The Optical Munitions Industry in Great Britain 1888 to 1923

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Thesis submitted for the Degree of Doctor of Philosophy

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June 2005

Abstract

This study examines in detail for the first time the emergence and development of a highly specialised sector of British manufacturing industry, charting its evolution and explaining its growth predominantly through scrutiny of original source material relating to the key actors in the story. It proposes that after 1888 Britain produced an optical munitions manufacturing structure which succeeded in dominating production of the most militarily important and commercially valuable instrument in the field, and which by 1914 had achieved an hegemonical position in the international marketplace. The study also overturns the conclusions of the previous brief scholarship on the topic, asserting that the industry responded well to the challenges of the Great War and going on to show that there was a difficult, but ultimately successful translation back to peace.

This largely ignored branch of British technological manufacturing performed effectively and ran counter to notions of the relative decline or comparative failure of industries in the sector, and the narrative puts forward reasons to explain that success. To do this, the account employs a methodology embracing a combination of theories and models of historical explanation to demonstrate reasons for the industry's path and to test the interpretations put forward.

Acknowledgements

'This study has had a long and sometimes painful gestation and would not have been born at all without the help and support of a large number of people . . .' I make no apology for starting by using someone else's words without attribution, but they describe perfectly the process of preparing a doctoral thesis and their author will doubtless recognise them and perhaps smile at a now receding memory.

Many individuals and institutions combined to make the study possible, to assist its development and guide it to completion, but at the head of my list of thanks, no matter how it be ordered, must be my wife, Miriam, whose enthusiasm and support never wavered and who frequently showed the patience of a saint in tolerating my absences and inattention; without her the task would have been immeasurably harder.

My other debts are extensive. As an undergraduate, I was fortunate to have Dr. Alan Simmonds and Professor David Crouch at University College Scarborough drum into me the basics of reading, writing and researching history, and Alan was the first person to tell me that my idea was worth investigating. I must recognise that without the funding of an Economic and Social Research Council Studentship the project could never have been done, and express my thanks to the University of Glasgow's Department of Economic & Social History for the facilities and assistance it has provided during, and after, the duration of the studentship. My principal supervisor, Professor Ray Stokes, was a patient, tactful and enthusiastic guide whose unstinting encouragement and direction were beyond value. Dr Phillips O'Brien, my second supervisor, was generous with his time and assistance in helping me to unravel some of the complexities I encountered.

I must also thank and pay tribute to the Libraries and Archives which provided so much material from their stacks and distant dusty corners. The University of Glasgow's Archives must head the list, if only because I spent so much time there that I got to know both the institution and its staff better than any other. The National Archives at Kew, the

Bausch & Lomb Corporation Archive at Rochester New York, Bromley Library's Local History Section, Cambridge University Library, Cooke Optics Ltd, Cumbria County Archives, Hampshire County Record Office, Leeds Industrial Museum, Leicester County Record Office, the Ministry of Defence Admiralty Library, the Science Museum Library, and the University of York's Borthwick Institute for Historical Research all have my gratitude.

There are some personal thanks besides these. Alison Brech of the Borthwick Institute spent time and energy way beyond the call of duty following up ideas for me; Michael Gray passed a good deal of his scarce leisure hours listening patiently to many of my imperfectly-formed notions; Richard and Christine Gretton gave me some invaluable material support when I first began my search for information; Paul Hodgson volunteered to help me understand early 20th century accounting practices and to interpret balance sheets that would never get past today's auditing procedures; Barbara Lowrie of the ZGC Corporation generously gave me access to the private archive of Taylor Taylor & Hobson Ltd. and provided more information from her own collection of material relating to H. Dennis Taylor; William Reid provided insights into the British Army's early use of optical devices, took time to show me his extensive collection of instruments and provided insights about the working of the military mind; Viv Wray willingly proof-read my erratic typescripts, picking out surfeits of commas and other typographical errors. And Susie Fraser looked at drafts, pointed out my not infrequent weaknesses as the thesis developed, and became a wonderful friend in the process.

Finally, I wish that my friend John Freeman could have lived to read the finished document; his blunt good humour and willingness to argue a point are sadly missed.

Any errors in this work are entirely my own responsibility.

Declaration

I certify that this is my own original work and that all sources used in producing it have been duly acknowledged and cited in the text.

Stephen Sambrook.

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Introduction

1 The nature of optical munitions and the importance of the industry.

The British industry that made specialised optical instruments – 'optical munitions' – for use in warfare has not previously been systematically examined. It is curious in having been almost entirely overlooked, particularly as it constituted an important component in the evolution of scientific and technological industries in Britain during the late nineteenth and early twentieth centuries. Optical munitions were devices either specially designed or adapted for use in warfare, and used for observation, measuring target ranges, and controlling gunnery, torpedoes and aerial bomb aiming. They employed complex optical systems requiring great precision in manufacture and incorporation into mechanical mounting systems which were equally demanding in their construction, and represented highly specialised applications of optical technology that generally had no outlet into civil markets. Although optical devices such as telescopes had been used in warfare from the early seventeenth century, it was only during the last two decades of the nineteenth century that their development was accelerated by a combination of other advancing technologies that influenced and stimulated weapons design, a process that continued at an advancing pace and peaked during the Great War of 1914-1918, slowing with the return of peace and eventually being checked in 1923 through a combination of political will and financial constraint.

Optical devices became essential components of the most complex and important weapons systems that evolved during the period of this study. Without them, for example, neither the capital ship nor the submarine could have functioned effectively and would have been compromised as effective strategic instruments. The optical munitions industry that furnished these key components became a vital part of the British armaments industry.

2. Previous scholarship and conceptions.

The optical munitions industry which emerged in the latter part of the nineteenth century and grew to strategic importance in the following thirty years, has been almost entirely

overlooked and never closely examined, a state of neglect for which reasons will be suggested later. This study closes that gap in knowledge, and shows a capable and effective industry whose performance runs counter to some frequent conceptions of shortcomings in British technological manufacturing in the early 20th century. It explains why this new industry emerged, charts its evolution, provides a chronology and a cast of players in the perspective of contemporary events, and describes and explains the relationship that developed between the industry, the State client, and the armed forces which used its products. The account demonstrates the growing importance of optical instrumentation in warfare and explores how the armed forces' attitudes to optical munitions were influenced not only by national and international politics but also by institutions and traditions within their own structures, which in turn affected both the pre-war development and post-war survival of the optical munitions industry. The story shows that an overlooked facet of British technological manufacturing had sufficient skill and commercial ability to compete so successfully for foreign business before the Great War that it reached a hegemonical position which was eroded only by the massive political and demographic changes caused by the reversion to peace in the early 1920s.

Despite its importance, the optical munitions industry has not only been almost entirely overlooked, but what little that has been written about it has created a number of misconceptions. The nature of optical munitions themselves has not generally been understood by historians dealing with industry and individual businesses, who have accepted that military optical devices were either the same as those intended for civil use or little more than modifications of them. Nor have they recognised the growing importance and significance of optics in warfare after the 1890s and the consequent importance of the firms making them, and none have made the connection that places optical munitions manufacture within the field of the armaments rather than the scientific instruments industry.

The first printed account dealing with the optical munitions manufacture was in the *History of the Ministry of Munitions*, prepared in 1922 as an official record of that body's

work during the Great War.[1] Its relatively brief coverage of war-time optical manufacturing (just forty four pages in a twelve volume work) related to what it described as 'The Optical and Scientific Instrument Trade'. Two principal problems have arisen from this account and misdirected later scholars. Firstly, it located the production of optical munitions within the commercial instruments industry, a position which has subsequently been accepted without question but which this account will show to be erroneous. And secondly, it maintained that the earlier production of optical munitions took place within the context of a backward and inefficient optical industry, an impression that has also been generally adopted. This study demonstrates the inaccuracy of those interpretations and illustrates how they have helped to generate misconceptions and errors in the recognition and understanding of optical munitions production in Britain.

For example, Roy and Kay MacLeod's study of the British government's relationship with the optical instruments industry during the Great War drew on both the official *History* and some Ministry of Munitions files, reinforced by contemporary reports and published correspondence.[2] They saw optical munitions production as part of the general optical instruments industry's activities rather than in a separately identifiable sector. Their concern was principally with the State's 'mediations' in what they described as the 'science-based industries' that included those making optical instruments, and they considered that the production of optical munitions took place 'at the extreme end of the science-based industries'.[3] Following the lead given by the Ministry's account, they emphasised the inadequacy of the pre-war optical industry and the transformation achieved during the war, whilst recognising that they had 'been unable to look in detail at individual optical technologies . . . or the business histories of individual firms'.[4] Had they been able to direct their examination down those routes, a very different picture would have emerged.

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[1] Great Britain, Ministry of Munitions, *History of the Ministry of Munitions*. 12 vols. (London: HMSO, 1922).
[2] R. and K. MacLeod, "Government and the Optical Industry in Britain 1914-1918." In *War and Economic Development*, edited by J. M. Winter. (Cambridge: Cambridge University press, 1977) p. 165.
[3] MacLeod (1976) p. 191.
[4] MacLeod (1976) p. 166.

Mari Williams touched on optical munitions production when she compared aspects of the British and French 'precision industries' between 1870 and 1939, in the context of connections between precision engineering and the military sciences.[5] She identified precision industries as those 'at the forefront in scientific, technical and industrial research',[6] and although not dealing specifically with optical manufacture recognised there were links between such industries and the armed forces that had a catalysing effect on them. Williams cited the case the case of the Glasgow rangefinder makers Barr & Stroud as an instance of how such connections could encourage and shape the growth of a particular business.[7] Nevertheless, she saw Barr & Stroud as part of the instrument making community and, despite the company's total lack of either commercial products or civil clients, failed to recognise its close connection with the armaments industry. In her discussion of the Great War period, Williams took up the theme developed by Roy and Kay MacLeod, citing from their earlier work and archival material from surviving Ministry of Munitions' files, accepting that a weak pre-war industry had been in need of State intervention.

A third reference to optical munitions manufacture is found in Anita McConnell's history of the York optical firm of Thomas Cooke Ltd.[8] She showed the firm's involvement in optical munitions production before the Great War, but because much of that was 'instruments adapted to military needs', or derived from earlier types of survey instruments designed originally for the civil market, she regarded them as essentially no different from the firm's other commercial optical apparatus.[9] However, McConnell made it clear that by no means all of the optical munitions produced by Cooke had any likely civil sales; the Watkin depression rangefinder and Grenfell gunsights, for example, were designed specifically for use with artillery, and a marketing agreement with Grenfell and the arms producers Vickers was signed in 1896.[10] Despite this separation

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[5] M. E. Williams. *The Precision Makers; a History of the Instruments Industry in Britain and France 1870-1939.* (London: Routledge, 1994). In particular, see chapters 2, 3, and 4.
[6] Williams (1994) p. 1.
[7] Williams (1994) p. 34.
[8] A. McConnell. *Instrument Makers to the World; a History of Cooke, Troughton & Simms.* (York: William Sessions, 1992).
[9] McConnell (1992) p. 64, and pp. 72-78.
[10] McConnell (1992) p 65.

from civil marketing, like the MacLeods and Mari Williams, she still saw optical munitions manufacture as an adjunct to commercial instrument production rather than a separate enterprise.

This failure to identify the importance of optical munitions in the context of industry and business has been paralleled in the study of military technology and warfare, where optical devices have been seen as subordinate elements of other more elaborate weapons systems, rather than as critically important artefacts in their own right. Jon T. Sumida's detailed study of the introduction of gunnery direction (fire-control) systems into the Royal Navy between 1889 and 1914 emphasised the primary importance of the mechanical computational elements that predicted the future position of a moving target, minimising the vital role played by the optical instruments that provided the initial target distance required to set the process in train.[11] Norman Friedman's lengthy examination of the evolution of the U.S. submarine confined discussion of the periscope – the only means by which a submerged vessel could see what was happening above the surface and thus function as an underwater weapon – to an appendix, even then concentrating largely on the context of its installation and maintenance in the boat's hull.[12] Like Sumida, he relegated optical instrumentation to a secondary role within a larger technological system, and in his companion history of U.S. battleships gave even less attention to the question, mentioning optical fire-control on only seven of 450 pages without indicating its importance at all.[13]

British historians have followed similar paths. In their major history of the design of British capital ships after 1912, Alan Raven and John Roberts devoted only one paragraph specifically to rangefinders in the period between then and 1922, and Ian Hogg and John Bachelor allowed just one page to optical munitions in their comprehensive

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[11] J. T. Sumida. *In Defence of Naval Supremacy; Finance, Technology and British Naval Policy 1889-1914.* (London, Routledge, 1993). See chapters 3, 5, and 6 for details on fire-control systems as a self-contained technological entity.

[12] Norman Friedman. *U.S. Submarines through 1945; An Illustrated Design History.* (Annapolis, MD: Naval Institute Press, 1995). p. 267 ff.

[13] Norman Friedman. *U.S. Battleships; An Illustrated Design History* (London, Arms and Armour Press, 1986). See Index.

history of the naval gun and its employment.[14] John Brooks examined the location of fire control equipment aboard early twentieth century battleships in great depth without giving any attention to the nature of optical instruments themselves.[15] This characteristic passing-over of optical technology was partly explained by D. K. Brown, another historian of warship design, when he said that he took into account 'the technology of … fire control … only [in its] impact on the overall design of the ships'.[16] Historians of naval armament technology have not been oblivious to optical munitions, but through a repeated subordination to other considerations have minimised their importance and so failed to introduce any significant body of knowledge into the literature of armaments and their application.

The only published work dealing in any detail with optical munitions manufacture remains Michael Moss and Iain Russell's history of the Glasgow rangefinder makers Barr & Stroud Ltd, commissioned by the firm to mark its centenary in 1988.[17] Not intended to be either a critical or analytical account of the company, still less a survey of an entire industry, it is a straightforward record of the firm's inception and growth that provides a narrative account of its fortunes as a specialist maker of optical munitions. The authors had access to the company's large archive, and the book contains much useful basic factual content about the business, as well as some contextual information. However, its 'broad brush' nature precluded any analysis of the company's development and inter-action with the State, so that the book is something of an aperitif to the whole subject of optical munitions production rather than being a meal in itself.

3 Themes, theories and models.

The history of the optical munitions industry cannot be encapsulated or fenced-off from other history. It existed not only within its own business world and the pursuit of its

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[14] A. Raven and J. Roberts, *British Battleships of World War II* (London: Arms and Armour Press, 1976) p.79, and I. Hogg and J. Batchelor, *Naval Gun* (Poole, Dorset: Blandford Press, 1978) p. 108.
[15] J. Brooks, "The Mast and Funnel Question: Fire-Control Positions in British Dreadnoughts 1905-1915." In *Warship 1995* (London: Conway Maritime Press, 1995) pp. 40-60.
[16] D. K. Brown, *The Grand Fleet; Warship Design and Development 1906-1922.* (London: Chatham Publishing, 1999) p. 7.
[17] Michael Moss and Iain Russell. *Range and Vision; the First Hundred Years of Barr & Stroud.* (Edinburgh: Mainstream Publishing, 1988). In particular, see chapters 1 to 3.

specific scientific research, but also in context of evolving military technology and the political will to employ and exploit such technologies within a framework of national security and foreign policies. As a result, its story embraces not only elements of entrepreneurship and invention, of business history and the growth of business structures – what may be called 'internal' elements – but also has a content concerning the evolution of military technologies, of naval and military history, as well as domestic and international politics – the 'external' elements. Although the principal theme is of an evolving industry responding to developments in military and naval technologies and growing eventually to become a strategically critical part of the national armaments industry, there are other themes which emerge from the external context, interweaving with and adding layers to the story, enriching the account but complicating its telling and explanation. These contributing themes include the nature of military and naval societies, the State's attitude to rights of inventors and the international proliferation of armaments, the economic factors influencing expenditure on arms, and the willingness of government to sustain vital elements of the defence industry in peacetime. The story of the industry is diverse and complicated, and it must look for the theoretical underpinnings of historical scholarship to guide and facilitate its interpretation and explanation.

There is no shortage of theoretical underpinning to draw on; the problem is to decide if any one theory or model might possibly serve as a unifying thread to run through the study. Notions of technological determinism might seem highly appropriate to the understanding of the industry at a time when advances in military technology were acting 'as a crucial agent of change' in how armies and navies saw the potential of new weaponry and acted to acquire it.[18] Advances in armaments technology between the late 1880s and the early 1920s could be interpreted as having led the governments of the major (and some minor) powers into 'a situation of inescapable necessity' where they had to acquire the latest and most sophisticated weapons systems, a seemingly clear-cut case of what Merritt Roe Smith and Leo Marx called 'hard determinism' where technology itself is credited with 'the power to effect change'. As the following account

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[18] M. R. Smith and L. Marx, editors, *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge, Massachusetts: MIT Press, 1994) pp. ix, xii, xiii and xiv are the locations of the quotations in the rest of this section.

will show, this seems sufficiently convincing at the start of the story, when the technology of new explosives led to the development of weapons whose effective deployment demanded the creation of new instruments for their direction. However, subsequent changes through time indicate that the development of both instruments and industry was influenced as much by those involved with them as by the inexorable pressure of technological evolution.

The accommodation of this trend could be more suitably reached through the alternative understanding, still in the area of determinism, that 'the history of technology is a history of human actions', demanding comprehension of the social, political and economic circumstances surrounding those responsible for a particular advance in order to provide explanation for it. This 'soft determinism' argues that the agency for change through technological development lies not in technology itself but in the structure of the society in which it is located. Comprehension of the nature of technological power requires understanding the 'actors' who were at the heart of the process.[19] These approaches lend themselves to a process of fusion where, as Smith and Marx suggest, technological determinism may be understood as being the human characteristic of producing societies, whether military or civil, that 'invest technologies with enough power to drive history'. However, the industry's evolution will be seen to involve a great deal of influence from areas which were not themselves directly connected with the developing technology, raising the question of whether the 'softly deterministic' approach can actually be adequate to explain the process of evolution that took place.

The nature of those outside influences and forces will be seen frequently as other than technological in their nature, issuing from a variety of sources located outside the industry itself, all having their own particular interests and priorities which were by no means always similar. The industry's story is made up of a 'seamless web of technology and society', where the overall context in which technological developments were located played a significant part in the identification and solution of problems in the

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[19] Smith and Marx (1994), p. xiii.

development of optical munitions.[20] Contextual factors frequently heavily influenced the nature of solutions to perceived problems. The 'social construction of technology' method (SCOT) might be used to explain how non-technological factors, emanating from distinctly identifiable social groups whose interests or goals were by no means identical, shaped the evolution of instrument design (and the industry itself) and then influenced the recognition of a particular solution as being appropriate for its intended purpose. SCOT suggests that technology is socially constructed by groups of people involved in a process of innovation and who, individually and collectively, interact with each other in order to produce a particular artefact. In this study, the term artefact can be applied both to the instruments being made and to the industry which produced them. These groups, or 'actors', may have differing views of the 'proper' form of the artefact involved, but work towards a 'stabilised' outcome to achieve 'closure' of a process which is essentially social rather than technical in its nature.

Although the social constructivist approach promises here to allow a better understanding of contextual factors than soft determinism might, it still leaves some difficulty in explaining certain aspects of the industry's evolution. This is particularly so in respect of events during the Great War, where attempts to overhaul the optical munitions industry were frustrated by a set of factors which were by no means covered by the social dimension, being inherently technical in their nature and suggesting a decidedly determinist nature. Taking into account the apparent appropriateness of some aspects of the industry's development for deterministic interpretation, it seems fitting to ask whether SCOT is, after all, the ideal model to adopt.

The 'systems' approach to the study of the history of technology adopted by Thomas Hughes, which stresses the importance of attention to 'the different but interlocking elements of physical artefacts, institutions, and their environment', seems best suited to facilitate the assimilation of the variety of factors bearing on the development of the

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[20] W. E Bijker, T. P. Hughes and T. J. Pinch, editors., *The Social Construction of Technological Systems: New Directions in the Sociology and History and Technology* (Cambridge, Massachusetts: 1989) p.10 supplies the quotation.

optical munitions industry.[21] Although recognising the essentiality of considering both non-technological and social factors, Hughes maintained it was not possible 'to deal separately with the technological and the social' in considering the evolution of technology.[22] Unlike the SCOT approach, in Hughes' view social interests should not be seen as especially privileged. Furthermore, he argued that those involved in the development of technological industries had to consider how their artefacts related to the social, political, economic and scientific contexts that surrounded them, defining them as 'system builders' who perforce had to manage a plethora of variables in order successfully to place their artefacts in 'an enduring whole'.[23] Hughes went on to explain how these system builders evolved strategies to cope with problems that occurred in the growth of their particular areas, providing a 'model-within-a-model' to understand their development.

Of all the models considered, this approach promises to allow the most satisfactory understanding of the range of social and technological forces that bore directly and indirectly on this industry, Hughes' model may indeed be interpreted as 'a kind of soft determinism'[24] but he maintained that his emphasis on what he termed technological momentum permitted 'a more flexible mode of interpretation', a condition which will be particularly useful here. In his view, the social constructivist approach was particularly applicable to the understanding of 'young' technological systems, whereas determinism was better adapted to the comprehension of 'mature' ones. In the case of the optical munitions industry, whose history here goes from embryonic to mature, this model has more to commend it than the others.

Any of the 'determinist', 'constructivist' and 'systems' approaches could therefore be employed successfully in considering the optical munitions industry, although one promises to be more successful than the others. But, because of the diversity of themes

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[21] Bijker et al. (1989) p. 4 supplies the quotation.
[22] D. Mackenzie, 'Missile Accuracy: a Case Study in the Social Processes of Technological Change' in Bijker et al., p. 196.
[23] J. Law, 'Technology and Heterogenous Engineering: The Case of Portuguese Expansion' in Bijker et al (1989) p. 112.
[24] David Hounshell, 'Hughesian History of Technology and Chandlerian Business History: Parallels, Departures and Critics' in *History and Technology*, 1995, Vol. 12, p. 215.

that occur through the phases of its development, it seems appropriate to consider whether any single theory or model can in fact be applicable throughout. No matter how attractive may be the idea of a single one to bind together the story, the changing nature of the emphases revealed throughout the account (as in the Great War period mentioned above) suggests the need to consider the appropriateness of employing, or at least referring to, more than one type of theoretical underpinning. Although proponents of determinism and constructivism may argue that those approaches are frequently mutually exclusive, as the story unfolds it will suggest that at different stages in the industry's evolution one approach does better suit the case than another. Accordingly, even though Hughes' systems approach has much to commend it as the most suitable model which will be chiefly used as an aid to understanding the changes that took place during the period of this account, where necessary it will be supplemented by reference to the other models mentioned above.

4 Strengths and weaknesses of resource bases.

The scarcity of published material on the industry means that this study relies on archival sources for almost all its detail and also for much of its supporting background matter. So far as the industry itself is concerned, it is frustrating that so few records have survived for many of the individual companies, and in some cases almost nothing could be located. Details for two of the Royal Navy's largest suppliers of sighting instruments – W. Ottway & Co. Ltd. and the Ross Optical Company Ltd. – are virtually non-existent, apart from trade catalogues and advertisements. Little more than trade catalogues remain for R. & J. Beck Ltd., which became a very large munitions producer during the Great War. Happily, more details remain for other firms such as Adam Hilger & Co. Ltd, and Thomas Cooke & Sons Ltd, both of which had significant roles in the production of optical munitions. The Hilger material, although modest in quantity, provides details of the firm's size and its premises, and includes a memoir left by its Managing Director relating to his work with the firm before 1925. Cooke's records, although incomplete, include the indexes to its design office drawings for the period up to 1914, and the Directors' Minute Book up to the business being wound up in 1923.

Most importantly, a very large amount of material has been preserved by Barr & Stroud Ltd. which not only became by far the largest British optical munitions producer, but also made the single most important type of instrument, the rangefinder. The collection includes material relating to the firm's foundation, and its earliest correspondence with the War Office and Admiralty, as well as letters and memoranda passing between the firm's principals during its early years. The material increases substantially for the company's later years, and after 1900 there is an almost complete set of financial records, orders and contracts, as well as a wealth of correspondence with British and foreign State clients, foreign agents and domestic sub-contractors. It provides the 'thick description'[25] that yields much detail not only about the company's day to day activities, but also its attitudes to its domestic and foreign customers.

Company sources alone however, no matter how detailed, would not permit a balanced and reasoned assessment of the optical munitions industry's progress. Even the Barr & Stroud collection lacks the letters written to the business, only their replies having survived. Fortunately a large body of Admiralty, War Office, and Ministry of Munitions records provide both qualitative and quantitative information relating to the Services' and the State's attitudes to both the industry and the instruments themselves. The naval and military material provide much important and highly relevant context to allow explanations of how the industry evolved, particularly in the period up to the Russo-Japanese War. Other context, particularly relating to dealings with both the Royal Navy and foreign navies, is to be found in published works dealing with the technological and political background to the growth in armaments from 1905 to 1915. For the Great War, when the industry was placed under previously unimagined pressures, the surviving Ministry of Munitions records provide information that reveals a great deal more about the industry than the printed account even hints at, and allow an explanation of why the official history came to paint such a misleading picture of the pre-war optical industry as a whole.

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[25] Bijker et al. (1989) p. 5.

5 Chapter outline.

The opening chapter considers the underlying reasons that led to the War Office's public advertisement for a practical and effective distance measuring device in 1888, an event that conveniently marks the start of systematic optical munitions manufacture in Britain. In exploring how evolving late 19th century military technologies created a new demand for specific optical aids to gunnery, it introduces the notion that social forces within the Army itself had already begun to generate a specific understanding not only of what forms those aids should take, but also what was the relevant social group to design them and by what means they should be procured. It shows how those ideas became so firmly entrenched that they acquired a significance that would influence attitudes towards both instruments and industry until the upheaval of the Great War finally forced their wholesale revision. This combination of deterministic and constructivist factors develops to the start of the Boer War in 1899, when the emergence of a distinct specialised manufacturing structure for optical munitions becomes clear. At the same time, the growing importance of the Admiralty appeared, stressing the increasing significance of the rangefinder. In considering the emergence of the monopoly of Barr & Stroud in British rangefinder manufacture, the account shows how that firm was able to establish itself so successfully and quickly, and suggests why other established companies in the optical field failed to capture this business.

The period from the Boer War to the end of the Russo-Japanese war in 1906, dealt with in the second chapter, marks an increasing use of optical devices on land and at sea, together with a growing complexity in the story. These were the first occasions when optical munitions were systematically used in battle and the chapter discusses the influence that both conflicts had on the progress of their subsequent development and incorporation into both British and foreign armies and navies. Questions of the relationship between specialised British industry and the State and the capacity for industrial mobilisation in time of war add layers to the account, emphasising the financial and organisational problems involved in optical munitions production besides the technical difficulties involved in the development of the instruments themselves. The continued growth of Barr & Stroud and its simultaneously deepening relationships with

both the Royal Navy and foreign powers opens up issues concerning conflicts of commercial interest, involving secrecy, patent protection and monopoly of supply.

The succeeding chapter covers the stage from 1907 up the outbreak of the Great War, illustrating how optical munitions (and by extension their makers) became confirmed in their importance, especially through their incorporation in the most important contemporary strategic weapon system, the Dreadnought battleship. It emphasises how one firm and one instrument came to dominate the whole question of optical munitions production, and shows how far political and economic considerations rather than advancing technology were coming to affect the whole question of market potential. Scrutiny of the relationship between the British armed forces and the optical munitions suppliers emphasises the weakening of a case for a straightforwardly deterministic explanation of the industry's evolution and suggests that the growing complexity of relations between the key maker and the British government was influenced as much by technological as by social factors, emphasising the relevance of Hughes' systems approach in the interpretation of events.

Because the Great War of 1914-1918 was by far the most important episode in which the industry was involved during the period of this study, three chapters are devoted to it. A number of new issues are introduced there, some of which seemingly shift the emphasis back to the appropriateness of a more determinist explanation for the industry's evolution, whilst others similarly appear to emphasise the validity of social explanations, reinforcing the better applicability of an analytical model that embraces both fields. The first war-time section analyses and assesses the performance of optical munitions making up to the summer of 1915 and suggests that, contrary to some previous accounts, the failures in delivery stemmed principally from the War Office's own organisational inadequacies rather than shortcomings in the structure of optical manufacturing. Nevertheless, the analysis identifies weaknesses in the trade, relates them to contemporary perceptions of the whole optical industry, and then explains how they influenced the State's subsequent efforts to mobilise and transform it.

The second chapter on the Great War period examines how the creation of the Ministry of Munitions resulted in what amounted to the conscription of the civil optical instruments trade into what became a hugely expanded but temporary 'hostilities only' optical munitions military-industrial complex, and explains the agenda that was pursued by some Ministry officials in an effort to rejuvenate optical manufacturing capability and produce an efficient instruments industry that would compete successfully in the expected post-war market place. The account demonstrates that the relatively restricted success that was achieved was largely through the immediate pressure of technical issues resulting from the pressures created by the war itself, which were sufficiently powerful to negate the efforts of the social group attempting to further reorganisation. It also considers the massive scale on which the war-time industry was expected to operate, and the means by which the Ministry regulated and directed its daily activities.

The third of the sections devoted to the war uses case studies to examine the performance of three distinctly different instances of optical munitions production, examining by what means and with what degree of success each one operated. It is in this stage that Hughes' model becomes particularly relevant to comprehending the complexity of the forces that were actually driving the social groups involved, a disparate grouping of military, technological, political and business 'families' responding both collectively and individually to a frequently conflicting body of requirements.

The following chapter deals with the problems of industrial demobilisation immediately following the end of the Great War, illustrating how the Ministry of Munitions' reformation plans for the optical industry were frustrated, this time by a range of factors that were more socially constructed than technologically determined . It details the extent of the problems facing both the 'regular' and the 'conscript' optical munitions industries, emphasising how different the two branches were and illustrating the differing strategies attempted in converting back to peace. The coverage of the industry once more becomes focussed on just one company, reflecting the increased importance that Barr & Stroud had acquired during the war and how the rapid and major cut-backs in both the Army and

Navy paradoxically accentuated its commitment to optical munitions rather than stimulating a determined effort to diversify into civil product lines.

The closing chapter describes how, by 1923, the development of optical munitions had been checked not by a limitation of scholarship in military technology, but by political will driven by fiscal prudence allied to military and naval uncertainties about the likely nature of warfare in the light of maturing weapons technologies such as the aeroplane and submarine. The account shows how these factors effectively led to the beginning of a hibernation that lasted until the re-armament programmes of the late 1930s. At this point, the momentum of military technology might be seen to exert what could be termed a 'reverse hard deterministic' effect on the industry, where the financial costs and political implications of armaments programmes led the principal powers once again into 'a situation of inescapable necessity', but this time with the opposite effect of the same condition before 1914. Then, the condition had led to massive expenditures, but by 1923 it was pressing governments to scale back spending drastically. At the close of this story, optical munitions production in Britain is shown to be reduced in scale to a level at which its continuation by those involved represented almost a gesture of faith and patriotism rather than sound business sense, a circumstance again best explained through a fusion of deterministic and constructivist theories on the lines suggested by Thomas Hughes.

5 Summary

This study continually shifts focus to bring into clear view the internal and external factors that governed the industry's evolution in response to unprecedented changes in the scale and scope of military technologies. As with an optical system, the closer the study gets to its subject, the harder it is to keep it all in focus, particularly where the shape of what is under examination is often ill-defined. Inadequacies and gaps in the source material used to build up an image of the industry mean that there are unavoidably parts of the larger picture that cannot be seen clearly, despite the best efforts to interpret and extrapolate meaning from established facts in order to re-construct events and provide explanation. The total elimination of aberrations that distorted the images

produced by the lenses of the optical instruments described in the following pages was indeed impossible, and their designers were obliged to settle not for perfection but for what was possible with the knowledge and materials available. This account is governed by similar constraints, and if at times the picture is less than crystal clear then (like the instruments themselves) it must rely on having enough clarity to show this particular portion of the past essentially as it was.

Chapter 1
The emergence of the industry, 1888 to 1899

1.1 Introduction

In 1888 there was no recognisable optical munitions industry in Britain, principally because neither the Army nor the Royal Navy used specialised optical instruments on a scale large enough to support any business in their manufacture. Although both employed telescopes for observation and signalling, they were issued in small numbers and were little different to those sold commercially. Telescopic gun sights were rarely used and rudimentary rangefinders were found only in the Army.[1] This situation began to change after the late 1880s, not because of progress in optical science but because developments in armaments technologies created problems in maximising the potential of new weapons that were capable of solution only by the application of optical technologies. As the range and accuracy of guns increased, it became essential to know target distances in order to set elevations correctly, and to have some means to aim at targets so far distant as to be almost invisible to the eye. These needs were not entirely novel, and both services had experimented with rangefinding instruments and aiming telescopes in a haphazard manner since the 1860s, but only with the arrival of the new more powerful 'nitro' or smokeless propellants did the conditions emerge where optical aids to gunnery became not just desirable but essential. As a result, the Army and Royal Navy began separately to seek new instruments and so created conditions which could nurture the growth of a distinctive optical munitions industry. By far the most important of these gunnery instruments was the rangefinder, and this first chapter examines its manufacture in the light of developing technology and the contextual influences affecting it, considering how innovation in armament technology came to drive specialised optical manufacturing into a completely new sector that sat between civil optical instrument production and the armaments industry.

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[1] For descriptions of observation instruments, see W. Reid, "Binoculars in the Army, Part 1: 1856-1903." *Army Museum* (1981), and R. J. Cheetham, *Old Telescopes* (Southport, Lancashire, 1997), and for descriptions of early rangefinding devices, see Great Britain, Army. *Regulations for Musketry Instruction 1896* (London: HMSO, 1896).

1.2 The War Office and its Rangefinder Paradigms

In May 1888, faced with the introduction of a new infantry rifle that could be used at ranges of a mile or more,[2] the War Office published an advertisement in the London journals *Engineering* and *The Engineer* inviting designs for a rangefinder suitable for use by the Infantry, which marked a convenient point to start chronicling the emergence of specialised optical munitions production in Britain.[3] The Army already used small numbers of rudimentary range measuring devices based on surveying instruments using techniques that were well known to civil engineers.[4] These used the principle of triangulation, setting out a base-line of known length perpendicular to the object whose range was required, and then measuring the angle subtended between the target and the extremity of the base in order to calculate the target's distance. They had all been devised by serving officers and manufactured by optical instrument makers who produced for the civil market. The only successful rangefinder then in service was a highly specialised device used by Coastal Artillery in fixed and elevated defensive positions and which was incapable of being used by mobile forces.[5] This 'Depression Rangefinder' (so-called because it measured the angle of depression between itself and the target in order to produce a distance reading) had been devised by a Royal Artillery officer, Major H. S. Watkin, who had also produced another instrument for Infantry known as the 'Field Rangefinder', based on the surveyor's box-sextant.[6] Like earlier attempts to make military rangefinders by Captain Nolan and by Major Weldon in the 1860s and 1870s,

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[2] For the background to the new rifle, see E. G. B. Reynolds, *The Lee Enfield Rifle* (London: Jenkins, 1960) Chapter 1.

[3] M. Moss and I. Russell, *Range and Vision: The First Hundred Years of Barr & Stroud* (Edinburgh: Mainstream Publishing, 1988) p. 13. Their illustration is not the notice of 25.5.1888, for which see University of Glasgow Archives, Barr & Stroud, City of Glasgow, Optical Instrument Makers, collection, reference UGD 295 (subsequently UGD 295) 16/1/4, Letter Books and Correspondence, Archibald Barr, 27.5.1888.

[4] See W. F. Stanley, *Surveying and Levelling Instruments* (London: Spon, 1901) chapters 1, 2, and 6 for the history of survey techniques and descriptions of instruments relevant to rangefinding.

[5] A. McConnell, *Instrument Makers to the World: A History of Cooke, Troughton & Simms* (York: William Sessions Ltd, 1992) pp. 64,65 and 78.

[6] For details of the box-sextant, its history and use, see W. F. Stanley, *Surveying and Levelling Instruments* (London: Spon, 1901) pp. 413-420, and for background to the development of earlier rangefinders see *Minutes of the Proceedings of the Royal Artillery Institution,* Vol. II, p.332ff, Vol. IV, p.1ff, Vol. VIII, p.161 ff, Vol. IX p. 47 ff and pp. 549-553, Vol. XI, p. 365. For descriptions of some of these devices, and comments on them, see Great Britain, Army, School of Musketry, *Annual Report* 1891. (London: HMSO, 1891) p. 20, and Great Britain, Army, *Regulations for Musketry Instruction 1896* (London: HMSO, 1896).

his portable device had been far from satisfactory and had attracted criticisms of inconvenience, fragility, and inaccuracy.[7] These were of relatively little consequence whilst combat distances for rifle-fire were usually short enough for sight-settings to be less than critical, but the advent of a new high-velocity cartridge and a magazine-fed repeating rifle presented the possibility of delivering high volumes of fire at ranges where, without knowing the range correctly, errors in sighting would mean missing even massed ranks of men.[8] The decision was therefore taken to seek a new rangefinder, and a public request made for submissions.[9] The successful rangefinder had to be hardy enough for use on active service in all weathers, had to be portable by one fully equipped soldier and require no more than two men in use, and had to be able to measure ranges with an accuracy of 4per cent at 1,000 yards. The designs had to be received before August 1st, 1888, an interval of only eight weeks.

Even if all the Army's previous rangefinding devices had originated from serving officers, there had been earlier commercial efforts to design instruments similar to what was now requested. In 1860, the Scottish instrument maker Patrick Adie had been granted British Patent 37/1860 for 'improvements in means to measure angles', and he obtained a second one in 1863 (608/1863) for improvements to his first design. Adie's rangefinder differed from those tried by the Army; it was a self-contained type operated by one man, with a short measuring-base of three feet six inches rather than the 75 feet or more used with the 'long-base' patterns in the Army.[10] Two other designs for short-base rangefinders had been patented in the mid-1880s by H. R. A. Mallock (British Patent 8043/1885) and by the Astronomer Royal, W. H. M. Christie (British Patent 12404/1886), but neither had been marketed. Adie had tried to sell his for survey use, and it had been included in trials held by the Royal Artillery in 1869, although it had

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[7] Great Britain, Army, School of Musketry, *Annual Report* (London: HMSO, 1893) p. 18.
[8] E. G. B. Reynolds, *The Lee Enfield Rifle* (London: Jenkins, 1960) p. 21 describes the origins of the Lee Metford rifle, and Great Britain, Army, *Regulations for Musketry Instruction*, editions for 1887 and 1896 (London: HMSO, 1887 and 1896) illustrate the differences in ranges between the old new rifles in Tables E and F (1887) and fig. 419 (1896).
[9] The following conditions are extracted from the advertisement itself preserved in UGD 295/16/1/4.
[10] Moss and Russell (1988) describe and illustrate this and other patterns on pp. 18-21; L. C. Martin, *Optical Measuring Instruments: Their Construction Theory and Use* (London: Blackie, 1924) discusses the principles of the short-base rangefinder on pp. 104-107.

performed poorly and was dismissed as fundamentally unsuited for Army service.[11] These designs offered the advantages of being compact,convenient and quick to use, qualities that apparently made them well-adapted to the Army's newly published requirement.

There was also a substantial British optical instruments industry that could consider the problem. At least 34 optical instrument makers existed in 1888 who were making, or had recently made, survey instruments, telescopes or microscopes, all of which had some of the characteristics of rangefinders in using precisely worked optical systems incorporating lenses, prisms and mirrors mounted in protective housings.[12] These firms made up an industry producing a wide range of precision-made artefacts which sold not only domestically and throughout the Empire, but also in Europe, the Far East, the United States of America, and South America. There were telescopes from small hand-held opera and field glasses up to complete astronomical observatories, surveying instruments from the simple box sextant up to the largest transits for primary surveys, laboratory microscope bodies and their eyepieces and objectives, as well as stereoscopes, spherometers, ophthalmoscopes, and lenses for photographic cameras and lantern-slide projectors. A panoply of contemporary optical instruments was being made in Britain and it might be expected that such a diverse industry would have produced ideas for a new military rangefinder.

That did not happen. Despite this substantial manufacturing base, not one firm entered a design of its own in the trials of 1889, and the only civilian submission came from private inventors.[13] The apparent lack of interest may have been connected with the short time allowed for the submission of designs, eight weeks being perhaps considered insufficient to produce even draft plans for a device that was being considered *ab initio*. There was also the question of cost and likely return on such a project, particularly as the

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[11] Captain Nolan, "The Range-Finder." *Proceedings of the Royal Artillery Institution* II (1874): 161-207.
[12] Extracted from R. G. W. Anderson, J.Burnett and B.Gee, *Handlist of Scientific Instrument Makers' Trade Catalogues 1600-1914* (Edinburgh: National Museums of Scotland., 1990) and the unclassified collection of makers' catalogues held by the National Museum of Photography, Film and Television, Bradford, West Yorkshire.
[13] Moss and Russell (1988) pp. 22-23.

War Office had given no indication of how much business might result or the likely rewards. The only civilian design that reached the end of the trials came from two academics who took up the idea as an alternative to a moribund research project with which they had become disillusioned.

In 1888, Archibald Barr (1855-1931) was Professor of Engineering at the Yorkshire College in Leeds, and William Stroud (1860-1938) was Cavendish Professor of Physics there.[14] Neither had any connection with the armed forces or the optical industry, and Stroud's later description of their decision to enter the competition suggests it was rooted in little more than momentary caprice. The two men had met in Leeds during August 1885 and in 1887 they began to design a camera to simplify the production of lantern-slides as teaching aids. Early in 1888 they decided to collaborate in a research project on the numerical value of the mechanical equivalent of heat but had made little progress by the time the War Office advertisement appeared on May 25th. Stroud subsequently recorded that

> On the morning of May 26th, Dr Barr came round to see me and proposed to drop the subject of the determination of the mechanical equivalent of heat and take up the invention of Rangefinders; so there and then we decided to enter for the competition for Rangefinders, about which neither of us knew anything. In blissful ignorance of what had already been done on the subject, we dashed off regardlessly.[15]

Stroud's account was written late in his life, possibly to be read by his family as an informal memoir, and it suggests a levity not mirrored in Archibald Barr's surviving correspondence. However, it indicates that they really did know nothing about rangefinders and only after their first and hastily constructed rudimentary prototype was a 'ghastly failure' at the beginning of June did they begin to approach the problem in a deliberate and scientific manner. They began by obtaining Adie, Mallock and Christie's

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[14] See Moss and Russell (1988) Chapter 1 for background material on Archibald Barr and William Stroud..
[15] William Stroud (n.d., but circa 1936) *Early Reminiscences of the Barr and Stroud Rangefinders* (privately printed) p.6

patents and examining them in the light of their failure to produce a satisfactory model. Unlike earlier designers, the pair could employ simultaneously a combination of optical and mechanical skills that allowed them to integrate ideas first in analysis and then to work on the invention of solutions by scientific methodology. They were sure that the principal reason for the failure of earlier short-base rangefinders had been in the weakness of the mechanical engineering around one key part in the optical system. Previous attempts had all provided a distance reading by aligning a movable image of the target with one that was fixed to the operator's view. The displacement of the movable image was done by rotating either a lens or a mirror about its vertical axis, but the amount of rotational movement was so small that reading errors resulted through what Moss and Russell colourfully described as 'drunken screws' and 'deranged reflectors'.[16] To Stroud, the solution was obvious and easily attained by the replacement of one type of optical component with another, coupled with a new mechanical arrangement to house it. Instead of rotating a lens or a mirror, the image displacement could be done by moving a wedge-shaped prism along the optical system's axis, converting a rotational movement of a few thousandths of an inch into a much longer lateral motion. Neither aspect of his proposal was novel but their application and combination were, and the 'invention' could therefore be patented and protected. Moss and Russell noted that it was 'the most important innovation' in the design, which perhaps under-stated its significance; the tracking-prism patent alone was enough to keep any other serious competitor out of rangefinder manufacture until it expired in 1903 and gave the professors a head start in making and selling them.[17] The realisation of such a simple solution to a serious difficulty must have prompted them to act quickly before anyone else considering the same question arrived at the same answer. A second force to urge them was the War Office's response to an enquiry made by Barr on June 13th.[18]

Barr asked what would happen to the intellectual property in the design if it were taken up by the War Office. He enquired whether it would become the Government property, or would the inventor 'be at liberty to treat with foreign governments' and if it would be

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[16] Moss and Russell (1988) p. 21.
[17] UGD 295 Unclassified material, J. M. Strang manuscript, p. 18.
[18] UGD 295/16/1/4, Barr to War Office, 13.6.1888.

'necessary or advisable' to seek patent protection for the invention. The reply was dismissive, saying that arrangements about ownership and rights would be made only after the trials, without any indication as to how the questions of title and reward would be dealt with. As for patents, an inventor should decide for himself about the desirability of protection. What Barr made of all this is not recorded in the surviving records but a reasonable interpretation was that the War Office regarded itself as the sole arbiter of how inventors should be treated and would offer only the terms it thought fit. In that event, patent protection was clearly an advantage and the pair quickly drafted a provisional specification and lodged it at the Patent Office before the end of June.[19]

Moss and Russell's account of this emphasised the collaborative nature of Barr and Stroud's work, stressing that Barr's pragmatic approach, espousing sound engineering methodology that worked towards "the elimination, as far as possible, of the need for accurate and difficult craftsmanship", enabled Stroud's 'inventive' solutions to be translated in to a practical form.[20] However, the authors placed less emphasis on Barr's entrepreneurial instinct that was vital in advancing the rangefinder through the processes of invention and development to introduce it successfully to a specialised market place in which he had neither personal experience nor prior training. Barr's ability to anticipate and manage business problems was evident throughout this first phase in the development of the industry, demonstrating his capacity for devising lateral strategies to deal with them.

