Looking to the Second World War, historians of mathematics have shown how key cognitive advances in mathematics originated in the war efforts to break encryption, optimize logistics or process and manage information. The impact of the Great War on such 'internal' aspects in mathematics is less obvious, but, repeatedly, the chapters emphasize the operation of artillery as a military and scientific problem. During the war, mathematicians played roles in enabling the technological advances of sound ranging, aeronautics and ballistics since these were known to depend on mathematical and computational skills, as well as on technological innovation, for improvement.

Therefore the proving grounds at Gâvre in France, at the Anti-aircraft Experimental Section in Britain at Aberdeen, and the Ordnance Department in the United States became venues where different perspectives on mathematics met: military and academic, technological and more scientific, national and international. Chapters by Aubin on Gâvre; Tom Archibald, Della Dumbaugh and Deborah Kent on the United States; and Barrow-Green on Britain each situate these meetings and conflicts in their local contexts, introducing a fascinating range of individual careers to make a general claim: considerable mathematical research – in an extended, non-academic setting – emerged from the technological, military challenges of precisely firing artillery on targets that were either moving or out of sight. Moreover, these military institutions also became hybrids where knowledge and relations were built that would later shape the academic milieu in the Allied countries. Key players of post-war academia, such as Oswald Veblen, would have formative experiences and build networks through the war effort.

Thus the volume presents a wealth of information and perspectives on a topic that has received little attention in the history of mathematics but which can – and will – be of great interest not only to historians of mathematics, but also to historians of science more generally. It shows how structural grounds for comparison can emerge from careful case studies, of which more have subsequently been published from the research project.

For good reasons of focus and delineation, the present emphasis is on the Allied side, but more research should benefit from even more explicit comparative analyses of the material presented here, from comparison with similar analyses of the Axis powers, and from integrating even more with existing research into issues such as the internationalization of mathematics and the institution-building efforts of the post-war period.

The chapters are comprehensive, expertly researched and clearly presented. They make available in the English language existing, vernacular knowledge and new archival research by leading experts who contextualize developments in both local and thematic contexts. The volume is enriched by well-curated photographs and quotations, which help authentically situate mathematics within the catastrophe of the Great War. It is strongly recommended to all historians of science in the twentieth century.

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Hermione Giffard, **Making Jet Engines in World War II: Britain, Germany, and the United States**. Chicago: The University of Chicago Press, 2016. Pp. 349. ISBN 978-0-226-38859-5. $45.00 (cloth).
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In 1937, the German Otto von Ohain ran a jet engine he designed and later that year British Frank Whittle did the same. The British government, however, did not capitalize on Whittle's genius, and so Germany came to outproduce Britain in jet fighters during the Second World War. The United States, meanwhile, failed to produce their own jet engines and had to purchase British designs. With such a well-established story, it is not immediately clear why anyone should delve again into this familiar moment of aviation history. But, as *Making Jet Engines in World War II* convincingly shows, our blindness to the problems that beset our histories of the jet engine exposes much larger faults that run deep within how scholars think about technical change in the twentieth century.

Central to studies of innovation in the twentieth century is a story about the replacement of the independent inventors of the nineteenth century with the industrial research laboratories of the twentieth. This 'transition narrative' was in the textbooks in the 1970s and has remained there since. But, Giffard argues, the story is misleading. It suggests the design of a new machine as the endpoint in the process of innovation and so skips everything in between the drawing board and the use of a novelty. Within this space, the unappreciated creativity of industry appears: the laboratory and the lone inventors move away from the centre of the story while the processes of development and production are written into it.

The structure of Giffard's book reflects this important conceptual reorientation. Giffard discusses the production of the jet engine first, then its development, and finally its invention. For it was the production needs of each country that defined the aeroplanes that were made. Following this point through radically changes how we understand the creation of jet engines during the Second World War. Contrary to the familiar story, we find that Britain poured a great number of resources into developing jet engines, but concluded that they would be of little use in wartime and so refocused on building powerful and reliable jet engines that could form the basis of a strong post-war industry. Germany may have produced eight times as many jet engines as Britain in the Second World War, but not due to technical might. The Nazis were short on the strategic metals needed to develop piston-powered aeroplanes, but had masses of labour. Thousands of slave labourers in underground factories were central to the manufacture of German jet engines, which were designed so that they could be built by unskilled workers. Performance was sacrificed for production need. German jet engines were so unreliable that they were useless in combat. The decision of the United States to purchase a British-designed jet engine was not a sign of failure, but a shrewd move that ensured the Americans could develop a jet engine industry as quickly as possible. Even more than the British, the Americans came to focus on the long-term strength of their jet engine industry, not on an imagined wartime need. The American strategy worked. Not long into the post-war years, the United States came to challenge British superiority in jet engines.

