,012	89,990	364,214
<b>Total:</b>	<b>120,093</b>	<b>613,461</b>	<b>952,928</b>	<b>1,205,672</b>	<b>1,062,072</b>	<b>3,954,226</b>

America: Ross Rifle Co. (Arrivals) (USA)	-	2,650	33,476	82,360	-	118,486
(Acceptances)	-	-	373,282	870,283	-	1,243,565
<b>Total:</b>	-	2,650	406,758	952,643	-	1,362,051
<b>Grand Total:</b>	<b>120,093</b>	<b>616,111</b>	<b>1,359,686</b>	<b>2,158,315</b>	<b>1,062,072</b>	<b>5,316,277</b>

Table 1: Small Arms Production Output Figures from August 1914 to November 1918 (actual acceptance from English and American sources of supply)<sup>[19]</sup>

More than this, increased demand for weapons and ordnance produced social tensions on the shop floor between skilled, semi-skilled and unskilled workers. The working class had always prized gaining an apprenticeship at government factories like the Royal Small Arms Factory (RSAF) at Enfield Lock. Not only did this bring better paid and more consistent work, it also meant access to night schools and accommodation. In 1892, Enfield had around 2,300 workers. By 1917, however, there were around 7,000 workers on the site, 1,000 of whom were boys and shop lads and 1,448 women. Output at this time reached 10,500 rifles a week, with a further 2,500 assembled from sub-components made elsewhere. Through the Amalgamated Engineering Union (AEU), skilled workers at the RSAF sought to protect their privileges and maintain their status even as the country geared up for mass production. During the war, union membership had helped to maintain existing controls on access to high status jobs in the tool rooms, the jig and tool drawing offices and in planning and production engineering. By Easter 1919, however, AEU membership might protect skilled workers from the worst of the downturn but the union could not stop the workforce from shrinking to 2,700 and subsequently declining to 1,350 in 1922.<sup>[20]</sup>

## Science and Society

Before the war, Britain's universities had two main functions. One was the advance of knowledge and understanding and the other was as nursemaid to the country's social elite. Much to the frustration of those scientists who were keen to make a contribution, as the war got underway, government departments were surprisingly unreceptive to offers of assistance. Sir George Paget Thomson (1892–1975), a Cambridge physicist and future Nobel laureate who went to France with the Queen's Regiment in September 1914, later recalled that, "the employment of scientists for war purposes in the First World War was a very haphazard business. Most of the young scientists joined ordinary combatant units and were sorted out afterwards, if at all."<sup>[21]</sup> Reduced to working within existing scholarly societies or organising local initiatives with industrial partners, scientists initially worked on wartime problems without much central direction from government. Specialists at the University of Sheffield, for instance, worked closely with local industry to help find ways of boosting production. In 1915, this resulted in the creation of the Sheffield Committee on Munitions of War, whose main aim was to resolve production problems. By the end of the war the committee had

contact with 450 local businesses.<sup>[22]</sup>

The efficient organisation of scientific resources within the country was further hampered by the fragmented and hierarchical structure of learned societies and academia itself. This produced intellectual and scholarly silos, which in turn were exacerbated by those government departments that finally did recognise the importance of science for the prosecution of the war. Admiral Sir [John Fisher \(1841–1920\)](#), for example, established the Board of Inventions and Research in the Admiralty in 1915. That same year, the Department of Scientific and Industrial Research was established as a committee of the Privy Council. Like the Sheffield Committee on Munitions of War, this department was expected to apply scientific knowledge to industry problems. One month later, a Munitions Invention Department was established for the Ministry of Munitions, which itself had similar responsibilities to the Admiralty's Board of Inventions and Research. With overlapping responsibilities, the central coordination of scientific research was shaped by and reflected the nature of academic life in Britain.<sup>[23]</sup>

Problems were solved but not necessarily in the most efficient ways. Sound ranging, for instance, was a technique for triangulating on and calculating the location of distant artillery fire. Done accurately, artillery guns could be laid onto their targets quickly and in ways that made the destructive and suppressive capacities of these weapons more effective. However, solving the problem of using sound to calculate range happened without central direction from the War Office. Instead, the Cambridge physicist, [William Lawrence Bragg \(1890–1971\)](#), worked with former students and mobilised Cambridge scientists and the Royal Engineers to independently work out a solution to range-finding through sound, which itself had been inspired by French innovations.<sup>[24]</sup>

Nevertheless, the problems and challenges associated with the government's initial engagement with science did produce the conditions for drawing more closely on the work of imperial and colonial universities in [Canada](#), [Australia](#), [South Africa](#) and [New Zealand](#). Settler universities reflected the narratives and politics of colonial interests. This tended to reinforce existing prejudices about race and the superiority of British civilisation. At the same time, despite having an ambition to educate a colonial elite, these institutions were much more willing to embrace practical curricula such as engineering and medicine. With the start of the First World War, this put colonial institutions in a position where they became "indispensable to national survival."<sup>[25]</sup> However, as one scholar noted, if the efforts of universities across the Empire helped to produce victory, then they also served to reinforce a narrative of British superiority.<sup>[26]</sup>

## Conclusion

Britain's ability to engage in total war evolved over the course of the First World War. Lacking central government direction, soldiers, engineers, scientists and industrialists were, for the first half of the war, compelled to improvise and do their best. They did find solutions to battlefield problems. The ability to produce optimal results that properly drew technologists and scientists down to the

frontlines nevertheless meant institutionalising a number of relationships between constituencies who had previously only worked together in ad hoc ways. As the war progressed, the creation of the Ministry of Munitions helped to address bottlenecks in ordnance and equipment supply. However, the possibility that science and technology might be systematically harnessed to deliver truly war-winning innovations would only come closer to full realisation in the lead-up to and during the Second World War.

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## Notes

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18. † Official History 2009, part I, chapter 1, p. 30.
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20. † Birchmore, Graham/Burges Roy: *The Lads of Enfield Lock. 172 Years of Apprentice Training at the Royal Small Arms Factory, Enfield, Middlesex, England 1816–1988*, Enfield 2005, pp. 16–18.
21. † Quoted in Irish, University 2015, p. 44.
22. † Quoted in *Ibid.*, pp. 55–56.
23. † Quoted in *Ibid.*, pp. 53.
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25. † Pietsch, Tamson: *Empire of Scholars. Universities, Networks and the British Academic World, 1850–1939*, in: MacKenzie, John / Thompson, Andrew (eds.): *Studies in Imperialism*, Manchester 2013, p. 145.
26. † See *Ibid.*, pp. 174–178.

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