The first difficulty came after the War Office examined the design and requested a prototype for examination by its Trials Committee before the end of December 1888. The costs had to be met personally by the inventors as the War Office refused even to consider any claims for expenses until after the trials, and there was no guarantee that they would be met if the submission was unsuccessful.[21] According to Stroud, both he and Barr suffered from 'acute impecuniosity', so to minimise their cash outlay they used

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[19] British Patent 9520/1888 records the application date as 30.6.1888.
[20] Extract from Barr's inaugural address to Glasgow University's Engineering Society, January 1892. Cited by Moss & Russell (1988) p. 22.
[21] UGD 295/16/1/4, Barr Personal papers, War Office to Barr, 16.6.1888, extract from War Office *Memorandum for Inventors.*

the College's Physics Department technician to do all the mechanical construction work, assembling mechanical components made by James White & Co, in Glasgow (where Barr had connections from his earlier work at the University there as assistant to Sir William Thomson). The pair, taking care not to broadcast what they were about, kept 'a rigid account' of his time at Barr's suggestion, so that in the event of the rangefinder being successful they could pay for the man's services in order that the Yorkshire College 'should have no claim to a share of the proceeds'. Barr, according to Stroud had 'the wisdom of the serpent',[22] although when word of the clandestine construction work eventually came out after the rangefinder's adoption Stroud came in for considerable censure from the College, irrespective of his willingness to foot the bill for Departmental labour.[23] The authorities considered the institution should have an interest in the rangefinder, and pressed Stroud so severely on the matter that his position came under review before he eventually convinced them to settle for payment of the technician's wages.

But long before then, while the first rangefinder was being built, Barr began lobbying to gain access to the Trials Committee to allow him to replace it with an improved model. In November or December, he obtained 'letters of introduction' to Major General Clark (the senior reviewing officer) which led to Barr getting a meeting on January 18th 1889.[24] He and Stroud had refined the optics and their housing to produce a more easily used and durable instrument which they wished to build and substitute for the one recently delivered.[25] The Committee refused this because it contravened the terms of the competition, but Clark told Barr that if the original rangefinder passed, the improved version might possibly be entered in later trials.[26] The first prototype was tested in March and performed well, and immediately afterwards Barr persuaded the new senior

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[22] Stroud, *Early Reminiscences* p. 7.
[23] See Moss and Russell (1988) p. 23, and UGD 295 unclassified material ACC1539, 'Notes by Mrs Shaw Murray (Dr Stroud's daughter) in which she describes the effect the business had on Stroud's health.
[24] UGD 295/16/1/1, Barr to Ripon, 1.1.1889, and UGD 295/16/1/17, Barr to Ordnance Committee, 18.3.1889.
[25] UGD 295/16/1/17, , Barr to Ordnance Committee,18.3.1889, and Archibald Barr and William Stroud, *Memorandum to the Ordnance Committee, Royal Arsenal Woolwich* March 18th 1889. Copy in GUA, UGD 295 'Un-classified papers'. Subsequently '*Memorandum*'.
[26] UGD 295/16/14, Barr to Ordnance Committee acknowledging their decision, 21.1.1889.

reviewing officer, Major-General P. Smith, to follow the lead of his predecessor and allow the submission of detailed proposals for the modified design. Before the end of May it was agreed the new model could be entered for the second set of trials in August as the 'Barr and Stroud Improved Rangefinder' and on the 19th Barr was told to have it delivered by the end of July.[27]

Barr wanted to enter the best instrument possible, and was prepared to employ sophistication in design to obtain the required accuracy. This did not conflict with his desire to eliminate 'accurate and difficult craftsmanship', by which he meant hand-fitting individual components, but actually endorsed his methodological approach to appropriate engineering solutions where he was prepared to use whatever means were essential to attain an essential goal. Stroud's original design used right-angled prisms for its 'end-reflectors' in place of the mirrors in earlier rangefinders. Prisms, which had only started to become common in optical instruments during the 1880s, were more stable and resistant to the distortions that were almost impossible to avoid in glass mirrors and had affected the accuracy of earlier rangefinders. Stroud's proposed optical improvements used a novel 'objective prism' that had one face ground to a curve to let it also function as a lens and so improve the image's brightness besides providing an assembly that could be more rigidly mounted, improving the performance substantially.[28] However, they were a novel concept and both difficult to make and more expensive than the more usual plane-surfaced types, a combination of difficulties that was to prove disastrous.

Sometime after the March trials, according to Moss and Russell, the inventors decided their rangefinder's high selling price 'might prejudice its chances' and they looked to make 'substantial savings' which subsequently had a catastrophic effect on the

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[27] Archibald Barr and William Stroud, *Memorandum*, compares the two types in detail, and UGD 295/16/1/4, Barr's personal papers, Barr to Ordnance Committee acknowledging their decision, 3.6.1889. and Ordnance Committee to Barr, 19.6.1889.

[28] For information on prism designs see G. Smith and D. A. Atchison, *The Eye and Visual Optical Instruments* (Cambridge: Cambridge University Press, 1997) Chapter 8. For other background information on optical systems, see L. C. Martin, *Optical Measuring Instruments: Their Construction Theory and Use* (London: Blackie, 1924) and D. F. Horne, *Optical Instruments and Their Applications* (Bristol: Adam Hilger Ltd., 1980).

instrument's performance in the second set of trials.[29] The authors' sources for this were Stroud's later memoir and a letter from Barr to the Ordnance Committee on May 18th, whose contents were not given in detail and which is not in the now-surviving records. There are grounds to believe that matters were by no means as simple as this account suggests, raising questions about the ability of contemporary optical manufacturing technology to provide what was needed.

Having justified the submission of a new instrument to the Ordnance Committee entirely on the grounds of significant optical and mechanical advantages obtained through using 'objective prisms', the Professors' change from them to 'plane-parallel silvered reflectors' (glass mirrors) is not easy to understand and difficult to reconcile with the later claims about economies alone being responsible for it. The problems with mirrors were well known to Barr and Stroud, and they had always recognised that their use had been partly to blame for the failures of earlier rangefinders. The relatively thin sheets of glass were virtually impossible to mount in a manner that let them respond to temperature changes without flexing and distorting to give false range readings. Even if the economies had been great enough to bring the price down to anything like the Mekometer's, the dangers of using them still remained. But reducing the rangefinder's cost so greatly was highly improbable, because even without any optics the complexity of its strain-resisting body inevitably meant a higher price greater than the simple sheet-metal box used by Watkin in conjunction with an optical system that was no more than two mirrors and three meniscus lenses similar to those used in spectacles. Despite Stroud's later abbreviated account of the trials, the change must have been driven by some other factor.

The most likely explanation is a failure to obtain the complex prisms that were at the heart of the improved model. Although Moss and Russell said that Stroud had gone to the York instrument makers Thomas Cooke and Sons for his first lenses and prisms, it is unlikely that Cooke's actually did all the optical work.[30] By 1888, the London firm of

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[29] Moss & Russell (1988) p. 23, and Stroud, *Early Reminiscences,* p. 8.
[30] Moss & Russell (1988) p. 22.

Adam Hilger & Co. had established itself as the country's leading maker of prisms, and Archibald Barr may already have been acquainted with its owners, Adam and Otto Hilger, through his earlier connections with Lord Kelvin in Glasgow.[31] The Hilgers had made optical parts for Sir Archibald Campbell, an associate of Kelvin, since 1875, and in 1888 Otto Hilger had moved to Glasgow to work for Campbell in his laboratory. Barr had been Kelvin's assistant before he went to Leeds, and maintained contact with him during the time he and Stroud were developing the rangefinder, sending him details of the design and receiving comments on it.[32] Hilger's having made prisms for the 1889 instrument is supported by a reference in the firm's surviving papers that although the first order from the partnership of 'Barr & Stroud' came in 1891, there had been other earlier ones from the 'individuals'.[33] Hilger's prism expertise was considerable, but it was a small firm which, as will be seen in subsequent chapters, regularly had difficulty keeping its work on schedule, and in 1889 relied almost entirely on Adam Hilger himself for the most difficult and exacting work such as Stroud's objective prisms. If their unusual form caused problems and delayed completion, then the delivery deadline of 31st July for the rangefinder would have demanded an urgent solution for which the use of mirrors must have been the only course open.

Much of this is conjectural, but the behaviour of the rangefinder at its trial was indubitably a shock for which Moss and Russell advanced no explanation. When Stroud used it in the cool of the August morning it worked well, but as the day progressed the sun's heat 'distorted the mirrors' and 'to Dr Stroud's dismay' it produced 'wildly inaccurate readings'.[34] That the failure clearly came as a surprise suggests either gross negligence in preparation or that there had been inadequate time to test it properly beforehand. The notion that the change to mirrors was solely on grounds of cost hardly

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[31] For a summary of Hilger's history see D. F. Horne (1980) *Optical Instruments and their applications* (Hilger, Bristol) p. 34, and for details of connections with Campbell see Science Museum Library, Hilger collection, HILG 3/1, History, 'Notes from Mr Johnson in connection with his history of Adam Hilger', 6.11.1952, and HILG 3/1, 'Mr Twyman's Lecture, August 1944'.
[32] UGD 295/16/1/3, Barr, Personal Correspondence, William Thomson to Barr, 8.3.1889, commenting on the design.
[33] HILG 3/1, Sales Manager, Hilger & Watts (successor company to Adam Hilger Ltd) to Barr & Stroud Ltd, 25.1.1952.
[34] Moss and Russell (1988) p. 23.

stands in the context of what Barr and Stroud already knew about rangefinder design. Moss and Russell drew their account from Barr & Stroud archive material that apparently failed to survive the later removal of records from the factory,[35] and Stroud's own account of the trials makes no reference to the performance being different to previous experience. The authors noted that 'the professors were left to agonise over their mistake in substituting a cheaper design' but the cause of the mistake may have been due to limitations in the level of contemporary optical manufacturing technology in Britain.

An understanding of this may be reached through the ideas propounded by Thomas Hughes in his 'systems approach' to understanding the evolution of technological systems. Stroud had encountered what Hughes categorised as a reverse salient, a situation where a component in a system has 'fallen behind or gone out of phase with others' holding back progress on what he termed a 'broader front' and which will, when solved correct the problem.[36] Hughes recognised that such situations may be by-passed, allowing progress to be resumed pending a solution, which appropriately describes Stroud's problem. Because satisfactory prisms were unobtainable – whether for technical or financial reasons – and time was pressing, Stroud had no option but to deal with the problem by substituting an inferior technology. Ironically, his success in devising the tracking-prism to overcome an earlier reverse salient that was a greater 'critical problem' in rangefinder construction, was negated by the unexpected failure to deal with the second one of end-reflectors. There, the issue was not one of an appropriate solution, but the unanticipated problem of prism procurement. The production of large prisms was a reverse salient that would remain for several years but, as the narrative will show, a lateral solution was devised that enabled progress on the broader front of rangefinder development to continue in the meantime.

After the trials, Barr and Stroud were told that their instrument had not been selected and the Watkin Mekometer had been chosen. However, it is by no means certain that the

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[35] Moss and Russell (1988) p. 238, notes 32 and 34 state 'Cash Book No. 1' referring to letters received.
[36] T. P. Hughes, "The Evolution of Large Technological Systems." In *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, edited by W. E. Bijker, T. P. Hughes, and T. J. Pinch. (Cambridge, Massachusetts: MIT Press, 1989) pp. 73 and 74.

decision for the Watkin was made simply because it performed more accurately. The published specification of May 25th 1888 might have been written around the Mekometer; in fact it described exactly the kind of instrument the Mekometer was. All the Army's previous rangefinding devices had been, like the Mekometer, the 'two-observer long-base' type and the Army had become habituated to their use, largely because when used deliberately under test conditions they did indeed produce far more accurate readings than the single-observer designs.[37] In a lecture at the Royal Artillery Institute in 1881, reviewing every variation of rangefinder tried since 1861, the speaker emphasised that the only types proven as definitely unsuitable were the 'yard telemeters', by which he meant the self-contained single observer types.[38] He emphasised that what was needed was refinement and simplification of the long-base type and that no other system was likely to perform satisfactorily. This pre-disposition had come to constitute a 'rangefinding paradigm' that was reflected in the 1888 specification and which would continue to influence the Army for the next fifteen years.

William McBride has considered the concept of both intellectual and technological paradigms in the context of what he designated military hierarchical structures.[39] He defined a military intellectual paradigm as an established philosophy within an army or navy, and suggested that the military technological paradigm differed from Edward Constant's earlier definition of 'an exemplary artefact and a cultural framework devoted to sustaining it' in that the military one interacted not only with the surrounding culture but also with the intellectual paradigm of the related military profession.[40] This combination can be used as a model to explain the selection process which the War Office followed in 1889 and its later attitude towards rangefinding apparatus, particularly when applied in conjunction with McBride's other thesis that 'military hierarchies seek stability' and when presented with a new technology which is perceived as challenging such stability, they can react adversely towards it. This sits within the broader framework

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[37] Captain Nolan, "The Range-Finder." *Proceedings of the Royal Artillery Institution* II (1874): p. 162.
[38] E. G. Edwards, "Field Range-Finding." *Proceedings of the Royal Artillery Institution* XI (1883): 202-14.
[39] W. McBride, *Technological Change and the U.S. Navy 1865-1945* (Baltimore: Johns Hopkins University Press, 2000) pp. 4-6.
[40] MacBride cites E. Constant II, *The Origins of the Turbojet Revolution* (Baltimore: Johns Hopkins University Press, 1980) as the basis of his modified definition.

of Thomas Hughes' understanding of the growth of technological systems (which here are represented by the rangefinder), in which he emphasised the interaction of both social and technical factors in shaping the evolution of artefacts.

With the British Army and the rangefinder, the evolved intellectual paradigm was that only long-base rangefinders could provide sufficient accuracy, and the technological paradigm was manifested in the assorted instruments in use that all conformed to the principle of extended bases. The 'exemplary artefact' was not one single device, but a family of similar devices that had in common inventors who were all drawn from the cultural framework of serving officers which supported the paradigm itself. From that, it can be adduced that the intellectual paradigm was extended to project the concept that only members of the military society could be expected to understand the Army's needs, and so be competent in evolving suitable designs for it. The War Office was pre-conditioned to frame its May 1888 specification in the way it did, because its rangefinding paradigm postulated that a successful instrument would have pre-determined characteristics that would favour, or even demand, a particular form of instrument. At the same time, according to Mc Bride, the hierarchical structure of the Trials Committee would tend to reject any anomalous artefact that challenged the existing (though still imperfect) stability. The outcome of the trials can be construed in exactly that manner.

The Mekometer's operation was far more complicated than a single-observer instrument.[41] Two operators stood erect twenty five yards apart and aligned their separate instruments on a pre-determined target, and then manipulated one *vis-à-vis* the other until images reflected from the target and the other instrument were brought into alignment. With the single-observer type, all that was needed was to aim the instrument and align two images by means of an operating wheel. Its tactical advantages were acknowledged, but the previous failures to make a practical example had consistently reinforced the paradigm of the two-observer instrument. Despite Barr and Stroud's success in the

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[41] Great Britain, Army, *Handbook of the Mekometer* (London: HMSO, 1911) pp. 9-13 describe the instrument's operation..

March trials, the failure in August was, to the cultural framework of the Trials Committee, predictable on the basis of past experiences and the expected outcome reinforced the existing rangefinding paradigm, not only because it confirmed the notion that such designs were intrinsically unsuited but also because it originated outside the military society that defined expectations of it. What McBride described as 'inherent paradigmatic inertia' then deflected attention away from the potential tactical advantages in Barr and Stroud's design and directed the selection process towards the Mekometer despite its operational drawbacks.

1.3 The War Office and Thomas Cooke & Sons

The Mekometer was 'introduced into service' in October 1891.[42] It was produced by Thomas Cooke & Sons who must have been given a contract slightly earlier, because by April 1891 they had already prepared the necessary drawings to commence manufacture.[43] Production, or at least its issue to troops, went ahead slowly, with the School of Musketry commenting in its Annual Report for 1892-1893 that the only rangefinders in service with the Infantry were still the older Watkin and Weldon types which the Mekometer was intended to supersede.[44] It was by no means the first optical device the firm had made for the Army, and Cooke's had an acquaintance with its designer that went back at least to the 1870s when as a Captain in the Royal Artillery Watkin had designed his Depression Rangefinder for coastal artillery.[45] Its selection had been protracted, with trials taking place between 1876 and June 1881 when it was finally adopted and ordered from Cooke's who produced it 'under a cloak of great secrecy'.[46]

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[42] Great Britain, Army, School of Musketry. *Annual Report* (London: HMSO, 1893) p. 18.
[43] University of York, Borthwick Institute of Historical Research, Vickers Instruments Archive, Company Records of Cooke, Troughton & Sims (subsequently VIA), AJB 070/1.3/ Box 1, Drawings Index 1882-1921, drawings number 369 and 370.
[44] For instruments in service, see Great Britain, Army, School of Musketry. *Annual Report* (London: HMSO, 1893) p. 18, and for obsolescence of earlier types see Great Britain, Army, *List of Changes in War Material* (London: HMSO, 1891), entry 24.8.1891.
[45] For general background on Cooke's early involvement with optical munitions, see McConnell (1992) pp. 64-65. For the Depression Rangefinder, PRO WO 32/8902 provides the source material for the following section, unless otherwise indicated.
[46] McConnell (1992) p. 64 provides the quotations associated with Watkin in the rest of this section.

The Depression Rangefinder also fitted the Army's rangefinding paradigm, being a sophisticated derivation of the surveyor's level intended to be used in gun batteries which were sited well above sea level. It could only be used from a permanent mounting whose height above a mean sea level was precisely known and which formed the extended measuring base for the system. Its optical component was a high magnification telescope incorporating an aiming mark that was similar to those which Cooke's already produced for survey instruments; the device's sophistication came in a complex system of cams and gears that translated the depression angle into a range reading and target bearing for the guns. The combined 'Depression Range-and-Position Finder' formed a key component in the network of coastal forts and batteries that had been set up since the 1860s as a strategic defence system against attack and invasion and it was vital to the doctrine of engaging an enemy at long range before he could approach closely enough to deploy his own armament.[47] Watkin's device was considered important enough for the Crown to award him £25,000 in 1888, for 'transferring his patents to the War Office.' It is difficult to resist the idea that, given Watkin's personal standing at the time of the 1889 trials, their outcome might have been a foregone conclusion.

In 1891 Cooke's had become sole maker of Watkin's devices which, to the British Army, were state-of-the-art rangefinding instruments. Their commercial worth to Cooke's is not easy to determine accurately as no directly relevant material from the company has survived, but some idea can be formed from other sources. The Army's contemporary scales of issue for Infantry rangefinders meant that only 300 Mekometers were likely to have been ordered, plus a small number for spares, so that with a selling price of £7, its total value could scarcely have exceeded £2,500.[48] The Depression Rangefinder is harder to assess without knowing how many were needed or its price, but some details preserved by Cooke's bankers give clues, as well as telling a good deal about the firm's financial condition in the early 1890s.

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[47] M. J. Bastable, *Arms and the State: Sir William Armstrong and the Remaking of British Naval Power, 1854-1914* (Aldershot: Ashgate Publishing, 2004) pp. 68-69.
[48] The scale of issue and cost are supplied by National Archives, Kew, Records of the Treasury (subsequently PRO) TI /11223, Proceedings of the Ordnance Council, 12.6.1908, p. 4.

Anita McConnell's history of Cooke's makes clear that although the business had a large domestic and export trade it had a record of liquidity problems that ran from the late 1860s into the 1890s, caused largely by losses from the mismanagement of large contracts for astronomical telescopes.[49] By the early 1890s, despite an expanding market for survey apparatus, profits from general instrument making were inadequate to cover losses on the astronomy side and the firm saw optical munitions manufacture as a potential solution to its financial difficulties. In January 1891, when the Mekometer contract was obtained and the Depression Rangefinder was in production, Cooke's current account with the Yorkshire Banking Company was overdrawn by £1,914 against an agreed limit of £1,000.[50] In September, the firm asked for its overdraft to be raised to £6,000 to cover current liabilities, and for a further £4,000 to purchase additional premises. Cooke's assured the bank that the money was required only until February 1892 when 'the account would be put in credit by moneys to come to them from the Government'. If Cooke's was truly expecting War Office business to rectify its financial difficulties then the Depression Rangefinder was worth approximately £7,500 over the next year. The bank turned down the application, and in June 1892 the firm was forced to ask for 'a three month extension of credit to £5,000'. Either the War Office payments had failed to come in or trading had deteriorated markedly, but optical munitions work had not significantly changed the company's overall financial condition as expected. Cooke's may have been excessively optimistic about its prospects, anticipating orders that failed to materialise. The amount of business likely to result from optical munitions in the 1890s was limited by the Army's very limited employment of them and although Cooke's had a monopoly of manufacture for the two Watkin rangefinders, neither was likely to be bought in large numbers over a protracted period; the reality was that their capacity to generate a continuous and substantial income hardly existed at all.

Although the Army, *via* the War Office made the first move towards adopting a rangefinder, it did relatively little to encourage the development of an optical munitions

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[49] McConnell (1992) p. 61.
[50] HSBC Bank Group Archives, *Abstract of entries in the Yorkshire Banking Company Board Minutes relating to T. Cooke & Sons*, 1882 –1900, references X19 to X24, provides the source for the financial details in this section.

industry. It was the Royal Navy that did most to stimulate growth through its own efforts to find a rangefinder that began shortly before the Army decided to adopt the Mekometer and continued over several years until a suitable instrument had been developed.

1.4 The Admiralty and the Rangefinder

Unlike the Army, the Royal Navy had never officially employed any instruments for measuring distances at sea and had evolved neither an intellectual nor a technological paradigm on rangefinding. The Navy was directed towards the problem by the same emerging weapons and propellant technologies that had affected the War Office, as well as the growing in attention to naval policy after 1884 that led to the large spending programme of the Naval Defence Act of 1889.[51] Faced with the prospect of new ships armed with improved guns which could shoot further and quicker,[52] the Admiralty decided to investigate whether a satisfactory rangefinder for shipboard use could be obtained. This is one situation where it may be claimed that 'hard' technological determinism in the shape of new guns and propellants was indeed 'driving' the process of change, at least in the Navy. There, the combination of rapid-firing guns with far greater effective ranges than anything previously made created a situation where the advances were so great as to overcome any social factors of resistance within the professional community faced with the implications of change. Irrespective of the nature of the evolution of those new technological innovations, once they attained a condition of practical utility (or stabilisation) their advantages were so manifest that the next stage in the progress of naval gunnery was set in motion. That process, though, was effected through a combination of circumstances whose explanation resists a deterministic model and which is most appropriately achieved through the ideas of Thomas Hughes' systems approach.

In 1889, the Royal Navy still depended on the War Office for its supplies of guns, and it was to the Director of Artillery at Woolwich that the Navy first took the issue of

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[51] For background to the 1889 Act, see Bastable (2004) pp. 189-192, and C. Trebilcock, *The Vickers Brothers: Armaments and Enterprise 1854-1914* (London: Europa Publishers, 1977), pp. 52-55.
[52] For details of the new guns, see E. W. Lloyd and A. G. Hadcock, *Artillery: Its Progress and Present Position* (Portsmouth: J. Griffin & Co., 1893) Chapter VII.

rangefinding in June that year.[53] The first Infantry rangefinder trials had just been held and the second set was due to start soon when the Navy' Ordnance Committee announced on June 14th that 'the question of a naval rangefinder is one of pressing importance'. The Navy's gunnery school, HMS Excellent, was also asked for an expert opinion. Its captain's reply on the 26th was that he did 'not attach great importance to rangefinders' as 'a far more practical means of obtaining the ranges quickly' was by observing the splashes made by misses from the new quick-firing guns that were then being introduced. He thought there was no need for the Ordnance Committee to pursue the matter. The Director of Naval Ordnance (DNO) was but little impressed with Excellent's advice and on July 9th told the Director of Artillery that it would be a 'great advantage' to have an effective ship-borne rangefinder and asked for the benefit of his experience. The Director passed on the names of the entrants to the current trials but offered neither advice nor comment.[54] A year later, the DNO asked him to set in motion the process of finding a suitable naval rangefinder, and on April 8th 1891 sent a set of conditions which the successful instrument must achieve.

Although the War Office was responsible for instigating the selection process, it took no part in the actual trials which were conducted entirely by the Navy, and there were significant differences in the way that the Admiralty competition was managed. Firstly, a number of inventors were specifically invited to submit designs for it, including the entrants to the 1889 trials.[55] And secondly, the specification itself was framed in such a way as to seek a solution rather than define the nature of what was expected in the way the War Office had done.[56] The technical demands were considerable: the device had to measure ranges to an error no greater than 3 per cent at 3,000 yards, irrespective of ship motion, speed, or the course of either its own vessel or its target, it had to take ten readings per minute (to produce a mean range) and have provision for 'some system of instantaneous communication' to send them to the guns, and it had to be as simple and as

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[53] Hampshire County Record Office, Priddy's Hard Material, collection reference 109/M/91 (subsequently HCRO)PQ2, Great Britain, Admiralty, Gunnery Department. *Monthly Record of Principal Questions Dealt with by the Director of Naval Ordnance* July-December 1889, provides the source material for this section unless otherwise indicated. Dates are given in the text.

[54] Moss and Russell (1988) p. 25.

[55] HCRO/PQ6, Recommendation of Director of Naval Ordnance, 9.2.1892.

[56] See Appendix for the full list of conditions.

durable as possible to withstand conditions at sea. William McBride suggested that in late 19th century navies, although 'officers had become members of a technology-based profession' they did not necessarily accept new technologies automatically as improvements.[57] HMS Excellent's Captain of two years previously, who considered that observing shell splashes was the best way to find the target's range, may have been an extreme example of 'filters against adoption' of the new, but the 1891 specification's demand for transmission of data suggests that the Royal Navy was looking for new technology by asking not just for a rangefinding device but for what amounted to a system for gunnery control centred on an optical instrument.

Submissions were made by a mixture of private inventors and serving officers. The Admiralty trials in 1892 and their favourable result for Barr and Stroud have been described by Moss and Russell, but it is worth noting that once again the outcome may not have been as straightforward as they imply.[58] The two strongest contenders were Barr and Stroud and, once again, Major Watkin whose submission was a derivation of his successful coastal range-and-position finder. He had integrated his two-observer design into an electrical circuit which supplied two angle-readings from widely separated points to a central control station which, like the depression type, converted them into ranges for transmission to the guns.[59] This was an attempt to transfer the Army's rangefinding paradigms to naval use, and in the context of a technologically conversant society might have been expected to find favour. Its failure was, officially at least, due to its inferior accuracy, but in the light of later attitudes shown towards similar ideas for integrating gunnery direction, the fact that it demanded the installation of a whole system was likely to count against it, and not just with those gunnery officers who espoused the philosophy of HMS Excellent's captain.[60] Watkin's system demanded the installation of cabling and a control room, both of which were likely to be expensive and also difficult to arrange

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[57] McBride (2001) p. 4.
[58] Moss and Russell (1988) pp. 24-26.
[59] A. Pollen, *The Great Gunnery Scandal* (London: William Collins & Co. Ltd, 1980) pp. 66 and 260.
[60] See Pollen (1980) Chapter 2, and J. T. Sumida, *In Defence of Navel Supremacy: Finance, Technology, and British Naval Policy 1889-1914* (London: Routledge, 1993) Chapter 5 for attitudes towards shipboard instrumentation.

with existing ships. The Barr and Stroud design made little impact on a ship's structure. It was only five feet long and could be used – literally- as a 'stand alone' item capable of being moved around from one mounting point to another, almost like a telescope.[61] Although the Royal Navy's gunnery branch recognised the need for integrated fire control, the still-evolving state of gunnery and weapons together acted as filters amongst some officers to resist changes whose immediate application seemed of little import.[62] The absence of any rangefinding paradigm in the Navy, together with a still imperfectly defined one for gunnery would have combined to favour Barr and Stroud even if their rangefinder had not shown a superiority in accuracy.

1.5 Barr and Stroud – from Cottage Industry to Manufactory

Winning the competition was still no guarantee of financial reward. On June 10th 1892 the Admiralty wrote to Barr about what might happen next about the rangefinder.[63] The letter raised the question of terms and conditions in the light of Barr and Stroud proposing to sub-contract manufacture and asked what 'you and Mr Stroud [sic] are willing to accept for these instruments' should Navy adopt them. There were three points which the Admiralty wanted answered before it would consider whatever price the inventors might ask. Was the rangefinder patented? Had its details been made public? Could secrecy be guaranteed? The final issue materially affected the terms to be offered. If secrecy could be assured, then the Government was interested in acquiring the sole rights to the rangefinder, either by a lump sum or a royalty on each one bought. Moss and Russell said that after further trials in June 'the Admiralty then asked [the inventors] to offer their patents to the Crown', a privilege for which Barr demanded £75,000 in view of their 'enormous commercial potential' and which was subsequently declined.[64] As the Admiralty's main pre-occupation was secrecy rather than buying-up a potential commercial investment, there can have been little chance of Barr being paid such a large sum, irrespective of the accuracy of his valuation. Having set aside any ideas of buying

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[61] For details on the uses of telescopes, see PRO ADM 116/407, 'Long distance telescopes: trials and issue to H. M. Ships', 1893 to 1896.
[62] For examples of 19th century naval attitudes, see P. Scott, *Fifty Years in the Royal Navy* (London: John Murray, 1919) Chapters 2 to 5.
[63] UGD 295/16/1/5, Correspondence, Admiralty to Professor Barr, 10.6.1892.
[64] Moss and Russell (1988) p. 26

sole rights, at the end of November the Admiralty asked Barr to quote for six of his 'improved single-observer rangefinders for further trials' marking the start of a commercial relationship that was to outlast the naval life of the optical rangefinder.

The procession from inventors to successful entrepreneurs by Archibald Barr and William Stroud between 1888 and 1899 accords well with Thomas Hughes' ideas in his systems approach to development, and in particular with his three-stage model of technological innovation which stressed the importance of contextual influences outside the immediate field of a particular technology.[65] Hughes modified Joseph Schumpeter's earlier analytical model, which divided technological change into the three phases of invention, innovation and diffusion, by first defining invention as an idea that may solve a problem rather than it necessarily being a working artefact. He then fused the notions of innovation and diffusion into what he called the development stage, where the proposed solution was tested and modified until it became viable. And finally he re-defined innovation to mean its transfer first into an appropriate commercial marketplace and subsequently into a wider contemporary 'social and cultural context'.[66] In that phase, entrepreneurial factors became paramount in building up what he called the 'momentum' of the technology which enabled it to exert a progressive influence over external contexts such as political or economic factors. The growth of Barr and Stroud's rangefinder business in the 1890s was the most important aspect of optical munitions manufacture in Britain and its examination in the light of Hughes' ideas also gives an understanding of why there was little development in other areas during these years.

In February 1893 Archibald Barr and William Stroud had neither the means to make the instruments' parts themselves nor even a workshop in which to assemble bought-in components.[67] Barr was by then Regius Professor of Engineering at the University of Glasgow and Stroud still at the Yorkshire College in Leeds, a separation of some 250

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[65] Hughes, T. P. "Technological Momentum." In *Does Technology Drive History? The Dilemma of Technological Determinism*, edited by M.R. and L. Marx Smith (Cambridge, Mass.: MIT Press, 1995) pp. 103-113.

[66] Bastable (2004) p. 8.

[67] UGD 295/4/11, Letter Book, Barr to Director of Naval Contracts acknowledging receipt of Admiralty acceptance of tender for contract CP NS4886-927383/1620.

miles which complicated the production of the first batch of rangefinders for the Royal Navy.[68] The instruments to be made reflected the research done by the pair since 1888, which had, in the meantime, produced another five rangefinder-related patents.[69] The new model had advanced considerably since 1889, having a longer measuring base of five feet, a stronger double-tube body of non-ferrous metals to avoid influencing ships' compasses, and finally a revised optical system that avoided the use of the problematic large end-reflecting prisms by the substitution of speculum-metal reflectors that were intrinsically more stable than glass mirrors. The components were all made by outside contractors and gathered together for final assembly in Glasgow, this time not on University premises but in Barr's own home under circumstances that Moss and Russell described, engagingly enough, as a 'cottage industry'.

The fabrication of mechanical parts was done by James White & Co. in Glasgow, but the optical work was spread between Adam Hilger in London and Chadburn Brothers in Sheffield, Yorkshire.[70] Chadburn's is not mentioned at all by Moss and Russell, but the firm was an important supplier of the simpler optical components in Barr and Stroud's rangefinders from at least 1892 until well into the Great War. Founded late in the 18th century, Chadburn's made a wide range of optical instruments, as well as lenses for the ophthalmic trade.[71] Although the main telescope part of the rangefinder demanded high-grade lenses, its aiming viewfinder and some other parts could be made satisfactorily with simple ophthalmic lenses, and it made no sense to pay Hilger's or Cooke's for higher quality components when they were not needed. For the more sophisticated achromatic lenses and the small complex eye-piece pentagonal prisms, orders continued to go to Hilger's who supplied some of the components directly to Glasgow and others to

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[68] Moss and Russell (1988) pp. 25-31 provides source material for this section unless otherwise indicated.
[69] UGD 295/22/1/8, patent specifications, includes British Patents 11025/1889, 4185/1890, 12448/1890, 12736/1890, and 3172/1891.
[70] UGD 295/4/11, Letter Book 1893, contains a series of eighteen letters from Barr to Chadburn's ordering n assortment of lenses. See in particular 3.3.1893 requesting plano-convex lenses, and 25.5.1893 ordering eight different types of plano-convex lenses. .
[71] *The Century's Progress: Yorkshire Industry and Commerce 1893* (London: The London Printing and Engraving Co., 1893. Reprint, Brenton Publishing 1971) p. 141.

Stroud in Leeds.[72] He then built up the complicated central arrangement of prisms and lenses that presented the separate images to the operator's eye before despatching each finished component to Glasgow for assembly in the rangefinder body and final adjustment.

This method of sourcing and assembling components was adequate only for orders for small numbers of instruments, and Barr was aware that once demand grew a transformation would be required. The first stage in the progression from cottage industry to a manufacturing organisation came when Barr hired one of his own university students, Harold Jackson, as his full time salaried administrative and technical assistant in 1893.[73] Although then only 21, Jackson quickly came to occupy a key role in the progress of the business, and to play a part scarcely less important than Barr himself. The second step was the negotiation of a sales agency agreement the same year with the Newcastle-on-Tyne armaments maker and warship builder, W. G. Armstrong Mitchell & Co.

The circumstances of this agreement are, once again, not as straightforward as the published account suggests. For an informal partnership of two academics whose total business to date amounted to just one order for six rangefinders, the need to set up an international marketing structure so soon seems premature. However, as William Stroud noted later, once the Admiralty had announced its decision to buy rangefinders, foreign interest rapidly burgeoned and 'within a few months enquiries poured in from places as far apart as Tokio [sic] and Washington'.[74] Naval and military attachés arrived 'to study the instrument' and the prospects for foreign business quickly seemed encouraging. According to Moss and Russell, Barr approached Armstrong's in April 1893 to ask if they would become 'sole agents' for sales to foreign navies, but in fact it was the company that first approached Barr through one of its technical staff, Commander E. W.

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[72] UGD 295/16/1/5, Correspondence, Strang papers, Stroud to Hilger on methods of making pentagonals for the rangefinder,6.10.1890 and UGD 295/4/11, Letter Book, Barr to Hilger complaining of incorrect angles of pentagonals.
[73] Moss and Russell (1988) p. 29.
[74] Stroud, *Early Reminiscences*, marginal note in Stroud's own handwriting on p. 12 of the copy in UGD 295/26/1/55.

Lloyd. In late March, Armstrong's had set matters in train by asking Barr whether he was able to supply rangefinders and at what price.[75] Having quoted a figure, he followed it up by enquiring in May whether or not Armstrong's would be able to get any orders, which seems to have prompted Lloyd to arrange a meeting at which he put the question of an agency to Barr.[76]

Lloyd, who had recently retired from the Royal Navy, already knew about the Barr & Stroud rangefinder and had mentioned it in his recently published work *Artillery: its Progress and Present Position*, although when he wrote it he was still – like the Captain of HMS *Excellent* some two years earlier – unconvinced of the instrument's value.[77] However, when the Admiralty's decision triggered foreign interest, Armstrong's would have recognised that orders were likely from their overseas clients and moved to concentrate the export sales of the rangefinder in their hands rather than any competitor's. The discussions with Lloyd led Barr to prepare a draft agreement which he returned to Armstrong's after some amendments in early July with an accompanying letter that said:

> One of my chief concerns for desiring to come to some such agreement **as you had proposed** was that we had not the machinery for securing prompt payment in the case of business being done with the Smaller States. This, Captain [sic] Lloyd said would be no difficulty to you and I understood that you are willing to undertake the financing of foreign business in so far as the securing of payment is concerned.[78]

Barr may have been stimulated by the idea of foreign sales, but financing them would indeed have been problematic. By 1893 the expenditure on research and patenting had become considerable, and according to Stroud 'We were now approaching the end of our

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[75] UGD 295/4/11, Letter Book, Barr to Armstrong Mitchell quoting for supply of thirteen rangefinders at £700 less 12.5 percent commission.
[76] UGD 295/4/11, Barr to Armstrong Mitchell 9.5.1893, and Barr to Armstrong Mitchell 3.7.1893.
[77] E. W. Lloyd and A. G. Hadcock, *Artillery: Its Progress and Present Position* (Portsmouth: J. Griffin & Co., 1893) p. 9 for the rangefinder and p. 10 for the spotting the fall of shot as an aid to ranging..
[78] UGD 295/4/11, Barr to Armstrong Mitchell, 3.7.1893. Emphasis added.

financial tether'.[79] Their losses so far were at least £1,247, all of which except for £300 had come from their own resources.[80] Barr's income at Glasgow University in 1893 was £468,[81] and Stroud's salary at Leeds was unlikely to have been greater, so that their situation in the absence of outside financing must indeed have been difficult. Work done for the British government was 'safe' in the sense that payment was guaranteed and could be financed through eking out suppliers' credit terms, but foreign sales were a different matter, as Barr's letter to Armstrong's made clear.

The ten-year agreement that was signed in September 1893 was potentially advantageous to Barr and Stroud.[82] Armstrong's would promote the Barr and Stroud rangefinder to the exclusion of any other by using their influence on foreign navies who were their clients for ships or guns. Barr and Stroud would fix the selling prices, and Armstrong's would guarantee payment within three months of taking delivery, irrespective of whether or not the foreign client had paid for them. In return, Armstrong's would earn a 12.5 per cent commission on all sales from foreign enquiries except – at Barr's insistence – those from Germany. Almost at a stroke, and at no cost, Barr had acquired both a foreign sales department and a guarantee of payment within a set time limit, a combination he might well have been pleased with.

Despite the expectation that Armstrong's would generate new trade, few orders resulted until well into 1894, when Barr and Stroud's total business amounted to just thirteen rangefinders, eight of which were for the Admiralty. Despite Stroud's insistence that there was much foreign interest, there was little concrete to show from it. Navies – including the Royal Navy – were still to be convinced that the rangefinder worked efficiently or was even necessary, and Barr was keen to get the Admiralty to commit

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[79] Stroud *Early Reminiscences* p. 10.
[80] This figure is taken from J. M. Strang's research material for the unpublished history of Barr & Stroud cited by Moss and Russell. Both the material and typescript are in UGD 295 Unclassified Material, Strang papers.
[81] Extracted from UGD F2/16, University of Glasgow Records, Ledger II, pp. 80-87.
[82] UGD 295/4/11, Letter Book, Barr to Armstrong Mitchell, 7.7.1893 and 9.8.1893 detail the terms; 28.9.1893 confirms signature of agreement.

itself in order to gain what he rightly saw as a valuable endorsement.[83] In late May, Jackson asked the Admiralty whether the Navy thought the rangefinder was 'suitable' for adoption, and encouraged a favourable answer by saying further improvements had been made and offering a discount of 10 per cent for orders of 50 or more.[84] Eventually in February 1895 the Admiralty confirmed that the instrument had been 'definitely adopted' by the Navy.[85]

Foreign interest was still not stimulated to the point where large orders were being placed and the stance of the Imperial German Navy perhaps sums up contemporary attitudes. In April 1894, the German Naval Attaché in London, Captain Tülick, had asked about delivery of a sample to Berlin, asking if someone could be sent to demonstrate it 'without charging anything, or only a moderate sum'.[86] The response to that has not survived but a fortnight later, undeterred by what he had been told, the Attaché wrote again to enquire 'if you are doing any other interesting work for the British Admiralty'. Irrespective of whatever he learned from that attempt at espionage by post, a rangefinder was subsequently ordered, to be collected by a German 'expert' in July, but only after payment had been made. The correspondence illustrates some of the problems that Barr was having promoting sales. Tülick had asked to visit what he thought was Barr's factory in Glasgow to see for himself not only the rangefinder but whatever else Messrs Barr and Stroud were making, and he also wanted a firm delivery date for the one just ordered.[87] The reply, sent over Barr's signature but from its style composed by Jackson, neatly juggled assurance and embarrassment. Firstly, Barr and Stroud were specialists; they only made rangefinders, a subject with which 'few men are acquainted'. On delivery times, the 'peculiar nature' of the work meant that 'unforeseen accidents might slightly retard completion', but once finished it would be best to gather as many experts in Berlin as could be managed at one time to show them the rangefinder. As for a factory visit, the

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[83] For the influence that Royal Navy had on foreign powers, see C. Trebilcock, *The Vickers Brothers: Armaments and Enterprise 1854-1914* (London: Europa Publishers, 1977) chapters 3 and 4.
[84] UGD 295/4/12, Letter Book, Jackson to Admiralty, 26.5.1894.
[85] UGD 295/4/13, Letter Book, Jackson to Armstrong Mitchell informing them of the decision.
[86] UGD 295/16/1/13, Foreign Letters, German Embassy, London, to Barr and Stroud, provides the source material for the following quotations in this paragraph, 2.4.1894, 20.4.1894, 23.6.1894, and 12.7.1894.
[87] UGD 295/4/12, Letter Book, Barr to Captain Tülick, 23.4.1894 provides the source material for the rest of this paragraph.

letter confessed 'We have not a workshop of our own, except a small one in Professor Barr's house...' and that 'the important parts' were made in various locations. This did not deter German interest, and the rangefinder was duly delivered on time and sent to Berlin where, instead of Barr being to show it off, it was (according to Stroud) immediately 'forwarded to Zeiss to be copied'.[88]

Orders were slow to come in from sources other than the Admiralty and income remained modest until 1896.

Table 1.1: Barr & Stroud, comparison of British and foreign orders 1893-1899.[89]

Year	British Orders (units)	Foreign Orders (units)	Total Orders (units)	Sales £s
1893	5	1	6	400
1893	8	5	13	2,700
1895	20	9	29	3,025
1896	41	14	55	13,409
1897	50	7	57	11,668
1898	Nil	29	29	14361
1899	105	26	131	8,556

The slowness of growth up to 1895 was influenced by both the Admiralty and the Professors still being in the early phases of developing both its application and design, a combination of social and technical factors. For the Navy, the question was one of how to employ the rangefinder, and for Barr and Stroud the problem was how to refine the instrument to produce a satisfactory product that could be marketed with the endorsement of large-scale adoption by the British Admiralty. In Hughes' model of technological change, the development stage has the proposed solution to a requirement being

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[88] Stroud, *Early Reminiscences* p. 14.
[89] These figures are extracted from UGD 295/26/1/93, Personal papers of Dr. W. Strang, 'rough notes', and UGD 295/26/1/27 and 28, 'historical notes' prepared for Dr Strang's proposed history of the firm..

redesigned and re-tested until a satisfactory state is reached, a case that describes what was happening with Barr and Stroud. The two inventors had not only to develop the rangefinder but also to evolve a commercial structure that would be appropriate to how they thought the business should develop.

Moss and Russell hinted at the rangefinder's gradual technical evolution, but it is clear that up to 1895 each instrument delivered differed slightly from its predecessor.[90] Only in that year was the 'FA2' model introduced, representing the reaching of a plateau where a standardised product could be manufactured to a fixed specification rather than individual examples being modified as they were produced.[91] In April 1895 the Admiralty asked for a quotation for twenty,[92] so that with the design having reached a stage of stability and a substantial order from the Admiralty, it became feasible to advance the development of the business by acquiring, for the first time, workshop premises and operatives to do part of the manufacturing. The previous year, the inventors had created the formal partnership of 'Barr & Stroud's Patents' to exploit the value of the designs already registered.[93] That had allowed for either licensing or manufacturing, but by early 1895 the partners' attention was concentrated on the latter, not least because the earlier question of producing some means of transmitting data electrically from the rangefinder to the ship's guns had been resurrected.

The original specification had called for the provision of such a system even though it had not been required at the trials, and in November 1893 the Admiralty had finally asked for the submission of the necessary 'electrical apparatus'.[94] A set of these 'Range and Order' instruments was tested by mid-April 1894, but no decision about them had been made when in early 1895 Armstrong Mitchell had raised the question on their own

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[90] UGD 295/4/12, Letter Book, Barr to Captain Hall on HMS Resolution, compares differences between individual rangefinders delivered, 27.8.1894.
[91] Moss and Russell (1988) p. 33.
[92] UGD 295/4/13, Letter Book, Barr & Stroud to Director of Naval Contracts, tender dated 22.4.1895.
[93] Moss and Russell (1988) p. 31.
[94] UGD 295/16/1/5, Admiralty Correspondence, Admiralty to Barr, 11.11.1893.

account in the context of incorporating them into ships under construction.[95] The possibility of extra business coming from Armstrong's sooner than from the Admiralty must have impressed on Barr the increasing urgency of having some workshop premises of his own.

Although Barr's University of Glasgow contract left him free to undertake whatever consultancy work he wished, the earlier unsettling experience of Stroud at the Yorkshire College emphasised the need to keep different domains clearly separated.[96] In June 1895 he signed a lease for a 700 square-feet workshop in Byres Road, conveniently equidistant between the University and his home.[97] The move marked the start of a substantial increase in activity, but with a workforce of only six, including Harold Jackson and two boy-workers, Barr & Stroud's Patents was still almost wholly dependent of out-sourcing for almost all its components and only equipped to do assembly work and some fine machining for experimental work like the Range-and-Order (R&O) instruments.