Giffard shows how the jet engine was largely developed within the aero-engine industry, whose pre-existing engineering culture, machines and methods were crucial in transforming jet engines from designs into aeroplanes. One of the most transformative companies was the British firm Rolls Royce, whose work in jet engine development Giffard details for the first time. Rolls Royce identified the turbojet as key to its future and dedicated huge internal resources to the new engines, as well as taking advantage of the knowledge of other firms, the resources of the government, and their pre-existing expertise. But continuities of knowledge could also hamper the development of the jet engine. Sometimes firms held out a commitment to awkward jet engine designs because of a prior experience with certain elements of it. Different areas of industrial knowledge also mattered. Steam turbine companies were almost universally unsuccessful in developing jet engines as they found aeroplanes vastly different from the design of heavy, immovable plant. For better or for worse, the old shaped the new in jet engine development.

In talking about invention, Giffard broadens the traditional focus on Whittle and von Ohain to look at Power Jets and the Ernest Heinkel Aircraft Company, the institutions where these figures worked. For more than five years, Whittle had much control over Power Jets. But ultimately it alienated the government and the aero-engine industry by pursuing designs that served little market or military need. In stark contrast to Whittle, von Ohain had little influence over executive decisions in his firm. Against his wishes and for several years, the Ernest Heinkel Aircraft Company focused on building stunt engines to attract funding, rather than making jet engines for military use.

Neither Whittle nor von Ohain got their jet engine designs into production. Stories of their importance to the creation of the jet engine were constructed, in part, for political reasons. In post-war Britain, Whittle was consciously turned into the singular inventor of the jet engine by a country relishing its own technological brilliance and by politicians who thought championing him would bring export orders. Von Ohain was brought into a dual-inventor story as Germany sought to normalize its aviation industry and rid it of its Nazi past. Both narratives gain much of their potency from the wider cultural significance of stories about heroic, lone inventors.

Historians should not adopt popular judgements of what innovation is and where it takes place. Such assumptions, as Giffard points out, have produced a great loss of understanding that we can no longer countenance. The first step in building a far richer history of technical change is for all historians interested in invention to look at this book. Perhaps then we will see some more novelty in our histories of innovation.

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Thomas W. Patteson, **Instruments for New Music: Sound, Technology, and Modernism.** Oakland: University of California Press, 2016. Pp. xii + 236. ISBN 978-0-520-28802-7 £32.95 (paperback).
Andrew J. Nelson, **The Sound of Innovation: Stanford and the Computer Music Revolution.** Cambridge, MA: MIT Press, 2015. Pp. 248. ISBN 978-0-262-02876-9. £29.95 (hardback).
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If there is a field of human culture that is as fixated on novelty as we know the sciences and technology to be, then it may well be music, at least on the evidence of the books under review here. But what may well be of particular interest to members of our discipline is that musicians and composers have so consistently turned to new technology to realize their dreams of new music. In this sense at least, music may well provide an ideal vantage point from which to consider the histories of science and technology in modernity.

For anyone of my generation, who in the 1970s encountered the first waves of cheap synthesizers, Thomas Patteson's *Instruments for New Music* will read like an astonishing counterfactual. This delightful book reveals that the novelty sought and enjoyed by electropop fans of the punk era had its direct antecedents in the high modernism of Weimar and Nazi Germany. As many as 369 novel instruments, it seems, may have been invented between 1929 and the outbreak of the Second World War (p. 151). The composer Busoni, one of the evangelists of the millennium of new sound, wrote in his 1907 *Sketch of a New Aesthetic of Music* that the musical possibilities of symphonic instruments were almost exhausted, and that it was necessary to turn to 'abstract sound, unbounded techniques and technologies, tonal limitlessness. All efforts must push in this direction, in order to bring about a new, virginal beginning' (p. 13).

Composers, musicians, artists and engineers were all to be found pressing new and recent technologies into service to realize new kinds of music. Theremins and ondes martenot are only the remembered tips of the tip of the iceberg of new devices that seized the opportunity presented by vacuum tubes for the making of sound, and Patteson has revealed fascinating examples of what lies below the waterline of historical memory, in devices bearing names such as 'trautonium' and 'partiturophon'. But this book is much more than a prehistory to the conventional accounts of electronic music that start in the late 1940s with Pierre Schaeffer in Paris and Karlheinz Stockhausen in Cologne, as Patteson shows how many new technologies, including sound-on-film equipment, gramophone records and player pianos were put to work by artists seeking to create previously unheard kinds of music. Here we meet the artist László Moholy-Nagy joining composers such as Paul Hindemith, who fancied that, as gramophone grooves can represent any sound, it should be possible for the composer to conjure sound by direct inscription of