At the same time, Barr began to put pressure on Armstrong's to produce some substantial business, showing that he had made himself aware of naval and military affairs generally. At the end of April he warned Armstrong's that the move to Byres Road would cause short-term delays, but subsequently delivery times would improve. Five days later he suggested promoting the idea of rangefinders to shipping lines, and in the same letter asked if there was not an opportunity to sell more to the Imperial Japanese Navy, whose Naval Attaché he had just met. In early May, he urged that they should persuade the Chilean Navy to order rangefinders, and reminded them of their contractual obligation to 'influence prospective clients'.[98] In August, he badgered Armstrong's again, expressing 'disappointment' that no orders had come in. He reminded them that the Imperial Japanese Navy was ordering 'large quantities of new material' and hoped for 'an order for a considerable number' as a result, particularly as he had provided a rangefinder

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[95] UGD 295/4/12, Letter Book, Barr to Admiralty,25.4.1894 summarises submission dates and trial results; UGD 295/4/13, Letter Book, Barr to Armstrong Mitchell, 7.5.1895, summarises work done and the Admiralty's current attitude.
[96] Moss and Russell (1988) p. 24 describes his terms of employment.
[97] Moss and Russell (1988) pp. 31-33 describe the premises at Byres Road
[98] UGD 295/4/13, Letter Book, Barr to Armstrong Mitchell, 24.4.1895, 29.4.1895, and 5.5.1895.

gratis for demonstrations. Five weeks later he told Armstrong's that he could not understand why foreign navies for whom they were building ships were not buying rangefinders, and suggested promoting them for land artillery as well. By November, Barr wanted pressure putting on the French and American governments, and then in the following January pointed out that Armstrong's orders were far less than the Admiralty's.[99] In fact, they were not doing as badly as Barr implied and had sold fifteen rangefinders to seven different foreign powers since the agency was set up, but what he wanted was large orders, rather than small trial purchases.

Armstrong's apparent lack of success resulted from circumstances that, ironically, the firm had created. The problem was not with the rangefinder, but with the question of what was to be done with it by its purchasers. There was still no intellectual paradigm to direct its tactical use, not least because of Armstrong's success in promoting the 'quick-firing' (QF) gun which was one of their main ordnance specialities.[100] The tactics of the QF gun prescribed large volumes of fire delivered rapidly at relatively short ranges, rather than deliberately aimed shots at greater distances. So long as Armstrong's were building warships whose main armament was the QF gun, the tactics of the weapon tended to diminish the usefulness of the rangefinder which seemed more appropriate to the largest ships with the biggest (and slowest-firing) guns. The British Admiralty was as interested in the rangefinder's role for navigation and ship station-keeping as it was for gunnery control in the large cruisers and battleships it was tried on.[101]

Despite Barr's frustrations, business continued to grow. In 1896 the Admiralty ordered another forty FA2 rangefinders, and foreign business added another fifteen to the total. The year saw another stage in the firm's enlargement, with seven staff added and, for the first time, some optical work being done in-house.[102] Moss and Russell paid little attention to 1896, but it was an important year for the firm. They omitted completely the long trip that Barr made to the USA, ostensibly on University business but largely as a

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[99] UGD 295/4/14, Letter Book, Barr to Armstrong Mitchell, 9.8.1915, 9.8.1895, 6.11.1895, and 20.1.1896.
[100] Lloyd and Hadcock (1893) Chapter VII.
[101] Moss and Russell (1988) p. 29.
[102] UGD 295/4/14, Letter Book, Barr to Adam Hilger & Co. confirming he had obtained an optical worker.

research and marketing exercise for Barr & Stroud's Patents, lasting from mid-April until late June and taking in 'sixteen colleges and many engineering works' as well as the US Army and Navy.[103] Apart from studying engineering methods and business management practice, he gave quotations to the US Army's Chief of Ordnance and even got a US Navy order for a trial rangefinder, before coming home convinced that if Barr & Stroud wanted to sell in quantity to the US Government, then arrangements to manufacture there would be essential because of a prohibition on the purchase of war *matériel* abroad. He returned to a situation that, despite the growth, had underlying difficulties that demanded attention.

There were two particular difficulties retarding growth: the development of the electric range-and-order instruments was bogged down, and the problem of obtaining consistently high-grade optical work from Hilger's was getting worse. Matters came to a head in January 1897, revealing serious tensions in the firm that were not touched on by Moss and Russell. Shortly before, Adam Hilger had raised with Barr the possibility of 'an amalgamation of some kind' that would benefit both firms.[104] That did not wholly appeal to Barr, who thought that nevertheless some kind of working agreement could be reached if Hilger moved part of his business to Glasgow into vacant premises close to the Byres Road workshop. This, he told Stroud, would ease matters by avoiding the 'the great delays we now have in sending things back and forward and writing to and fro – just as we now have in writing about [range-and-order] recorders instead of talking the matter over with you on the spot'.

It was, he continued, 'a very serious matter' about the slow progress being made with the complex stepping motors and circuitry needed for the control system that was evolving.[105] It was 'quite impossible' to continue under current conditions, and 'the whole position requires to be well talked over and the course of the future mapped out'.

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[103] UGD 295/4/14, Letter Book, Barr to Capt. W. S. Cowles, US Navy, US Legation London, announcing his proposed itinerary; Barr to Armstrong's from New York announcing he was there on University business, 24.4.1896; Barr to Jackson, 24.6.96, and Barr to Colonel Ludlum, 13.4.96.
[104] UGD 295/16/1/9, Archibald Barr, Personal Correspondence, Barr to Stroud, 26.1.1897, provides the source material for the rest of this section, unless otherwise indicated.
[105] Moss and Russell (1988) pp. 34 and 35 describe and illustrate the equipment.

Stroud should come to Glasgow without delay – 'Make some arrangement whereby you can come down' he concluded peremptorily. Three things drove Barr to lecture his partner so strongly and atypically. He saw the R&O system as crucial to the Royal Navy adopting the rangefinder on a large scale, and so opening an even larger foreign market. It was not a diversion from rangefinder manufacture, but an extension of it, so the delay in the process of invention was unacceptable. Jackson, upon whom Barr was increasingly relying, was 'quite down in the mouth' about the lack of progress; if he left the business replacing him would be far from easy. And, for reasons that are far from clear, Stroud was loathe to visit Glasgow, a reluctance that meant every detail of design had to be sent by letter which resulted in misunderstandings and further delays because Jackson and Barr found themselves dealing separately with him on aspects of the same problem.[106]

The proposed association with Hilger did not go through, possibly because Stroud thought Hilger's standards would not automatically improve through moving to Glasgow, but more likely because Hilger's skilled workers were unwilling to go with him. The tensions between the partners then seem to have relaxed, although what remedies were taken is unknown. Some of Barr's letters to Stroud from 1897 and 1898 were removed posthumously from his private papers because they contained 'some details that should not be published'.[107] Business also improved, and although Barr continued to tell Armstrong's that they were not 'pushing the matter [of rangefinders] sufficiently',[108] the workload increased enough to justify taking additional premises and the Admiralty ordered another fifty rangefinders before the end of 1897. Most importantly, by June the following year, the R&O problem was finally solved and a viable system introduced which was offered to the Admiralty.[109]

The R&O system was also offered to foreign clients, and the Imperial Japanese Navy acted quicker than the Admiralty, deciding in July 1898 to install the equipment in every ship already fitted with Barr & Stroud rangefinders. This was the marketing break-

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[106] Neither Barr's nor Stroud's surviving papers give any reason for this reluctance.
[107] Typescript note initialled 'JWF' on an empty envelope labelled ' Letters from Dr Barr of period 1897-98' in UGD 295/16/1/2, Barr's Personal papers.
[108] UGD 295/4/15, Letter Book, Barr to Armstrong's, 26.4.1897.
[109] Moss and Russell (1988) p. 34.

through that Barr had been seeking. Firstly, equipping a battleship with R&O installations as well as rangefinders doubled the value of business, adding approximately £800 to the £750 cost of the rangefinders.[110] Even more importantly, the system removed one of the main obstacles to persuading navies' gunnery specialists to adopt the rangefinder on a larger scale by providing an effective means to convey range readings around the ship, irrespective of weather or battle conditions. In overcoming a technological 'reverse salient', Barr & Stroud had also dealt with a tactical one, so creating for themselves the possibility of moving forward on a much broader commercial front.

Both foreign sales and the expectation of greater domestic business grew in 1898, although the total orders actually received fell from the previous year's 57 to only 29. The Admiralty bought none that year, mainly because it was preparing to fit rangefinders on every capital ship in the war fleet. In anticipation of the very large order, and in response to the growing foreign interest, the firm looked for larger premises where the growing business could be better handled. In May 1899 Barr & Stroud moved into a factory building of 3,360 square feet, only a hundred yards from the existing premises. New machinery was installed, increasing the range of work that could be done and reducing the dependency of outside supplies of mechanical components, although the need to buy-in optical components was still not reduced. By late 1899, Barr and Stroud was running as the world's only 'naval rangefinder manufactory' with a workforce of about sixty, six of whom were university graduates.

1.6 Conclusion

The story of the optical munitions industry from 1888 to 1899 is largely about the growing importance of one instrument – the rangefinder – and of one maker in particular. Where there had been no identifiable optical munitions industry eleven years earlier, by the close of the 19th century there was a small, concentrated, and distinctive British manufacturing base for a device whose sole application was for use in warfare. Its

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[110] Moss and Russell (1988) p. 35.

emergence had been governed not just by the deterministic influence of advancing weapons technologies, but also by a set of evolving social forces that influenced the scale and variety of demand as well as the predicted use for optical devices in war. These forces lacked the experience of combat to act as an evaluator of either technological or intellectual paradigms, and as only the lessons of battle could be an effective arbiter of both equipment and tactics there was still no definite understanding of the utility of optical munitions. The next chapter examines the effect of the Boer War on the industry and considers the influence of increasingly rapid developments in armaments technology and the interaction between manufacturers and the armed forces.

Chapter 2

The growth in importance from the Boer War to 1906

2.1 Introduction

Before the start of the Boer War in 1899, the optical instruments employed by the British armed forces had yet to be used on active service, and there had been no experience to demonstrate their effectiveness. By the end of 1906 the British Army had not only accrued experience of how its optical munitions performed in the Boer War but had started to consider more carefully its needs for them, even though its expenditure on them remained small. The Admiralty continued to be the industry's more important British service client, its demands increasingly driven by a combination of both social and deterministic factors evident in evolving attitudes to gunnery, improvements in ordnance, and the emergence of what amounted to entirely new weapon systems in the submarine and the Dreadnought battleship. The optical munitions industry grew during this period partly through those developments in the Royal Navy, and partly through growing foreign demand. The Royal Navy's example in adopting the Barr & Stroud rangefinder stimulated foreign attention and helped to create a substantial export market which was further encouraged by the Russo-Japanese war of 1904, so that by late 1906 most major navies were either using or evaluating rangefinders, almost all of which were supplied by Barr & Stroud. This chapter examines how British service attitudes to optical munitions evolved during this time and affected manufacturers, and considers how Barr & Stroud came to dominate the British industry.

2.2 The Army's experience of optical munitions in the Boer War, 1899 - 1902, and the reactions to it.

The Boer War was the first to see optical munitions employed to any significant extent. Although fought on land, it nevertheless provided experience for both services which indicated the benefits to be gained from the use of optical aids in warfare whilst simultaneously demonstrating the shortcomings of those then in service. Although the war's lessons were of greater relevance to the Army, the Royal Navy's involvement in the fighting ashore with 'naval field artillery' provided some useful education about the need

for efficient telescopic gun sights in an era when the war fleet had no opportunity for action at sea.[1]

The guns used in South Africa reflected recent progress in weapons technology and design. In particular, a new nitro-glycerine based propellant had displaced the less efficient black powder, substantially extending the ranges of both small-arms and artillery.[2] These longer distances demanded more exact sight setting, for which the Infantry and the Artillery used variants of the Mekometer rangefinder which had been adopted in 1891. Criticisms of its effectiveness had been quick to emerge, and its eventual performance in action fell far short of expectations.[3] The topographical and climatic conditions of the veldt were unlike any experienced previously, and the Mekometer's shortcomings soon became evident in the clear air which permitted visibility at far greater distances than the British Army was used to. The Boers regularly opened fire at long ranges, inflicting casualties on British troops who were frequently exposed with little cover. Problems using the Mekometer to find the range quickly for effective retaliatory fire soon became apparent. The 1889 trials had been conducted using 'clearly defined' targets under conditions which posed no threat to the operators' safety, but in South Africa the enemy dressed to blend in with the background making it hard to identify a rangefinding mark, and was able to shoot at the Mekometer teams because they had to stand in the open while taking readings. [4] Range readings were erratic, and the ever present risk of high casualty rates led to the instrument being little used.[5]

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[1] For an account of the involvement of the Royal Navy, see P. Padfield, *Aim Straight: a biography of Sir Percy Scott* (London: Hodder & Stoughton, 1966) Chapters 6 and 7.

[2] For details of the artillery weapons used, see H. C. B. Rodgers, *Artillery through the Ages* (London: Seeley, Service, 1971), Chapter X.

[3] For more extensive comments on conditions generally, and problems in rangefinding particularly, see C. Callwell and J. Headlam, *History of the Royal Artillery,* 3 volumes (Woolwich: The Royal Artillery Institution, 1937) Vol. 2, Chapter III.

[4] Callwell & Headlam (1937), Vol. 2, p. 46 supplies content about South Africa. For details of the method of using the Mekometer, see Great Britain, Army, *Regulations for Musketry Instruction 1896* (London: HMSO, 1896).

[5] William Stroud, *Early Reminiscences of Barr and Stroud Rangefinders* (privately printed, ca. 1932-1936) p. 9, refers to high casualties; George Forbes *Experiences in South Africa with a New Infantry Rangefinder* (London: J. J. Keliher & Co. Ltd, 1902), p. 4 refers to the Mekometer's lack of use.

The earlier criticisms during the 1890s indicated both a lack of confidence in the Mekometer and an awareness that something better was needed, even before the fighting began.[6] Barr & Stroud had been promoting their own design for infantry and artillery use since 1892, and the German firm of Zeiss had recently introduced a model which competed with it.[7] Officers set about acquiring these instruments privately, either buying or borrowing them from their makers, and their published comments invariably emphasised the superiority of the commercial products over the service ones.[8]

The Mekometer was unsatisfactory in South Africa for both the Artillery and the Infantry, who subsequently followed separate paths in seeking replacements. The 'functional failure' experienced in the Boer War affected the two branches differently; the Artillery remained wedded to the existing type of instrument whilst the Infantry began to reconsider what might best serve its needs.[9] In the Artillery, the existing paradigm of the long-base two-observer rangefinders continued, despite the Mekometer's acknowledged deficiencies. This supported William MacBride's suggestion that, when presented with new technology, established military hierarchies can react in a manner that is hostile to change.[10] Despite the favourable impression made by the Barr & Stroud single-observer rangefinder in trials for fortress use in 1899,[11] the Artillery not only ignored its potential as a mobile instrument but subsequently set out to 'reconsider the claims of the telemeter' (an earlier long-base device) simply because it was 'undoubtedly more accurate than the Mekometer'.[12] This completely ignored the South African experience that had shown the difficulties in operating a similar instrument outweighed any potential increase in

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[6] Great Britain, School of Musketry, *Annual Report 1893* (London: HMSO, 1893) p. 89.
[7] Gleichen, A. *The Theory of Modern Optical Instruments: A Reference Book for Physicists, Manufacturers of Optical Instruments and for Officers in the Army and Navy*. Translated by H. Emsley and W. Swain. (London: HMSO, 1918) p. 196.
[8] Michael Moss and Iain Russell, *Range and Vision: the first 100 years of Barr & Stroud* (Edinburgh: Mainstream Publishing, 1988) p. 42, and G. Forbes, *Experiences in South Africa with a new Infantry Range-finder* (London: Keliher & Co. Ltd., 1902).
[9] Callwell and Headlam (1937) Vol. 2 pp. 107 and 108.
[10] W. M. McBride, *Technological Change and the United States Navy 1865-1945* (Baltimore: Johns Hopkins University Press, 2000) p. 4.
[11] University of Glasgow Archives, Barr & Stroud collection reference UGD 295, (subsequently UGD 295): UGD 295/4/744, Letter Book 1897-1911, Barr & Stroud to War Office asking for details of W.O. requirements, 29.8.1899.
[12] Callwell & Headlam (1937) Vol. 2 p.108 provides the source material for the rest of this paragraph.

accuracy. Although the Artillery would eventually adopt the single observer rangefinder for general service in 1913, the persistence in clinging to the older, and already discredited, two observer types can be explained through the idea of an intellectual paradigm being strong enough to overcome the 'presumptive anomaly' formed by the internal-base design. [13]

Edward Constant's conceptualisation of a 'presumptive anomaly' provides an appropriate explanation for the Royal Artillery's attitudes and policies relating to the rangefinder during this period. The notion involves an alternative technology being presumed to be superior to an existing technological paradigm.[14] That paradigm, according to Constant, involves 'an exemplary artefact and a cultural framework devoted to sustaining that artefact.' The Royal Artillery's exemplary artefact was the two-observer rangefinder, and the cultural framework sustaining it was the regimental mind-set which regarded the use of artillery as the sole domain of the professional artillerymen within that society. The two-observer long-base rangefinder had been the only pattern used by the Artillery since the 1860s, and repeated consideration of the problems in rangefinding had emphasised that such instruments were the only ones that could be expected to give accurate distance readings; the failure of early single-observer designs reinforced this belief and by the early 1880s it had become accepted as a canon that such designs were bound to be inferior and unacceptable to the Artillery. The Infantry rangefinder trials of 1889 apparently confirmed this, and the Mekometer was subsequently taken up by both Service branches.

In the years immediately after 1902 the Royal Artillery clung to the idea of inherent technical superiority in the long-base instruments justifying their retention and refinement, using as a basis for its justification the tactical philosophy - or intellectual paradigm - for the employment of its guns in action which had evolved since the introduction of rifled artillery in the 1860s. That philosophy held that speed of deployment was the prime requirement and if range readings were to be taken, then their

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[13] Edward Constant II (1980) p.15
[14] Edward Constant II (1980) see Chapter 1.

accuracy was paramount and they needed to be made as guns were being brought into action in order to deliver immediately effective fire. In the late 1850s, the presumptive anomaly of greater accuracy in rifled weapons, as compared with the existing smooth-bored ones, had successfully overcome any latent resistance to change. In 1903, however, even though the existing technological rangefinding paradigm had been proven wanting, the Royal Artillery clung to the intellectual component of its rangefinding philosophy and for the present rejected the presumptive anomaly that the Infantry began to consider. To the artillerists, the technical benefits apparent to the Infantry were much less apparent. The South African war had been largely fought by the Infantry, and the experiences of the Artillery had not provided the same degree of stimulus for change.

There was considerable significance in this rejection of the concept of superiority of the single observer instrument. Although an assortment of optical devices would be taken up by the Army in the next ten years, after approval by committees made up largely of artillerymen, none of these instruments challenged any technological or intellectual paradigm. The new observation instruments adopted in small quantities, such as the prismatic binocular telescope, caused no controversy because they did not impinge on an existing tradition and because they had no influence of the performance of the guns themselves.[15] No decision on the large-scale adoption of the self-contained artillery rangefinder was finally made until 1913. Such sustained conservatism, which at the time effectively denied the opportunity for any firm to build up a business in optical munitions optimised to the Army's needs, was in contrast to the Admiralty's attitude in taking up the rangefinder. In essence, the Artillery's policy towards rangefinding remained scarcely modified from 1889 almost up to the start of the Great War, reflecting the ability of internal social factors to resist external technological progress.

Like the Artillery, the Infantry had found the Mekometer greatly lacking but, instead of looking to improve an exemplary artefact, it set about finding its replacement even before the war was over. Less influenced by the existing technological paradigm, the Infantry turned more readily towards the single-observer rangefinder as the preferred type and in

the autumn of 1902 began trials to select a new instrument.[16] However, that was not to say the Infantry was free of a cultural framework influencing the selection process, and the conduct and outcome of the 1902 trials suggests that the Army's pre-disposition to prefer solutions originating within its own hierarchical structure could have just as inhibiting effect on progress as commitment to an existing application of an individual technology.

There were three principal contenders in the 1902 trials, two from outside the Army and one from a serving officer. The first of the civilian designs was submitted by Professor George Forbes as a private venture, and the other by Barr & Stroud who, at the War Office's request, had prepared 'two specially constructed instruments' that were essentially smaller versions of the firm's well-established naval models.[17] The third was designed by Captain A. H. Marindin, an infantry officer who had been interested in rangefinders since 1895 and had produced his first working model in 1901, entirely at his own expense without any assistance from the Army.[18] Barr & Stroud, having acquired unmatched rangefinder experience and having being specifically asked to submit for trials, ought possibly to have been encouraged as to its chances of success but, as in 1889, its partners had doubts that were to be fully justified.

After its earlier failure to get War Office orders, the firm had turned its attention to naval rangefinders, not least because it considered any infantry model it made would be – to the Army – 'prohibitively expensive' compared to the Mekometer.[19] Having this in mind, William Stroud was uncertain about what type was most likely to win the competition, being particularly worried by Forbes' entry. George Forbes's rangefinder first came to Barr & Stroud's attention when an account of it was published in the journal *Nature* late

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[15] Callwell and Headlam (1937) Vol. 2, p.109.
[16] PRO TI/11223, Proceedings of the Ordnance Council, 12.6.1908, Question of Reward to Captain A. H. Marindin, p. 3.
[17] UGD 295/4/26, Letter Book, H. D. Jackson to Major Guinness, 25.10.1902. The request must have been made in 1901 – see UGD 295 16/1/10, Correspondence from William Stroud, H. D. Jackson to Stroud, 29.11.1901.
[18] PRO TI/11223 (1908), p. 8.
[19] UGD 295/16/1/10, , letter to H. D. Jackson, 26.5.1902.

in July 1901.[20] The device was quite unlike the company's own design and used the principle of stereopsis (binocular vision) to measure distances.[21] Although the German Zeiss company already made a patented rangefinder working on the same basic idea, Forbes' design did not clash with any of its patents and he had persuaded them to make the special prismatic binocular which formed the basis of his instrument. A folding lightweight accessory unit was attached to the binocular to give the stereoscopic images, the binocular itself providing a series of measuring marks that were used to judge the range of a target. The Forbes instrument worried Stroud, who was entirely responsible for the firm's optical design, because it offered light weight, accuracy and, he believed, relatively low cost. By late November, he was so convinced of its advantages that he suggested taking it up because in his opinion Barr & Stroud could 'lick Forbes at his own game' and there was 'no justification' for making a short-base rangefinder of lesser accuracy.[22] Stroud's concerns were not taken up. Harold Jackson immediately reminded him that the firm had not been asked to design a rangefinder on a new principle, but to produce one on their established pattern: 'It is what the War Office has asked for . . .' he wrote,[23] anxious to restrain Stroud from being diverted into efforts that would inhibit the production of satisfactory competition instruments.

Between November 1901 and the late summer of 1902, Forbes promoted his design vigorously, presenting papers to the Society of Arts, the Royal Society, and the Royal United Service Institution. The final one, delivered after his return, recounted his experiences and claimed wide endorsement by officers in the field, including the theatre commander, Lord Kitchener.[24] Much encouraged by his field trip, Forbes dismissed the

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[20] UGD 296/16/1/10, Stroud to Jackson, 26.7.1901.

[21] For an explanation of this principle, see F. Auerbach, *The Zeiss Works and the Carl Zeiss Stiftung in Jena*. Translated by F. Cheshire and S. Paul. 2nd ed. (London: Marshall Brookes & Chalkely, 1904, (pp. 66 and 67, and G. Smith and D. A. Atchison, *The Eye and Visual Optical Instruments,* (Cambridge: Cambridge University Press, 1997) pp. 450 and 451.

[22] UGD 296/16/1/10, Stroud to Jackson, 27.11.1901 and 29.11.1901.

[23] UGD 296/16/1/10, Jackson to Stroud, 29.11.1901.

[24] VIA AJB 210.2.5, lecture to the Society of Arts, 18.12.1901, paper read *in absentia* to the Royal Society, 20.3.1902, and lecture to the Royal United Service Institution, 13.5.1902. Professor G. Forbes, 'Experiences in South Africa with a new Infantry Rangefinder' in *Journal of the Royal United Service Institution*, 13th May 1902, describes his experiences and test results in detail and provides the source for the rest of this section, unless otherwise indicated.

Mekometer out of hand, saying it was never actually used by the Infantry because of its inconvenience and danger to its operators, and hardly ever by the Artillery as 'officers seldom rely on it'. All this worried Stroud, who continued to suggest ways of beating Forbes stressing the need to produce a rangefinder costing no more than £25 (less than half the price of the firm's own instrument) to 'win the day'.[25] Although no one else at Barr & Stroud agreed with him, Stroud's concerns were by no means misplaced even if he was not absolutely correct in his reasoning. The third competitor in the trials, the Marindin rangefinder, was to deny the firm War Office business through a combination of factors that embraced both cost and institutional bias.

Marindin had approached the London firm of Adam Hilger & Co. Ltd. in 1900 for help in making up his design.[26] Hilger's were by then making optical parts for Barr & Stroud which formed 'a very important part' of the firm's activities and absorbed most of the attention of its senior staff.[27] Hilger's close involvement with Barr & Stroud meant the firm knew as much about the instruments as anyone else in the country and was well-placed to assist Marindin in developing his ideas. Frank Twyman, then Hilger's manager and later its managing director, recognised the problems posed by existing patents and translated Marindin's plans into a design which not only avoided the protected features of Barr & Stroud and Zeiss, but had sufficient novelty to patent in its own right.[28] Irrespective of Twyman's contribution, British Patent 16647/1901 was in Marindin's name alone, probably because Twyman was uncertain about Barr & Stroud's reaction to his involvement and unwilling to prejudice the relationship between the two firms which was not always harmonious, but on which Hilger's relied for a substantial part of its business.[29]

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[25] UGD 296/16/1/10, Stroud to Jackson, 6.7.1902.
[26] Science Museum London, Library, Adam Hilger Collection (subsequently HILG), 3/1, Typescript of Mr Twyman's Lecture, August 1944, p. 15.
[27] HILG 3/1, p. 24.
[28] HILG 3/1, p. 15.
[29] UGD 295/4/21 Letter Book, H. D. Jackson to Hilger, a series of letters between 3.10.1900 and 3.12.1900 describes how relations fluctuated.

By June 1901, Marindin was involved 'in earnest', and Hilger's was building a functioning rangefinder.[30] Between then and June 1902, Hilger's submitted thirty three invoices to him totalling £416.00, and by August 1902 had manufactured a number of prototypes, the first of which Marindin had been sent to the Chief Inspector of Rangefinders as early as December 20th 1901.[31] Having experimented with them over the next seven months, and before the start of the rangefinder trials scheduled for the autumn, the Chief Inspector reported 'satisfactory results' and on August 26th the War Office formally asked Marindin 'to state on what terms he was prepared to offer his invention for the use of the Crown'.[32] This suggests that the Infantry had already signalled its wish to adopt the Marindin as its standard instrument and that the War Office was prepared to adopt it without necessarily giving serious consideration to any other instrument. None of this was known to either Forbes or Barr & Stroud, although the latter was certainly not over-optimistic as to the outcome of the trials.

In late September, George Forbes had sufficient confidence to propose to Archibald Barr that they should each concentrate on one of the Services.[33] Without revealing his production plans, he suggested that he should supply rangefinders to the Army, and that Barr & Stroud should continue with the Admiralty. Barr's reply showed some caution as to the outcome of the tests. Having had dealings with committees at Woolwich before, he pointed out that there was no guarantee that either of them would actually get any orders, and any agreement would be premature. And, he said, even if there were orders the financial benefits were uncertain as 'the War Office can claim the use of any patented invention with or without the consent of the inventor', implying – quite incorrectly – that the State had powers of sequestration without reward.[34] Under the circumstances, he saw no possibility of coming to any accommodation with Forbes and declined to go further.

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[30] PRO TI/11223 (1908), p. 8
[31] PRO TI/11223 (1908), p.13, List of payments received by Adam Hilger Ltd., and PRO TI/11223 (1908), p. 3.
[32] PRO TI/11223 (1908), p. 3.
[33] UGD 295/4/744 Letter Book, Barr's reply to Forbes' undated proposal, 2.10.1902 provides source material for the rest of this paragraph.

Perhaps endorsing Barr's caution, efforts to enhance the firm's chances by endorsement were not accompanied by any success. In early December – when the testing programme was almost complete and the Rangefinder Committee was starting to evaluate the results – Jackson attempted to organise the appearance before it of Major C. D. Guiness of the Royal Artillery as an expert witness.[35] The Committee's president had already agreed to this in principle, but on the 10th Guiness telegraphed Jackson to say he could not appear without the direct authority of the War Office.[36] Three days later, Jackson wrote in terms suggesting either he did not expect Guiness to give evidence, or that whatever he said would be of limited help: 'We have noted what you say concerning the probable tone of your evidence before the Committee. We quite understand the position…'.[37]

Barr's earlier caution was entirely justified. In January 1903, the Committee reported its unanimous endorsement of the Marindin rangefinder's suitability, and its recommendation that 'at least 100 instruments should be provided for tests…'.[38] Barr & Stroud believed the choice was based on price, echoing Stroud's earlier concerns, but Frank Twyman thought it was rather because of lighter weight.[39] Neither was apparently aware of the preference shown for it before the trials, and Twyman may actually have been surprised by the decision. He later noted that the 'government experts' on the Rangefinding Committee were convinced that the Marindin was 'much more imperfect than its competitors, an opinion with which I may say I privately agreed'.[40] That the design was not wholly satisfactory is partly borne out by the failure to place any substantial order in 1903, despite the recommendation. The Army asked Marindin for further trial models in 1903, and then carried out more rangefinder testing in October

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[34] See Patents, Designs and Trade Marks Act 1883, Section 27 (2) which refers to terms between inventors and the Crown.
[35] UGD 295/4/26, Letter Book, Jackson to Guiness, 8.12.1902.
[36] UGD 295/4/26, Letter Book, Jackson to Guiness, acknowledging receipt of his telegram, 10.12.1902.
[37] UGD 295/4/26, Letter Book, Jackson to Guiness, 13.12.1902.
[38] PRO TI/11223 (1908), p. 3.
[39] For Barr & Stroud's opinion, see GUA UGD 295 Unclassified Material, Russell Research Notes: 9.1.1903, H. D. Jackson to Archibald Barr. Russell cites a Letter Book 'BS4/21'. UGD 295/4/31 is noted as having an earlier designation as '21', but this book covers April to June 1904. Russell's notes were made before the University acquired the Barr & Stroud records, and some of the material which Russell quotes is not now present in the University Archives. For Twyman's interpretation, see HILG 3/1, p. 15.
[40] HILG 3/1, p. 15.

1904, February 1905 and July 1906, each time asking for modifications to his design.[41] None were ordered for troop trials, and a final decision to take it into general service was not made until early 1907, an account of which will be given in the succeeding chapter.

Given Twyman's reservations, it is possible that the choice was influenced by factors not unlike those bearing on the 1889 trials. In its separate evaluation of the Marindin before the official trials, the Infantry chose it without reference to any of its civilian designed competitors, an apparently premature decision that might be explained through the tendency of 'social groups [to] identify with and champion' artefacts emanating from within themselves, and the accompanying characteristic of favouring one artefact over another through social rather than purely technological pressures.[42] In such cases, the 'appropriate solutions' to perceived problems are coloured by the nature of the evaluation process, and in this case the intra-societal origin of the Marindin may have encouraged its ready, and perhaps inadequately questioned acceptance. Even though the Infantry successfully avoided the Royal Artillery's inclination to maintain an existing inferior technological paradigm, by prematurely endorsing a design which originated from within their own society they may have encouraged the adjudicating committee to succumb to a parallel latent instinct which was predisposed to attain closure of the issue and attain 'relative social tranquility' in respect of the rangefinding question. Whatever the motivations or intentions, the Marindin rangefinder was to prove a far from stable entity, and will be encountered again later in this story.

2.3 The effects of Army demands on the optical manufacturers

The effects of the Boer War were of little long-term significance for the optical munitions industry. War Office Contracts Department records show that purchases of telescopes and binoculars increased greatly during the war itself, peaking in 1902 but

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[41] PRO TI/11223 (1908), p. 12 and PRO TI/11223, Proceedings of the Ordnance Council, 8.6.1909, pp. 5 and 10.
[42] W. McBride, *Technological Change and the U.S. Navy 1865-1945* (Baltimore: Johns Hopkins University Press, 2000) p. 234.

tailing off sharply once the war had ended and contracts had been filled.[43] Roy and Kay MacLeod suggested that during the war government orders for 'quantities of magnifying devices (particularly field glasses and telescopes)' and 'new types of optical munitions [rangefinders]' led to the creation of additional manufacturing capacity within the optical instrument manufacturing trade but that this capacity did not last once War Office orders were discontinued, and much of the new machinery was then '. . . sold for little more than scrap value'.[44] The implication is of substantial business being placed and firms being encouraged to expand, but the evidence for this is not convincing. The MacLeods cited in support just two editorials from trade magazines published in 1916 when the optical industry was lobbying hard for the creation of an institute for optics in London and pointing out past failures to gain support for British optical manufacturing.[45] Neither did more than assert that such events took place and gave no corroborative evidence.[46] It is more likely that War Office orders during the Boer War, even if much larger than previously, were still relatively small, issued piecemeal and by no means confined to domestic makers, so that the possibility of a substantial enlargement of the optical industry was never great.

There is no doubt that the sudden surge in demand caught the War Office unprepared, without sufficient stocks of many optical stores. To make good those shortages the Director of Army Contracts began issuing 'Requests for Tender' to firms on its list of approved makers, irrespective of whether they had experience in producing any particular product.[47] The notice sent to Barr & Stroud in July 1901 included the Mekometer, the Watkin Depression Rangefinder, observation telescopes and telescopic

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[43] These figures, and others in this section, are extracted from PRO WO 395/1, Annual Report of the Director of Army Contracts, Financial Years ending 31.3.1899 to 31.3.1902, and PRO WO 395/2, Annual Reports 31.3.1903 to 31.3.1906, unless otherwise indicated.

[44] Roy and Kay MacLeod, 'War and economic development: government and the optical industry in Britain, 1914-18' in J. M. Winter, ed. *War and Economic Development* (Cambridge: University Press, 1975) p. 168.

[45] For the background to this, see Great Britain, Ministry of Munitions, *History of the Ministry of Munitions:* Vol. XI *The Supply of Munitions;* Part III *Optical Munitions and Glassware.* (London: HMSO, 1922).

[46] *The Optician*, editorial articles in issues 31st March 1916 and 14th July 1916.

[47] These procedures remained unchanged until after the Great War began: for details see *OH* Vol. I, Part 1, pp. 53 to 58

sights, all of which the firm subsequently tendered to supply, with varying degrees of success.[48] In August the War Office rejected a tender for observation telescopes, but in September accepted bids for the Mekometer and Depression Rangefinders. The same month, the company told the Director of Contracts that an order offered for a hundred telescopic sights was 'not of sufficient magnitude' to be profitable, and in November that it would not even tender for them in smaller numbers. By February 1902, Barr & Stroud was clearly unhappy about the way the War Office was issuing contracts for only parts of tenders, and scaling-down or cancelling orders already issued.[49] The total value of business resulting from the Boer War between 1901 and 1903 came to little more than £1,020, a figure too small to justify creating any additional capacity.[50] Indeed, the theme of the correspondence was that Barr & Stroud's existing capacity was being under-used by the War Office whose Contracts Department seemed oblivious of how best to organise the distribution of orders.

It is also clear that orders were placed outside Britain, particularly for binoculars, so that far from generating new capacity, the chance to open up a new branch of the industry was completely ignored. The Annual Report of the Director of Contracts for 1901-1902 noted that 'a considerable number' of the 5,810 binoculars bought that year were made 'on the continent', and the next year that 'a considerable proportion' of the 13,500 obtained was bought 'as usual, from the continent'. The average unit price of £1.25 shows that these were simple non-prismatic instruments, but numbers of the more complex (and expensive) prism types of commercial production were also bought in South Africa by the Army Ordnance Department and regimental commanding officers for issue directly in the theatre.[51] Reports from troops receiving these commercial types (mostly German, made by Zeiss) showed how much better they were than the non-

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[48] UGD 295/4/23, Letter Book, H. D. Jackson to War Office stating that Barr & Stroud could produce those types if asked, 30.7.1901. This letter book provides the source material for the rest of this section, unless otherwise indicated.
[49] UGD 295/4/24, Letter Book, Jackson to Director of Army Contracts, 12.2.1902.
[50] UGD 295/19/2/1, Customer Order files 1901 to 1903, order numbers CO 193,215,235,245,291,294 and 348.
[51] PRO WO 395/1, Annual Reports of the Director of Army Contracts, Financial Years ending 31.3.1899 to 31.3.1902 provide the unit prices: such instruments sold commercially at prices between £1.00 and £1.50.

prismatic ones issued officially by the War Office. Only 10 percent of those reporting on the latter were satisfied with them, whilst 95 percent of those commenting on the prism patterns gave favourable reports.

The overall benefit of War Office business to the optical manufacturers from 1899 to 1906 seems to have been very small. The immediate fillip given by the Boer War was not on a scale large enough to justify the creation of new businesses specifically for optical munitions, or to set up special departments within existing businesses. Nor did any increase in demand last much longer than the war itself.[52] If there was the kind of expansion that the MacLeods suggested during the war, any firm that had been so optimistic as to invest in plant or tooling would have been disappointed after 1902. But to have made any such investment without thought as to the long term prospects for military business would have been, at best, commercially imprudent. Without any significant permanent expansion in the size of the British Army, and in the absence of any tendency to adopt new patterns of optical munitions on a large scale, there could not have been any reasonable expectation of new opportunities for business with the War Office.

2.4 The Admiralty and its approach to optical munitions

In 1899 the Royal Navy was the British industry's largest customer for complex optical munitions such as the rangefinder, even though it employed them on a relatively small scale. Up to then it had bought 123 Barr & Stroud rangefinders out of the 189 the firm had sold,[53] but in the next seven years its purchases of rangefinders and other optical gunnery instruments grew substantially as more attention was paid to accurate shooting at increasingly long ranges.

PRO WO 108/278, Extracts from Reports by Officers Commanding Units in South Africa during 1899 – 1901: Signalling Equipment, Telescopes and Binoculars, provides the data regarding local purchases.

[52] Barr & Stroud's last War Office order is recorded on 8th October 1903, and was for seven shillings' worth of Mekometer spares GUA UGD 295/19/2/1 Customer Order files 1901, 1902 and 1903 (CO 348).

[53] UGD 295, Strang papers.

The subject of gunnery in the Royal Navy between 1889 and 1906 has been examined by Jon Sumida in his *In Defence of Naval Supremacy*.[54] In explaining the genesis of 'fire control instruments' (devices to enable the gunfire of one moving ship to hit another at long ranges), he stressed the importance of understanding 'the history of the Royal Navy's previous efforts to find a solution to the problem of naval range-finding [sic].'[55] However, his coverage of rangefinding was largely confined to the dates of introduction of different Barr & Stroud models, their relative standards of accuracy, and the difficulties of using them.[56] Sumida correctly emphasised that the rangefinder gave neither 'a final or complete solution to the sight-setting problem', but his emphasis on the instrument's limited utility because of the lack of means to transmit ranges to the guns,[57] suggested he was unaware of Archibald Barr and William Stroud's early understanding of the need for an integrated control system which was demonstrated in their development of 'range and order' instruments to transmit range and bearing data automatically either to individual guns or a central control point.[58] Sumida subordinated the importance of optical devices, and gave hardly any attention to the essential need for telescopic sighting devices in the system of gunnery then evolving.

There were problems in hitting even stationary targets. In 1900, firing tests against a battleship moored at 1,700 yards showed that more than 60 percent of the shots missed.[59] Two reasons, separately or jointly, could account for this poor showing; the range had been wrongly set on the sights, or the guns had not been aimed properly at the target, both problems that could be corrected by suitable optical apparatus. Setting the range correctly was important – Admiralty ballistic tables showed that at 1,700 yards to hit a 20 foot high target representing a ship, the permissible aiming error was 142 yards, at 2,000 yards it was 38 yards, and at 3,000 yards only 24. Aiming correctly was as important as having an accurate range, but the 'open sights' in general use required the gun-layer to

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[54] Jon T. Sumida, *In Defence of Naval Supremacy: Finance, Technology, and British Naval Policy 1889-1914* (London: Routledge, 1993) see Chapters 1 and 2.
[55] Sumida (1993), p. 71.
[56] Sumida (1993), pp. 72 to 76.
[57] Sumida (1993), p. 73.
[58] Moss and Russell (1988), pp. 34 and 35.

line up two points on the sight with the target itself, giving considerable scope for human error.[60] Although telescopic sights giving a magnified image and a single aiming mark had been in service since 1887, their use had actually been discouraged by an Admiralty Order in March 1896 and they were rarely used except for occasional drills.[61] An aiming error coupled with a range setting error could easily cause a battleship to be missed even at close range, as the 1900 trials had demonstrated.

Aiming problems were addressed robustly after 1898 by Captain Percy Scott, who became an eloquent and aggressive advocate for the universal employment of telescopic sights.[62] Peter Padfield suggested that Scott was responsible for the introduction of such sights into the navy,[63] but Scott rather revived their use. He also became a ruthless critic of the quality of the existing types in service, lobbying for more powerful types with finer aiming reticles.[64] His appointment to command the gunnery school, H.M.S. *Excellent*, in April 1903, lead directly to the Admiralty's decision in 1905 to carry out a wholesale revision of gun sighting and gunnery control arrangements of all fighting ships in the fleet.

In 1904, *Excellent* had prepared a report on the navy's sighting equipment which recommended the general introduction of new improved telescopic sights.[65] On 11th May 1905, the First Sea Lord approved a programme to accomplish the 're-sighting' of the entire fleet, a substantial programme to be funded out of both the current and following years' Estimates. A circular in June showed the extent of the proposals, detailing which ships were to receive what telescopes, and pointing out that 'These alterations will necessarily take a considerable time to carry into effect as the number . . . to be provided

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[59] D. K. Brown, *The Grand Fleet: Warship Design and Development 1906-1922* (London: Chatham Publishing, 1999) p. 26.
[60] H. Garbett *Naval Gunnery* (London: George Bell, 1897) pp. 201 to 203.
[61] Gun Sighting Telescope type AP 360 had been introduced in 1887, and type AP 700 in 1891: PQ 109/M/91/PQ11 details the instructions not to use the sights.
[62] Sumida (1993), p. 46 ff.
[63] P. Padfield, *Aim Straight: a biography of Sir Percy Scott, the father of modern naval gunnery* (London, Hodder & Stoughton, 1966), Chapter 5.
[64] PRO ADM 116/602 Naval Armaments and Equipment; experiences gained on active service in South Africa, has comments on the quality of naval telescopic sights.
[65] *PQ* 109/M/91/PQ16, 16.2.1905.

is very large'.[66] The 1905-1907 programme represented, numerically, the largest order for optical instruments that the Admiralty had ever placed, amounting to approximately 4,000 assorted telescopes.[67] The Director of Naval Ordnance (DNO) had pointed out that 'as far as efficiency permits' existing telescopes would be used in the programme,[68] but either efficiency did not so permit, or the DNO was being disingenuous, as neither of the two patterns of sighting telescopes then in service was to be used.[69]

Five new types were to be ordered: two of fixed magnification at 3 and 6 power, and three of variable magnifications at 3 to 9, 5 to 15, and 7 to 21 power. They were all of straightforward optical design, but made to standards of robustness far beyond any civil telescope and quite unlike anything being sold commercially. The standards of optical design and precision in manufacture needed, though, were no higher than any high class optical firm would have employed in its regular production. The contracts were divided between two established London makers, Ottway & Co. Ltd., and the Ross Optical Company. Design details were left to each firm within the general specification governing magnification, angle of view and connections for attaching them to the guns.[70]

Ottway received orders for all five patterns, Ross for only two. Using the values given in the Admiralty's *Rate Book for Naval Stores*,[71] it is possible to assess the total contract value as about £50,000, spread over the financial years 1905-1906, and 1906-1907. This was indeed a significant order (some £3.5 million at 1998 values).[72] Some measure of its size and importance to the optical munitions industry can be gained from comparison with the approximately £22,000 of rangefinder orders Barr & Stroud received from the

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[66] *PQ* 109/M/91/PQ16, 2.6.1905.
[67] This figure has been extrapolated from the scales of issue in the schedule, and from armament details in *Jane's Fighting Ships* 1905-1906.
[68] *PQ* 109/M/91/PQ16, 16.2.1905.
[69] They are not mentioned at all in the Royal Navy's *Manual of Gunnery for His Majesty's Fleet* Volume 1, Part I (London: Eyre & Spottiswood, 1907)
[70] Great Britain, Admiralty, Gunnery Department. *Manual of Gunnery for His Majesty's Fleet* (London: HMSO, 1907) .
[71] *Rate Book for Naval Stores: Authorised List and Price List of Naval Stores* (HMSO, annually from 1870).
[72] Calculated using data from R. Twigger, *Inflation: The Value of the Pound 1750-1998*: (London: House of Commons Library, London., 1999.

Admiralty in the same years.[73] In the absence of company records for either Ottway or Ross, the effects this business had on them must be conjectural, but Ross' advertisement in the 1907 edition of *Jane's Fighting Ships* announced that they had made extensive additions to their works in consequence of what they demurely described as 'increased demand' for their telescopes, and that their production and prices would benefit as a result.

Important as this business was, it was not sustainable in the way that manufacture of the rangefinder was. The Royal Navy's very size, and, it may be argued, its earlier backwardness in failing to keep up with the growing potential of naval gunnery, provided a unique business opportunity for the firms who won sighting telescope contracts in 1905. It was a 'one-off', much in the same way that the War Office orders had been in the Boer War. Once the re-equipment was complete, demand for sighting telescopes would be geared to new shipbuilding and replacement of attrition. The telescope, as an instrument, offered little possibility of radical improvement in design or performance, and so early obsolescence was unlikely, and it was not individually of particularly high value. The rangefinder, though, was a much more expensive device that was still evolving, and new, improved designs had the potential to render obsolete earlier versions, creating a self-sustaining demand. Welcome as the sighting telescope orders undoubtedly were, they did not presage the development of a sustainable new branch of optical munitions manufacture. Their significance was that they established Ottway and Ross as the Navy's telescopic sight makers, a status which was sustained (albeit at a low level of activity) by the shipbuilding programmes that continued until the Great War.

At the same time that new sighting apparatus was being considered, the construction of the novel battleship *Dreadnought* emphasised the pressing need for a rangefinder of greater accuracy. Unlike earlier capital ships, *Dreadnought* had a main armament of uniform calibre where five turrets each mounting two 12-inch guns replaced a mixture of

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[73] Extracted from UGD 295/19/1/2, Customer Orders 1900-1910.

turrets with guns of different calibres.[74] The guns themselves were little different from those of immediately preceding battleships, but the important difference, the presumptive anomaly, was the potential improvement in the damage that the new ship's heavy armament could inflict at longer ranges.[75] To hit at increased distances demanded greater precision in the aiming process, errors in aiming and distance setting had to be eliminated before satisfactory shooting could be expected. The whole question of 'fire control', the integration of all the problems involved in long range artillery fire at sea began to be studied seriously in late 1903 and 1904, even before the design of *Dreadnought* had been finalised. Once again, as in the previous decade, technological advances were so strong that they not only challenged established norms but demanded investigation of the way to further efficiencies in gunnery. The Royal Navy was unavoidably faced with the need for 'inventing accuracy', to provide a targeting system that would enable an unguided projectile fired from one moving ship to hit another moving vessel whose course between the projectile's despatch and arrival was unpredictable.[76] The start of the process had to be the knowledge of the range of the target vessel, and as any error in range would disrupt any possibility of accuracy, the performance of the rangefinder was of paramount importance. Without that instrument, gunnery control would be inadequate and the performance of the entire weapon system that was the battleship would be devalued. Serious as that was, there was another situation in which the presence of optical instrumentation alone permitted the deployment of a new military technology.

2.5 The Submarine Periscope

In 1901, the Royal Navy acquired its first submarines to evaluate the menace posed by the underwater vessel armed with torpedoes, and to determine the best ways to counter

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[74] For examples of earlier armament combinations, see A. Preston, *Battleships of World War 1: An Illustrated Encyclopaedia of the Battleships of All Nations 1914-1918* (New York: Galahad Books, 1972) pp. 98 to 111.
[75] Sumida (1993) p. 49.
[76] The quotation is taken from D. MackKenzie, *Inventing Accuracy: a Historical Sociology of Nuclear Missile Guidance* (Cambridge, Mass: MIT Press, 1990).

it.[77] The threat of the underwater vessel lay principally in its invisibility when submerged, but to exploit its potential the vessel's crew needed to be able to see what was happening above the water in order to navigate and position the boat for an attack. Neither the idea of the submarine nor a device to see from it was new; experimental submarines had been built by several navies in the late 19th century, and all used some kind of primitive device to permit observation when under water.[78] The effectiveness of these early methods was far from satisfactory, many being little more than glazed panels in an extension of the boat's hull that projected above the water when the vessel was below the surface. In other cases, combinations of simple lenses and mirrors were employed in a tube passing from the crew space through the hull to reach above the water. These 'periscopes' were more useful, but by no means widely adopted in the early submarines partly because of their optical limitations and partly because of the mechanical problems of making them watertight and durable. The early development of the submarine as a weapon was inhibited as much by the lack of the means to see as by other engineering difficulties.

All the first British submarines had periscopes that were, by contemporary standards, effective enough to allow the boat to be used as a weapon. The earliest ones were made up to the specification of Captain Reginald Bacon in 1901 or 1902.[79] Bacon, a leading proponent of the military utility of the submarine was subsequently introduced by the boats' builders, Vickers, to Sir Howard Grubb, the owner of the Dublin astronomical telescope making firm, who – according to Bacon – subsequently produced an improved version of his original design.[80] Bacon's claim may have been mistaken, as Grubb's first periscope patent was granted in 1901.[81] The patent specification shows this to have been a sophisticated prismatic design, providing an erect, normal image, unlike earlier devices which either reversed or inverted what the observer saw. Grubb's good relations with

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[77] N. A. Lambert, *Sir John Fisher's Naval Revolution* (South Carolina: University of South Carolina Press, 1999) p. 38 ff.
[78] M. F. Suetter, *The Evolution of the Submarine boat, Mine, and Torpedo* (Portsmouth: Griffin,1908) describes these in some detail in the text.
[79] Cited in I. S. Glass, *Victorian Telescope Makers: Thomas and Howard Grubb* (Bristol: Institute of Physics Publishing, 1998) p.206.
[80] Glass (1998) describes the other accomplishments of the firm.

Vickers gave him a monopoly of supply for all the Vickers' submarines built in the next five years, and he had the vast majority of periscope business from the Royal Navy until 1914. Norman Friedman suggests that Grubb may have supplied periscopes for U. S. submarines built by the Electric Boat Company as early as 1902, and describes the firm as one of the major manufacturers 'early in the century'.[82] Assessing Grubb's contribution to the early development of the optical munitions industry is made difficult by the paucity of available records for the firm and a more extensive consideration of its activities must remain contingent on the emergence of more information.[83]

The importance of the periscope in the development of the submarine cannot be underestimated. As the rangefinder made effective gunnery at long ranges possible, so the periscope permitted the submarine to become a practical weapon delivery system. It became not just a navigational tool (its original purpose) but also the sighting device to permit the submarine's offensive weapon, the torpedo, to be aimed with precision. Proponents of the submarine were quick to see the possibility of using the periscope as a type of fire control system, and in 1903 L Y. Spear of the Holland Torpedo Boat Company, New York, asked Barr & Stroud to design a rangefinder that could be incorporated into the periscope.[84] Archibald Barr had reservations about the possibility of doing this, because the company had no knowledge of periscopes, and subsequently declined to take on the project.

The Royal Navy's willingness to consider an alternative paradigm in naval warfare in response to an emerging technology permitted another branch of optical munitions manufacture to become established in Britain, although without further research it is not possible to understand the relationship between the appearance of the essential optical device and the weapon itself. Unlike large surface warships, which were typically produced to meet a government requirement, the submarine was a private venture which

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[81] Glass (1998) p.208
[82] N. Friedman, *U.S. Submarines through 1945; an illustrated design history* (Annapolis, MD: Naval Institute Press, 1995) p.270.
[83] Tyne & Wear Archive Services, Newcastle on Tyne, holds unsorted records for the successor company.
[84] UGD 295, unclassified material, Russell Research Notes, Barr to Spear, 6th October 1903.

was promoted by its inventors to governments. Possibly the desire to offer an effective weapon stimulated the builders of submarine to hasten the development of the periscope, the reverse of what had happened in the emergence of the rangefinder.

2.6 Barr & Stroud – the principal optical munitions maker

The increasing commitment to long range gunnery, and the concomitant necessity for fire control, meant that Barr & Stroud was virtually guaranteed a monopoly of Admiralty rangefinder business by 1905. No other British optical maker had that firm's accrued expertise in the mechanics of rangefinder construction, nor such an established working relationship with the Royal Navy. Donald MacKenzie points out that accuracy (in missile targeting) is 'the product of a complex process of conflict and collaboration between a range of social actors' and not merely the 'inevitable consequence of technical change'.[85] It was the Royal Navy's willingness to accept Barr & Stroud as its monopoly supplier as much as the firm's command of technology that allowed the firm to build up not just its domestic business but its even more successful export trade up to the close of 1906.

The Admiralty had indicated during 1898 that it wanted to acquire a very substantial number of rangefinders and because of concerns that prices were excessively high through Barr & Stroud's monopoly, had raised the question of acquiring the rights to produce them, either itself or through other contractors. [86] The firm's response indicated how far it had shifted from the founding partners' original intention to derive an income from licensing their patents to others.[87] Having had the potential value of the rangefinder indicated by the growing interest from both the Admiralty and foreign enquiries Barr & Stroud was now much more interested in supplying than in licensing, and had no inclination willingly to relinquish its monopoly. On May 30th, the firm reiterated its insistence on a royalty of £100 per instrument made by anyone else, and insisted that the

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[85] D. MacKenzie (1990) p. 3.
[86] UGD 295/5/744, Letter Book, Barr & Stroud to Admiralty, 30.5.1898, cites Admiralty letter CP/4919/8720, 27.4.1898.
[87] See Moss and Russell (1988) p. 17 for details of Archibald Barr and William Stroud's first joint design, a patented device for making lantern slides, licensed to another to manufacture.

selling price of £250 for each rangefinder was absolutely the lowest possible. The firm refuted robustly the Admiralty's allegation that the bulk of the selling price represented 'royalty and commission', rather than a more usual mark-up on manufacturing costs.[88] The company's riposte was that, besides materials costs, the final price actually reflected the expenses of setting-up, research and development, and a return on the accrual of expertise. To this aggregation, which they termed their 'oncost', they added a percentage to cover labour costs, operating overheads, and then a final margin for profit.

Faced with what may be interpreted as either a reasonable commercial assessment of their products' value, or as downright obduracy by the company, the Admiralty abandoned the idea of acquiring the manufacturing rights and eventually issued a contract for a hundred rangefinders on 30th June, 1899, at the price demanded by Barr & Stroud. The Admiralty found itself in an unusual position with Barr & Stroud. Although a monopsonist domestic customer, the Admiralty was never able to exert its 'enormous market powers' over Barr & Stroud.[89] Even though the Patents Act gave the Crown the right to 'use [a patented] invention for the service of the Crown' without the prior arrangement of terms or conditions,[90] no matter how much the Admiralty may have objected to the firm's prices and the proposed licensing fee, it was hardly in a position to take advantage of that right. The Act did not give the Crown any power to compel an inventor to manufacture for it, nor was there any other maker of naval rangefinders to whom the Admiralty could turn in the hope of obtaining a better deal. The scale of its demand by 1906 had been insufficient to support more than one maker, even if any other firm had been able to produce competitive instruments. Barr & Stroud's various patents made the task very difficult, and the key one covering the prism and range scale arrangements to measure and display the range remained in force until 1903.[91] The only potential rival for Barr & Stroud in 1898 was the German Zeiss rangefinder, which was built on a fundamentally different principle and itself well protected by patents. The

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[88] UGS 295/5/744, Letter Book, Barr & Stroud to Admiralty, 30.5.1898.
[89] C. Trebilcock, *The Vickers Brothers: Armaments and Enterprise 1854 - 1914* (London: Europa Publications, 1977) p. 3.
[90] Patents, Designs, and Trade Marks Act, 1883, Section 27(1).
[91] The provisions of British Patent 9520/1888 were also in force in France, Germany and the USA.

Zeiss instrument was both foreign, which made it less than desirable to the Admiralty, and exceedingly demanding in manufacture, which would probably have made it even more expensive than the Barr & Stroud instrument.

The Admiralty's options were limited either to agreeing to the company's royalty demands or to paying the price demanded for complete instruments. The decision to continue buying from Barr & Stroud rather than seeking another maker was perhaps influenced by the company's emphasis in its riposte on setting-up costs and accrued expertise. If the Admiralty wanted another and presumably cheaper source for its rangefinders, it would need a contractor both willing and able to manufacture at a lower price, and would also have to allow for delays while such a firm became proficient in making a specialised instrument which was quite unlike anything else being made by the British optical or scientific instrument industry. No doubt these difficulties persuaded the Admiralty to maintain the *status quo*, a circumstance that repeated itself some fifteen years later and will be described later in this story. However, the continued dependence of Barr & Stroud on outside suppliers for many of its components was a potential weakness for the firm that might have provided a means by which another source of supply could have been established had the Admiralty been so minded. So long as the patents remained in force, Barr & Stroud could dictate royalty terms, but once these expired in 1903, then the firm might be vulnerable to competition, particularly if it was still dependent on outside suppliers. The Admiralty's principal need in 1899 was the immediate acquisition of rangefinders, and short-term priorities overcame any question of future alternative sources of supply. The company was therefore safely able to anticipate the Admiralty's new business and proceed with plans to expand both the scale and scope of their operations.

By the time the contract was signed in mid-1899, Barr & Stroud had completed its expansion into a purpose-built engineering workshop equipped with a range of machine tools to allow the manufacture of some at least some of the components used in the rangefinder, its mounting, and the 'Range and Order' instruments which formed part of

the rangefinder's shipboard operating system.[92] This investment was in a year when turnover declined from over £14,000 to £8,500, and it represented the anticipation of Admiralty business rather than a response to orders already received. It showed the measure of confidence which the firm then had. The move marked the beginning of a period of sustained expansion which was to lead the firm into a second move only three years later. This short interval saw the company's business expand and diversify, not just in the products being made but in the clients to whom they were supplied. This growth also directed Barr & Stroud towards an increasing level of autarky which was achieved only with some difficulty.

The growth of the business can be measured from the surviving details of orders and turnover. The turnover and sales figures quoted below are partly from schedules prepared during the late 1960s in connection with a proposed, but uncompleted, company history. Other figures were prepared in 1987 by Barr & Stroud Ltd from then-surviving cash books in connection with Michael Moss and Iain Russell's *Range and Vision*, which was published in 1988. Those books apparently did not survive subsequent company re-structuring, but Strang's draft material contains extensive details which, where comparisons can be made, do correspond with the abbreviated material published in *Range and Vision.* The order figures before 1901 come from Strang's material which was produced from then-existing factory records, seemingly now lost. Order records from 1901 onwards survive in their entirety for the period under review, providing a wealth of detail about quantities, prices and delivery times.[93]

Moss and Russell suggest that the firm's order book shrank between 1900 to 1902 to such a level that serious concerns were felt about prospects for the immediate future. Orders had been received for 44 rangefinders in 1900, 33 in 1901 and 26 in 1902, and consequently turnover had shrunk from £27,731 in 1900 (largely composed of receipts

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[92] Moss and Russell (1988) p. 37.

[93] UGD 295/19/2/1, 19/2/2. 19/2/3 Customer Orders December 1900 onwards.

from the Admiralty's large order of June 1899) to £15,070 in 1901, and to £14,522 in 1901.[94] As a result the partners became

> acutely aware of the over-reliance of the business on the willingness of the governments of the world to continue to spend vast sums on expanding and modernising their navies.

Moss and Russell point out that William Stroud was 'particularly concerned' that the business had failed to get War Office to adopt its designs, and he persuaded the other two partners that 'the time had come to diversify the range of products' the business was making. In 1899 Stroud wrote a series of letters from Leeds to Archibald Barr revealing an assessment of the firm's prospects which was much less optimistic than his partners'.[95] He was still living in Yorkshire as Cavendish Professor of Physics at what had then become the University of Leeds, and spent very little time in Glasgow . In March, when in poor health, he wrote a letter revealing his thinking. Referring to the drafting of a new co-partnership agreement to avoid the possibility of bankruptcy following the death of one partner, he wrote

> You see, I regard the business as a very precarious one. If we had [vacuum] pumps really selling, and recorders [range and order instruments] &c &c I should believe in the stability of B&S much more. [96]

Between April and July, still in poor health, he wrote a series of generally pessimistic letters on the financial problems that might result from the death of a partner but then, probably recovering from his illness, he became more positive and specifically urged on Barr the need to reduce manufacturing costs so that, if necessary, selling prices could be reduced when the original patents expired in 1903 and other competitors might appear.[97] The point about the likely problems when the original patents expired was particularly

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[94] Moss and Russell (1988) p. 42 provides the source for figures and quotations in this section.
[95] UGD 295 16/1/10 Personal Correspondence of William Stroud.
[96] UGD 295/16/1/10 Personal correspondence, Stroud to Barr, 16th March 1899.
[97] UGD 295/16/1/10 Personal correspondence, Stroud to Jackson, 7th July 1899.

telling, and ties in with the decisions made soon afterwards to expand and assume greater control of components manufacture.

This picture Moss and Russell paint is only partly correct, as it can be shown that, despite Stroud's concerns about the future prospects for military and naval orders, the business was actually starting to grow substantially. The subsequent decision in 1902 to move again, this time to a much larger site, was taken because of the developments in naval business, and not through any programme of diversification into non-military products. The revenue from the firm's own vacuum pumps, and the licensed Becker electric clocks, which were sold from 1899 and 1901 respectively, was very small indeed.[98] The order records after December 1900 show little demand for them, their individual selling prices were less than a tenth of a rangefinder and their contribution to the business could at best have been only marginal compared to that from naval orders.

The value of orders received for rangefinders and associated items grew steadily in value from 1901.

Table 2.1: Barr & Stroud: comparison of British and foreign orders, 1901-1906.[99]

Year	British Orders £s	Foreign orders £s
1901	2,908	8,776
1902	6,569	13,906
1903	11,583	12,525
1904	36,651	52,975
1905	11,537	33,162
1906	24,315	28225

[98] Moss and Russell (1988) p. 43.

[99] Extracted from UGD 295/19/2/1, Customer order file.

Order values increased steadily through this period, the peak in 1904 being influenced by the large amount of business from the opposing navies just before and during the Russo-Japanese war. However, even without those atypically large orders, the value of business would still have been substantially up on that for 1903: even excluding foreign orders from 1904's figures, incoming business still rose by approximately 52 percent.

The overall growth came not only foreign orders but also from the Admiralty's increasing investment in fire control instruments. The original specification for the rangefinder in 1891 had called for the provision to relay ranges from the instrument to the guns, and Barr & Stroud had begun work on such apparatus at the same time as the rangefinder. In 1892 the Admiralty had decided that there was no immediate need for this transmission device, but the firm carried on and by 1893 they had developed a basic design which was submitted for trials at in 1894.[100] The Admiralty's tests continued until 1901, with the design of the 'range and order' instruments evolving steadily. In that year, despite Barr's irritation at the time taken,[101] the first of a series of substantial orders was placed. Between 1901 and the end of 1906, British contracts for fire control instruments totalled £33,522 compared with £50,318 for rangefinders.[102]

Important though this was, it was overshadowed by the growth in overseas orders in the same period. In every year from 1901 to 1906 foreign orders were greater than domestic ones, as shown in figure 1 above. The customer records show that these orders were almost entirely for rangefinders, the reverse of the pattern of Admiralty ones, implying either that foreign navies had failed to appreciate the need to integrate rangefinding into a gunnery control system, or that the extensive (and expensive) shipboard modifications needed to accommodate the electrical circuitry were unacceptable. Only the Imperial Japanese Navy was a regular purchaser of control instrumentation, but by no means on the same scale as the Royal Navy. In 1904, when Russian and Japanese purchasing was its greatest, less than 5 percent of the spending was on fire control apparatus.[103]

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[100] UGD 295/4/12 Letter Book, Archibald Barr to Secretary, Admiralty, 25.4.1894.
[101] UGD 295/4/23 Letter Book, Barr to Stroud, 7.9.1901.
[102] extracted from UGD 295/19/2/1 Customer Orders 1901 to 1910.
[103] UGD 295/19/2/1 Customer Order files 1901 to 1910.

Moss and Russell considered that 'when demand for rangefinders picked up in 1903' this was because of the introduction of an improved model, the FA3.[104] There certainly was an increase in Admiralty orders for rangefinders after 1903, but whether the FA3 itself was responsible for them is not certain. By 1904, the Royal Navy was increasingly accepting that gunnery improvements were possible through the better methods emphatically prescribed by Captain Percy Scott when he took charge of the navy's gunnery school, HMS *Excellent* in 1903,[105] and it was the Navy's willingness to entertain a 'paradigm shift'[106] in its approach to gunnery that caused larger purchases of rangefinders, rather than simply the availability of a better instrument. As for foreign business, the escalating tension between Russia and Japan would have generated the same orders, irrespective of recent technical advances. The Russian Navy was severely disadvantaged in its gunnery methods compared to the Japanese and its purchases of the older (and less expensive) FA models suggested that it was principally concerned with quantity rather than the latest improvements.[107]

Even before this surge of business, the actual and expected growth in orders for a increasing range of naval gunnery instruments led, in 1902, to the decision to build a much larger factory.[108] The existing site at Ashton Lane was unsuitable for expansion because of the density of surrounding building, and the workshops themselves, spread over three levels, were increasingly inconvenient and not big enough to handle the larger instruments being considered for development. The new site was some two miles from the existing works, in largely open country, adjacent to a railway station and at the end of tram route which conveniently served the areas where most of the existing workforce lived, as well as others from which extra workers might be drawn. The firm hoped the clear air of the more rural setting, free from the effects of Glasgow's atmospheric

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[104] Moss and Russell (1988) p. 43.
[105] Padfield, P. *Aim Straight: A Biography of Sir Percy Scott* (London: Hodder & Stoughton, 1966) p. 135.
[106] W. McBride (2000) p. 6
[107] For the relative state of gunnery in the two navies, see H. W. Wilson, *Battleships in Action*. 2 vols. Vol. 1. (London: Conway Maritime Press, 1995) Chapter XI; Russian order details extracted from UGD 295/19/2/1, Customer Order files 1901-1910.

pollution, would allow the final visual checking of the rangefinders to be done more efficiently and without interruption. A further benefit, from Barr's point of view, was that the new factory would be 'a place where workers could earn a decent living under clean healthy and happy conditions'.[109] The land for the new works was purchased in 1902, and building began in the autumn of 1903. Additions to building plans were made in 1904 and 1906, largely in the expectation of more Admiralty business.[110] The story of Barr & Stroud between 1899 and 1906 is largely one of expansion and profitability, based partly on the firm's own abilities and partly on a fortuitous combination of circumstances which saw a steady increase in concern with gunnery in the Royal Navy, bolstered by the profits generated from supplying both protagonists in the Russo-Japanese war.

It would be wrong, however, to assume that the progression to 1906 was straightforward. This was certainly not the case, and although the business grew substantially and was generally profitable as shown in table 2.2 below, there were problems to be dealt with.

Table 2.2: Barr & Stroud, turnover and pre-tax profits 1899-1906.[111]

Year	Turnover	Pre-tax Profit
1899	8,556	Loss (688)
1900	27,731	11,761
1901	15,070	3,699
1902	14,522	920
1903	20,889	5,906
1904	49,691	23,924
1905	77,512	29,196
1906	64,246	23,586

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[108] Moss and Russell (1988) p. 45 provides source material for the rest of this section, unless otherwise indicated.
[109] UGD 295, unclassified material, Strang manuscript, p. 61.
[110] Sumida (1993) discusses the reasons for the Admiralty's policy about rangefinder purchases in Chapter 3.
[111] Extracted from UGD 295/26/1/47, Table of Sales.

Some organisational weaknesses became apparent in the development of Barr & Stroud after 1898. When the firm moved into the Ashton Lane factory, its chief abilities were in mechanical and electrical engineering, rather than in optics. Archibald Barr's own abilities lay firmly in those fields, and the staff he had recruited in Glasgow added to this strength.[112] William Stroud, who was still living in Leeds, was the only person in the firm who was able to design optical components, and he also played a very significant role in the design of the Range and Order instruments which were to assume an increasingly important part of the business after 1901. Stroud's location, some 250 miles away, was to cause difficulties in the process of product development.

Stroud's letters to Glasgow show the volume and detail of correspondence between him and Archibald Barr when new designs were in progress. Daily letters suggested ways to overcome difficulties, and arguments over the best ways to proceed were conducted on paper. At times, Barr's frustrations were evident. In 1904, when the War Office had asked for a design for a new type of artillery sight, Stroud had dismissed the type of instrument as being of no value. Barr wrote to him bluntly, saying 'I do not agree with you [about the sight's utility], but we need not discuss that; they are wanted and are to be introduced into the service . . .'[113] In December 1904, Barr wrote 'I do not agree that you can do the best for B&S by staying at home [in Leeds]'.[114] Stroud obdurately refused to visit Glasgow, and the question of his moving to live and work there was not once mentioned directly in any of the personal correspondence still preserved from this time. His continual, and at times seemingly determined, absence could hardly have helped the process of optical design development.[115]

When the move to the Ashton Lane factory was made in 1899, Barr & Stroud were relying on one principal supplier of mechanical components and two suppliers of optical

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[112] Moss and Russell (1988) provides details of the qualifications of scientific staff, p. 37, 38.

[113] UGD 295/4 /739, Letter Book, Barr to Stroud, 16.11.1904.
[114] UGD 295/4/739, Letter Book, Barr to Stroud, 14.12.1904.
[115] In March 1901 he refused to travel up to Glasgow, citing the presence of smallpox in the city as too great a risk. UGD 295/16/1/10, Stroud's personal correspondence.

parts. James White, the Glasgow firm with which Lord Kelvin, (Barr's earlier mentor at the University of Glasgow) was closely associated,[116] had supplied castings and fabricated parts for both the rangefinder and its mounting. Chadburn Brothers of Sheffield, Yorkshire, supplied both spherical lenses and plane glass panels, and Adam Hilger of Camden, London, made some spherical lenses and all the prisms. Barr & Stroud constantly had difficulty with the quality of the optical contractors' products, as well as deliveries.

The problems with optical components were frequent and sometimes serious. Chadburn Brothers had been suppliers of the simpler optical parts since 1889, when they made parts for the very first instrument.[117] Barr & Stroud used them for the less critical components in the rangefinder's optical system, such as the optics for the aiming viewfinder and the protective glass covers for the objectives. Even with these relatively simple items Barr & Stroud frequently returned parts to Chadburn's with complaints about inadequate quality and errors in execution,[118] but rather than looking for a replacement supplier seemed content to instruct and educate, presumably because there was no other closer or more convenient source.[119]

The relationship with Adam Hilger & Co. was particularly important because for much of this period Hilger was practically the only company in Britain able to provide the most important optical parts of the rangefinder. The Barr and Stroud instrument used two telescopes which provided the operator with separate images of a target: these images were brought into alignment through a system of prisms to provide a direct reading of the target's range. The telescopes were not particularly complex in design, but it was important that they provided images of almost identical magnification as possible. They

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[116] T. N. Clark, A. D. Morrison-Low, and A. D. C. Simpson, *Brass & Glass: Scientific Instrument Making Workshops in Scotland* (Edinburgh: National Museums of Scotland, 1988) for an account of this business and the connections with Lord Kelvin.
[117] UGD 295/Unclassified material/ Russell research notes: Private Ledger No.1 (1888-1902) is mentioned as showing payments to Chadburn Brothers from 1889 onwards.
[118] For example, UGD 295/4/22, Letter Book, Barr & Stroud to Chadburn Bros, 25.2.1901 complains that 'in almost every instance . . . we get a wrong lens...'. ;
[119] Clark *et al.* (1990) gives no listing of optical manufacturers.

presented a manufacturing problem rather than a design difficulty. Stroud specified their necessary magnifying power and angle of view and left Hilger's to compute the lens curves necessary to provide them. Stroud's skill lay in the design of the prism systems which provided for the superimposition of the telescopes' images, but as with the telescopes he was entirely dependent on Hilger's to produce them accurately; not achieving precisely the specified angles would cause a prism to fail in its purpose.[120]

Problems with both quality and delivery times from Hilger had been evident almost from the start of the companies' relationship. Sometimes Hilger's work was praised, but often it fell below Barr & Stroud's requirements. As early as February 1893, Barr & Stroud were returning prisms as unsatisfactory and difficulties continued on a regular basis.[121] In 1897 Adam Hilger, presumably as a result of the increasing volume of business, mooted the idea of moving the business to Glasgow, and Barr reported to William Stroud that 'Hilger appears to favour an amalgamation of some kind'.[122] However, despite the 'great delays in sending things back and forward', neither partner was 'disposed to favour this' and nothing came of the idea. The following year though, Barr & Stroud complained that the defects in Hilger's prisms were causing them 'endless worry and expense'.[123] Between October and December of 1900 a series of letters to Hilger written by Harold Jackson, Barr & Stroud's general manager, showed how bad matters had become between the two firms.[124]

Having had yet more problems with prisms, Jackson warned Hilger's on 4th November that Barr & Stroud now had the means to check precisely the standards of optical work delivered. By the 28th, Jackson was saying that the Hilger's proposed mutually acceptable standards were 'ridiculous' and on the 30th he threatened to go elsewhere for prism work. The threat, which was repeated on 3rd December, was really a hollow one

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[120] for a description of prisms and their working in the rangefinder, see L. C. Martin, *Optical Instruments, their Construction, Theory and Use* (London: Blackie & Sons, 1924) p. 113 ff.
[121] UGD295/4/11 Letter Book, Barr to Hilger, 23.3.1893 and 4.4.1893.
[122] UGD 295/16/1/9, Letter Book, Barr to Stroud, 26.1.1897.
[123] UGD 295 Unclassified Material, Russell Research Notes, H. D. Jackson to Hilger, 10.9.1898.
[124] UGD 295/4/21 Letter Book, H. D. Jackson to Hilger, a series of letters between 3.10.1900 and 3.12.1900.

because Barr & Stroud no other source to turn to and although its real purpose was doubtless to encourage Hilger's to improve their quality, Jackson may have been overzealous and pushed the London firm to a point where it wanted to cease doing optical work for Barr & Stroud. A complete breakdown in relations between the two firms during December 1900 seems to have been averted only by Barr's personal intervention in a letter of 13th December, apologising for the 'hurt' which earlier correspondence had caused.[125] But, even this conciliatory letter reiterated (if less harshly) the possibility of taking orders elsewhere, and difficulties between the firms over quality control continued to surface periodically, although business between them continued without interruption.

The dependence on Hilger clearly concerned Barr & Stroud, and they periodically investigated obtaining optical components not just from other domestic sources, but from the German optical industry as well.[126] In 1897 they had made C. P. Goerz of Berlin their German agent, and afterwards periodically bought lens samples from them, as well as asking for quotations for the manufacture of prisms.[127] In 1899, they attempted to buy objective lenses from Steinheil of Munich, but encountered problems similar to those they had already had with Hilger: either the very specific instructions given were not adhered to or the quality was inadequate and sometimes the price was considered excessive.[128] In 1899, Stroud suggested asking Carl Zeiss of Jena to quote for optical components, but there is no record that his idea was followed up. [129]

Barr & Stroud's continued dependence on Adam Hilger through to the end of 1906 was principally the result of an established relationship that, despite frequent problems, worked well enough to let them produce satisfactory rangefinders. It was also because they still lacked the expertise to do the work themselves, although after 1904 they began

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[125] UGD 295/16/1/9 Letter Book, Barr to Hilger, 13.12.1900.
[126] UGD 295/4/17 Letter Book, Barr & Stroud to Ross Optical Co., requesting them to tender for telescope objectives 12.12.1898.
[127] for example, see UGD 295/4/22 Letter Book, Jackson to Goerz, 28.3.1901, requesting quotations for 'fine quality prisms'.
[128] UGD 295/4/17 Letter Book, 10 objective lenses ordered 31.12.1898. They were returned faulty on 6.3.1899 and the subject of a subsequent dispute.

to organise the means to do this, partly from the desire to control costs but also to gain greater control of the quality and speed of delivery of components for experimental work.[130] Attempts to obtain more satisfactory quality from German suppliers had failed (suggesting that contemporary perceptions of the superiority of the German optical industry were not wholly justified), and even if Barr & Stroud had been inclined work their way through the entire catalogue of German makers, the growing inclination of the Admiralty to be independent of foreign suppliers even for materials in British made products would have been a strong deterrent. Given the lack of any other British firm who could be relied on to perform better than Hilger, Barr & Stroud had little alternative to becoming optical workers themselves. This process began in 1904, but only developed significantly after 1907.

2.7 Conclusion

The period from 1899 to 1906 saw an increasing complexity in both the industry and its relationship with its government clients, the War Office and the Admiralty. Those complexities were brought on not simply by the increasing complexity of instruments and their scale of use, but also by a range of external and internal factors contingent on both makers and buyers. Those included both political and financial dimensions, as well as the goals and prejudices of the social groups that constituted the communities producing and using the apparatus. At the close of 1906, the optical munitions industry in Britain was both larger and more important than at the start of the Boer War. The Royal Navy was by far its largest single customer, although providing less income than the total of foreign orders. When the business placed by foreign navies up to 1906 is added, it is clear that optical munitions were still predominantly naval artefacts. Driven by a combination of improved weapons, an increasing realisation of the potential effectiveness of gunnery, and new types of ship, the Royal Navy's capabilities were becoming inextricably connected to its optical equipment. That growth was to confirm the Admiralty as the optical munitions industry's largest domestic client, but as the

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[129] UGD 295/16/1/10 Personal correspondence from William Stroud to H. D. Jackson 7.7.1899.
[130] UGD 295 Unclassified Material. Russell Research Notes. Barr's Private Letter Book No. 1, Barr to Mr A. Hilger [sic] 19.1.1904.

succeeding chapter will show, the increase in European land armaments was to start to generate an increasing demand from the War Office.

Chapter 3

Expansion and consolidation, 1907 to 1914

3.1 Introduction

The period from 1907 to the start of the Great War saw optical munitions production grow at increasing rate and by 1914 a clearly identifiable sector of industry was engaged permanently, if not always entirely, in the production of instruments which, with few exceptions, had no civil applications. Only a small part of the optical instruments trade was engaged in this work, reflecting not just the specialised nature of what was being made but also the scale of demand for military and naval optics. That demand grew after 1907, not so much because advances in optical technology permitted the creation of new instruments, but because developments in weapons technologies and increasing political instability created a climate that encouraged European states in particular to increase their expenditure on armaments and take up equipment which increasingly depended on optical instrumentation for its effectiveness. For the first time, the British War Office became a systematic buyer of optical munitions, greatly increasing its spending in the last two years of peace. Even though its budgets for such equipment were far less than the Admiralty's, it brought firms regularly into munitions work and established them as regular contractors. The Royal Navy's demands increased at a faster rate than the Army's, although a smaller number of firms produced its requirements and established closer working relations than with the War Office. This chapter examines the extent to which the optical munitions makers benefited from government business, assesses existing conceptions of the industry at this time, and compares the relative success and failure of the businesses that competed to supply what continued to be the single most important item in the optical armoury, the large naval rangefinder.

3.2 The industry and the War Office's influence on it.

In 1907 the Army was still a very small-scale user of optical munitions, most of which were already acknowledged within the service as unsatisfactory and obsolescent. Little had been done to rectify the shortcomings demonstrated in the Boer War and the Army's

spending on optics since then had averaged only £1,700 a year.[1] That changed after 1908 when decisions were made to adopt new instruments, causing spending to increase and generating new business for optical manufacturers. It has been previously suggested that not only did the War Office do little to support the domestic optical industry, but through a combination of favouring foreign makers and distributing orders piecemeal amongst British companies it discouraged the home industry from becoming involved in military contracting.[2] An examination of ordering patterns does not bear out this view, showing rather that War Office business was concentrated on a few British firms who thus became progressively more experienced in optical munitions production. That is not to say that the British Army was a prolific spender or that, unlike the Admiralty, it deliberately encouraged the home industry, but nevertheless military orders were placed at an increasing pace after 1910. The interaction of the War Office with the optical manufacturing community can be demonstrated by examining the process of selection and purchase of three key types of optical munitions – the single-observer rangefinder, the panoramic artillery gun sight (the 'dial sight'), and the prismatic binocular.

The records of the Army Contracts Department from April 1907 to 31st March 1914, show that some £175,000 was allocated to optical orders.[3] Approximately £49,000 was for rangefinders, £66,000 for dial sights, and £45,000 for binoculars. Of the balance of £15,000, some £10,000 was spent on telescopes for signallers, and the rest on an assortment of other telescopes and gun sights. None of those latter purchases were recorded in sufficient detail to give any meaningful picture of their distribution amongst manufacturers and they are excluded from following account.

3.3 The Rangefinder

In 1907, the Army still lacked a satisfactory rangefinder despite numerous trials which had repeatedly recommended that the Marindin design should be adopted by the

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[1] The National Archives, Kew, London, War Office records (subsequently PRO) WO 395/2, Annual Reports of the Director of Army Contracts, financial years 1903-1904, 1904-1905, 1905-1906, 1906-1907; data extracted from Contracts for Scientific Instruments.
[2] R. and K. MacLeod, "Government and the Optical Industry in Britain 1914-1918." In *War and Economic Development*, edited by J. M. Winter. (Cambridge: Cambridge University Press, 1977) p. 170.
[3] Extracted from PRO WO 395/2 and WO 395/3, Annual Reports.

Infantry.[4] Only in January that year was it finally considered necessary 'that an infantry rangefinder should be immediately supplied' and the following month the Marindin was formally approved.[5] The quantities needed were, however, uncertain, because the scale of issue for rangefinders was currently being reviewed. If the Marindin simply replaced the earlier Mekometer, then the Field Army's Infantry (the 'front line' troops) would need only 300, but if a wider issue were adopted then the total for the entire Infantry of the Regular Army would be 1,040.[6] Budgeting for either quantity was problematical because no detailed costings had ever been requested by the War Office.

Captain Marindin, the inventor, had his trial instruments made by Adam Hilger & Co., but there had been no formal liaison between the firm and the Army and the only price mentioned had been Marindin's informal estimate of £35 if 'very large' numbers were ordered. The Master General of the Ordnance was being pressed to organise the rangefinder's 'early introduction' even before its formal adoption, and he proposed to supply the Field Army with 300 during the next two years. He thought Marindin's estimate unrealistic as the trial instruments had each cost at least £85 each, and he reckoned the likely cost to be 'nearer . . . £50 each', possibly using as his yard-stick the current price of the Barr & Stroud infantry rangefinder. Having decided on the need to buy 300 rangefinders at a cost likely to exceed £15,000, the Master General could only allocate £5,000 in the Annual Estimates for the fiscal year 1907-1908 but nevertheless was content that, somehow, 'steps will now be taken as to …obtaining a supply'.

Obtaining any supply was complicated because Marindin and the War Office were in dispute about the question of financial reward.[7] When asked in 1902 about his terms for making the rangefinder available to the Crown he had valued it at £25,000, but no further discussions took place until Marindin learned in early March 1907 of the decision to

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[4] See Chapter 2 above.
[5] The National Archives, Kew, Treasury Records,(subsequently PRO) TI/11223, Proceedings of the Ordnance Council, 12.6.1908, *Question of Award to Captain A.H. Marindin, The Black Watch for One-man Range-finder for Infantry* (subsequently TI/11223 (1908), p. 5.
[6] PRO TI/11223 (1908), p. 4. This provides the source material for the rest of this section, unless otherwise indicated.
[7] PRO TI/11223, Proceedings of the Ordnance Council, 8.6.1909, *Question of Award to Captain A.H. Marindin, The Black Watch for One-man Range-finder for Infantry* (subsequently TI/11223 1909) p. 6.

adopt his rangefinder and immediately resurrected the matter. Pending a judgement, he refused to hand over the its detailed drawings to the Chief Inspector of Optical Stores at Woolwich Arsenal, stopping the War Office from drawing up a specification in order to request tenders for manufacture. The impasse was only broken by the Secretary of State for War who reminded Marindin that he was 'witholding the information necessary for the manufacture of the instrument for His Majesty's Service' and, in practical terms, ordered him to surrender the details immediately. As a serving officer, he had little alternative but to acquiesce and hand over what was needed, trusting to fortune about his eventual reward.

A request for tenders was issued by July 1907, but it was five months before any contract was placed. In November, Adam Hilger & Co. was given an order, not for the hundred which had been budgeted for, but for just sixteen instrument for troop trials.[8] That was because the War Office had decided that Marindin's claim could only be judged after seeing how well the rangefinder performed when issued to 'ordinary' infantry units, linking its monetary value to its utility in general service. Until the claim was settled, the War Office was reluctant to commit itself to further purchases until an offer was been made to Marindin in June 1908, after which only fifty were ordered despite funds for a hundred already being available. Marindin rejected the offer and then appealed to the Treasury, a process that took a further year and gave him not £25,000 but a royalty of just 15 percent on each rangefinder accepted for service, plus his earlier expenses.

The number of Marindin rangefinders ordered up to April 1914 was just 337 at a total value of £22,305, far less than was either needed or originally expected. It was never ordered on a scale large enough to equip the entire Infantry, partly because there were problems with it in service, partly because Hilger's were unable to manufacture at a rate greater two than per week, and not least because the War Office was unable to persuade any other maker to attempt its production.[9] The only other firm to tender and supply

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[8] University of Glasgow Archives, University of Glasgow Archives, Barr & Stroud, City of Glasgow, Optical Instrument Makers, collection reference UGD 295 (subsequently UGD 295) 295/4/744, Letter Book, H. D. Jackson to Adam Hilger Ltd., 9.8.1907, and 20.11.1907.
[9] PRO TI/11223 (1908) p.4 and p. 10.

sample instruments was Thomas Cooke & Sons Ltd in 1908, but the company never received any production contracts.[10] The Marindin provided few benefits for the industry, either through large orders or any kind of spin-off that might have opened up new avenues for its maker. Adam Hilger's problems that restricted their benefiting from it will be described later in this chapter, but the rest of the optical industry was deterred from competing to produce it principally because the technical and logistical difficulties in setting-up outweighed the guarantee of reward; without the assurance of continuing orders no business was willing to tackle a manufacturing problem that was outside its prior experience.

Eventually, in 1912, the War Office ordered a small quantity of infantry rangefinders from Barr & Stroud and the next year followed almost every other European army's example and began to buy them in bulk. Orders in 1912 totalled £4,313, rose in 1913 to £9,724, and in the first seven months of 1914 leapt to £54,000, almost two and a half times the money spent on the Marindin in the previous six years.[11] The War Office also spent £13,055 on German Zeiss rangefinders for experimental issue to the Field Artillery in 1911 and 1913, apparently supporting the notion that domestic industry was being discouraged. However, no decision had been made about standardising a pattern, and the purchases demonstrated the Artillery's inability to decide on what design of rangefinder it actually wanted rather than discrimination against domestic models. By the summer of 1914, with a European war looking ever more likely, the Infantry was finally starting to be equipped with a satisfactory rangefinder, but the Field Artillery was still deliberating over what was required. The management of rangefinder procurement over the previous seven years may not have reflected well on the War Office, but the procurement of artillery sights and prism binoculars went far more satisfactorily.

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[10] PRO WO 395/3, Contracts Department, Annual Report 1907-1908.
[11] Extracted from UGD 295/19/2/1, 295/19/2/2 and 295/19/2/3, Customer Order files.

3.4 The Artillery 'Dial Sight'.

The Russo-Japanese war had emphasised that a more effective means of aiming artillery weapons was needed when the line of sight was obstructed.[12] Engaging obscured targets by 'indirect firing' was not new to gunners, and was accomplished by aiming-off from a proxy target whose angular displacement from the actual one had been measured, so that the gun's sight could be set to an appropriate deflection in order to point the barrel in the correct direction.[13] The displacement angle was measured using surveying techniques, and the sighting done with an instrument using an aiming telescope fixed to a large, precisely divided circular dial – the so called 'dial-sight' which was awkward to use, bulky, and relatively fragile. In 1904, the Berlin company, Optische Anstaldt C. P. Goerz, introduced a radically new type of optical sight that significantly improved on previous designs.[14] This 'panoramic' dial sight was a compact prismatic aiming telescope that functioned as periscope: it traversed through a full circle whilst maintaining a magnified normal image for the observer who could now remain protected behind the gun's shield. Tests began in Britain in 1904 and, as with the Marindin rangefinder, went on for several years before the device was eventually approved for service in 1909 and ordered as the 'Dial Sight No.7'.

It was taken into use far quicker and more successfully than the rangefinder, and on a larger scale. Between April 1909 and April 1914 it accounted for more expenditure than any other single optical store purchased by the Army Contracts Department - £65,698, or 37 percent of the total expenditure on optical munitions, with 1,662 sights eventually being contracted from six makers.[15] Sufficient were ordered to match the gradual introduction after 1904 of new guns which were the principal recipients of the sight. Between then and July 1914, approximately 1,650 new guns were ordered for the British and Indian Armies, and although contracts for dial sights only began in 1908 they did

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[12] Callwell, C. E. and J. F. Headlam. *The History of the Royal Artillery*. 3 vols. (Woolwich, London: Royal Artillery Institution, 1937) Vol. II, Chapters III and X.
[13] Callwell and Headlam (1937) Vol. II, pp. 95 to 101 describe the problems of indirect firing and aiming and provide the source material for the rest of this paragraph..
[14] See B. K. Johnson, "The No. 7 Dial Sight, Mk. 2." *Transactions of the Optical Society* 21 (1920): pp. 176 to 86.
[15] Extracted from PRO WO 395/2 and 395/3, Annual Reports of Director of Army Contracts.

eventually match gun deliveries.[16] The scale of orders, unlike the Marindin rangefinder, was therefore as much as the optical industry could have expected to receive.

Roy and Kay MacLeod suggested that before 1914 the War Office did not aid its optical suppliers in the way it went about doing business with them. In particular it 'was a customer for German dial sights which . . . led to the active discouragement of British firms in this area'.[17] And, they said, the War Office spread small contracts across different firms 'in a misguided effort to stimulate competition' which had the unfortunate opposite effect of forcing up prices and discouraging mass production through the small quantities – just 'tens' – of instruments involved. Although the War Office did buy dial sights from Germany, and did spread orders across a number of makers, the evidence of contract records leads to a conclusion rather different to the MacLeods'.

The sight was made in Britain under a licensing agreement with the German Goerz company which held international patents for it. The arrangement required the purchase of some instruments from Goerz and the payment of royalties for those made in Britain. Only 30 percent of the orders went directly to Goerz and, in an apparent paradox, the War Office may actually have considered Goerz as a British supplier. The Contracts Department identified all foreign purchases in its yearly reports, but only two of Goerz's four contracts were so described, in the financial years 1910-1911 and 1911-1912; those in the next two years were listed along with domestic ones. Goerz had set up a London subsidiary company ('Tochtergesellschaft') in 1908, partly in response to the new requirements of the Companies (Consolidation) Act, 1907 which required foreign businesses trading in Britain to disclose full details of their parent company's financial affairs, and partly because of the new Patents Act of the same year.[18] Under the latter, if a British patent held by a foreign patentee was not being 'worked' on a commercial basis in Britain, the patentee was obliged to grant a licence to any 'interested person' who

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[16] For numbers of guns ordered, see Hogg and Thurston (1972) pp. 58, 80, 102 and 116, and for introduction into service see Callwell and Headlam (1937) Vol. II, p. 101.
[17] MacLeod (1977) p. 170 is the source for this and other quotations in this paragraph.
[18] A. Hagen, *Deutsche Direktinvestionen in Grossbritannien, 1871-1918* (Stuttgart: Steiner Verlag, 1997) pp. 174 and 175 provides information about Goerz, and A. Hagen "Export Versus Direct Investment in the German Optical Industry." *Business History*, no. 4 October 1996 (1996) p.5 details on the effects of new legislation on German companies trading in Great Britain..

wished to take it up. The creation of a British company – the C. P. Goerz Optical Works Ltd. – avoided the demands of the Companies Act and opened the way to side-stepping the Patents Act through the licensing arrangement with the War Office. The business was incorporated with an initial share capital of £5,000 that was subsequently increased to £10,000.

It is not clear if Goerz actually made, or even assembled, instruments in Britain. Antje Hagen's brief description of the firm's British activities suggests that, unlike the larger firm of Zeiss (which did set up a manufacturing business in addition to its import and marketing structure), it remained no more than a marketing company – 'einer Vertriebgeselleschaft'. However, its share capital of £10,000 was the same that Zeiss employed in both its manufacturing and distribution, raising the question of why such a large amount was needed by a smaller business operating, according to Hagen, on a lesser scale. Without more evidence, any answer must be conjectural, but so far as the Army's purchasing department was concerned, by April 1912 the company was being treated as a British supplier.

The other 70 percent of dial sight orders were spread between six companies, again seeming to support the MacLeods' argument that War Office contracts were spread too thinly to be attractive to makers. Barr & Stroud, Beck, Cooke's of York, Goerz, Ross and Vickers all received orders. However, Vickers had no optical capability, and the contract would have been carried out by Cooke's which had both connections with Vickers and earlier experience making the sight.[19] The orders given to them and to Barr & Stroud were very much smaller than the others:

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[19] A. McConnell, *Instrument Makers to the World: A History of Cooke, Troughton & Simms* (York: William Sessions Ltd,, 1992) p. 65 describes the connections with Vickers.

Table 3.4: Dial Sight contracts, 1909-1914.[20]

Firm	1909-10	1910-11	1911-12	1912-13	1913-14	Total	%
Cooke	15			63		78	4.7
Barr & Stroud	55		25			80	4.8
Beck	15		125	130	222	492	29.6
Goerz		168	100	100	124	492	29.6
Ross		20	100	196	204	520	31.3
total	85	188	350	489	550	1662	

Over 90 percent of the orders were divided between just three firms, in roughly equal proportions. To what extent this was through a misplaced desire to 'stimulate competition' is open to debate, but the assertion that it drove up prices seems far from justified. The original Goerz order in 1910 was at £40.05 per instrument, a figure repeated in 1911 and 1912, and the final Goerz contract in 1913 was lower at £38.00. Goerz was already making the sight in large numbers for the German forces, and allowing for the resulting economies of scale and lower German wage costs, it might be expected that, if the MacLeods were correct, then the British firms' prices would have been significantly higher. Beck's were more, but only by 5 percent: £42.50 in 1911, £42.20 in 1912, and £40.00 in 1913. The prices from Ross were actually cheaper - £35.00 in 1910 and 1911, £37.50 in 1912 and £37.75 in 1913. Although one of the Contract's Department's responsibilities was to ensure that prices charged were reasonable, it also had to ensure deliveries were made at rates appropriate to service requirements, and the division between Beck and Ross may have been necessary to obtain the numbers required to match gun deliveries.

The idea of distributing orders in small numbers primarily to stimulate competition has to be questioned. The size of contracts was governed both by the funds available and the timetable of need. Even under pressure to provide an effective infantry rangefinder 'immediately' at a cost exceeding £25,000, the War Office had only been able to budget

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[20] Extracted from PRO WO 395/3 Director of Army Contracts, *Annual Reports*, except for the Barr & Stroud order 1909-10 which comes from UGD 295/19/8/1, Customer Order records, Works Order CO 1115, 2.1.1910.

£5,000 in each of the current and following financial years because that was the limit of funds available.[21] Spending on munitions contracts in 1907 was the 'lowest for twelve years,' and orders for weapons for the Army until the end of 1910-1911 continued to be lower than even before the Boer War.[22] The need for dial sights was geared to the delivery of new artillery weapons whose rates of production were initially slow, so with limited budgets it made no sense to contemplate ordering in advance the full outfit of sights for the whole gun programme. Fiscal prudence rather than misguidance would better account for the absence of larger-scale dial sight orders. A single large contract might have resulted, as the MacLeods suggested, in economies of scale which could have reduced production costs, but the financial conditions to place such an order simply did not exist, even if any single contractor had been able or willing to take on the work. Although ordnance spending was low, the overall level of commercial trade was good,[23] and if the War Office had offered a very big order it may well have found itself having to persuade instrument makers to take the contract, rather than finding them eager to bid for government work, a situation that would hardly have driven prices down. Many of the same factors also applied to the prism binocular, the third category of optical munitions ordered in substantial numbers up to 1914.

3.5 The Prism Binocular

The organisation of prismatic binocular purchasing differed from rangefinders and dial sights. The quantities involved were greater, the unit pieces much lower and, importantly, the instrument was already being made in Britain for the commercial market so, unlike the dial sight or rangefinder, there was not necessarily any obstacle to persuading firms to compete for contracts. Military binoculars were little different to civil ones, although the high levels of compliance to specification demanded by the War Office were unknown in the civil market. The MacLeods placed prismatic binoculars alongside the dial sight in censuring War Office policy, their most serious criticism being that the

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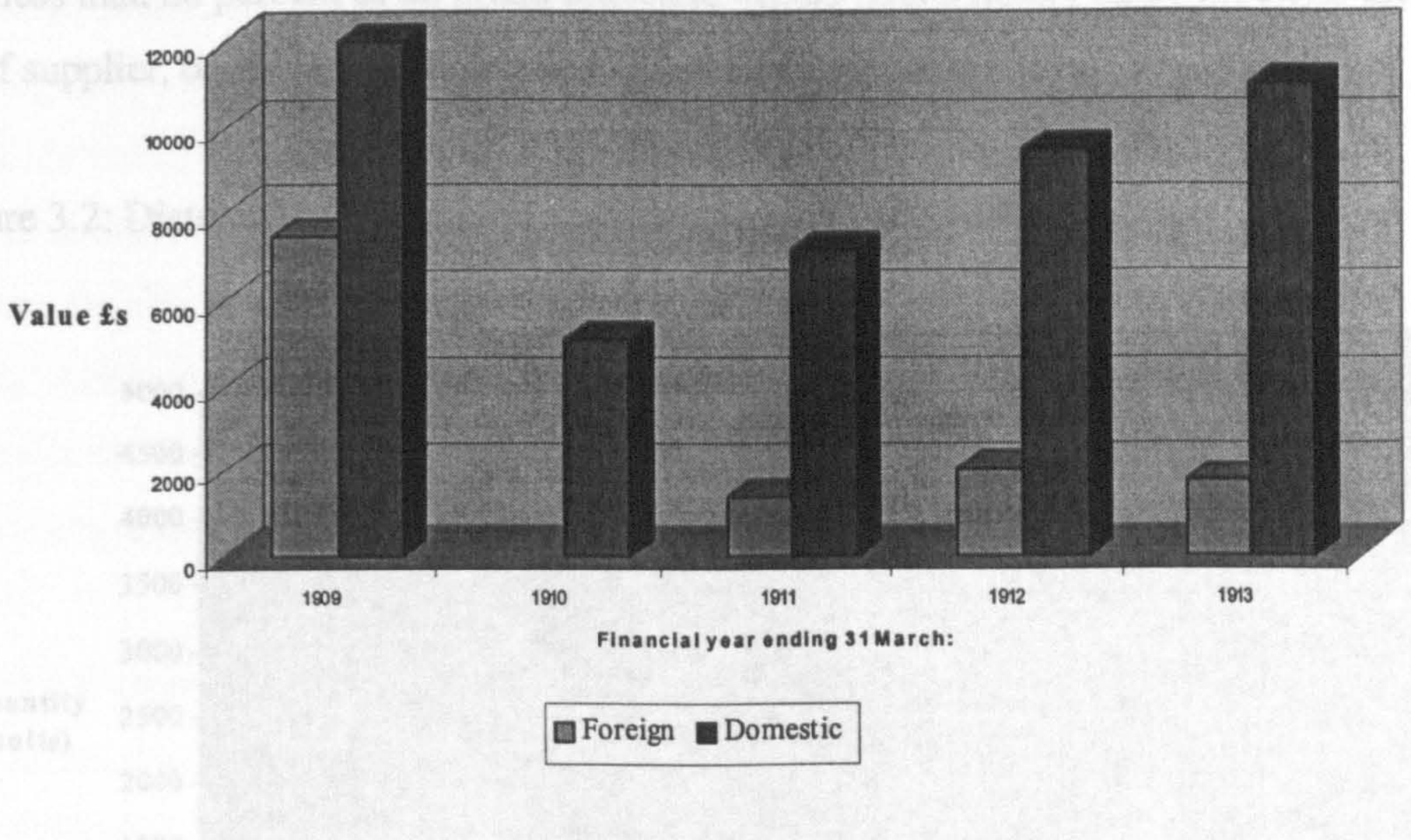
[21] PRO TI/11223 (1908) p. 4.
[22] C. Trebilcock, *The Vickers Brothers: Armaments and Enterprise 1854-1914* (London: Europa Publishers, 1977) p. 12 and then p. 11.
[23] Clive Trebilcock *The Vickers Brothers* p.14.

British Army was actually a client of the German optical industry so that domestic firms were consequently disadvantaged.[24] Once again, the evidence in contracts records shows these strictures to be unfounded.

Figure 3.1 : Distribution of Prismatic Binocular Orders, 1908-1909 to 1913-1914:[25]



Between 1908 and 1914, approximately 11,500 prismatic binoculars were ordered which was enough for the peacetime Army on a scale of one for every twenty officers and men.[26] Their total value was some £45,000 of which, in contradiction to the MacLeod's claim, only £7,500 or 17 percent was directly spent abroad. Purchases began in 1908, when 1,500 were ordered from the German firm of Carl Zeiss whose only British representation was then a sales office in London. In 1909, driven by the same considerations as Goerz, Zeiss set up an additional British subsidiary manufacturing company at Mill Hill, London, which 'produced field glasses' whose components were sent from Jena.[27] This new business, Carl Zeiss (London) Ltd., received approximately

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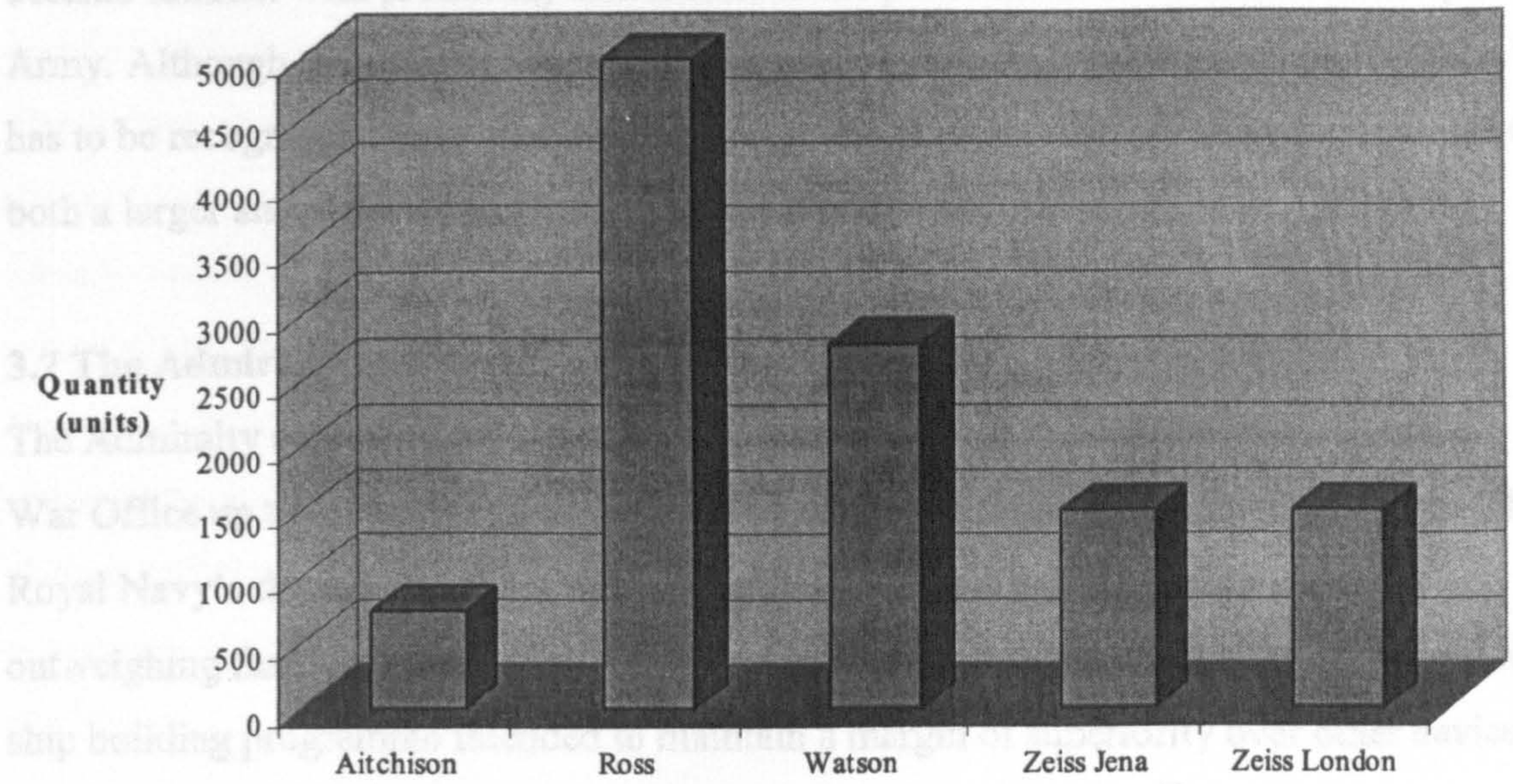
[24] R. and K. MacLeod (1977) p.170.
[25] PRO WO 395/3 Annual Reports of the Director of Army Contracts.
[26] This proportion is obtained from PRO TI/11223, as the scale of issue laid down by the Master General of the Ordnance.
[27] Antje Hagen, 'Export versus Direct Investment in the German Optical Industry' *Business History* no.4, October 1996, p. 6.

£5,600 worth of orders between 1911 and 1914 which, as with Goerz, the War Office treated as domestic business.[28] The Mill Hill Zeiss works was jointly managed by German and English staff, but its workforce was predominantly English and its binoculars were marked as though made entirely in England.[29] Even if all the business placed with Zeiss were counted as foreign, then the approximate total of £13,100 was still less than 26 percent of all prism binocular orders which hardly made the Zeiss the chief supplier, or the War Office reliant on foreign instruments.

Figure 3.2: Distribution of binocular orders by maker, 1908-1914:[30]



3.6 Summary of the War Office's ordering patterns

The War Office may not have been a large customer and may have deserved censure because of the way it handled its rangefinder needs, but its business was scaled to an army only a quarter the size of Germany's and it could not have offered the optical makers orders on the scale that the German industry received from its own War

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[28] Some of the orders are listed in the Director of Contracts' Annual Reports as being shared with other companies. Assuming an equal share of contract values produces this figure.

[29] For example, see Binocular No.3 Mk II, number 810 marked 'Zeiss London'; collection of William Reid.

[30] Extracted from PRO WO 395/2 and 395/3, Annual Reports.

Ministry.[31] Its hesitant selection procedures certainly retarded the placing of rangefinder orders but nevertheless it was still a far better client than the MacLeods suggested and generally ordered as many instruments as the Army actually needed. It certainly did not place obstacles in the way of the domestic industry, nor was it so badly served by British contractors that it had to depend on German imports. Its suppliers were a group of specialist British makers who had emerged from within the general optical instrument-making community and so far as these devices were concerned were separate from it. Far from scattering small contracts across the greater optical trade before 1914, the War Office actually concentrated its orders on a small number of firms who accordingly became familiar with producing instruments to the particular standards demanded by the Army. Although the scale of War Office spending increased between 1907 and 1914, it has to be recognised that it was still very much less than the Admiralty's which provided both a larger and different market for optical munitions.

3.7 The Admiralty and its effects on the industry

The Admiralty continued to be a much larger customer for optical munitions than the War Office up to the outbreak of war in 1914, and rangefinders dominated its orders. The Royal Navy's demand for them was substantial and of very considerable value, far outweighing that for other optics. Rangefinder requirements were linked to a substantial ship building programme intended to maintain a margin of superiority over other navies, and which is usually associated with battleships and battlecruisers.[32] However, the cruisers and destroyers that were also built added to the scale and variety of demand for optical munitions. Although capital ships demanded the largest and most sophisticated types, cruisers were to be provided with outfits of optical instruments which, only a decade earlier, would have been seen as lavish even on the biggest warships. In addition, from 1907 the Admiralty began to ask for rangefinders that could be used on the smaller

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[31] D. G. Hermann, *The Arming of Europe and the Making of the First World War* (Princeton, New Jersey: Princeton University Press, 1996) p. 234.
[32] J. T. Sumida, *In Defence of Naval Supremacy: Finance, Technology and British Naval Policy 1888-1914* (London, Routledge,1993) p. 185 to p.196.

vessels such as destroyers, which carried weapons of lesser range, and lacked the space to mount the nine-foot base models which were becoming standard on larger vessels.[33]

The Royal Navy not only purchased rangefinders, it also bought other optical instruments, particularly for its larger ships. Telescopic sights and observation telescopes of increasingly sophisticated design were needed for the gun turrets of capital ships, as well as simpler sighting telescopes for their secondary armament.[34] Similar sights were also required for the cruisers and destroyers built during this period. The massive 're-sighting' programme of 1905 – 1907 described in the previous chapter had provided only for ships in commission or about to complete so that the construction of new ships, coupled with increasing attention to gunnery, meant that by mid-1914 the Admiralty was demanding greater numbers of more varied and sophisticated optical munitions. These orders continued to be placed amongst the contractors with whom the Admiralty had already built up working relationships, so that only one firm – Barr & Stroud – supplied rangefinders, two – Ottway and Ross – made gun sighting telescopes and three – Ottway, Ross, and Thomas Cooke's of York (which supplied them to Vickers) – produced observation and sighting periscopes for surface vessels.[35] Submarine periscopes were almost entirely made by Sir Howard Grubb & Co. of Dublin, who made them under contract to Vickers at a time when they had a virtual monopoly of submarine building for the Navy.

The amounts spent on optical instruments by the Admiralty were not recorded in the same way as those by the War Office, and it has not been possible to calculate the total value of the Navy's optical munitions business. However, Barr & Stroud's records detail the sums spent with the firm on rangefinders and their related instrumentation, making it at least possible to indicate how much larger a customer was the Admiralty than the War Office.

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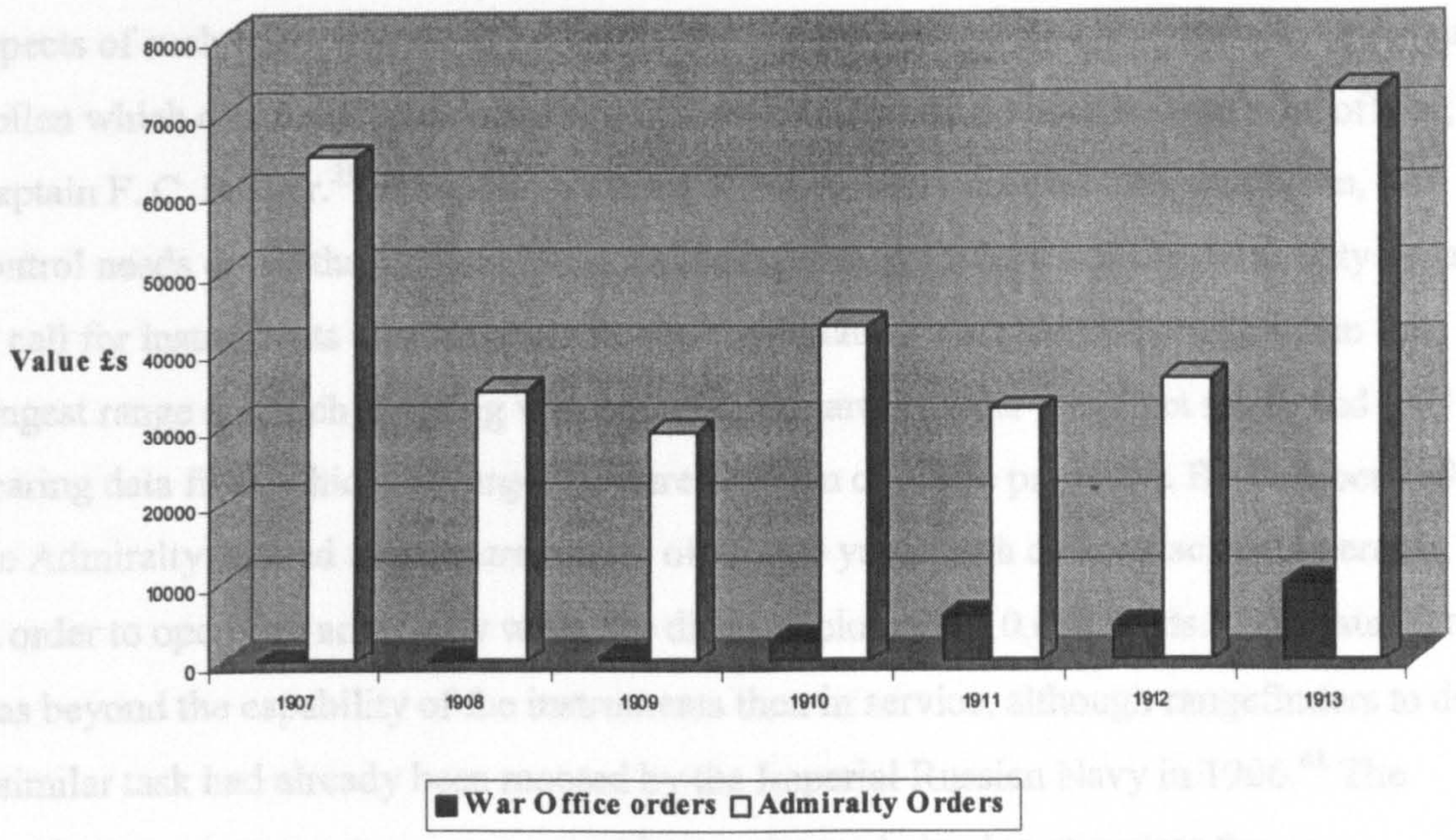
[33] UGD 295 Unclassified material: Russell Research Notes refer to Barr & Stroud letter book BS4/25: J. B. Henderson, Naval College, Greenwich, to Harold Jackson, 5 October 1907, describing the problems for rangefinding caused by vibration in destroyers.
[34] Great Britain, Admiralty, *Manual of Gunnery for His Majesty's Fleet,* 1915. (London, HMSO, 1915) Vol. 1, Chap. XII, p. 291 to p. 304 describe and illustrate various patterns.
[35] Great Britain, Admiralty, *Manual of Gunnery for His Majesty's Fleet*, 1917, (London: HMSO, 1917) Chap. XII.

Figure 3.3 : Barr & Stroud: comparison of War Office and Admiralty orders, 1907-1913.[36]



From 1907 to the end of 1913, the Admiralty spent almost £313,000 with Barr & Stroud alone, compared with the War Office's total expenditure on optics with all suppliers of £47,000.

Greater demand did not only come from a growing modern fleet after 1907, it was also driven by efforts to improve the probability of hitting distant moving targets as fighting ranges of 10,000 yards and more were being increasingly envisaged.[37] Shooting at such distances necessitated some means to predict where the moving target would be at the end of a projectile's flight time, which at 10,000 yards was more than 15 seconds.[38] The concept of 'fire control' – a systemised means to direct a ship's guns against a moving

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[36] Extracted from UGD 295/19/2/1, 295/19/2/2 and 295/19/2/1, Customer Order files 1907-1914.
[37] See J. T. Sumida (1993) Chap. 5 for background material.
[38] Great Britain, Admiralty, Gunnery Department, *Manual of Gunnery for His Majesty's Fleet* (London: HMSO, 1917) p. 423.

and distant target – became gradually accepted as essential, and increasingly complex electrical and mechanical systems were developed using the optical rangefinder as the primary means for generating the required data. The development of fire control systems has been examined in detail by Jon Sumida, but he paid little attention to the optical instrumentation involved. He concentrated on the evolution of the mechanical computing aspects of such schemes, and in particular the one devised by the civilian inventor Arthur Pollen which competed unsuccessfully against another one devised by a serving officer, Captain F. C. Dreyer.[39] In another instance of a seemingly deterministic condition, fire control needs drove the demand for more accurate rangefinders, and the Admiralty began to call for instruments to measure accurately at distances considerably further than the longest range at which shooting was expected to start, in order to collect range and bearing data from which the target's future position could be predicted. By October 1907 the Admiralty wanted to measure ranges of 15,000 yards with an accuracy of 1 percent, in order to open fire accurately when the distance closed to 10,000 yards.[40] This standard was beyond the capability of the instruments then in service, although rangefinders to do a similar task had already been mooted by the Imperial Russian Navy in 1906.[41] The growing stress on greater accuracy and longer ranges helped to stimulate the development of larger and more complex instruments as part of a system of gunnery, emphasising that large naval rangefinders could no longer be seen as isolated from the rest of a ship's armament. It was this evolutionary state of fire control instrumentation that introduced Thomas Cooke & Sons Ltd of York as potential commercial rivals to Barr & Stroud, and a comparison of their progress during this period offers some insight into the variety of technological and social forces acting on and within optical munitions contractors.

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[39] See J. T. Sumida (1993) Chapter 3.
[40] UGD 295 Russell Research Notes Box 2: letter from J. B. Henderson, Admiralty Research Laboratory, to William Stroud, 5 October 1907.
[41] UGD 295 Russell Research Notes Box 2: Acknowledgement of order for a 4m 57cm rangefinder from Col. Petrov, Imperial Russian Navy.

3.8 Thomas Cooke & Sons Ltd as a competitor for Barr & Stroud

Cooke's of York was no stranger to optical munitions in 1907, although everything that it had made previously had been relatively simple in optical design and construction.[42] The firm's chief designer, H. D. Taylor (1861-1943) seems first to have been directed towards optical munitions during the Boer War when he designed an optical sight to improve accuracy of shooting at long ranges. He was granted a patent in connection with rangefinders in 1903, soon afterwards obtaining two more relating to a novel layout and the use of rotating prisms to produce a high level of robustness.[43] Between 1904 and 1906 Cooke's built five different experimental models to his designs, culminating in the unsuccessful submission of a ten-foot instrument for Admiralty trials against Barr & Stroud's latest nine-foot model.[44] During this period, Cooke's had come into contact with Arthur Pollen through making the optics for his own abortive two-observer rangefinder in 1905,[45] an experience which seems to have encouraged the firm to delve deeper into rangefinder design as the connection between it and Pollen grew stronger. In 1907, Taylor began to refine his earlier efforts and between then and 1911 was granted seven more patents covering a range of increasingly sophisticated designs.[46] These seem to have produced only two experimental models, which were superseded by a radically new design in 1912 that was meant to form an integral part of Pollen's fire-control system and to be sold as a component of it .[47]

The extent and complexity of Pollen's relationship with Cooke's is outside this account (and only hinted at by both McConnell and Sumida), but some mention of it must be given to provide essential context. Pollen's involvement with Thomas Cooke & Sons Ltd came firstly through his need for the high precision mechanical engineering that Cooke's employed in survey instruments and astronomical telescope clock controls, in order to

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[42] See Chapter 1 above.
[43] British Patents 1436/1901 for an optical rifle sight, and 23038/1903, 12735/1904, and 12902/1905 for rangefinders.
[44] VIA AJB 070 1.3, Drawing Office Index, drawings 1674/5, 1873, 1885/6, 1898, and 2175.
[45] Sumida (1993) p. 85.
[46] British Patents 7322/1907, 13562/1907, 15200/1907, 20315/1908, 6082/1910, 7392/1910, and 9306/1911.
[47] See British Patent 30090/1912 for details of the instrument, and McConnell (1992) p. 74 for a summary of the evolution of Pollen's system.

produce the high precision cams and intricate gearing used in the mechanical analogue computer he was developing.[48] In 1908 Pollen became a shareholder and director of the firm,[49] and so created for himself the opportunity of also using Cooke's optical skills to develop a complete fire control system including a sophisticated rangefinder which might be sold as a patented package.[50] This provided potentially serious competition for Barr & Stroud, because of Cooke's considerably greater optical design capabilities. H. D. Taylor was an internationally recognised expert in the design of telescope optics and, unlike anyone at Barr & Stroud, he was well able to compute complex lens and prisms systems which Cooke's by then were capable of making entirely by themselves.[51] Barr & Stroud saw Cooke's involvement with rangefinder design, either on its own or through Pollen's Argo Company (his marketing arm) as giving the Admiralty the prospect of an alternative supplier, and possibly ending the monopoly previously guaranteed by being the only British maker. Harold Jackson, Barr & Stroud's general manager, was taking Pollen seriously as early as 1908, when he told his resident engineer in Portsmouth (who had regular access to the Royal Dockyard) to find out all he could about Pollen's activities and plans as 'we understand . . . he is on with something'.[52] In March 1911 Jackson believed that Cooke's and Argo in combination would 'in all probability shortly be serious competitors'.[53] The Admiralty, although totally committed to buying British made instruments, was by no means contracted to one domestic supplier in perpetuity.[54]

Despite Barr & Stroud's concerns over the possible competition of the Cooke/Argo rangefinder it is likely that such fears were misplaced, because the Admiralty had a number of forces acting on it to shape its policies concerning rangefinders. These included not just technological issues but also cultural and political ones that had

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[48] McConnell (1992), Chapter 7 describes the range of Cooke's engineering activities.
[49] VIA AJB 030/1.1.1, T. Cooke & Sons Ltd., Directors' Minute Book entry, Annual General Meeting 1908.
[50] Pollen operated through the Argo Co. Ltd, which Sumida treats as being the manufacturer of the Pollen instruments. Argo was Pollen's marketing company, and bought all its apparatus from Thomas Cooke & Sons Ltd.
[51] McConnell (1992) p.65 ff.
[52] UGD 295/4/1, Letter Book, H. D. Jackson to J. Heather, 24.12.1908.
[53] UGD 295/4/3, Letter Book, H. D. Jackson to J. Heather, 21.3.1911.
[54] PRO ADM 116/3458, Correspondence between Admiralty and the Treasury on the need for only British optical glass to used in Royal Navy instruments: Admiralty Report 27.8.1915, noting correspondence 1910 to 1913.

sometimes subtle, but sometimes very direct, influences on its decisions. Here, it is essential to consider simultaneously both the social and the technical in understanding what drove the Admiralty's thought and actions.

One advantage that Barr & Stroud undoubtedly had over Cooke's and Pollen was the existence of beneficial contacts within the Navy itself. One of those was Professor J. B. Henderson, who had earlier worked with William Stroud in Leeds and then with the firm in Glasgow as head of its scientific research department. Henderson was appointed Professor of Applied Mechanics at the Royal Naval College at Greenwich in 1905.[55] He subsequently corresponded regularly with his old employers, and in October 1907 wrote privately to Stroud to advise him of the influence Pollen's ideas were having on naval gunnery, and in particular of the problem of hitting moving targets at very long ranges. Henderson not only told Stroud that a rangefinder of much greater accuracy would soon be called for, but also directed him diplomatically towards the idea of becoming involved in fire-control instrumentation by saying 'Pollen is a fairly skilful mechanical inventor, but he is not a scientist and cannot tackle the problem'.[56] Stroud had previously worked on the design of the firm's electro-mechanical 'Range-and-Order Indicators' which transmitted range and other gunnery information to individual gun mountings and were the rudimentary precursors of what Henderson was now discussing, so he would have appreciated the amount of work and the complexity of the problems likely to be involved.[57] That knowledge may have persuaded him that were the idea be taken up successfully, it would require more expertise than the firm had available, leading the company to begin a collaboration with the Dutch artillerist and engineer Admiral W. Mouton that proceeded until temporarily interrupted by the outbreak of war.[58]

As with the earlier Indicators, Barr & Stroud saw fire control instrumentation as an extension of its activities rather than diversification, although to what extent it saw the

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[55] Moss and Russell (1988) p. 38.
[56] UGD 295 Unclassified material, Russell research notes, Box 2, Henderson to Stroud, 5.10.1907. Henderson was eventually proved quite wrong, as Sumida clearly demonstrated.
[57] See Chapter 1 above for the difficulties encountered with those far more rudimentary devices.
[58] UGD 295/4/109, Letter Book, J. W. French to Adm. Mouton, Royal Dutch Navy, reviewing progress and attitudes, 29.7.1914.

Admiralty as its main client is uncertain. Given the Admiralty's long-running dealings with Pollen and Dreyer, which were certainly no secret, the firm may have seen the new product as wholly export-oriented from the outset; certainly a delegation from the Imperial Japanese Navy examined one of the earliest versions of the 'predictor' mechanism in March 1912 at a time when they were ordering large amounts of rangefinders and Range-and-Order instruments.[59] Progress was as slow as Stroud might have feared, and not even a complete prototype had been finished when the war began, most likely because the company was wholly occupied with other projects that were considered of more pressing importance.

Whilst Pollen's relationship with the Admiralty was frequently less than harmonious, leading to distrust and even hostility, Barr & Stroud retained a significant degree of confidence from the Navy, despite potential conflicts of interest over the amount and nature of foreign trade the firm carried out.[60] In 1908, the Director of Naval Construction asked for an assurance that foreign officers visiting the factory would not be able to see any 'confidential work' being done for the Royal Navy, to which Jackson had to reply diplomatically that there was actually nothing being supplied to the Admiralty that had not already been sold abroad. Despite numerous earlier offers to keep designs secret, he said, 'in no case [had] our offer been accepted' and the firm had repeatedly been told it was free to submit them to foreign governments, which it had done.[61] Jackson tactfully pointed out to the Director that in consequence foreign trade had become so important that 'we cannot ignore it'. Irrespective of whether he was mollified or chastened, the Director let the matter drop, but four years later, on a different tack, he asked Jackson for details of what foreign navies were ordering and whatever else they were asking about. Jackson responded that as he had no specific instructions from any overseas client to observe confidentiality he considered the firm was 'quite at liberty' to tell the director whatever he wanted to know.[62] By that time, much of the Admiralty's work was sufficiently different to foreign contracts that a special department had been set up to

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[59] UGD 295/4/80, Letter Book, J. W. French to W. Stroud, 25.3.1912.
[60] For examples of Pollen's problems, see A. Pollen, *The Great Gunnery Scandal* (London: William Collins & Co. Ltd., 1980).
[61] UGD 295/4/53, Letter Book, Jackson to Director of Naval Construction, 26.9.1908 and 30.9.1908.
[62] UGD 295/4/4, Letter Book, Jackson to Director of Naval Construction, 30.11.1912.

handle it, and soon after telling the Director exactly what every foreign power had ordered recently, Jackson asked if he could allow trainee rangefinder technicians from the Imperial Japanese Navy into the rest of the factory as orders from Japan were 'by no means inconsiderable'.[63] The director was quite happy to permit this, evidence that both parties were tacitly recognising the symbiotic relationship that had developed between them, something that Cooke's lacked and which they were never able to cultivate, very much to their detriment.

The intricacy of Cooke's association with Pollen and the Argo Company may not have been clearly understood by Barr & Stroud, but the construction and significance of Taylor's 1912 rangefinder design mentioned earlier most certainly was.[64] Jackson described its principal features to the firm's Austrian agent in July 1912, detailing its novel optical design and gyro-stabilised data-transmitting mounting, both of which he had to concede Barr & Stroud had nothing to compete with. Putting a brave face on it, he observed the rangefinder was 'very complicated and . . . very costly' but had to concede that its unusual optical system provided 'extra brightness' that made it more useful in the bad lighting conditions typified in the North Sea. He also noted that the gyro-stabilised mounting let the operator take readings more quickly and certainly than either the pedestal or turret mountings provided by Barr & Stroud.

Despite Jackson's concerns about the threat from the 'Cooke-Pollen' rangefinder, it stood little chance of being adopted by the Admiralty. There were several reasons. Firstly, it was an integral part of Pollen's fire control system, which he was struggling with increasing difficulty to persuade the Royal Navy to accept. As Sumida has shown, by 1912 the Navy was inclined to prefer a simpler and more familiar system designed by a serving officer – another instance of an established paradigm resisting a destabilising anomalous technology, and similar to the War Office's circumstances with the Mekometer in 1889.[65] By 1914, when the trials finally ended, the Pollen system was

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[63] UGD 295/4/4, Jackson to Director of Naval Construction, 7.12.1912.
[64] UGD 295/4/88, Letter Book, Jackson to Capt. A. H. Seibert, 20.7.1912, saying he believed Pollen was Argo's 'designer'. This letter is also the source material for the rest of this paragraph.
[65] See Chapter 1 above.

rejected, and with that went the chief hope of selling the complex rangefinder. However, although the Argo system demanded the Cooke-Pollen instrument, the rangefinder did not need the complex fire control system to work with, and could therefore be sold independently of it. But, adding to the difficulties of association with Pollen in selling it to the Royal Navy, Taylor's design had constraints that made it virtually impossible for the Admiralty to consider it as a possible replacement for the existing Barr & Stroud patterns.

Taylor's rangefinder provided a brighter image of higher contrast than the Barr & Stroud models, which enhanced its use in adverse lighting conditions.[66] This had been achieved through Taylor's ability entirely to re-design the telescope portion of the rangefinder to benefit from the properties of new advanced optical glasses being made by Schott & Genossen of Jena in Germany, which permitted substantial improvements in the performance of telescope lens systems.[67] Barr & Stroud had never used these glasses, partly because the firm had no designer of sufficient ability to compute systems around them, and partly because using the 'old' flint and crown glasses it was possible to make telescopes that, even if less than 'state-of-the-art', were still satisfactory for most purposes (such as in a rangefinder). Taylor had used the 'new' Jena glasses almost as soon as they became available, had suggested modifications in their formulation to Otto Schott, their inventor, and become wedded to their employment wherever possible.[68] These sophisticated glasses were hardly made at all in Britain, which would have posed a considerable difficulty in selling the rangefinder to the Admiralty in view of its insistence on domestically made glass for all its optical instruments.

That policy was rooted in the desire to be independent of foreign suppliers in time of war. In 1910, fearing that relying on imported optical glass would lead to severe problems if supplies were interdicted by an enemy, the Admiralty had begun to stipulate

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[66] E. W. Taylor, 'The New Cooke-Pollen Rangefinder' Journal of the United States Artillery, Vol. 41, No. 3, May-June, 1914 describes and illustrates the instrument.
[67] F. Auerbach, *The Zeiss Works and the Carl Zeiss Stiftung in Jena*. Translated by F. Cheshire and S. Paul. 2nd ed. (London: Marshall Brookes & Chalkely, 1904) describes the advances in optical design in this period and the benefits of the new glasses that were constantly being introduced.
[68] VIA AJB 220/2.6: H. D. Taylor's 1895 paper on the adjusting and testing of telescope objectives made clear his espousal of the new types.

that British optical glass should be used wherever possible.[69] Consultations were encouraged between the instrument makers and the only British optical glass maker, Chance Brothers of Birmingham, to assure supplies of both the established and new formulations. Chance already made a wide range of 'old' glasses but attempts to get them to produce domestic alternatives to the new Jena glasses met with only limited success. The firm saw optical glass as an unprofitable aspect of its business, it lacked both the technical staff and facilities to make rapid headway in catching up lost ground, and was unwilling to invest heavily in its development.[70] This greatly restricted the 'new' glasses available in Britain but represented little difficulty for Barr & Stroud who had already given a categorical assurance in 1911 that they were independent of imported material. Taylor may not have been aware of the problems he had created in producing a rangefinder that depended on what were in effect proscribed raw materials for its much of its optical superiority, but in the end the Cooke-Pollen rangefinder was rejected for an altogether different reason. Its failure to gain Admiralty endorsement came not because it was part of a larger rejected system, had unfavourable associations with Pollen, or used unacceptable materials, but simply because in its 1914 trials it consistently failed to read ranges accurately. Its obituary notice pronounced by the Admiralty read that 'It is a beautiful instrument but it has one serious defect, namely that it will not measure distances'.[71] Taylor's sophisticated rangefinder failed through mechanical difficulties that might well have been remedied by revision and modification, but the declaration of war only three months later ended its chances of success and Cooke's were kept out of the business of making large naval rangefinders.

Cooke's failure to break into the rangefinder market was not because the firm lacked optical expertise, but because it was coming, at an inopportune moment, late into a field where the Barr & Stroud models had already established, in Thomas Hughes' expression, a considerable technological momentum. For the Taylor-designed instrument to have

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[69] PRO ADM 116/3458 Correspondence between Admiralty and Treasury on optical glass supplies, 1910-1913 provides the source material for the following section unless otherwise indicated.
[70] J. F. Chance, *A History of the Firm of Chance Brothers & Co.* (London: Spottiswoode, Ballantyne & Co., 1919) p.182 to p. 184.
[71] UGD 295/4/107, Letter Book, Jackson to S. Vronski, quoting from an unidentified Royal Navy officer, 14.5.1914.

displaced them would have required firstly the clear demonstration of superiority and secondly the institutional willingness to accept it as a 'presumptive anomaly' – an alternative technology presumed to be superior to the existing technological paradigm which had become wholly identified with the Barr & Stroud models in service.[72] Given that they apparently functioned well, in the absence of failure there was little incentive for the Navy to discard the familiar and adopt a new pattern, particularly when it was associated with a novel technology which the Navy was culturally and institutionally disposed to reject. It was perhaps ironic that Barr & Stroud, a business far less able in optical design, should enjoy a conspicuously greater degree of success selling complex optical munitions.

3.9 Barr & Stroud's evolution

Barr & Stroud did indeed enjoy business considerable success between 1907 and 1914, both in sales and profits, and its domination of the rangefinder market. The development of Barr & Stroud between 1907 and the start of the Great War has been described by Michael Moss and Iain Russell, who observed that the business 'grew steadily… as the firm brought improved instruments onto the market'.[73] There was indeed growth, as figure 4.8 shows: the firm made a substantial profit every year, and although pre-tax margins on turnover slipped between 1909 and 1912 to an average of 25 percent they recovered in 1913 to 32 percent. For the seven years, turnover was almost £806,000 and earnings after tax £240,381, equal to a healthy net margin of 29.8 percent.[74]

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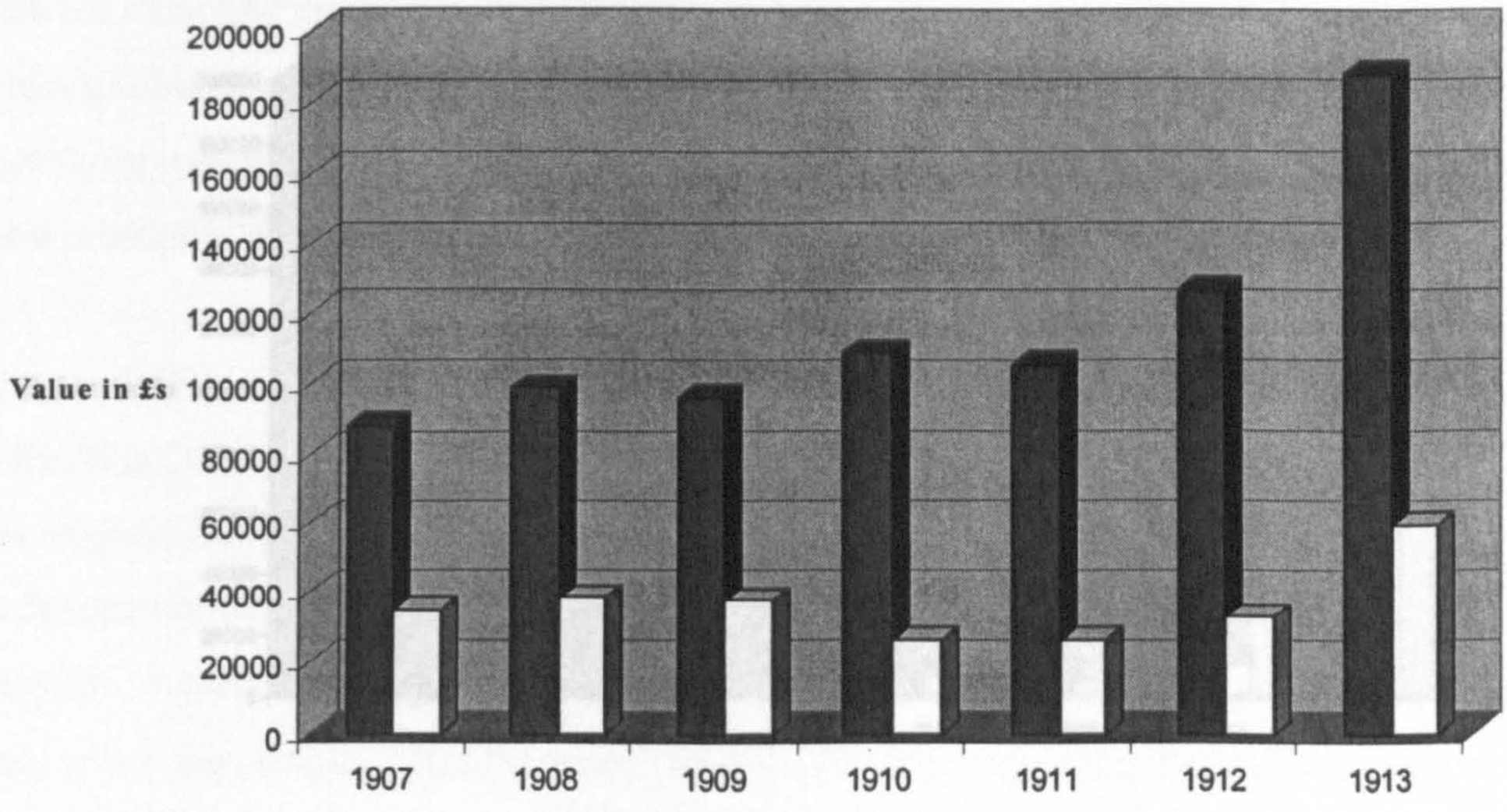
[72] See W. McBride, *Technological Change and the U.S. Navy 1865-1945* (Baltimore: Johns Hopkins University Press, 2000).

[73] M. Moss and and I. Russell,. *Range and Vision: The First Hundred Years of Barr & Stroud.* (Edinburgh: Mainstream Publishing, 1988) p.69.

[74] The figures up to 1912 have been extracted from UGD 295/26/1/27 'Correspondence and notes', and UGD 295/26/1/47 Table of Barr & Stroud sales 1901-1912. The later figures come from UGD 295/11/1, Balance sheets for 1913.

Figure 3.4: Barr & Stroud, turnover and pre-tax profits 1907-1913:[75]



A substantial proportion of those earnings came from foreign business. Moss and Russell referred to the extent of the firm's overseas sales efforts, describing particularly how Barr & Stroud went about securing European orders for infantry and artillery rangefinders, but they gave no indication of the relative size of foreign and domestic business. The company's Customer Order files record the distribution of orders, and provide a picture of the extent of the company's dependence on foreign armies and navies.

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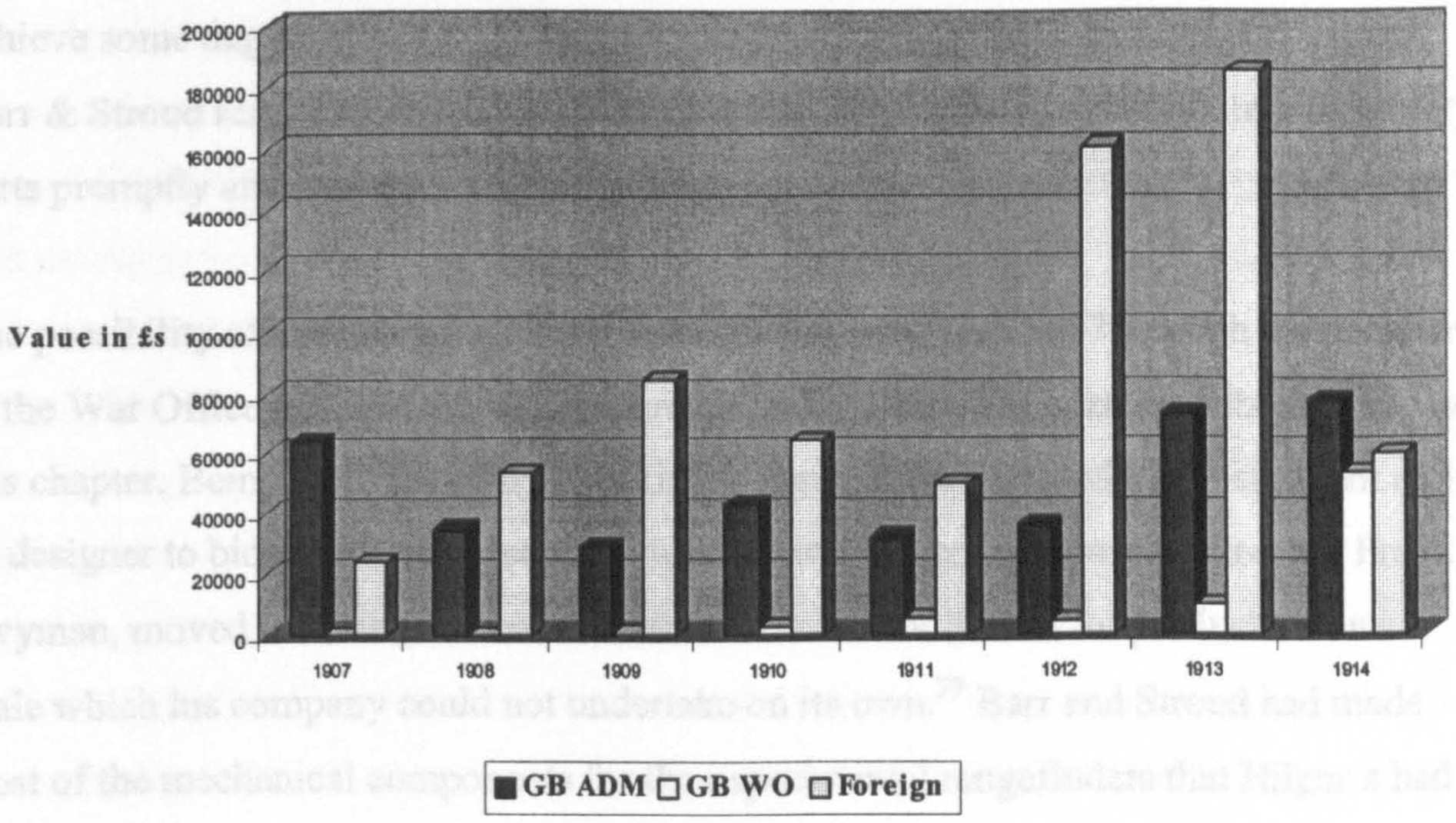
[75] Sources as note 74 above.

Figure 3.5: Barr & Stroud, orders received from the British Admiralty and War Office, and all Foreign clients, January 1907-July 1914:[76]



Apart from 1907, when foreign orders accounted for 27 percent of the total received, overseas business formed the majority of the value of work coming in to the firm from 1901 (when the detailed records started) until the end of 1913. Between January 1907 and December 1913, British orders amounted to £335,583 and foreign ones £623,217, a total of £958,800 excluding repairs and spare parts. Moss and Russell have described in some detail the efforts made by the firm to secure this business and the effects of competition by the German makers Hahn, Goerz and Zeiss, but they gave little attention to how Barr & Stroud actually managed the growing amount of trade, and in particular, they passed over the efforts that the company made to extend its optical capabilities.[77]

The production of lenses and prisms was still largely done by outside contractors in 1907, with most the simpler lenses bought from Chadburn Brothers in Sheffield and the

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[76] Extracts from UGD 295/19/2/1, 295/19/2/2, and 295/19/2/3, Customer Order files 1907-1914.
[77] Moss and Russell (1988) pp. 59-72

more complex ones and prisms from Adam Hilger & Co. in London. Most of the optical work done at Glasgow was still connected with the building up prism assemblies and the mounting of lenses into their cells for incorporation in the rangefinder bodies, rather than the grinding and polishing of optical glass into finished components. This was a difficulty that had vexed the firm since it began, and despite two previous attempts to achieve some degree of self-sufficiency through integrating the Adam Hilger business, Barr & Stroud remained dependent on remote suppliers who frequently failed to deliver parts promptly and of adequate quality.[78]

The possibility of acquiring the Hilger business reappeared in 1907 through the decision of the War Office to adopt the Marindin rangefinder which has been described earlier in this chapter. Being well-placed by the existing association with both the instrument and its designer to bid for whatever contract was offered, Hilger's managing director, Frank Twyman, moved to establish a collaboration with Barr & Stroud for production on a scale which his company could not undertake on its own.[79] Barr and Stroud had made most of the mechanical components for the experimental rangefinders that Hilger's had built, and had dealt personally with Marindin on several occasions. Having learned of the War Office's selection, Harold Jackson wrote to him on July 12th 1907 observing, perhaps a little sourly, that as it had been 'impossible' to work with the War Office Barr & Stroud would in future concentrate on foreign armies. Soon afterwards, Twyman approached Jackson with the idea of tendering jointly for anticipated business, a proposal which Jackson accepted on July 26th but quickly set aside in favour of a plan to set up a completely new business. On August 9th a detailed draft proposal was sent to Twyman under which each firm would provide half the capital for a venture to 'erect and complete' rangefinders using mechanical parts from Barr & Stroud and optical ones from Hilger's.

At first sight, the proposal looked simply to establish a cartel to market the Marindin design. The draft agreement noted that it was 'to their mutual advantage to work in

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[78] See Chapters 1 and 2 above for examples.
[79] UGD 295/4/46, Letter Book, provides the source material for the following section unless otherwise indicated. Dates and correspondents are given in the text.

association', and that in its seven year life Barr & Stroud would not make the instrument on their own behalf and Hilger's would not make 'rangefinders or parts for rangefinders' for anyone except the new company and Barr & Stroud. The failure to fulfil any of the agreement's clauses by either party would incur a penalty of £5,000. Despite Twyman's acceptance within a week, the draft was very much to his disadvantage because it committed Hilger's to not making any rangefinder products at all on the firm's own account. Jackson's draft did not limit the prohibition to the Marindin, which precluded Hilger's, or Twyman individually, from benefiting from any opportunities of spin-off that the rangefinder might generate. That sat slightly at odds with the covering letter Jackson sent with the draft, which hoped that the project would 'enable the intimate relationship … between us to be continued'. During September, Twyman began to have second thoughts and requested changes that would let him exploit any new skills or opportunities that arose, only to be rebuffed by Jackson who refused point-blank to give way. His letter on October 2nd said Barr & Stroud would not continue to give Hilger's optical work while Twyman was free for work that might 'seriously tell against [Barr & Stroud's] interests'. He closed by saying that he would nevertheless be 'best pleased' if a closer working arrangement could be achieved and invited Twyman's suggestions.

Between October and mid-November, proposals for a 'wider agreement' were prepared, but nothing had been signed either for it or the earlier idea when it became clear that there was not going to be any large order for the Marindin.[80] In November 20th Jackson congratulated Twyman on his War Office contract for just sixteen rangefinders, and although assuring him that Barr & Stroud would supply the parts, cast him adrift to handle the work alone, saying 'I hope you will be entirely successful'. Jackson then raised issues which suggest that despite the pleasantries, he was actually seeking to annex Adam Hilger's. Twyman was reminded that the failure to win a large order 'only postponed' the earlier proposal to form a joint production company which would be immediately implemented if a big contract eventually emerged, or if 'the suggested wider agreement' was not carried through. This apparently left Twyman in a difficult situation, where failure to accept Jackson's proposals would require him to find half the capital for

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[80] The agreement is referred to in Jackson's letter of November 20th, but no details of it were given.

a new company and works which would subsequently have nothing to do except make sixteen rangefinders. If he demurred and sought to avoid that expense, then he would be liable to pay Barr & Stroud a very substantial penalty of £5,000 that would possibly have left him seriously harmed financially. Jackson's assurance that the 'wider agreement' would not change either the name or the character of Adam Hilger & Co. Ltd was doubtless of little consolation to him.

Having brought Barr & Stroud to a position where it looked likely to gain practical control of Hilger's, Jackson's next action comes as a surprise. With Twyman in a situation where he seemingly could do little but agree to whatever was being put to him, on December 3rd Jackson wrote that Barr & Stroud now wished to withdraw from the matter and retain the *status quo*. His reason was that 'Mrs Hilger' (the widow of the firm's founder and Twyman's fellow-shareholder) might suffer if Barr & Stroud encountered poor trading which would, under the proposed arrangements, 'seriously affect Hilger's financial position' and even wipe out its profits completely. Barr & Stroud, said Jackson, had previously had years of trading at an 'absolute loss'(by which he was referring to the early 1890s) and 'we would not like to contemplate such a contingency'. He ended with the comment that under the circumstances it would be better for the firms to remain independent 'unless you are willing to consider the sale of your business outright, which I do not think likely', a remarkable *volté-face*.

This curious outcome has only one likely explanation, which relates to the firm's management structure and the characters of its owners. Although the business was a partnership wholly owned by its two founders, Jackson was, in Moss and Russell's words, its 'commercial manager in all but name [who was] undoubtedly the architect of the business organisation' and also a man who, in his own words, believed that good management involved someone with 'the power of putting his foot down' and being prepared to get things done.[81] His frequent letters to Twyman at Hilger's show the extent of the complaints he made about workmanship and delivery times, and the frustrations were sometimes evident – on one occasion he wrote that 'We cannot express … how

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[81] Moss and Russell (1988) p. 38.

strongly we have been annoyed by the way you have neglected us [over an order]'.[82] Nor was he alone; William Stroud also had strong feelings about their chief optical contractor's abilities, writing in early 1907 that he doubted if Hilger's knew 'one hundredth of what Zeiss knows'.[83] Given Jackson's philosophy of business management, his letters to Twyman suggest that he believed improvements could be made by reconstructing Hilger's direction, which was solely under Twyman's control. The careful phrasing of the proposed agreement in 1907 indicates that Jackson intended to achieve a situation where Barr & Stroud would have management control, if not outright ownership of its principal optical contractor. His change of mind may have been dictated by pressure from the Professors Stroud and Barr, although each of them might have been motivated by quite different reasons. Stroud thought little of Hilger's or Twyman, and although always unable to suggest any alternative, had previously resisted suggestions of any formal connection.[84] Barr, on the other hand, had had a long acquaintanceship with the now-dead Hilger brothers, both of whom he had respected and seen as friends, as well as a largely amicable attitude towards Twyman.[85] Jackson's efforts to badger the latter into relinquishing control of Hilger's would have been unlikely to appeal to either partner – to Stroud because of his low opinion of the firm, and to Barr because of his previous personal involvement. Despite his energy and commitment to the business, Jackson lacked the power to force his principals into acquiescing in his proposals and he was obliged to extricate himself as well as he could from a situation that had escaped his control, leaving the firm still with an unresolved problem about optical components.

Relations with Hilger's reverted to their earlier pattern, and not until 1912 did conditions force Barr & Stroud seriously to reconsider their arrangements for high-grade lens and prism work. By then, the large pentagonal prism end-reflectors which had become standard in the rangefinders were being flat-polished at Glasgow from pre-moulded

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[82] UGD 295/4/41, letter Book, Jackson to Hilger, 7.6.1906. See also index entries in other Letter Books in the UGD 295/4 series for evidence of the volume of correspondence.
[83] UGD 295 Unclassified material, Russell Research Notes, Folder 'Private Letter Books, BS4/21' Stroud to Barr, 24.1.1907. ('BS4/21' is not listed among the re-classified material now in the UGD 295 collection.)
[84] See chapters 1 and 2 above.
[85] UGD 295/4/744, letter Book, Barr to Twyman expressing condolences on Otto Hilger's death, and explaining the sense of loss he felt, 20.12.1902.

blocks supplied by Chance Brothers in Birmingham, with nineteen glass-workers employed full-time.[86] Most of the spherical lens work was still done by outside contractors. Orders increased substantially that year and Jackson began to seek suppliers besides Hilger's, not just because of quality problems or limited capacity there but also because the Admiralty had begun to suggest that Barr & Stroud should reduce its dependency on a single supplier.[87] He approached the Dallmeyer Optical Company, the Ross Optical Company, and Taylor, Taylor & Hobson Ltd for lenses, as well as ordering more from Chadburn Brothers.[88] In an effort to acquire a full complement of skilled workers and all the expertise needed to let Barr & Stroud attain self-sufficiency in spherical lens production, Jackson took the bold step of attempting to recruit (or poach) simultaneously the entire workforce of the Periscopic Prism Company in London, a firm with which he had been doing business since April 1911.[89] He told his contact there, Paul de Braux, that if Barr & Stroud could get an 'energetic and capable foreman' the firm would enlarge its optical shop and be 'quite willing' to employ as many skilled men as could be persuaded to leave the Periscopic Company. As de Braux was the firm's proprietor, he was (perhaps understandably) somewhat unwilling to give up his own business to be Jackson's energetic foreman, and he declined the offer leaving Jackson to carry on the search.

The problem was made worse for Jackson because there was no comparable work being done in Glasgow (or anywhere else in Scotland), nor any facilities for training in optical manufacturing outside London. Starting a spherical lens shop from scratch could not be done without a nucleus of skilled labour, and all efforts to tempt workers from England had so far been almost wholly unsuccessful. Then unexpectedly in November 1912, seven optical workers from Thomas Cooke & Sons approached Barr & Stroud and offered to move to Glasgow because work at the York factory had 'become slack'

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[86] UGD 295/4/80, Letter Book, Jackson to Chance Brothers, urging delivery of pentagonal blocks; Jackson to Twyman on wage rates for polishers, 3.4.1912; and Jackson to P. de Braux 3.4.1912..
[87] Science Museum Library, Hilger Collection, History of Adam Hilger (subsequently HILG) 3.1, Typescript of 'Mr Twyman's lecture, August 1944'.
[88] UGD 295/4/81, Letter Book, Jackson to Dallmeyer, 23.4.1912, to Ross 23.4.1912, to TT&H 23.4.1912, to Chadburn 6.4.1912.
[89] UGD 295/4/81, Jackson to P. de Braux, 3.4.1912.

following Arthur Pollen's delays in selling his fire control system to the Admiralty.[90] Welcome as the recruits doubtless were, the increasing level of orders throughout 1912 and 1913 meant that the lack of optical capacity continued to cause delays in output. Jackson added the London firm of W. Watson & Sons to his lens and prism suppliers and even began buying large pentagonal prisms from the German firm of J. D. Moeller in response to their unsolicited offer of supplies, presumably to meet overseas orders in view of the Admiralty's proscription of foreign glass.[91]

Barr & Stroud's efforts to integrate backwards into lens and prism and production by 1914 were still not enough to make the firm independent of suppliers over whom it had little direct control. Had Jackson's moves to annex Hilger's been allowed to proceed in 1907, then the firm would have been able to develop its capacity either by wholesale removal of the factory and workers or, more likely, by the acquisition and transfer of technology and the *savoir-faire* of craft technique that was still part and parcel of optical manufacture in the early 20th century. Passing over the opportunity delayed that phase of development, and the Admiralty's later emphasis on the dilution of suppliers temporarily diverted attention away from the need for self-sufficiency with the result that the firm failed to match optical capacity with that for mechanical engineering and assembly, a situation that, as the following chapter will show, posed serious (though not insuperable) difficulties when the Great War began.

3.10 Conclusion

By 1914, Barr & Stroud had become the world's largest maker of optical munitions, and was far closer in character to the armaments industry than to the scientific instruments industry where it has usually been thought to belong.[92] Clive Trebilcock has defined the characteristics of armaments firms just before the Great War in terms that endorse the

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[90] UGD 295/4/86, Letter Book, Jackson to J. W. French, 26.11.1912.
[91] UGD 295/4/95, Letter Book, Jackson to Watson, 12.5.1913, and Jackson to Moeller, 14.5.1913.
[92] See M. E. W. Williams, *The Precision Makers: A History of the Instruments Industry in Britain and France, 1870-1939* (London: Routledge, 1994) Chapter 2, and R. and K. MacLeod, "Government and the Optical Industry in Britain 1914-1918." In *War and Economic Development*, edited by J. M. Winter. (Cambridge: Cambridge University Press, 1977).

inclusion of businesses making military and naval optics amongst them.[93] Compared to commercial manufacturing, military supply was 'a terrain both unwelcoming and largely unrecognisable' and those who catered for it bore little resemblance to 'their peaceable contemporaries.' He noted that private enterprise rather than government was responsible for 'the major part of advanced weaponry design' and included in a list of such innovations the rangefinder. The bulk of these innovations were 'as far removed from articles of general commerce as the best of contemporary science . . . could take them.' The 'real forte' of the arms industry, according to Trebilcock, lay in its ability to combine such disparate skills as heavy engineering and 'the most delicate' engineering work. The last sentence might have been written especially to describe the kind of work done by Barr & Stroud, who fitted prisms as small as an inch long into massive metal structures fifteen feet in length and so heavy that they required lifting gear to move them around the assembly shop. Even if large rangefinders were not wholly typical of optical munitions manufacture, other instruments like the dial sight and submarine periscope nevertheless conformed equally well to Trebilcock's characterisation of armaments, in that they had no civil market and their demand was inseparably linked to the State's needs at any time, so that attempts to sell them were constrained by factors quite different to those in civil markets.

By the beginning of August 1914, Britain had evolved an optical munitions industry that had the capacity to supply not only all the nation's own peacetime demands, but many of those of foreign powers besides. It was a numerically small but distinct industry specialising in the manufacture of optical goods for the armed forces that the majority of optical companies were unable or unwilling to tackle. Most of the constituent firms produced military optics in addition to, but separately from, other unrelated commercial products, deriving only a proportion of their incomes from government contracting, but the largest one relied entirely on the international demand for armaments to provide its business. None of these firms had been given any State assistance in developing what they made, but neither had they been discriminated against as has been previously

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[93] See C. Trebilcock, *The Vickers Brothers: Armaments and Enterprise 1854-1914* (London: Europa Publications, 1977) pp. 1-7 for the following quotations in this section.

suggested. The armed forces most certainly did not rely on imported instruments; they could – and did – draw their whole requirements from an independent and generally capable domestic industry that was geared to the level of peace-time demand.

The factors bearing on the shaping of the industry up to the outbreak of the Great War may be interpreted at first as showing the characteristics of technological determinism, with inexorable advances in gunnery and weapons systems driving the need for more complex optical support systems, but on closer examination it becomes clear that the industry's evolution was governed by a combination of social and technological issues whose understanding is crucial in understanding the path that was taken by all the actors on both sides of the story. It is not possible properly to comprehend the industry without grasping the complexities of the forces driving clients as well as suppliers.

The ability of the optical munitions industry to deal with the challenges and problems that followed the declaration of war in August 1914 will be considered in the next three chapters, the first of which charts the first stage of industrial mobilisation up to the middle of 1915.

Chapter 4

The impact of war, August 1914 to mid-1915

4.1 Introduction

The optical munitions makers, like almost all of British industry, were unprepared for war and encountered problems between August 1914 and the early summer of 1915. These difficulties were partly outside the industry's own control but came also from the structure of optical instrument making generally. The principal difficulty was an unanticipated, increasing demand from an Army that was expanding on an unprecedented scale and which had been inadequately equipped with optical apparatus before the war. The War Office failed both in not quantifying its own requirements and not concentrating its orders on the makers who were best suited to deal with them, and there was consequently an inability to recognise, let alone come to terms with, the strengths and limitations of both the general and specialised optical sectors of the industry. The strengths were largely ignored during 1914 and early 1915, and historians have subsequently emphasised the ensuing shortcomings as signifying a chronic weakness, particularly in having failed to keep up with German competitors. In fact, the problems in optical munitions output, were more rooted in the problems of industrial mobilisation than in any backwardness of the industry. The procurement process was, initially, the greater difficulty.

Of the two British services, the Army's equipment with optical munitions was by far the more unsatisfactory, with the large-scale ordering of rangefinders having only just begun. Most of the problems met by the optical munitions makers in the first year of war were in trying to satisfy the War Office's rapidly developing needs. The Navy's requirements were geared to the quantities and types of ships in service rather than its manpower, but the Army's was directly related to its numerical strength which grew with extreme rapidity in contrast to the Navy's ship strength which increased far more slowly. Emphasising the differences, the Admiralty had previously been a regular and substantial purchaser of optical instruments and had established an efficient supply chain with

makers who were familiar with its needs, whereas the Army had never been either a large or consistent buyer from the optical community.

4.2 The capability and capacity for optical munitions manufacture

Even before 1914, there had been concerns about the Army's ability to get the optical apparatus it would need in the event of war. These worries focussed on the British optical instruments industry as a whole, which was seen by some as inadequate to meet possible requirements should Britain be drawn into a European war. The British Science Guild considered that under such circumstances British firms 'could not, unaided, produce sufficient quantities' of the optical devices that would then be wanted by the armed forces.[1] These sentiments echoed others already voiced by some of the members of the optical industry itself.

According to the account subsequently left by the Ministry of Munitions, which was created in the spring of 1915, the capacity for the supply of optical instruments to the British Army in late 1914 became a matter of grave concern. The official *History of the Ministry of Munitions* described British optical manufacturing as then being both 'seriously undercapitalised' and 'very conservative', with 'such machinery as existed [being] antiquated'. There was also 'a singular lack of comprehension' of the benefits of machine tools, suggesting that a serious or even chronic lack of capacity to manufacture quickly and in quantity.[2] That gloomy depiction was echoed by Roy and Kay MacLeod who considered that the industry was 'a fragmentary collection of craft based family firms' which suffered from a 'scarcity of capital for investment and research.[3] Furthermore, they believed that British makers had actually been discouraged from making some key optical munitions because 'the War Office was a customer for German dial sights and prism binoculars . . .' Mari Williams shared this view, considering that once the war began 'it was vividly brought home to the British government . . . that they

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[1] British Science Guild; *Report of the Technical Optics Committee respecting the Proposed Establishment of an Institute of Technical Optics,* June 1914, Appendix C to the *Ninth Annual Report of the BSG* (June 1915) pp. 29-31. Cited in Roy and Kay MacLeod; 'Government and the optical industry in Britain, 1914-18', in J. M. Winter, ed. *War and Economic Development* (Cambridge: University Press, 1975) p. 170.
[2] Great Britain, Ministry of Munitions; *History of the Ministry of Munitions*, (subsequently *OH*) Vol. XI 'The Supply of Munitions', Part III. (London: HMSO, 1922) p.13, p. 9, and p.18.
[3] R. and K. MacLeod (1975) p. 170 provides this and the subsequent quotation.

were heavily dependent upon Imperial Germany both for finished precision instruments and for many component parts.'[4] The domestic industry's ability to meet even the immediate demands of the Army was clearly doubted by contemporary accounts which have been uncritically accepted subsequently.

This impression is far from correct. In mid-1914 there was a viable British optical munitions manufacturing base which was more than adequate for all the requirements of the peace-time armed forces. Its constituents were well able to manufacture high precision complex military optics, frequently progressively minded, and far from antiquated. The Army's problems in obtaining its optical requirements after August 1914 ought not to be laid solely at the industry's door. They came about from the combination of a totally unprecedented scale of demand, shortcomings in the War Office's procurement mechanisms, and limitations in the optical munitions sector which were principally – though by no means exclusively – a consequence of the British Army's pre-war attitude towards its optical inventory.

The first stage in the industry's war-time growth was largely concerned with increasing output to meet the growing demands of the Army. Most of the pressure exerted on the makers from August 1914 to the summer of 1915 was to produce more of what was already being made. The Admiralty and War Office competed for manufacturing capacity without any co-ordination, each exerting pressures on makers to satisfy its own requirements and apparently ignorant of conflicts of interest, with the greater pressure coming from the War Office. In addition, the Army's need for new types of optical munitions began to emerge early in 1915 in response to specific requirements shown by the fighting, and the design of items like the telescopic rifle sight was passed by the War Office to firms who usually did not have the expertise to design for large scale manufacture, compounding delivery problems still further. There was, as Roy and Kay MacLeod rightly pointed out, little in the way of co-ordination of research, design or

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[4] Mari Williams; *The Precision Makers: a History of the Instruments Industry in Britain and France 1870-1939* (London: Routledge, 1994) p. 8.

output during this stage.[5] The optical industry – unlike, for example, the small arms industry – was left entirely to its own devices in organising its industrial mobilisation.[6]

4.3 The industry that was available to meet increased War Office requirements

Although the British Army was no stranger to optical munitions, its pre-war deployment of them had hardly been lavish. The relatively small scale of War Office purchasing has already been mentioned in the preceding chapter, and in the financial year to 31st March 1914 only £49,000 had been spent.

Table 4.1: War Office optical munitions contracts 1913-1914:[7]

Maker	Financial Year 1913-1914
Aitchison & Co. Ltd London	£1,752
Barr & Stroud Ltd Glasgow	£8,720
Beck & Co. Ltd, London	£8,880
C. P. Goerz, Berlin*	£4,712
Ottway & Co. Ltd, London	£ 640
Ross Optical Co. Ltd, London	£10,865
Troughton & Simms, London	£ 214
W. Watson & Sons Ltd, London	£4,279
Carl Zeiss (London) Ltd	£8,850

* The business was part of a licensing arrangement for artillery dial sights that included their manufacture by Beck and by Ross.

Irrespective of the small value of recent business, there was nevertheless a core group of makers experienced in producing specialist instruments to War Office requirements. Those included strict conformity to specifications and quality at a level not required in the civil markets where almost all the contractors except Barr & Stroud also competed. In

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[5] MacLeod 1975, p. 175.
[6] For details of the organisation of private sector small-arms production, see *OH* Vol. XI, Part 4, 'Rifles', pp. 3-21.
[7] Details extracted from The National Archives, Kew (subsequently PRO) Records of the War Office, WO 395/3, Director Army Contracts Annual Report 1914.

the preceding three years, ten British companies had supplied seven categories of optical munitions to War Office contracts:

Figure 4.2: British optical munitions contractors to the War Office, 1911-1914:[8]

Manufacturer	Products
Aitchison & Co. Ltd, London	Prismatic binoculars
Barr & Stroud Ltd, Glasgow	Single-observer rangefinders
Beck & Co, Ltd, London	Panoramic gun sights (Dial sights)
Cooke & Sons Ltd, York	Depression rangefinders, Panoramic gun sights
A. Hilger & Co. Ltd, London	Single-observer rangefinders
W. Ottway & Co. Ltd, London	Sighting telescopes
Ross Optical co. Ltd, London	Panoramic gun sights, Prismatic binoculars, Signalling telescopes
Taylor, Taylor & Hobson Ltd, Leicester	Signalling telescopes
Troughton & Simms, London	Sighting telescopes, Signalling telescopes
W. Watson & Sons Ltd, London	Prismatic binoculars

In addition the German Carl Zeiss company had established a 'branch factory' in London in 1909, setting up a British company called Carl Zeiss (London) Ltd. It produced prismatic binoculars principally for sale to the War Office which by 1914 regarded the business as a domestic manufacturer.[9]

These companies manufactured all the types of optical instruments used by the Regular Army. Their apparent failure to meet the Army's needs can be explained through examining the course of events after the declaration of war.

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[8] Extracted from PRO 395/3, Director of Army Contracts Annual Reports, 1912, 1913, and 1914.

[9] Antje Hagen; 'Export versus Direct investment in the German Optical Industry', *Business History* Vol. 38 No. 4, October 1996: see also chapter 4 above.

4.4 Procurement Problems

The despatch of the Expeditionary Force to France started a process which was to lead to the creation of an unfavourable image of the optical munitions industry in the light of its apparent lack of success in meeting demands. This was, in fact, largely due to a failure of the War Office in organising procurement rather than a breakdown of production. There were two problems facing the War Office. Firstly, the equipment of the peace-time Army with up-to-date optical apparatus was still far from complete because some of the most important orders had only recently been placed. Earlier contracts (described in the preceding chapter) were still being filled, so that initial deficiencies in numbers resulted not from failure on the makers' part, but from the timing of War Office orders. The second difficulty compounded the first; the immediate calling-up of reserves drew into the Army large numbers of men who were largely un-provided with optical instruments of any kind.

The peace-time strength of the Army was approximately 234,000, of whom 192,000 were front-line troops.[10] From these, an Expeditionary Force of 150,000 was meant to be despatched to the continent. The domestic Territorial Force of 256,000 men was to be mobilised to 'take over the defence' of the British Isles.[11] The only optical munitions available for the latter were those which had earlier been released from the front-line units as new patterns came into service, and those left over from acquisitions made during and immediately after the Boer War. Nothing else had been done to provide optical instruments for the Territorial Force because no pressing need had been recognised and because funds were more urgently needed to supply front-line units. Then, there were additional reserves of 200,000 men of whom 56,000 formed a 'Special Reserve' intended to 'feed the Expeditionary Force' with replacements and reinforcements. These soldiers needed the same equipment as the Regulars, but once again no provision had been made for optical munitions. The Army thus had the immediate prospect of mobilising for front-line service 150,000 men who were inadequately supplied with optical stores, plus another 56,000 who were totally without

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[10] *OH* Vol. I Part I, Appendix 2, p.145, and David G. Hermann, *The Arming of Europe and the Making of the First World War* (Princeton: Princeton University Press, 1996) p. 234.
[11] *OH* Vol. I Part I, p. 8, provides the source material for the rest of this paragraph.

up-to-date instruments. Besides those, another 400,000 men in the Territorial and general reserves almost entirely lacked optical equipment, constituting a problem that would have to be addressed if they were to be committed to action.

The supply problem almost immediately worsened as it became apparent that a much larger field force than 150,000 was going to be required.[12] On August 6th Parliament approved the provision of an extra 500,000 men, of whom 100,000 enlisted before the end of the month. A further half million was voted for on September 10th, and before the end of November approval was given for another million, increasing the Army's pre-war strength eightfold, to around 2.5 million. By the beginning of November, enlistments of one million since the declaration of war were starting to impose a massive burden on the supply of all types of munitions. All these factors constituted a recipe for chronic problems in optical munitions supply.

The scale of the Army's need for optical devices had, like much else, rapidly multiplied beyond anything ever envisaged – 'nobody had planned for an expansion of the army on the scale undertaken by Kitchener'.[13] The head of Woolwich Arsenal's Optical Inspection Department quantified the Army's requirements in November 1914.[14] His department was responsible for inspecting all optical stores and he was fully conversant with their scales of issue. These meant that excluding gun sights and signal telescopes, 7 percent of the Army would require binoculars and every hundred men would want a rangefinder. In mid-November, the Army had reached a million, so that 70,000 binoculars and 10,000 rangefinders were already required in addition to what the pre-war Regular Army and reserves still needed. The provision for another million men meant the figures would double by the following July when those new soldiers had all been inducted, making a total shortfall of 140,000 binoculars and 20,000 rangefinders, excluding telescopes and gun sights.[15]

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[12] *OH* Vol. I Part I pp 9 and 10 provide the data for the rest of this section on the enlargement of the Army.
[13] H. Strachan, *The First World War: Volume 1: To Arms*.(Oxford: Oxford University Press, 2001) p. 1067.
[14] Roy and Kay MacLeod (1975), p. 171, and A. C. Williams, "The Design and Inspection of Certain Optical Munitions of War." *Transactions of the Optical Society* XX, no. 4 (1919), pp. 97-100.
[15] *OH* Vol. I Part I, p. 10.

The responsibility for procuring all munitions supplies lay jointly with the Master General of the Ordnance (MGO) and the War Office Contracts Department. The historian of the Ministry of Munitions provided an explanation of their respective functions which can hardly be bettered:

> The size of the Army being determined by Parliament, and the scale of equipment being approved, the formulation of definite requirements was a straight-forward matter. It was the duty of the Master General of the Ordnance and his officers to prescribe what equipments should be supplied and the duty of the Contracts Department was limited to procuring from the armaments firms such portions as might be definitely requisitioned. [16]

The MGO ought to have been able to calculate what 'definite requirements' in optical stores were needed according to the growing size of the Army, and then issue instructions – 'contracts demands' – to the Contracts Department to procure the quantities needed. The latter should then have sought tenders from manufacturers before awarding contracts.[17] Because the instruments needed in late 1914 were all of existing patterns, and because established sources of supply already existed, it might be expected that sufficiently large orders would have been placed to meet the immediately emerging demands. In fact this was not done, so that by mid-1915 there was both a substantial and growing deficit in orders to meet the growing demand and a shortfall in deliveries of optical munitions already required.[18] The pattern of ordering was as much responsible for the failure of the industry to provide adequate supplies as were the shortcomings in its structure and background suggested by the Ministry of Munitions. Unlike rifles, small-arms ammunition and artillery shells, where the ever increasing and massive orders eventually led to the re-organisation of the supplying industries, large contracts for

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[16] *OH* Vol. I Part I, p. 53.
[17] *OH* Vol. I Part I, pp 53 to 58 supplies the contract procedures in the rest of this section.
[18] PRO MUN 4/745, Orders Placed for Scientific and Optical Instruments &c., 1.8.1914 to 31.3.1917, illustrates the state of outstanding orders.

optical munitions were, with one important exception, never placed.[19] This was the exact reverse of most other munitions.[20]

The problems of industrial mobilisation certainly did apply to the optical sector. Clive Trebilcock has said that 'the requirements of modern hostilities . . . create unique problems of supply', pointing out that complex artefacts need to be made to standards of 'precise replication' in quantities not normally required in peace time.[21] In addition, Trebilcock drew attention to the fact that in normal times such items are usually made by only a small number of specialists. The pressures of war create the need for their products to be turned out 'in the greatest quantity possible and at the highest possible speed – adding the difficulties of mass production under crisis demand to those of quality and reiteration'.[22] This is a near-perfect description of the situation which the optical munitions makers faced during late 1914 and early 1915, but the true state of their problem was obscured by the failure of the MGO and Contracts Departments to place orders large enough to expose the real nature of the situation and meant that the ability of the optical industry to supply war demands was never properly examined until mid-1915 when it fell under the aegis of the Ministry of Munitions.

At first glance, this failure seems inexplicable. The scales of issue were known, as was the rate and extent of the Army's expansion. The items needed were not novel and a list of 'approved contractors' already existed, amongst whom orders could have been distributed. Furthermore, funding was available to cover whatever munitions stores the MGO put out to contract. The reasons why large-scale ordering across the industry did not take place were not to do with incompetence, but are to be found in the operating system imposed on the Contracts Department by the regulations governing the organisation of the War Office as a whole.[23]

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[19] *OH* Vol. XI, Part 4, 'Rifles', chapters 2 and 3.
[20] R.J.Q. Adams, *Arms and the Wizard; Lloyd George and the Ministry of Munitions 1915-1916.* (London: Cassell, 1978) Chapters 1 to 3 illustrate the events leading up to this.
[21] Clive Trebilcock, 'War and the failure of industrial mobilisation: 1899 and 1914' in J. M. Winter, ed. *War and Economic Development* (Cambridge: University Press, 1975) p. 140.
[22] Clive Trebilcock, 'War and the failure of industrial mobilisation: 1899 and 1914' in J. M. Winter, ed. *War and Economic Development* (Cambridge: University Press, 1975) p. 140.
[23] *OH* Vol. I Part I, pp. 46 to 71 provides the basis for this section relating to the handling of contracts.

The War Office procurement system was hedged around with safeguards to protect against exploitation and default by contractors, and to ensure that the Army obtained goods of consistently good quality which conformed strictly to specifications and for which the State paid no more than necessary. In summary, the system meant that priority was to be given to the lowest price tendered from an already approved supplier. To acquire that status, a manufacturer had to apply to go on the 'approved list' and be vetted to ensure he was actually capable of carrying out the work involved. The MGO's office issued instructions to place orders whose total levels it determined to the Contracts Department, which then sent 'invitations to tender' only to those who were on the approved list. The system worked well in peace-time but had serious defects in war. These were explained in 1916 by the civilian head of the Contracts Department, U. F. Wintour.[24]

His remarks highlight the mind-set of those responsible for munitions procurement and partly explain the inadequate levels of ordering for almost all optical munitions between late 1914 and mid-1915 when the Ministry of Munitions took over. Understanding the constraints under which his department operated helps to explain the allegedly poor performance of the optical industry in this period.

Wintour asserted that being forced by high levels of demand to obtain tenders simultaneously from all on the approved list had 'several vicious consequences' for the War Office. These included revealing to the supplying industry the actual scale of the Army's needs and letting the industry see for itself 'the relation of [Army] demand to the probable supply'. The urgency in 1914 and 1915 meant that 'all or most offers' had to be accepted, so that there was absolutely no chance 'to keep prices down to a reasonable level' by refusing tenders considered too expensive. Because one of the department's chief obligations was to secure the lowest practicable prices, attempts were made to force them down. This was done at first by issuing requests for tender in quantities lower than actually needed. That proved counter-productive because bidders quoted higher unit

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[24] *OH* Vol. I Part I, p.53.

prices reflecting the lost economies of scale on very large quantities. Another ploy involved asking for prices based on whatever quantity could be offered by a specified date. That, according to Wintour, created an impression of a potential demand larger than it really was, and encouraged the makers to keep prices at a high level. The Contracts Department seemingly worked from the premise that contractors would over-charge in the absence of any control mechanism.

Whether the optical suppliers fitted this pattern is uncertain. Barr & Stroud's records (the only detailed ones available for this period) suggest that prices only increased in line with actual costs.[25] There certainly were increases in the price of raw materials, particularly glass, and because much of the optical industry was concentrated in London there may have been opportunity for collusion over pricing levels, but the remaining War Office contract records do not give enough detail safely to reach any conclusion.[26]

Another, more insidious, effect of these attempts to manipulate market forces was the effect on the prices and apparent availability of raw materials. Wintour said that when all the firms on an approved list were simultaneously asked to tender for large quantities they all 'went into the market at the same time for the raw materials' needed, by which he meant that they took options on what they might need. In consequence, the apparent demand 'multiplied several times over' causing 'complete chaos in the market and [forcing up prices] to quite fictitious and unwarranted level'. With optical munitions, something on these lines may indeed have taken place with optical glass, whose price rose considerably and which was periodically in very short supply during 1914 and 1915.[27]

Shortcomings in the quality control role of the tendering system also affected deliveries. When a supplier was given a contract for an instrument not supplied previously, samples

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[25] Data extracted from prices charged in UGD 295/19/2/4 and /5, Customer Order files 1914 and 1915.
[26] PRO MUN 4/745, Orders placed for Scientific and Optical Instruments &c, 1st August 1914 to 31st March 1917, does not give any prices.
[27] For examples of Barr & Stroud's efforts to maintain supplies, see UGD 295/4/113, H. D. Jackson to Chance Bros., 11.11.1914, and Jackson to LePersonne & Co., 9.12.1914; UGD 295/4/118, Jackson to Chance Bros, 18.5.1915; UGD 295/4/119, Jackson to Parra Mantois & Cie.,16.6.1915.

had to be submitted for approval before a decision to order was made. This, according to Wintour frequently caused delays as samples went 'astray' and replacements had to be obtained. Further delays occurred, as the contractor had to be told of any shortcomings and given an opportunity of correcting and re-submitting them, when the whole cycle would be repeated.

For the Contracts Department, there was to be neither an open cheque book nor any relaxation in the procedural system despite earlier clear signals from Government to the MGO's department that changes were necessary to speed the machinery of procurement. The tendering system had already been effectively made redundant in October 1914 when Lloyd George, then Chancellor of the Exchequer, had given the Ordnance Department 'virtual *carte blanche* approval' for the purchase of munitions stores,[28] but little difference became apparent at the Contracts Department. The existing system of competitive tendering and its now largely redundant safeguards for the public purse continued, even after the Ministry of Munitions was created in 1915. As late as February 1916, Wintour complained that conditions of supply had become such that there was 'no real competition' between prospective suppliers so that even the allocation of orders according to price could not ensure 'that the Department gets the best value for its money.'

The tenacity with which the Contracts Department held on to its peace-time procedures suggests that William McBride's notion of military hierarchical structures tending to show inertia and resisting any change that challenges an established stability is by no means confined to the technological context that he cited as evidence.[29] Wintour, although a civilian, was summarising the Department's practices prior to the changes caused by the creation of the Ministry of Munitions which effectively took over the placing of contracts once requirements had been produced by the War Office. Despite the then-manifest shortcomings in earlier procedures, and the political will to disregard the emphasis on competitive tendering, he was emphasising that the Department considered

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[28] Adams (1978) p. 18.
[29] W. McBride, *Technological Change and the U.S. Navy 1865-1945* (Baltimore: Johns Hopkins University Press, 2000) p. 4.

its problem was essentially that the market was failing to conform to previous expectations, and that what had been perceived as necessary was some means to re-establish the earlier familiar stability in the procurement process. Whether or not institutional inertia was all that encouraged the Contracts Department to maintain the *status quo*, there is no doubt that the tendering system had an unfortunate effect, at least on optical munitions procurement. In fairness, though, it must be remembered that in the month before Lloyd George sanctioned the relaxation of procurement, von Donop had deliberately concealed from the armaments industry the provision of £20 million by the Treasury for plant extensions, 'fearing a great onrush of supplicants for the funds', and that he was generally reluctant to sanction large-scale expenditure.[30] It is not inconceivable that the implications of Lloyd George's removal of strict scrutiny in munitions purchasing in October 1914 never actually reached the Contracts Department.

The net result of all this for the optical munitions suppliers was that, apart from Barr & Stroud, they were never asked even to attempt to provide sufficient capacity to cope with the massive demands for the growing Army. The case of Barr & Stroud is particularly interesting because it shows simultaneously some of the strengths and weaknesses present in the early war-time industry, and suggests that had the War Office approach to ordering been modified to reflect the needs of the Army rather than the desire to preserve an existing administrative structure, then the Ministry of Munitions might well have found an altogether different picture to the one it claimed to discover in mid-1915.

4.5 Barr & Stroud's experience in the first year of war

By August 1914 Barr & Stroud was the world's only company devoted exclusively to the manufacture of optical munitions, and had become Britain's largest producer of high precision optical apparatus. The Admiralty depended wholly on the company for its rangefinders, and the firm had achieved a monopoly in supplying rangefinders to the navies of France, Italy and Japan, as well as an hegemonical position in virtually every other modern navy except Germany's. Its sales of rangefinders to the world's armies were also very substantial, with France being the largest single client between 1912 and

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[30] Adams (1978) p. 18, and then pp. 21-23.

1914. This success had been achieved without any substantial orders from the War Office before 1914, and there was no well-established relationship between the company and the Army.

The firm had been dependent on foreign orders for most of its profitability since 1901. In its financial year ending 31st December 1913, 64 percent of the turnover of £268,000 came from overseas business, compared with 34 percent from the British Admiralty and only 2 percent from the War Office.[31] Profit margins on overseas business were higher than on similar items sold to the British forces – infantry rangefinders for France were sold at £66.50 when the same item was priced at £55 to the War Office, for example.[32] Output was divided between large naval instruments, principally for the Royal Navy, and the smaller portable models for land service which had been sold almost entirely abroad. For these, the principal customers were European armies, with France being by far the biggest client with over £100,000 of orders in 1913 alone.

It was only in the spring of 1914 that Barr & Stroud received its first large War Office orders.[33] These were not awarded through the usual competitive tendering process because the firm was effectively a monopoly supplier. No other British maker could supply anything similar in quantity, and the only foreign competitors were both German. The uncertain political climate in Europe meant there was no possible source other than Barr & Stroud and the Contracts Department's duty to obtain best value was accordingly redundant. The first War Office orders were certainly large, but by no means unusually so for Barr & Stroud. Between January and July 1914 four separate contracts were placed for £54,000-worth of rangefinders, compared with over £185,000 of foreign business and £73,000 from the Admiralty. The War Office orders did not represent a complete outfit of instruments even for the Regular Army's front line Infantry strength of 150,000 men where at least 1,500 were needed but only 680 were ordered. Similarly, only 150 were ordered for the whole of the field Artillery, which was also inadequate. The declaration

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[31] Extracted from UGD 295/19/2/3, Customer Order files 1913, and UGD 295/11/1, audited accounts and balance sheet 1913.
[32] UGD 295/19/2/4, Customer Order files, sample French contracts 1913 and War Office ones 1914.
[33] UGD 295/19/2/4, and /5, Customer Order files 1914 and 1915 provide the source material for this section unless otherwise indicated.

of war prompted an increase in ordering, with new contracts before December 31st for £119,000-worth of instruments, followed by orders for over £300,000 by the end of July 1915. These later contracts were indeed very large. The firm's greatest annual peacetime orders had been £268,000 in 1913, but by the end of 1914 new business totalled over £491,000. Both the Ministry of Munitions' own history and Roy and Kay MacLeod noted that rangefinder supplies alone of optical stores for the Army were 'assured' right from the outbreak of war,[34] suggesting that the company had little difficulty coping with the new War Office business. Although Barr & Stroud did indeed keep up with demand, this came about only through a combination of fortuitous circumstances and the firm's largely successful management of a diverse set of problems.

The company's growth in 1912 and 1913 came through the rapid increase in demand for infantry and artillery rangefinders, a market encouraged by growing political tension in Europe. France had been the largest buyer, and the company had increased its capacity to handle the extra business. During the same years, Barr & Stroud had courted business from the Austro-Hungarian and Russian armies, and by mid-1914 already had its first contracts from the former and was close to finalising matters with the latter.[35] Manufacture for Austro-Hungary had begun, but the declaration of war saw the client become an enemy, and put the Russian negotiations into abeyance, freeing space and manpower already allocated for the anticipated business. The French contracts were coming to an end, all of which meant that spare capacity was available when the new War Office contracts arrived.

Factory space and tooling, although essential, by no means defined the limits of manufacturing problems. Despite making optical instruments, Barr & Stroud regarded itself primarily as a mechanical engineering company. The bulk of its shop space, tooling and workforce were allocated to fabricating the rangefinder's mechanical structure. Optical components were at the instrument's heart, but it also depended on skilled and precise mechanical engineering for its efficient working. Optical and mechanical

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[34] MacLeod (1975) p. 171.
[35] M. Moss and I. Russell. *Range and Vision: The First Hundred Years of Barr & Stroud* (Edinburgh: Mainstream Publishing, 1988) pp.65-67.

engineering were absolutely interdependent in a successful rangefinder. Barr & Stroud was entirely self-sufficient in the mechanical side, but still depended heavily on sub-contractors for many of its optical components. The way the business sought to manage the sudden increase in requirements for them provides a useful illustration of the ability of the optical industry as a whole to cope with war-time demands in 1914.

Although Barr & Stroud rangefinders all shared a basically similar optical design, the different models required their own outfits of lenses and prisms, depending on the base-length and magnification. Some were made in-house, but many were still being done by outside contractors who frequently failed to reach the specified standards needed for the instruments to work properly. Barr & Stroud's problems with increasing output in response to demands for rapid delivery were largely centred on maintaining the quality of externally-sourced components from suppliers over whom there was no direct control. The scale of demand for lenses and prisms was governed by the requirements of the two British armed services, which in turn influenced the extent to which Barr & Stroud had to depend on contractors who were both far distant and pre-occupied with their own business.

Once war was seen as inevitable, the directors began to put themselves on a 'war footing'. On 31st July they assured the Admiralty that priority would be given to Royal Navy contracts over foreign ones and, apparently, over War Office ones as well.[36] On 3rd August general manager Harold Jackson, wrote to his optical subcontractors urging immediate attention to 'all our orders in hand'.[37] When war was declared the following day he sent the Admiralty a detailed list of all rangefinders on order, for both allies and enemies alike, and specifically requested an assurance that there was no objection to continuing supplies to France. The company accepted that the Admiralty had the ability to direct exactly what it could and could not do, which stood to affect the firm's requirements for optical components from outside suppliers. Having been assured on the

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[36] UGD 295/4/6, Letter Book, Jackson to Director of Navy Contracts, 31.7.1914.
[37] UGD 295/4/109, Letter Book, a series of almost identical letters was sent out between 3.8.1914 and 5.8.1914.

6th that there were no objections to deliveries for the French army and navy, Jackson began attempting to arrange for adequate supplies of lenses and prisms.[38]

The correspondence in the following months illustrates the problems that the optical munitions makers had to deal with, and shows that irrespective of capacity, skill or ability, there was indeed a lack of organisation in the optical industry. The firm's efforts were ultimately successful not through obtaining larger deliveries from existing suppliers, but through the expansion of internal capacity and the establishment of a new relationship with one particular maker.

Barr & Stroud's oldest optical supplier was Adam Hilger Ltd, and it was their Managing Director, Frank Twyman, that Jackson first approached. The two companies had been associated since 1889, and on at least two previous occasions a merger had been discussed.[39] Nothing had resulted, and by 1914 Hilger's – although still the principal British maker of complex prisms – had lost the near monopoly of Barr & Stroud optical components it once had. Hilger's had felt the diminution of Barr & Stroud orders very keenly after 1913 when the effect had been 'very bad'.[40] This reduction may partly have been because Barr & Stroud was becoming more self-sufficient but Twyman later considered the real cause was Admiralty pressure on Barr & Stroud to insure against the dangers implicit in the possible failure of one key sub-contractor, which had led the company not only to expand its own optical output but to engage other suppliers as well.[41] Whilst the Admiralty certainly was aware of dangers in interruptions to its supply of optical munitions, it is equally possible that the stimulus for self-sufficiency may have been encouraged by Hilger's continued inability to maintain sufficiently high and consistent standards. Although orders were still being placed for lenses and prisms in

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[38] UGD 295/4/6, Letter Book, Jackson to Secretary of the Admiralty, 6.8.1914.
[39] See Chapter 2 and Chapter 4 above.
[40] Science Museum Library, Adam Hilger Collection (subsequently SML): HILG 3/1, typescript 'Mr Twyman's lecture August 1944, p.17.
[41] SML HILG 3/1, typescript p.27.

1914, complaints of poor quality were frequent. Nevertheless, it was on Hilger's that Barr & Stroud at first intended to rely for the expansion of deliveries.[42]

Scarcely a week after the war began, Jackson asked Twyman for delivery dates for everything on order. Jackson emphasised that the size and the new urgency of existing orders meant Twyman must hire as many optical workers as possible, and visit Glasgow to discuss the situation with Barr & Stroud's directors. That letter, dated the 10th, must have been written knowing that an urgent War Office order for 558 infantry rangefinders was already on its way to Glasgow.[43] A meeting was held on 21st August, when the firm presented Twyman with a proposition he may well have felt unable to refuse.

Barr & Stroud proposed to give Hilger's 'all the [optical] orders that we cannot undertake ourselves'.[44] These were greater than Hilger's own capacity, so the directors knew Twyman would have to subcontract many of them. As Barr & Stroud was already out-sourcing a substantial amount of optical work to firms besides Hilger's, the offer suggests that either the directors wished to simplify their own administration or, more likely, that such a desire was combined with the knowledge that their existing subcontracting network would very soon be insufficient. Tywman could subcontract, provided he would be responsible for the prompt delivery and quality of the work. The directors thought that Hilger's was 'at the centre of the optical trade' and therefore 'probably better able to subcontract [and] control the quality of the work than we are'. To assist Twyman, they would help to obtain optical glass from the sole British makers, Chance Brothers of Birmingham, as well as providing advice on manufacturing methods. This was, at first sight, a substantial vote of confidence in Hilger's which – if justified – would have left Barr & Stroud free to concentrate on its own manufacturing without the burden of co-ordinating the work of numerous subcontractors. It was, however, still short of a total endorsement and by no means gave Twyman any guarantee of subcontracted work because, irrespective of the proposed agreement, Barr & Stroud reserved the right

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[42] UGD 295/4/110, Letter Book, contains a series of letters from Jackson to Twyman which provides the material concerning Adam Hilger for the rest of this section unless otherwise indicated.
[43] UGD 295/19/2/3, Customer Order file.
[44] UGD 295/4/110, Letter Book, Jackson to Twyman, 21.8.1914.

to extend its own optical department as it thought necessary. Jackson's summary of the meeting noted that 'for the present neither you nor we can undertake [unaided] the work in hand', implying that that he saw no reason why his firm should not move closer to that condition.

Whether or not Barr & Stroud meant to flatter Twyman by saying that Hilger's were 'at the centre of the optical trade', the statement was literally correct. In 1914 London remained the principal locus of the optical instruments (but not necessarily optical munitions) industry. Apart from Barr & Stroud, the only substantial companies not based in London were Thomas Cooke & Sons Ltd in York and Sir Howard Grubb & Co. in Dublin, both of whom were directly involved in optical munitions. There were other optical makers in the provinces, but none of them were either large or substantially engaged in making for the armed forces. The London businesses ranged from relatively large and successful ones such as the Ross Optical Co. Ltd which employed over 350 workers,[45] down to small firms which were mainly engaged in ophthalmic optics and sometimes employed only one or two workers.[46] There was a concentration of makers in the Clerkenwell district where Hilger's was located, so that Twyman was indeed conveniently placed to liase with many optical manufacturers although his competence to do so was not so readily apparent.

Twyman's interests lay principally with the development of new types of optical instruments for science, particularly the spectrometer.[47] His company's other main area of expertise was the making of complex prisms, in which it had something approaching a monopoly in Britain. Both were essentially small scale operations reflecting contemporary levels of demand, so that Hilger's remained a small business of less than thirty workers and Twyman had no experience either of volume production or the organisation of subcontracting on the scale that was now necessary. Barr & Stroud's directors knew this, and it is unclear why they so readily devolved the task to him. The

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[45] A. B. Dewar, *The Great Munition Feat 1914-1918*. (London: Constable, 1921) p. 221.
[46] Hugh Barty-King, *Eyes Right: The Story of Dollond & Aitchison Opticians 1750-1985* (London: Quiller Press, 1986) p. 125.
[47] SML HILG 7/1, Twyman obituary reprint (unidentified), p.270.

most probable explanation is that Twyman, through his prism work, was well acquainted with most, if not all, of the London firms who regularly did the high grade spherical lens work used in the scientific instruments that employed Hilger's prisms. These firms, few of which Barr & Stroud had ever dealt with, were now likely suppliers, if they could be persuaded to take on the work. Personal persuasion and cajolery might have been recognised as more effective recruiters than Jackson's letters and telegrams from Glasgow.

Whatever Barr & Stroud's thinking, by the end of October it was apparent that Twyman's efforts were not going well. Although none of Hilger's surviving records relate to this, Barr & Stroud's letter books document the problems and the frustrations they caused. Despite offering to make Hilger's responsible for all orders beyond Barr & Stroud's own capacity, the firm not only excluded Taylor, Taylor & Hobson Ltd from Hilger's remit, but also continued to deal directly with three London firms who were already supplying parts. R. & J. Beck, the Periscopic Prism Company, and W. Watson & Sons all had contracts which continued to be administered from Glasgow subsequent to the arrangement with Twyman.[48] Nor did Barr & Stroud leave Twyman alone to get on with his task; Jackson repeatedly intervened with instructions as to how the subcontracting should be organised.

Twyman's instructions to exclude Taylor Hobson resulted from Archibald Barr's acquaintance with Wilfred Taylor and his high opinion of Taylor Hobson's workmanship and methods that dated from 1903.[49] The Leicester company moved into lens making as part of a programme of diversification from the manufacture of small precision machine tools and doing fine mechanical work, had begun contracting for the War Office from 1910, and by 1914 had expanded its optical side into the series-production of high quality photographic lenses to designs licensed from Thomas Cooke & Sons Ltd of York.[50] On

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[48] UGD 295/4/11, Letter Book, Jackson to Beck, 26.10.1914; Jackson to Periscopic Prism Co., 6.10.1914; Jackson to Watson, 14.10.1914

[49] UGD 295/26/1/25, Barr to William Taylor, 3.6.1903 requesting help in obtaining optical workers and endorsing Taylor Hobson's small machine tools.

[50] McConnell, A. *Instrument Makers to the World: A History of Cooke, Troughton & Simms.* (York: William Sessions Ltd,, 1992) p. 73.

August 9th, Taylor offered Archibald Barr his firm's 'assistance' in the production of rangefinder object lenses, and this was quickly accepted after a meeting of the two firms' directors.[51] Whether this was a deliberate hedge against Hilger's failure is uncertain, but in view of how the other subcontracting exercise turned out, it was a propitious move.

Taylor told Barr & Stroud on 25th August that he had received third-party enquiries (which he did not identify) for quotations for lenses to be supplied directly to Hilger's. Then, on September 2nd, he was asked by Cooke's of York to quote for objective lenses to be delivered to Adam Hilger & Co. Their specification identified them as being for Barr & Stroud rangefinders and Taylor consequently declined the business.[52] Cooke's were one of the country's best known lens and telescope makers, and were not currently engaged on any large scale British government contracting. The referral of the order to a third party could hardly to have been because of a lack of capacity or ability, but was more likely because they were attempting to sell rangefinders of their own design intended for use with the Pollen fire-control system to the Admiralty and the Russian governments, as well as promoting smaller versions for land-service use.[53] Whatever Cooke's reasons or motives, Taylor's letter warned Jackson that if Twyman's subcontractors were passing-on work, it could pose threats to maintaining quality control, and he promptly gave Twyman specific instructions to tell them that they were not to pass orders on to a third party.

This division and sub-division of manufacture highlights a problem facing firms seeking to increase optical output in late 1914 and early 1915. The capacity of most optical manufacturers to expand production rapidly and substantially was constrained by the structure of the pre-war industry which had operated on a scale geared to domestic and export demands that generally lacked urgency. The optical munitions component of the larger optical instruments industry had no significant peace-time problems in meeting the demand, whether through in-house manufacture or outsourcing. Even where the scale of demand had been consistently large, as with Barr & Stroud's business, the required

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[51] UGD 295/4/109, Letter Book, Jackson to Taylor, Taylor, Hobson, 11.8.1914 and 18.8.1914.
[52] UGD 295/4/110, Letter Book, Jackson acknowledges advice from Taylor, Taylor, Hobson, 25.8.1914.
[53] McConnell (1992) p. 75.

delivery rates had usually been leisurely enough to allow supplies to keep up with schedules. The expansion of orders and the need for increased speed of output strained the opticians to whom Barr & Stroud and Hilger's immediately turned. Beck, Cooke and Watson, for example, were already producing both optical munitions components and complete instruments but were not wholly devoted to those fields; they also had a substantial involvement in the general commercial market for optical goods which they were initially loathe to relinquish. Increasing output for Barr & Stroud meant either reducing output of something else or investing in new tooling and labour. Early in the war there was a general reluctance to do this when its duration – and hence commercial value – was expected to be short rather than long, and when there was no avalanche of orders from the War Office to counteract this view. Faced with such uncertainties and the lack of any centralised State direction, it is hardly surprising that firms attempted to cope with what they saw as a short term phenomenon by equally short term measures such as further sub-contracting.

For Barr & Stroud, that reasoning was secondary to the immediate problem of obtaining enough components of a sufficiently high standard. Throughout September Harold Jackson complained to Twyman about slow deliveries and erratic quality.[54] By the 14th, he was so worried about Hilger's prism output that he urged Twyman to approach the Periscopic Prism Company (with whom Barr & Stroud was already dealing) for extra supplies of the rangefinder pentagonal prisms which had previously been one of Hilger's specialities. On the 25th, he provided Twyman with a list of firms to approach, suggesting there had been little headway in organising deliveries. Matters deteriorated further throughout October, and by the end of the month were so bad that Jackson travelled to London to try to resolve the problem.

There were two difficulties for Barr & Stroud. Firstly, in Jackson's words, Hilger's could not supply 'even our minimum demands for optical parts' and secondly, the War Office had asked Hilger's to re-start production of the unsatisfactory Marindin rangefinder

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[54] UGD 295/4/110, Letter Book, Jackson to Twyman on various dates.

which it had bought in small numbers between 1907 and 1913.[55] To Barr & Stroud, that idea was wholly unacceptable. Many of the parts for the Marindin had actually been made in Glasgow, and Jackson knew that Hilger's had constantly struggled to maintain output and quality; its resurrection threatened to affect Barr & Stroud's output by diverting Hilger's efforts.[56] Ignoring the War Office's right to order what it chose, Jackson wrote bluntly that 'We do not see how you can undertake the manufacture . . .', and threatened that 'if we cannot get from you the supplies on which we have been counting we shall be forced immediately to get our supplies elsewhere.' Exactly where they might come from Jackson did not say, but the threat persuaded Twyman to convince the War Office that re-starting Marindin production was not feasible, probably because its mechanical components would be unobtainable.[57]

Hilger's inabilities were to some extent lessened by the Barr & Stroud's growing self-sufficiency. Jackson complained yet again to Twyman about shortcomings on December 9th, pointing out that Barr & Stroud had now increased its optical capacity to the point where 'we are held back by you, and only by you'.[58] In consequence, Barr & Stroud would start making the parts which Twyman had failed to deliver, and the ultimate outcome would be Hilger's exclusion altogether. Jackson possibly misled Twyman by implying that optical output at Glasgow had increased; although new equipment had been ordered from the Standard Optical Company in Switzerland in mid-September, there had been little enough time for it to be made, delivered and installed, and operatives trained to use it.[59] Indeed, the building extensions needed to accommodate the extra plant were only started in November and could not yet have been finished.[60] It is likely that the increased optical capacity was actually Taylor Hobson's in Leicester, whose ability to handle large orders was becoming established, so that the need to employ subcontractors at third-hand through Hilger's was starting to diminish.

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[55] UGD 295/4/110 Jackson to Twyman, 30.8.1914.
[56] UGD 295/4/744, Letter Book, Jackson to Hilger, 9/8/1907.
[57] UGD 295/4/112, Letter Book, Jackson to Twyman, thanking him for his co-operation, 7.11.14.
[58] UGD 295/4/112, Jackson to Twyman, 9.12.1914.
[59] UGD 295/4/112, Barr & Stroud to Standard Optical Company, 17.9.1914.
[60] UGD 295/4/112 Barr & Stroud to Sir William Arrol & Co. (builders), 5.11.1914.

According to Barr & Stroud, Hilger's performance was indeed greatly deficient. Jackson refused to give Twyman any further orders on 9th December, pending 'reliable information' about what improvements would be made.[61] The reply to this has not survived, but Jackson's riposte has.[62] The unfortunate Twyman was given a piece of Jackson's mind; less than 35 percent of 1,393 items ordered had been delivered on schedule, 804 others which had not been ordered at all had been sent in error, and Twyman's claims for Hilger's output were 'if you excuse us saying so . . . all nonsense'. Despite this, Barr & Stroud wanted to carry on with Hilger's, and would provide weekly requirements lists so Twyman could prioritise his own deliveries. Even if alternative sources were becoming available, Hilger's were clearly still essential to maintain output. Sentiment certainly had nothing to do with it. Although well aware that costs were escalating, Jackson flatly refused to tolerate a proposed price increase, countering that he hoped Twyman would instead be able to reduce costs through 'the experience you are now gaining with manufacturing large quantities'. His dependence on Barr & Stroud left Twyman little choice but to accept both criticisms and demands. Jackson's acknowledgement of his assurances twisted the knife still further by pointing out that quality was as important as quantity and speed, and that before the war the bulk of Hilger's current output would have been rejected at Glasgow.[63]

In January 1915, Barr & Stroud began to concentrate its outside orders on Taylor Hobson because the Leicester firm consistently worked to high enough standards and was willing to adopt 'novel' methods in both optical and mechanical engineering to improve quality and output.[64] Jackson conceded that Leicester-made objectives were better than those being made, or likely to be made at Glasgow, and asked Taylor Hobson substantially to increase production.[65] At the same time, orders placed with other previously substantial suppliers began to be cancelled or not renewed. Complaints were made to both Beck and Watson, both of whom had earlier been given large orders for lenses, about late deliveries and poor quality, and ordering from both firms apparently ended by June of

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[61] UGD 295/4/112, Letter Book, Jackson to Twyman 9.12.14.
[62] UGD 295/4/112, Letter Book, Jackson to Twyman 14.12.14.
[63] UGD 295/4/112, Letter Book, Jackson to Twyman 17.12.14.
[64] UGD 295/4/110, Letter Book, Jackson to Edward Taylor, 10.9.1914, records novel methods.
[65] UGD 295/4/114, Letter Book, Jackson to Taylor, Taylor Hobson, 8.1.1915.

1915.[66] This shifting of emphasis and reduction of dependency on a multiplicity of outside suppliers resulted principally from establishing an accommodation with a firm that was prepared to innovate to aid Barr & Stroud's output. The firm's letter books show that Jackson had never hesitated to complain about suppliers, so the lack of critical correspondence strongly supports the assumption that the working relationship with Taylor Hobson went well during the first half of 1915. Rather than simply complaining about inadequate quality, problems which arose led to collaboration in solving manufacturing difficulties, with both firms contributing equally to the effort.[67] That deliveries from Leicester met requirements for both speed and quality must have encouraged Barr & Stroud to dispense with less satisfactory suppliers, particularly if, as Jackson had claimed, the firm's own output was also starting to increase. [68]

The problems of achieving adequate optical production were also eased by the plateau in Army rangefinder orders that followed those in the autumn of 1914. Unlike the other optical munitions makers, Barr & Stroud's monopoly supplier status meant that it was not faced with tendering for a multiplicity of small contracts, and during the first six months of 1915 the company could organise its production (albeit not without difficulties) in the light of a known level of demand. As a result, its deliveries for War Office contracts kept largely on schedule, something that could not be said for most of the optical munitions industry.[69]

To increase optical output, Barr & Stroud had at first been able to employ a number of experienced makers who performed with varying degrees of success. Then it had embarked on a subcontracting exercise designed to supplement supplies without increasing its own burden of administration and co-ordination. When this proved unsuccessful the firm fostered relations with a new supplier which it helped to reach a position where it could replace virtually all the other subcontractors. That there was

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[66] Entries in the Letter Books cease after this date, the last one being to Beck.
[67] UGD 295/4/112, Letter Book entries for early 1915.
[68] UGD295/4/118, Letter Book, Jackson to Taylor Hobson, 18.5.1915 confirming that Taylor Hobson is now the sole outside supplier of FT20 objective lenses, and 2.6.1915 asking for quotation for another 1,100 similar lenses.
[69] From examination of progress details recorded in UGD 295/19/2/3 and /4, Customer Order files 1914 and 1915, and from contract progress comments in PRO WO/745, Order and Supply List.

sufficient capacity in the optical industry be able to pick and choose before selecting one prime sub-contractor suggests that the demands being placed on the industry were insufficient even to occupy its capacity let alone overwhelm it, a situation that could only have resulted from the War Office's failure to place substantial contracts across the optical manufacturers. In December 1914, the Periscopic Prism Company had asked Barr & Stroud for more work, despite already getting business directly from Glasgow and *via* Hilger's, and was also able to take on the design of a telescopic rifle sight for the War Office. Aldis Brothers in Birmingham also had sufficient spare capacity to take sub-contract work from Hilger's and to start making telescopic rifle sights of their own design.[70]

4.6 Labour shortages

Barr & Stroud's problems were by no means confined to obtaining components from outside suppliers. Like other manufacturers, the firm was affected by the loss of men who left to 'join the colours' in response to the government's recruiting campaign, particularly those who had skills essential to the production of optical components.[71] As early as 13th August the Jackson warned the War Office that optical workers (who made up just 6 percent of the workforce) were vital to production. If they left, they could not be replaced in Glasgow which would seriously compromise production.[72]. Even though some of the Territorial Army members in the workforce were called up and others volunteered for the Army, there was a net increase in workers from 1,200 in July to 1,400 by late October,[73] although most of them were likely to have been unskilled or semi-skilled. The greatest labour problem in August and September 1914 turned out to be the temporary loss of 'all our best rangefinder adjusters', the highly skilled men who were 'lent' to the Royal Navy in July to check the rangefinders of the fleet before it was dispersed to war stations.[74] Three days after the declaration, Jackson flatly refused to

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[70] I. Skennerton, *The British Sniper* (Margate, Queensland, Australia: I. D. Skennerton, 1984) pp. 41 and 47.
[71] Moss & Russell (1988 p.73.
[72] UGD 295 Unclassified, Russell research notes, Barr & Stroud Letter book Vol. 99, and UGD 295/4/625, Letter Book, Jackson to Ministry of Munitions, 20.7.1915.
[73] UGD 295/4/11, Letter Book, Jackson to Glasgow Tramways, 28.10.1914.
[74] UGD 295/4/7, Letter Book, Jackson to Director of Naval Construction, 7.8.1914.

provide any more of them, asked for the speediest return of those in English ports, and warned that Admiralty deliveries would be 'impossible' unless his request was met.

The loss of skilled labour in the munitions industry and its subsequent replacement has been discussed by R. J. Q. Adams, particularly the efforts in 1914 and 1915 to employ skilled Belgian mechanics who had been displaced by the German invasion.[75] In mid-December 1914, Barr & Stroud told the Board of Trade that although extra workers were urgently needed in all departments, it declined to take any of the 'skilled' Belgian workers which the Board had offered to provide.[76] The reason given was that the Admiralty had forbidden the employment of foreign workers in the factory, but this was a half-truth; what the Admiralty insisted on was that no foreign workers were allowed into the area where its contracts were being worked on. There was no reason why such workers could not have been employed elsewhere, and in fact Japanese naval personnel 'workers' were already present in the factory taking part in the assembly of rangefinders for the Imperial Navy.[77] Presumably the shortage was not critical if the company could afford to turn away skilled mechanical engineers. The complaint about a shortage of workers may have been a pro-active device intended as a hedge against the possibility of future difficulties rather than an immediate problem. What Jackson wanted was to keep men who were skilled in Barr & Stroud's methods, not to have to train and integrate foreign workers. His dealings with Hilger's illustrate a pronounced willingness to emphasise or deliberately exaggerate the severity of a problem in order to obtain a result beneficial to the company.

4.7 Barr & Stroud and Anglo-French friction

The first year of war produced other problems that were unique to Barr & Stroud. Before the war, the firm regarded the Admiralty as its most important client, not necessarily because the Admiralty was always the largest spender, but because the Royal Navy had come to involve the company regularly in its requirements for rangefinders and tended to influence other navies by its adoption of new equipment. Where the Royal Navy went,

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[75] Adams (1978) Chapter 7.
[76] UGD 295 unclassified, Barr & Stroud Letter book Vol. 103, 16.12.1914.
[77] UGD 295 unclassified, Russell research notes: this cites Barr & Stroud Letter Book 110, 31.10.1914.

others tended to follow and for Barr & Stroud the *cachet* of being the Navy's sole rangefinder supplier was invaluable. When European armies began to buy smaller, man-portable rangefinders in growing quantities, Barr & Stroud developed another kind of relationship with the French Army as it became by far the largest client for them. This differed from that with the Royal Navy in being principally one of supplier and client rather than the more complex and symbiotic one of design and production interaction that existed with the Admiralty. Nevertheless, Barr & Stroud developed a sense of responsibility towards its French client, because as with the Royal Navy there was the benefit of endorsement, besides the considerable income from French government business. The Admiralty had always recognised Barr & Stroud's need for overseas customers, allowing the company to balance its domestic and foreign commitments and obligations. The outbreak of war and the ascendancy of the War Office as a new major client had a significant effect on these arrangements and eventually came close to compromising Barr & Stroud's relationship with its French patron.

The possibility of conflicts of interest over new government business and existing private contracts between munitions suppliers and their customers became a matter of concern soon after the war began. The Board of Trade feared that firms might not give absolute priority to government orders when they already had existing orders to meet, as doing so might place them in breach of contract under civil law.[78] The Defence of the Realm Act already gave the Admiralty and the Army Council powers to take over part or all of the output of 'any factory or workshop in which arms, ammunition, or warlike stores' were produced, or even to take possession of the premises themselves.[79] Rangefinders were 'warlike stores' and at the outbreak of war almost all those still in Barr & Stroud's factory had been claimed by the Admiralty and the War Office. The only exceptions were French orders, for which the firm had already negotiated with the Admiralty what amounted to an immunity. By December though, the War Office had told Barr & Stroud to limit French deliveries to no more than fifteen per week, causing an embarrassed Barr & Stroud to explain to the French Military Attaché that supplies would be delayed by

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[78] *OH* Vol. I, Part II, pp. 58, 59.
[79] *OH* Vol. I, Part II, p. 59.

several months and depended entirely on the permission of the War Office.[80] This interference with foreign business was a matter of concern to the company, not just because of its perception of responsibility to the French, but because of the overall importance of its foreign trade.

The firm's frustrations over such restrictions were evident in Jackson's letter of January 4th to the Secretary of the War Office.[81] Jackson pointed out that although 'The whole of our output is at the disposal of the British Government' the War Office had actually failed to take all the rangefinders it had been offered. Those not taken were still in the factory, but they could not be sold elsewhere despite the firm still having uncompleted and urgent orders (for identical instruments) for Greece and France. Jackson complained of the ambiguity of War Office instructions which, if taken at face value, meant that no foreign orders at all could be dealt with until every British contract had been completely filled. He followed this with a second letter concerning a request from the United States Army to quote for rangefinders, which he had been forced under the War Office's instructions, to decline.[82] With ill-disguised spleen, Jackson stressed that it had taken 'several years of trials' to get so far, and as a result 'The order for these instruments will probably be placed with an American firm [Bausch & Lomb] who are agents for a German firm [Zeiss] to the detriment of the British trade'. Having got the bit between his teeth, he wrote again the following day about a new Russian naval enquiry for 32 large rangefinders which, he complained, Barr & Stroud would not be able to accept because of the War Office policy, despite the fact that it 'would not affect the production of small rangefinders for the War Office'. None of these letters had any effect on the War Office; the rangefinders earmarked for Greece remained in store until 1918, and the embargo on foreign business continued in force, even after the Ministry of Munitions was created.[83]

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[80] UGD 295/4/110, Letter Book, Jackson to French Military Attaché, 1.12.1914.
[81] UGD 295/4/110, Letter Book, Jackson to Secretary, War Office, 2.1.1915.
[82] UGD 295/4/110, Letter Book, Jackson to Secretary, War Office, 4.1.1915.

[83] For deliveries to Greece, see UGD 295/19/2/3, Customer Order files 1913-1915, and for prohibition of exports see PRO BT/55/23, Evidence to Engineering Industries Committee of Enquiry, evidence of Archibald Barr, 20.10.1916 and 16.11.1916.

4.8 Conclusion

The first nine months of the war saw the optical munitions industry make a by no means uniformly successful transition from peace to war. It was beset by problems that were rooted in the context of a war for which planning was virtually non-existent and had to cope simultaneously with technical, political, economic and social problems that truly made up the 'plethora of variables' in which the industry's artefacts had to be made and placed.[84] In this stage the industry functioned as a number of un-coordinated and disparate units, a collection of small communities that were rather pushed apart rather than drawn together by the pressures of war.

This period, unlike elsewhere in the industry, went relatively smoothly for Barr & Stroud and the process of industrial mobilisation was more successful than elsewhere in the optical munitions community. In a sense, the business was already mobilised because unlike every other business, all it made was optically-based systems for warfare and the lack of civil products meant that the conversion to war conditions was simpler than for anyone else in the optical industry. The most noticeable change at Glasgow was the disappearance of almost all the foreign clients and their replacement by the War Office rather than, as happened with much of the rest of the optical industry, the phasing-out of civil markets and products and their replacement by a State client whose requirements were inadequately formulated for products that were often unfamiliar, and whose procurement system entirely unfamiliar to those having to deal with it. The rest of the optical industry, or at least the part of it for which records are available, fared less well than Barr & Stroud, irrespective of the external factors bearing on it. As a result, the output of optical munitions other than rangefinders was, by the spring of 1915, far less than needed. In this, the optical sector was no worse than, say, small-arms or artillery shells, and the same remedy proposed for them by the government would be applied to instrument manufacture.[85] The creation of the Ministry of Munitions in May 1915 was to influence the optical trades significantly, and the next chapter examines the mechanisms

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[84] J. Law, 'Technology and Heterogenous Engineering: The Case of Portuguese Expansion', in Bijker et al. p. 112.
[85] For the difficulties of small arms manufacture, see *OH* Vol. XI, Part 4.

by which a large-scale and largely effective optical munitions industry was constructed out of an existing infrastructure that at first seemed reluctant to make the transition.

Chapter 5

Industrial Mobilisation – The Ministry of Munitions and its creation of an image for the industry

5.1: Introduction

The second stage of the optical munitions industry's war was one of industrial mobilisation, and is inextricably interwoven with the policies and attitudes of the Ministry of Munitions towards it. The creation of that Ministry in the late Spring of 1915, and in particular the setting up a department dedicated to optical output, was responsible for increasing both the volume and diversity of production between then and the end of the Great War in 1918, and so bringing into being what can be best described as a 'conscript' optical munitions industry that submerged the identity of what existed during the first ten months of war. The story of this mobilisation is complicated by the existence of parallel aims for both short and long-term change within the Ministry's Optical Munitions and Glassware Department (OMGD) that simultaneously looked back at the pre-war optical instruments industry and forward to a new, reconstructed post-war one that would replace both the old and the temporary conscript one that the OMGD was required to create. These 'socially constructed' aims were sometimes in conflict with each other, and struggled to find expression within a framework of problems that were essentially technical in character, being grounded in shortages of materiel and what may be called a technological infrastructure. The account of how these dimensions were managed, as left by the OMGD, has been responsible for colouring later perceptions of both pre-1915 optical manufacturing in Britain and the effectiveness of war-time measures. This account of mobilisation in this and following chapter therefore looks as closely, or even more so, into the motives and actions of the OMGD as into those of the industry itself in order to account for the process of mobilisation. It is here that the process of the creation of a 'system' of optical munitions production is better explained through the ideas of Thomas Hughes, which were introduced earlier in the story, than through other models of explanation for the development of technology.

5.2 Agendas and attitudes

The creation of the Optical Munitions and Glassware Department marked the start of an expansion in output as well as a considerable transformation in the industry. According to the Department's own records and its printed account in the Ministry's official *History*, this constituted a major achievement which contributed greatly to the war effort and was attained in the face of problems within the industry that had been brought forward from peacetime. Although acknowledging the efforts made by almost all the companies it was involved with, the *History* made the point that most – if not all – the improvements could not have come about without OMGD's initiatives. This has been accepted by later writers, particularly by Roy and Kay MacLeod, and Mari Williams, who concluded that the industry was indeed generally inadequate in education, training, organisation and equipment in early 1915.[1] Some of this is true, but the deficiencies did not all apply across the whole of the industry, and parts of it had as much to teach OMGD as the department had to tell them. The story of optical munitions manufacture after mid-1915 is really of a demand-led and conscripted industry that benefited principally from the co-ordination and allocation of resources provided by the Ministry of Munitions, rather than being transmogrified through the direct action of the Optical Munitions and Glass Department.

Even allowing for partiality in the official *History* there is no doubt that the Ministry's optical section acquired a chaotic and thoroughly unsatisfactory procurement structure, whose origins have been considered in chapter 5. The severity of the problems was considered to be so great that delivery prospects for optical items were then 'more unsatisfactory than in any other class of munitions' and the entire optical manufacturing industry was 'in a critical position'.[2] The condensed version of subsequent events in the official *History* gives little sense of the difficulties that were encountered.

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[1] R. & K. MacLeod, "Government and the Optical Industry in Britain 1914-1918" in *War and Economic Development*, edited by J. M. Winter (Cambridge: Cambridge University Press, 1977) p. 165 ff; M. E. W. Williams, *The Precision Makers: A History of the Instruments Industry in Britain and France, 1870-1939.* (London: Routledge, 1994).

[2] PRO BT 66/2/MMW11, Col. Wedgwood to Mr Booth CMG/5315, 20.8.1915, and Great Britain, Ministry of Munitions, *History of the Ministry of Munitions* (subsequently *OH*), 12 vols. (London: HMSO, 1922), Vol. XI 'The Supply of Munitions', Part 3 Optical Munitions and Glassware, p.1.

5.3 The influence and policies of Frederick Cheshire.

One of OMGD's first personnel was Frederick Cheshire (1860-1939) who was recruited by the Ministry from the Patents Office initially as 'an expert on optical questions'.[3] When the Optical Munitions and Glassware Department was formally established he was appointed as its joint head with particular responsibility for what the official historian coyly described as the 'technical side' of its operations. According to the official *History* he had 'an extensive knowledge of the [optical] trade and of the difficulties under which it worked', but this description hardly did him justice. Professor Cheshire had entered the civil service in 1880, joined the Government Laboratory in 1882 and then transferred to the Patent Office in 1885 where he rose to become Examiner of Patents, the senior post which he held on joining the Ministry. He was also lecturer in physics at Birkbeck College, London, a position he took in 1895 and still occupied in 1915, by which time he was an Associate of the Royal College of Science and a Fellow of the Institute of Physics.[4] Cheshire's work at the Patent Office had placed him in a privileged position to keep abreast of optical developments. He saw all the specifications received from British and foreign applicants, as well as the British ones suppressed from public view relating to military and naval applications of optics which the State wished to conceal in order to maintain secrecy.[5] In 1913 he had delivered the Royal Photographic Society's annual Traill Taylor Memorial Lecture on the subject of rangefinding instruments and its text was subsequently published as *The Modern Rangefinder*, one of the very few works on the subject in the English language.[6] Cheshire was better placed than almost anyone else in Britain to know the current state of optical instrumentation for warfare, and his appointment allowed him to exert a profound influence in the way energy was directed towards British optical manufacture during the war. He become the driving force in the optical department's efforts to reconstruct technical education and training in the industry, working towards achieving what he saw as essential changes in its constitution and performance.

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[3] *OH* Vol. 11, p.1 to 7 provides source material for the rest of this section, unless otherwise indicated.
[4] *Who Was Who 1929-1940* (London: A. and C. Black, 1941).
[5] For secret patents, see T. H. O'Dell, *Inventions and Official Secrecy; a History of Secret Patents in the United Kingdom* (Oxford: Clarendon Press, 1994), especially chapters 4 and 5.
[6] F. J. Cheshire, *The Modern Rangefinder* (London: Harrison & Sons, 1916).

His involvement with optics was not confined to Britain. He had long established connections with the influential German optical instrument firm of Carl Zeiss at Jena. In 1902 he had co-translated Felix Auerbach's history of Zeiss and the neighbouring optical glass manufacturer Schott & Genossen which was effectively its subsidiary.[7] *The Zeiss Works* drew attention not only to the size and diverse manufacturing programmes of the two companies, but also to their emphasis on scientific training and investment in technology. It was the first widely available detailed account in English of German optical engineering practice and appeared at a time when concerns over the condition of British 'opto-technics' were beginning to be voiced in England.[8] The book revealed the extent and variety of the firm's activities, giving details of staff and workers as well as its output and turnover, showing that no single British instrument maker was comparable in size, diversity or scale of trading. Auerbach was not a Zeiss employee but a close friend of Ernst Abbe, the principal motivating force behind Carl Zeiss,[9] and the book was meant to be a statement of Abbe's business philosophy and its translation into practice. To many, it emphasised the differences between German and British optical manufacturing, although in fact Zeiss was by no means typical of German (or any other) instrument makers, particularly in scale and the extent of its vertical integration. That Cheshire was greatly impressed by Zeiss is certain; he referred to his 'Jena friends' in a foreword to a subsequent printing of *The Zeiss Works* and freely acknowledged their pre-eminent importance in the fields of technical optics and instrument manufacture.

Cheshire's high opinion of Zeiss was echoed by many in Britain who had come to see German optical firms and their methods as inherently superior. This sense of inferiority was not new in 1915. There had been unease amongst the optical instrument makers for over a decade that German companies were taking an increasingly large share of the United Kingdom's optical market.[10] Matters reached a head in 1911 when the London County Council's Education Committee, under sustained pressure from members of the

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[7] Felix Auerbach, *The Zeiss Works* Trans from 2nd German Edition by S. F. Paul and F. J. Cheshire (Marshall, Brookes and Chalkey, London, 1902)
[8] Sylvanus P. Thompson, "Opto-Technics." *Journal of the Royal Society of Arts* (1902), pp. 518-27.
[9] Personal communication from Dr Wolfgang Zimmer, Archive der Carl Zeiss Jena GmbH, 12.11.2004.
[10] See R. & K. MacLeod (1977) pp. 169 and 170.

largely London-based optical industry, held an enquiry into the need for organised scientific training in technical optics.[11] This concluded that the establishment of an institute for training on the lines of the German system would be highly beneficial, but no funding was forthcoming either locally or nationally, let alone from the industry itself, so the matter was left in abeyance. The problems of munitions supply that led to the creation of the Ministry of Munitions gave those subsequently involved in the production of military optics an unprecedented opportunity to remedy what they saw as crucial shortcomings in the whole of the British optical industry.

The remedial process began almost immediately after the OMGD was created. At the start of August 'the whole trade was in a critical position' regarding deliveries.[12] Because of this, the War Office Contracts Department 'was quite unable to meet the [Army's] demands for optical munitions' and the optical section had to deal with 'the shortage of optical instruments'. The official historian was re-iterating what subsequently became OMGD orthodoxy, that the lack stemmed from inadequate output, and was a production rather than a procurement problem. Shortages resulted from a lack of organisation in the manufacturing industry, inadequate technical equipment, and a scarcity of raw materials. To make matters even worse, there was a lack of working capital which had not been properly addressed by the War Office Contracts Department in the preceding months. The situation was, by this account, at the least problematical. In Cheshire's privately expressed opinion it was even worse.

On August 13th he wrote to his immediate military superior, Colonel Wedgwood, summarising the severity of the difficulties the optical branch faced.[13] It did not make good reading. Cheshire began by saying that 'for many years before the war broke out, the optical [instruments] trade in England was a dying one'. He went on to say that very few of the makers were paying dividends and in his opinion 'it would be surprising to

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[11] London Metropolitan Archives, LCC/MIN/2967/1911 "Report of the Education Committee of the London County Council: Proposed Establishment of a Technical Institute for Optics, March 1st 1911." (subsequently LCC Report) London, 1911.
[12] *OH* Vol. XI, Part 3, p. 1 supplies this and the following quotations.
[13] PRO MUN 4/55, Control of Optical Firms 1915-1916, Cheshire to Col. Wedgwood, War Office: 13.8.1915 provides the source material for the rest of this section.

learn that a single one . . . was in a satisfactory and prosperous condition'. When the war began, the trade was in no condition to meet the demands suddenly made on it. By August 1915 output was only half of current needs, and his prognosis was that supplies would fall further behind as demands continued to grow from the Army's expansion and battlefield attrition. What Wedgwood received was a discouraging picture of a moribund industry in desperate need of assistance.

Cheshire must have known that his description of the pre-war optical trade did not accord with reality. His assertion that only 'a few firms had been more less kept alive' was, to say the least, misleading. Leaving aside the firms already involved in optical munitions manufacture in 1914 mentioned in the preceding chapter, there were at least fifteen more optical instrument makers who were very much in business producing optical instruments.[14] Whatever his reasons for writing in such a vein, that it was no temporary aberration is shown by a later draft report written on the progress made up to October 1917.[15] This said that when the war began the country had been in a 'deplorable condition' regarding its ability to produce optical munitions on a large scale, and that the machinery employed within the optical trade was inadequate and antiquated. Warming to its theme, it went to say that 'The workshops were shanties' and the trade as whole – in the opinion of 'many men in a position to judge, "already dead and damned" '.[16] Given Cheshire's experience and knowledge, such remarks must raise the question of motive. Why should he project such a misleading image in the first place, and why maintain it two years later ?

His concerns for the industry in 1915 were genuine, grounded on the fear that optical manufacturing in Britain would sooner, rather than later, be completely outclassed by Germany. With the exception of Barr & Stroud, all the peace time optical munitions makers had relied on their civil trade to provide part, if not most, of their incomes. Cheshire realised their commercial trade was vital and that if in the future it became

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[14] Extracted from R. G. W. Anderson, J. Burnett and B. Gee, *Handlist of Scientific-Instrument Makers' Trade Catalogues 1600-1914* (Edinburgh: National Museums of Scotland, 1990).
[15] PRO MUN 4/55 Draft Report 19.10.1917
[16] The draft gives no indication of who were those 'in a position to judge'.

unprofitable, there would be large-scale failure in the optical industry eliminating much or possibly all of the capacity to manufacture for the nation's defence. The 1911 LCC Report had highlighted apparently serious flaws in the structure of the British optical industry, the strongest evidence for which was that the country was a net importer of optical instruments.[17] That conclusion was derived from data published the in *Annual Statement of the Trade of the United Kingdom* up to 1909, but was not in fact properly justified.[18] The Report recognised that the classification providing the data – 'Scientific Instruments and Apparatus other than Electrical' – lumped together optical instruments with other items, such as photographic film and printing-paper, which made it difficult to identify the size of the optical component. Despite that problem, the Report's authors were content to assume that because the whole category was in deficit (£157,000 in 1909) then so must be optical goods. In 1910, however, Customs and Excise separated out all the sensitised and related photographic materials, leaving in the category telescopes of all kinds, photographic cameras and their lenses, microscopes and ophthalmic apparatus, lenses and prisms for scientific instruments, and survey instruments.[19] This re-arrangement caused a wholly different picture to emerge, although no attention was subsequently drawn to it, least of all by Cheshire, for whom it would have weakened the case for reform in the industry.

Table 6.1: Balance of Trade of Scientific Instruments, 1911-1914:[20]

Year	Imports	Exports	Surplus
1911	555,106	713,328	158,222
1912	645,379	707,061	61,682
1913	710,341	767,402	57,061
1914	471,525	646,493	174,968

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[17] LCC Report, p. 11.
[18] Great Britain, Government, Customs & Excise Department; *Annual Statement of the Trade of the United Kingdom with Foreign Countries and British Possessions* (HMSO, London, published annually). Subsequently *Annual Statement.*
[19] These corresponded to the categories identified in the 1907 *Census of Production* (London: HMSO, 1909) except for spectacle lenses which the *Annual Statement* recorded under a separate heading.
[20] Extracted from *Annual Statement*, 1911 to 1914.

Even though this showed a declining trend up to 1913, the optical trade *in toto* was clearly in a far from a terminal condition using the yardstick of overseas trade. The underlying condition was really one of relative rather than absolute decline, a condition also identified in other industries.[21] Although imports were rising, so were exports and the level of domestic optical production was increasing, even without taking into account the figures for naval and military rangefinders which, as 'munitions of war', were treated separately in the *Statement*.[22] With them, the recorded surplus would have been even larger. Taking into account the War Office's imports of all types of optical munitions, and Barr & Stroud's export orders for rangefinders, then an even stronger position appears:

Table 6.2: Balance of Trade of Scientific Instruments plus Optical Munitions, 1911-1914:[23]

Year	Civil surplus	Rangefinder exports	War Office Imports	Total
1911	158,222	50,241	-7,428	201,035
1912	61,682	160,768	-10,579	211,871
1913	57,061	185,330	-4,631	237,760
1914	174,968	114,057	nil	289,025

These figures also indicate the size of optical munitions exports relative to those of the whole optical instruments industry. In 1912 they accounted for 22.7 percent of the total, and 24.2 percent in 1913 before the declaration of war disturbed trading patterns and curtailed exports of optical munitions.

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[21] D. Edgerton, *Science, Technology and the British Industrial 'Decline' 1870-1970* (Cambridge: Cambridge University Press, 1996) pp. 3-5 discusses the idea of relative decline and its significance.
[22] Although exactly where they were buried is impossible to locate.
[23] Extracted from *Annual Statement*, 1911 to 1914, and PRO WO 395/3, Annual Reports of the Director of Army Contracts 1911 to 1914, and UGD 295/ 19/2/2 and /3, Customer order files, 1911 to 1914.

But Cheshire was not concerned in June 1915 to point out hidden strengths in the greater optical industry, rather he wanted to highlight and rectify the weaknesses in finance, scientific education and training, and the slow adaptation of modern technologies that might compromise the output of now urgently needed optical munitions. To go about this, he deliberately built on the existing idea that the optical industry was inadequate to the task it now faced. Whether or not that notion was entirely justified, the scale of the immediate problem demanded some sort of planned solution that would quickly ameliorate the difficult situation he had to manage. What Cheshire faced was the simultaneous need for a 'quick-fix' to overcome what was represented as a critical situation, as well as long term measures to lift the industry out of the circumstances that were represented as having brought about the predicament. His confidence in being able to tackle the problem is shown by the speed with which he defined the optical section's role. By the time he first wrote to Wedgwood he had already identified its intent as falling under five headings: [24]

1. to provide financial aid where necessary
2. to supply expert technical advice
3. to expedite deliveries of raw materials and components
4. to provide trained labour
5. to set up research centres 'to set the trade on a sound basis'

The first three might be implemented quickly, but the fourth and fifth would certainly require more time to bring about. The aim of setting up research centres was in harmony with the long term goal of the progressives in the industry since 1902, which was to provide advanced scientific training and establish systematic technological research.[25]

There were major problems to be addressed before the OMGD could begin to build a coherent and efficient optical munitions industry out of the chaotic conditions in the summer of 1915. Firstly, those firms already involved in military production lacked any real motivation to increase output because of previous War Office contracting policies. Then, making matters worse, many businesses felt threatened by the prospect of control

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[24] *OH* Vol. XI, Part 3, p. 1.
[25] Sylvanus P. Thompson, "Opto-Technics." *Journal of the Royal Society of Arts* (1902): 518-27; "The Proposed Establishment of an Institute of Technical Optics." 31-34. London: British Science Guild, 1914.

under the Munitions of War Act which been passed on 2nd July. Besides the question of corporate morale there was a shortage of machine tooling and skilled labour, as well as a critical lack of optical glass. And finally there was no trade organisation within the optical industry that might facilitate co-ordination between its constituents. Despite the sweeping powers conferred on the Ministry, and Cheshire's optimism, the OMGD frequently found it hard to bring about the influences on the industry it regarded as essential.

5.4: Immediate measures and the role of Alfred Esslemont

To apply Cheshire's five-point action plan, the OMGD was divided into technical and administrative sections. Although previous writers have concentrated on the efforts and achievements of Frederick Cheshire's technical section, so far as the contemporary industry was concerned the head of the administrative side had a more immediately important role to play. Little is known about the background of Alfred Esslemont (d. 14th September 1918), beyond his being a Fellow of the Optical Society;[26] the official *History* gives no details of his earlier career (beyond telling us that he came from the 'North East') and he is absent from any edition of *Who's Who*. His post in the Ministry suggests he was engaged for his combination of organisational abilities and technical knowledge, and throughout his work with the OMGD he was constantly engaged in liaison with both the instruments and glass industries, becoming a Director of the Department in 1917. Esslemont not only had to create a departmental structure that could bring some sort of order from the chaos of 1914 and early 1915, he also had to persuade the trade to adopt new working methods and to accept the subsequent imposition of the State's war-time controls. The administrative side of the OMGD extended far beyond keeping records and allocating contracts, overlapping Cheshire's remit and spreading into technical matters including instrument and machine-tool design it came to embrace a diplomatic role between industry and the State. The administrative section under Esslemont was vital to the success of the industry from 1915 until his premature death in 1918.

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[26] *Transactions of the Optical Society*, Vol. XX (May 1919), obituary notice.

Esslemont began by motivating the existing War Office contractors to increase their output, and in June he called them together to address 'the dangerous condition of affairs'.[27] According to the OMGD, the previous dealings of the War Office Contracts Department with the trade had created a 'most paralysing effect' on it, and firms had generally become 'dissatisfied' with government contracting, acquiring a 'strong distrust' for the methods used in placing orders. Their chief complaint was that no company ever received an order large enough to justify tooling-up for quantity production, with contracts for small numbers of instruments being scattered amongst a number of firms.[28] In short, they found it hard to make money working for the War Office. Its ordering policy, founded on considerations of peace-time fiscal probity and perpetuated by institutional inertia, had created a delivery situation that was unsatisfactory for everyone. Esslemont managed to re-assure the manufacturers that under the OMGD's umbrella, they would now be 'as fairly dealt with as possible under the circumstances' with regard to the distribution of orders. A subsequent series of 'personal interviews' with individual companies, along with the offer of some financial assistance were, perhaps optimistically, thought to be enough to ensure that 'a maximum of effort' would now be made, and as evidence of this the OMGD noted in late July that some makers were 'expending considerable sums on their own initiative, and output began to increase 'by leaps and bounds' according to the later words of the Department.[29] The department's own recording system, did indeed register a substantial increase during late 1915, but as not infrequently happened with the OMGD matters were not quite all they appeared to be.

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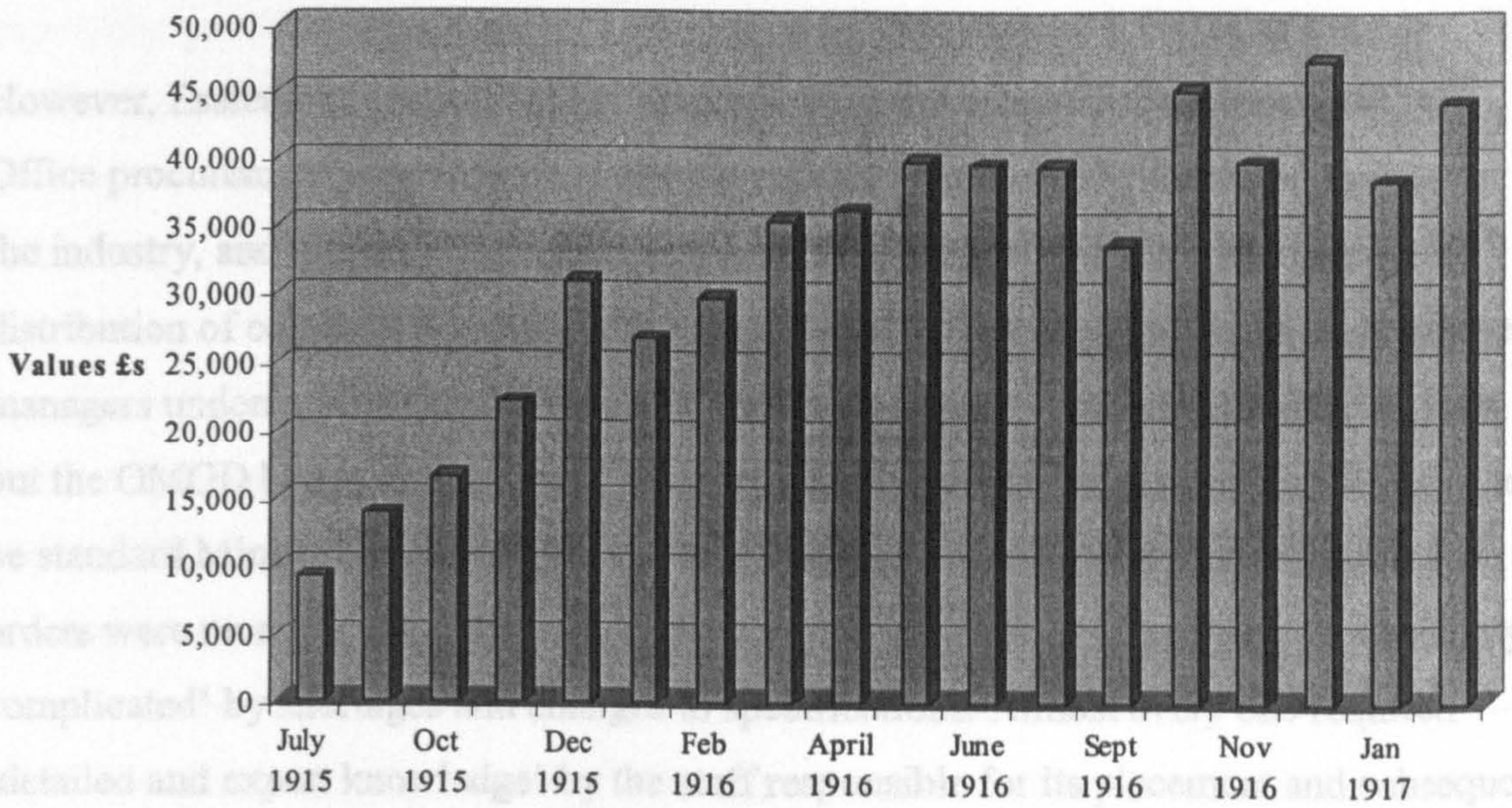
[27] PRO MUN 4/5006, Weekly Reports about Supply, Design and Production, Box 1, June 1917 provides the source for the rest of this section, unless otherwise noted.
[28] See Chapter 5 above for War Office policy on placing contracts.
[29] PRO MUN 4/55, DDGC to DGMS, 27.7.1915.

Figure 6.1: Monthly Optical Munitions output on War Office contracts, May 1915 to July 1917:[30]



The OMGD's figures call for some comment. July's output, before the department could have had any effect, was £9,186 for all contractors employed on War Office business. By October that had risen to £16,588 – an increase of almost 81 percent on July. This may have looked encouraging as a percentage, but as a proportion of the industry's total capacity it was miniscule. Gross exports alone of civil 'scientific instruments' in 1913 had been £767,402. October's output equalled an annual total of scarcely £200,000, which is so greatly removed from 1913's levels that the OMGD's figures need treating with some circumspection. It is unlikely that commercial production still accounted for the largest part of output because the Defence of the Realm (Amendment Act) had already empowered the Admiralty and the War Office to obtain precedence for their orders by requiring makers to put aside other work,[31] and by mid-1915 it is doubtful if any makers had not been affected by the changed circumstances of the war. A more likely explanation for the low figures is that they referred to acceptances after inspection at Woolwich Arsenal, a process which continually created back-logs; only then were invoices passed for payment and recorded by the OMGD. Another possibility, and one

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[30] PRO BT66/6/MMW46, Optical Munitions and Glassware Branch, Financial Turnover for Optical Munitions. There were no figures recorded in August 1915.
[31] PRO MUN 7/78, Instructions to Contractors, 13.5.1915, reminded suppliers of this obligation.

that best fitted Cheshire's agenda, was that the industry was simply incapable of doing any better without substantial assistance.

However, Esslemont's reports of his June meetings indicated that problems in War Office procurement procedures had been as much to blame as any structural failings in the industry, and one way Esslemont proposed to re-assure the trade was making the distribution of contracts a matter for the OMGD itself.[32] Dealing with an agency whose managers understood their problems was doubtless a vast improvement for the makers, but the OMGD had to argue strongly to justify this departure from what was intended to be standard Ministry practice. Cheshire and Esslemont asserted that optical munitions orders were more complex than others dealt with by the Ministry and were 'enormously complicated' by shortages and changes to specifications. Almost every one required 'detailed and expert knowledge' by the staff responsible for its placement and subsequent oversight.[33] The suggestion was that the optical industry was so specialised that only dedicated technically competent staff within the Ministry were properly able to manage dealings with it. This was not entirely accurate, but Cheshire and Esslemont had quickly produced an image of failure and chaos that let them employ an argument that was actually intended to let them manage the nascent optical munitions industry and control its development so as to maximise the benefits the optical instruments industry would derive from the expansion in war-time business. Their lobbying succeeded, and for the rest of the war the OMGD continued, uniquely, to operate its contracts directly with the trade.

A substantial part of Esslemont's success in gaining assurances of co-operation from the makers resulted from assuring them that orders would now be placed on a large scale and for a considerable length of time. The acceptance of the notion that the war would be measured in years and the accompanying necessity to ensure a continual and large-scale supply of munitions had together been responsible for the creation of the Ministry of Munitions for which Esslemont now acted as principal negotiator with the optical

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[32] *OH* Vol. XI, Part 3, p. 2
[33] PRO MUN 7/96, Wedgwood to DGMS, 23.3.1916. Cited by R. & K. MacLeod (1977) p.176

producers. The Ministry's powers to direct and control industry were vested in the Munitions of War Act which came into force on 2nd July 1915 and, although the legislation gave Esslemont considerable powers to assist the optical industry, some of its provisions quickly created considerable unease amongst the so-recently mollified manufacturers and led to friction between the OMGD and its political masters at the ministry.

5.5 Control and Profits

Industry had been subject to controls even before the Munitions Act was passed. In March 1915, the Defence of the Realm (Amendment) Act allowed the armed services to require manufacturers 'to give precedence to the completion of all orders and contracts' for government work, to ensure that neither commercial nor foreign government business obstructed production for the State.[34] The new 'Regulation 30A' prohibited 'all dealing in optical instruments which are of service to the Admiralty and War Office . . . except under special permit'.[35] This was intended to, and in the opinion of the OMGD actually did, bring about 'the extinction of private work' in the optical trade.[36] This may have been so; even before the 1915 amendment, Barr & Stroud had told the London instrument makers Negretti & Zambra it could longer sell to individual army officers, and informed Dollond & Co. that it would be 'many months' before there could be any hope of supplying any non-government clients.[37] These constraints may have been irksome, but they were nothing compared to those embodied in the Munitions Act.

Its broad purpose was to further 'the efficient manufacture . . . and supply of munitions for the present war', by imposing a body of regulation on both employers and workers.[38] For the optical munitions industry there were serious implications in the creation of what

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[34] PRO MUN 7/78, Instructions to Contractors, 13.5.1915.
[35] PRO BT 66/6/MMW47, 'Government Control of Industry: Report on the manner in which direct control is exercised'. 1918.
[36] *OH,* Vol. III, Part 3, p. 35.
[37] UGD 295/4/111, Letter Book, Jackson to Negretti & Zambra 13.10.1914; UGD 295/4/112, Letter Book, Jackson to Dollond, 27.11.1914.
[38] *OH,* Vol. I, Part 4, p.1, provides the quotation; for further background information and detail on the Act, see *OH* Vol. I, Part IV, Chapter I; *OH* Vol. III, Part 3, Chapter II; R. J. Q. Adams, *Arms and the Wizard: Lloyd George and the Ministry of Munitions, 1915-1916* (Texas A&M University Press, College Station, Texas and Cassell, London, 1978), Chapters 4, 5, 6 and 7.

was to be known as the 'controlled establishment' and the attendant regulation of profits. Broadly speaking, the Act sought to remove restrictive practices on the part of labour and as a *quid pro quo* to limit the profits employers might make from war work. The legislation gave the Minister of Munitions the power to declare as a 'controlled establishment' any business engaged on munitions production and whose output was considered as essential for 'the successful prosecution of the war',[39] so that any business involved in optical contracting for the Services was likely to be placed under Ministry control. The limitations on profits were seen by both Cheshire and Esslemont as an obstacle to improvements in the industry and they attempted to insulate it from direct control in much the same way that they had done with contracts.

Control under the Act 'did not involve any interference . . . with the management of the firm'. Rather, it 'relieved the establishment of the restraints imposed by trade union restrictions' although 'on the other hand' it did very much restrict the profits to be gained from government contracting.[40] It was that issue that most worried the optical makers who, having just been assured that they might expect a large volume of business for some considerable time, now faced the prospect of having their future earnings greatly diminished. The Act did not prohibit, or even restrict, the making of profits; instead it incorporated a formula restricting the amount of profit that a business could retain. A 'standard amount of profit' for a firm was to be determined by averaging its pre-tax profits for its last two financial years before August 1914. All but 20 percent of profits in excess of that went to the Treasury, the remainder being taxed at the same rate as the 'standard profit'. Although this was seen as politically essential to maintain the co-operation of the trades unions, it was a disincentive for businesses to maximise output, particularly where increased investment was needed to handle enlarged volumes of war work. Both Acts also demanded that contractors did not hinder production in any way, which meant that a firm coming under control stood to be locked-in to meeting the Ministry's demands at levels of profit that were significantly restrained.

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[39] *OH* Vol. III, Part 4, p. 17.
[40] *OH* Vol. III, Part 3, p. 31ff provides the source material for the rest of this section.

What made matters worse for the optical trade was that – according to Cheshire – its profits before the war had been far from good.[41] In mid-August he told the Ministry that very few companies had been paying dividends at all and 'indeed, it would be surprising to learn that a single one of these important firms was in a satisfactory and prosperous condition'. In his opinion, the placing of existing contractors under control would disadvantage them financially compared to firms left outside. Esslemont echoed this sentiment, which had already been expressed by some of the optical companies, adding that attempts to increase output depended largely on their 'goodwill' and so it was important 'to take notice of their points of view' if co-operation was to be maintained. However, despite the firmness of Cheshire's assertions, the accuracy of his profit assessments is open to doubt.

Few financial records survive for the firms Cheshire was writing about, but four of them have left figures that allow some evaluation of his comments. Barr & Stroud's audited accounts show pre-tax profits for 1912 and 1913 as £32,555 and £59,530 respectively, on turnovers of £126,593 and £188,007, which gives net margins of 25.7 percent and 31.7 percent, representing returns of 16.3 percent and 29.8 percent on the share capital employed and hardly those of an ailing company. For Thomas Cooke & Sons Ltd, entries in the Directors' Minute Book for the same years give profits of £7,287 and £7,899, with dividends of £2,615 and £5,545 to be paid from them. Taylor, Taylor & Hobson's Minute Book entries record pre-tax profits of £2,433 in the trading year for 1912 after payment of unspecified preferential dividends and new buildings costing £3,663. For 1913 the figure was £8,130 after dividends and a further factory extension costing £6,400.[42] Although the sales figures for the second two firms are not recorded, both were much smaller businesses than Barr & Stroud and their percentage margins seem to have caused no concerns in their records. These three companies certainly did not fit the image painted by Cheshire.

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[41] PRO MUN 4/55, Cheshire to Col. Wedgwood, 13.8.1915 is the source for this section.

[42] Sources for these figures: for Barr & Stroud, UGD 295/11/1, Audited Accounts: for Thomas Cooke & Sons Ltd, University of York, Borthwick Institute, Vickers Instruments Archive (subsequently VIA), T. Cooke & Sons, AJB 030 1.1.1, Minute Book 1897-1924: for Troughton & Sims Business Records, VIA AJB 060 1.2.3, Balance sheets 1908-1919: for Taylor Hobson, Cooke Optics Ltd, Leicester, unclassified records, Taylor Hobson Directors' Minute Book No.1, entries dated 8.10.1912, 7.1.1913, and 11.3.1914.

Troughton & Sims' accounts, however, give a picture which is less good. The firm was similar in size to Cooke's and produced a similar product range, but had little or no previous background in munitions production.[43] In 1912 there was a pre-tax profit of £4,347 on sales of £26,292, but in 1913 only £1,169 on turnover of £21,921, with no indication of any substantial expenditure on plant or premises to account for the reduction.[44] Not only were the end results poorer than the others', but the business apparently ran inefficiently, at least in comparison to Barr & Stroud. Profit on turnover was only 16.5 percent and 5.3 percent, compared to 25.7 percent and 31.7 percent at Barr & Stroud, while 'stock in trade' was equal to 47 percent of 1913's sales against Barr & Stroud's 12.4 percent. Wage costs were over 57 percent of sales, a proportion more than half as much again as the larger firm. Despite all this, 'less good' is by no means the same as 'bad', and Troughton & Sims was certainly solvent in 1913 with £11,800 cash in its bank and current trade debtors owing £3,884, with trade creditors standing at only £759.

Cheshire's woebegone depiction of the industry's financial condition was at odds with these companies. To what extent he was aware of trade's detailed economic circumstances is uncertain, but his connections with it must have given him some indication of its general state. This may indeed have been less than satisfactory, but the fact that three of these four businesses were solidly profitable in 1912 and 1913 implies that things were by no means as bad he alleged. The wording of his minute to Wedgwood suggests he was leaving himself some latitude in what he was saying. Terms such as 'prosperous' and 'satisfactory' could be applied to other areas besides financial performance and Cheshire may have had in mind less easily quantified aspects of business performance such as scientific and technological expertise, a theme to which both he and Esslemont would later return.

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[43] A. McConnell, *Instrument Makers to the World: A History of Cooke, Troughton & Sims* (York: William Sessions Ltd,, 1992) Chapter 5 describes Troughton & Sims' activities, but the author's suggestion of involvement in rangefinder production lacks evidence in support.
[44] VIA AJB 020 1.2.3.

Keeping the optical companies outside control in 1915 would have given them the opportunity to benefit from profits very much greater than in peace-time or the first year of the war, and would have aided Cheshire's intention to advance the scientific and technological basis of the optical industry. Long-term improvements would need companies to be financially sound; although State loans might overcome immediate cash shortages they would ultimately need repaying out of future profits. Expansion of output would require large spending on new tooling and premises and it was by no means clear in the early form of the Munitions Act that the State would cover any portion of this expenditure or permit businesses to derive any significant financial benefit from it.

Even though the Act provided for the introduction of rules to allow for 'any special circumstances such as increase of output, provision of new machinery or plant, alteration of capital or other matters which require special consideration' in assessing profits, none had yet been formulated when Cheshire wrote his August minute about excluding the optical industry from control.[45] They only appeared in September, 'after long and exhaustive discussion within the Department' and would have gone a long way to meeting Cheshire's aims, but 'before any definite system for treating special cases ... was able to take final shape' its implementation was interrupted by the a Finance Bill which introduced the idea of an Excess Profits Duty (EPD) to tax at a higher than normal level all profits 'in excess of a pre-war standard'.[46]

That had serious implications for Cheshire's desire to retain profits within the industry. It intended to take 50 percent of all 'excess' earnings from the outbreak of war, and unlike the Munitions Act allowed only for 'exceptional earnings and redundancy of plant'.[47] The Ministry of Munitions recognised that the EPD proposals were likely to overlap the munitions levy, with the prospect of controlled firms being liable to pay both, an illogical – and unreasonable – situation. Negotiations between the Ministry and the Treasury to exempt controlled firms from the new proposals were inconclusive, which must

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[45] *OH* Vol. III, Part 3, p. 32. Pages 31 to 35 provide the source material for the rest of this section on profits and taxation.
[46] *OH* Vol. III, Part 3, P. 33.
[47] *OH* Vol. III, Part 3, p. 34.

encouraged Cheshire and Esslemont to lobby persistently and tenaciously to keep the optical contractors outside control.

Both measures stood to deny the optical industry the opportunity for earnings whose previous lack was, according to Cheshire, responsible for much of its woes. Faced with still-incomplete rules in the Munitions Act and even greater uncertainty over the proposed finance bill, Cheshire's only feasible strategy was to plead that the optical firms' inclusion would result in loss of co-operation and a consequent catastrophic decline in output. Much of his denigratory comments on the industry in the confidential internal minutes could only have been deliberate hyperbole intended to increase the strength of his pleadings whilst concealing the true reason for them, which would have been wholly unacceptable in the political context of the Munitions Act. The Ministry of Munitions was, as the official *History* subsequently reminded its readers, 'primarily concerned with the output of munitions, not with revenue',[48] but Cheshire's tactics indicate that he was much concerned with earnings for the industry as with output for the State.

Both Mari Williams and the MacLeods pointed out that the OMGD dealt with its industry in ways different to other sections of the Ministry of Munitions but did not identify this important underlying reason. Williams considered that Esslemont opposed control simply because 'some instrument firms were reluctant' to be controlled and that their wishes had to be considered, whilst Cheshire wished to avoid what he described as 'upsetting a very delicate balance' between the trade and his department on the grounds that, in his own words to Colonel Wedgwood, 'the manufacturer is master in his own workshop and is stimulated . . . by the prospect of a fairly assured reward. But under the provisions of the Munitions Bill [sic] he loses . . . his status as master and no guarantee of reward is given him if he has not been a profit earner in the past'.[49] This could only have been a deliberate distortion of the truth; Cheshire must have known both that the Munitions Act did not interfere with routine management and there was provision in it

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[48] *OH* Vol. III, Part 3, p. 33.
[49] Williams (1994) pp. 63 and 64. She cites PRO MUN 4/55, Cheshire to Wedgwood, 13.8.1915.

for dealing with previously unprofitable businesses. Roy and Kay MacLeod also pointed out the 'delicate relationship' that existed, and although recognising that the OMGD was not in step with general Ministry policy they did not seek any other explanation.[50] The reality was that the joint directors of the OMGD were deliberately seeking to pursue a policy that ran counter to the very heart of the principles of the Munitions Act in order to let contractors derive substantial extra financial benefits from their war work in order to benefit the entire industry's efficiency and competitiveness once the war ended.

These efforts enjoyed some success. In July, Barr & Stroud, Cooke's, Heath & Co., Ross, Troughton & Simms, and Carl Zeiss (London) Ltd had been placed on the list of firms to be controlled,[51] but all were quickly (if only temporarily) removed, despite reservations and opposition within the Ministry. In late July the Ministry line was that firms 'should be controlled whether they want [it] or not' and it would be 'difficult to avoid including the [optical] firms in the controlled lists'.[52] Opinion then hardened in favour of listing, control being depicted as 'a status which carries with it material advantages' to which only Ross had so far objected. On August 9th a decision was taken to go ahead, but by the 14th, Cheshire had persuaded Wedgwood and Eric Geddes to tell the Director General of Munitions Supply that the Ministry now felt 'a very strong case was needed to justify putting these firms on the controlled list', a complete reversal of the earlier position. The Director General, F. W. Black, conceded the point although he excepted Barr & Stroud because of its 'engineering content'.[53] Cheshire's pleadings, perhaps better described as lobbying, on behalf of the optical instruments makers had been – for the moment – successful in their guise of creating an efficient optical munitions industry.

The only other optical firms taken under control in the remainder of 1915 were Ross and Carl Zeiss (London) Ltd., both at their own request. Ross' change of heart may have been because the Ministry was prepared to put up a sizeable proportion of the £25,000 the firm

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[50] Roy & Kay MacLeod (1977), p. 176.
[51] PRO MUN 4/55, Control of Optical firms, DDGC to DGMS, 27.7.1915.
[52] PRO MUN 4/55, Control of Optical Firms, Wedgwood to Sir H. Llewellen Smith, 30.7.1915.
[53] PRO MUN 4/55, Control of Optical firms, supplies the source material for this preceding section: DDGC to DGMS 27.7.1915, Beveridge to Sir H. Llewellen Smith 30.7.1915, Wedgwood to Eric Geddes 14.8.1915, Geddes to DGMS 14.8.1915.

had earlier decided to spend enlarging its works to handle an order for 2,000 dial-sights worth over £110,000 which the OMGD had placed in August.[54] Ross had previously suggested that if placed under control, the firm would be unwilling to spend its own money on the project, so the request to be designated a controlled establishment was very much a *volte face*. Carl Zeiss (London) Ltd. was a small subsidiary of the very large German Zeiss organisation which since the outbreak of war had been operating in a kind of limbo, cut off from its parent, unsure of its future and, ironically, assembling binoculars for the War Office from dwindling stocks of pre-war German-made components.[55] Matters came to a head when its directors and senior managers were interned in 1915, and the business put in the hands of a controller from the Board of Trade who doubtless found that control represented a solution to its current problems as well as removing any stigma that attached to it being an 'enemy' firm.

In January 1916, political pressure caused the Ministry to reconsider the status of the optical firms still outside. Cheshire's success in presenting the optical industry as a special case was beginning to rebound, the comment being made that that the exclusion of such 'an important industry' left the Minister (Lloyd George) 'with absolutely no answer to any criticism' of the decision. On February 1st, Esslemont was reminded that he had still to provide the names of firms to be placed on the controlled list but he still prevaricated, replying through OMGD's liaison officer that the Department did not see 'any sufficient reason' to include any other optical companies. He concluded with the blunt statement that 'I am not satisfied that the Ministry or the firms have anything to gain from control'.[56]

The tenacity with which Cheshire and Esslemont sought to keep most of the industry outside control reflects how much they were concerned that it would hinder not so much the creation of a temporary war-time munitions industry, but the long term growth of the

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[54] PRO MUN 4/745, Orders placed for Scientific and Optical Instruments &c, 1st august 1914 to 31st March 1917.
[55] Antje Hagen, "Export Versus Direct Investment in the German Optical Industry." *Business History*, no. 4 October 1996, p. 7.
[56] PRO MUN 4/55, Control of Optical Firms provides the source material for this section: Memorandum of Meeting 17.1.1916, O. H. Smith to Esslemont 1.2.1916, Wedgwood to Smith 4.2.1916.

entire optical industry, which they saw as being the future locus of optical munitions manufacture. Unfortunately for them, the political implications of what they wanted were too serious to allow success. Wedgwood's letter expressing Esslemont's ideas brought a measured and slightly menacing riposte from the Ministry's Owen H. Smith, who wrote that not only were the continued exclusions exposing the Minister 'to the possibility of serious criticism' but it was 'rather a grave decision' to continue them. 'If there is a real reason for exclusion, can you send me a short minute?' he ended. Wedgwood's reply had to admit there was little to add beyond reiterating that only the 'very careful handling' of the trade had permitted improved output, and that he was 'apprehensive of the effect' of anything disturbing current circumstances. Smith was un-moved and on March 1st told the Director General of Munitions Supplies that he considered fears about reduced output 'groundless' and that 'it seems there is no justification for excluding an industry which is so important from the point of view of munitions work'. He finished by asking for permission 'to issue [immediately] a special list including all the optical firms'.[57] That marked the end of attempts keep the optical trade outside the financial constraints of the Munitions Act and Cheshire and Esslemont's energies were henceforth more closely focussed on other efforts to transform the industry.

5.6 Scientific training and technical management

For Cheshire, the other pillar of support for the optical industry was significantly better scientific and technical education. In late 1915 and 1916 the argument for introducing new centres to provide this was reinforced by the argument that the existing industry was constantly being held back from meeting 'its production targets' because there were not enough 'skilled workmen, designers and [lens] computers available'.[58] This was substantially correct, although other factors such as the lack of machine tooling and factory space were greater and more immediate impediments to increasing output of equipment already in service.[59] The London County Council's Education Department took up the work it had done in 1911 and in June 1916 its Education Officer, Robert

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[57] PRO MUN 4/55, Control of Optical Firms, Smith to Wedgwood 11.2.1916, Wedgwood to Smith 17.2.1916, Smith to DGMS 1.3.1916.
[58] R. & K. MacLeod (1977) p. 185.
[59] PRO MUN 2/1a, Secret Weekly Reports Vol. 1, 18.9.1915, 23.10.1915 and 6.11.1915.

Blair, suggested a 'national scheme for training in technical optics'.[60] The only facility that then existed was at the Northampton Polytechnic Institute at Clerkenwell in London (the location of much of the London optical trade), which provided worker training for the production of optical components, rather than for design and computation.[61] Despite the need to increase output, Blair's consultations with the optical industry and the Ministry of Munitions had persuaded him that the manufacturers were 'less preoccupied with the need to train workmen, than with the need to secure advanced postgraduate and research work', and his recommendations took that requirement principally into account.[62] The existing Clerkenwell scheme would be enlarged to take 60 'students' at a time, evening classes would be provided at 'junior technical schools', but most importantly a new department would be created at Imperial College to provide undergraduate and post-graduate training, as well as facilities for research workers. That would provide a centre of excellence for optics which, although familiar in Germany, was still unknown in Britain.

Blair's suggestions were adopted and in May the following year Frederick Cheshire was appointed as Professor of Technical Optics at Imperial College. This meant his stepping down as joint head of OMGD, but he maintained a direct connection through reverting to his original Ministry post of 'expert advisor in technical optics'. The extent to which Cheshire influenced Blair's thinking must have been considerable, particularly as the greatest energies were devoted to the area where the immediate demand was least urgent. Despite the assertion that output was threatened by a lack of designers, the inescapable fact remains that in 1915 and 1916 what the War Office chiefly wanted was instruments that were already in production such as rangefinders, dial-sights, prism binoculars and telescopes.[63] Where novel items were required, such as the telescopic rifle sight or the trench periscope, the design was done by existing firms (such as Aldis Brothers, Beck, and Watson) who already had competent optical designers.[64] What the war-time munitions industry needed most was extra capacity, but the OMGD was convinced that

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[60] R. & K. MacLeod (1977) p. 186.
[61] *OH* Vol. XI, Part 3, p. 109.
[62] R. & K. MacLeod (1977) p.109.
[63] PRO MUN 4/745, shows the extent to which existing patterns made up the bulk of orders.
[64] See Chapter 7 below for details of Aldis Brothers.

in the context of the long-term, what the optical instruments industry needed was quite different.

Once Blair's ideas were accepted by the LCC, the Department of Scientific and Industrial Research and Imperial College, an advisory committee was set up to co-ordinate progress. Although the OMGD had no official part in what Blair proposed, it was represented on this Technical Optics Committee by Alfred Esslemont, along with Frank Twyman from Adam Hilger Ltd, Conrad Beck from R. & J. Beck Ltd, and T. Watson-Baker from W. Watson & Sons Ltd from the 'optical trades'.[65] Twyman, although now totally (if temporarily) committed to munitions contracting, was principally interested in scientific instrument manufacture, as were Beck and Watson-Baker. Before the war, although all had been engaged in optical munitions manufacture, their businesses had not been as heavily involved as others; Ottway and Ross both did more government contracting, and Barr & Stroud was totally committed to military and naval work. All three had been anxious to advance the instruments industry and Beck and Twyman had both been involved in efforts to establish a makers' association, continuing even after the war began. Their concept of what optical production would benefit most from were almost certainly more closely in tune with Cheshire's than anyone else in the London industry. This cross-influence was also reflected in the other appointments to the new department at Imperial College, with two of Watson's designers filling key posts.

Just before the first classes at Imperial College started in 1917, Cheshire published an open letter to the trade in the journal *Optician* that amounted to a summary of his policy for reforming optical manufacture in Britain, justifying it by the experiences of the war.[66] It was, he said, only the pressure of war-time demands that had impressed on the makers the need for scientific method to replace the old ways of trial and error, and had provided a climate where changes would be accepted. The setting-up of the department at Imperial College was the start of a systematic approach to optical design that, by implication, was long overdue. There is no doubt that much of what Cheshire wrote was true, but it did

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[65] R. & K. MacLeod (1977) p. 201.
[66] R. & K. MacLeod (1977) p. 186 and p. 201. cite the quotations in this paragraph.

not apply universally. In particular, the three firms represented on the advisory committee were no strangers to scientific method, nor were companies such as Barr & Stroud, Ross and Taylor Hobson. What the facilities at Imperial College were meant to do was provide a pool of scientifically trained opticians who would, it was hoped, bolster the abilities not only of companies who already employed such staff, but also of those who had previously been unable to hire skilled designers. In June 1918, the Technical Optics Committee summarised Imperial's first optical academic year by saying the courses would meet 'the urgent need' for 'first class designers and computers' and would eventually produce 'a sufficient supply of men . . . for the higher positions in the industry'.

Cheshire's policies for long-term improvements became more relevant to optical munitions production after late 1916, and his enthusiasm for using short-term pressures to promote progress on a broader front should not be allowed to distract from the benefits that parts of the munitions industry gained from his work. Even though he may initially have exaggerated the size of the 'reverse salient' of shortages in trained designers, the problems embedded in the War Office's methods of producing specifications for its optical munitions was a reminder that he had identified a significant problem. Whether, in the context of immediate war-time demand, he actually produced the best short-term solution is open to debate. The War Office had never prepared any optical specifications in detail so businesses coming into optical munitions manufacture were faced with designing lens systems for themselves. Once the OMGD began to look for new sources of supply in late 1915 and 1916, the problems inherent in this situation made themselves quickly apparent.

For firms like Beck and Ross, which had optical designers, computing optical systems was no problem, beyond the time-consuming nature of the work. But, because they were already fully occupied, the OMGD increasingly looked to newcomers who did not always have the abilities to do the calculations themselves. Making lenses was relatively easy once a suitable optical glass had been selected and their curves and thicknesses computed, but without those specifications nothing could be done, and it was in the

efforts to bring in firms who lacked these abilities that the shortage of lens computers was first and most keenly felt. Cheshire's planned three-year courses, though, were far beyond what was needed to solve that particular lack, and in recognition of that Cheshire and the chief designer of Watson & Sons, Eugen Conrady, set up six-week 'crash courses' at Imperial College in late 1916.[67] These were sufficient to allow both prism binocular and terrestrial-telescope systems for gunsights to be designed by people with no previous mathematical training, and proved adequate to set up an entirely new factory in Leeds for binocular production in 1917 without needing to rely on any outside optical design aid.[68] Despite the utility and importance of these short courses when they were run, the official *History* does not mention them, nor do the MacLeods in their examination of the optical industry's relationship with government in the Great War. Possibly they were not entirely successful, either in numbers trained or the skills transmitted. In February 1918, the Sherwood Optical Company, a firm which had been set up in 1915 and which had binocular contracts, was reported by the OMGD's Technical Branch to have suspended its output as it was waiting for a 'new optical system to be calculated by Mr Chalmers'. In March, the binocular makers Kershaw, who had designed their own lens system after training on one of the Cheshire-Conrady courses, changed over to making a system designed by Taylor Hobson.[69] The problem with both seemed to be rooted in design limitations rather than quality of manufacture.

5.7 The problems of failure to standardise designs

The lack of standardised design for optical instruments was a problem that the OMGD never addressed, despite the problems which it caused in extending sources of supply. Even the largest and most competent of firms found problems in dealing with it. In August 1916, after lengthy and detailed negotiations, Barr & Stroud were given a contract to make 200,000 binocular prisms for supply to other firms who were already

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[67] Leeds Industrial Museum, Armley Mills; Kershaw papers (unclassified), typescript by Norman Kershaw, 'The History of Kershaws', p.6 gives details of his lack of experience and training and the benefits of the course.

[68] This is detailed in chapter 6 below.

[69] PRO MUN 4/5006, Reports of Technical Branch; Inspection of Labour, report 28.2.1918 for Sherwood and 7.3.1918 for Kershaw.

making complete instruments.[70] The 'specification to govern manufacture' gave no information about the prisms beyond requiring that they be made of boro-silicate glass, and the firm had to consult OMGD for the necessary dimensions. Its technical branch could only confirm the glass type needed, and the permitted tolerances on the prism angles, telling Esslemont that 'It would be advisable to obtain from Ross two sample prisms to be forwarded to Barr & Stroud, from which they could take their own measurements.'[71] No standard existed (Ross presumably made prisms to fit their own gauges), and a binocular was eventually sent directly from Woolwich Arsenal, the OMGD seeing no purpose in recording the details for itself. It was Barr & Stroud who provided the dimensions for incorporation in the contract to manufacture. Then, having set up to produce prisms on a scale larger than ever done previously in Britain,[72] the firm found that its two clients (Kershaw and the Brimfield Optical Company) made binocular bodies that called for prisms of slightly different heights that differed from the samples provided. This complicated and slowed production, and eventually Barr & Stroud collaborated with Kershaw, by far the larger client, to produce a compromise that would fit both firm's bodies through relaxing the tolerances that had originally been decided in the contract issued by the ministry. Deliveries went directly from Glasgow to the two binocular factories, the prism were fitted and the finished instruments sent to Woolwich for inspection. Then, in October 1918, the Ministry's own Inspector of Optical Supplies became responsible for prism acceptances, and batches sampled began to be rejected because they failed to conform to the dimensions agreed in 1916. After a series of letters occupying a month, the Inspector finally agreed to accept the size that had been working perfectly for over a year, and assembly of binoculars was resumed.[73]

A different, though related, problem was illustrated when Barr & Stroud was asked to take on the manufacture of a gun sighting telescope in July 1918.[74] This was actually an Admiralty pattern that had been made previously by Ross and by Watson, and unlike

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[70] UGD 295/19/2/4, Customer Order files, CO 2965, 23.8.1916.
[71] UGD 295/26/2/49, Bryson to Esslemont 4.4.1916.
[72] PRO MUN 4/5004, Weekly Reports, 8.1.1917.
[73] UGD 295/4/634, Letter Book, Barr & Stroud to Director of Inspection of Optical Supplies, 8.10.1918, 17.10.1918, and 8.11.1918 provide the source material for this section.
[74] UGD 295/4/634, Letter Book, Barr & Stroud to Controller of Optical Munitions Supply, 23.7.1918, 24.7.1918 and 27.7.1918 provides the source material for the rest of this section.

War Office practice there were drawings for it. These were sent to Glasgow, along with a sample of each firm's manufacture. Difficulties were immediately found, because the two samples were distinctly different, each having its own set of drawings. A further complication was that the Watson telescope, which struck Barr & Stroud as being potentially easier to make, did not actually conform to its own drawings and used five different types of glass in its seven-component optical system, a degree of complexity which the firm thought un-necessary.

5.8 Maintaining output

Sampling the OMGD's weekly reports shows that its staff spent a large proportion of their time getting round similar problems for firms who were either too small or less able to take remedial steps themselves, and dealing with failures in firms that ought probably to have been better able to manage their own affairs.[75] R. & J. Beck Ltd, whose principal Conrad Beck, was associated with Frederick Cheshire's efforts, was criticised on October 18th 1917 for the poor overall quality of their output, and on 7th February 1918 for binocular deliveries that were so slow that the contract might as well be cancelled. At the same time, the firm was in dispute with the inspection department at Woolwich Arsenal – on which the OMGD's comment was (intriguingly) 'It is impossible to condense all that our inspector has to say about this firm and the testing at Woolwich'. On Adam Hilger Ltd the comments were even worse; on 26th January 1917 the firm's binocular lens sets were 'unsatisfactory', on 15th February they were 'far from satisfactory', and on 1st November they were still 'not fit for service' and the entire workshop was dirty and 'must be swept out'. The Dublin firm of Sir Howard Grubb and Co. was far behind with its deliveries and on 28th February 1918 the OMGD noted that not a single telescope from a contract placed in October 1916 had yet been supplied, and for it to get back on schedule would depend 'on the help of supernatural agencies'. Broadhurst & Clarkson, a telescope maker established well before the war, had been proposed as a maker of Admiralty-pattern gun-sighting telescopes, but on 12th July 1917 the OMGD dismissed the suggestion as 'its plant is inadequate, its men unaccustomed to the work and … the

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[75] PRO MUN 4/5004 Box 1, and MUN 4/5006, Weekly and other Reports, provide the source material for this section, dates as given in the text.

deliveries promised could not be made'. And in early February 1918 the Ross branch works at Mill Hill was noted to 'complain bitterly' that binocular bodies supplied by W. Watson & Sons for fitting with graticules were so dirty that it was impossible to work on them.

These reports are simultaneously telling and misleading. The OMGD staff making them were handling the day to day problems of firms who were, for the most part, trying to cope with large orders and the pressure to deliver quickly, whilst coping with shortages of hands and building extensions to their works. In August 1917 the Weekly Reports record ten firms with construction work going on, including Grubb, Hilger, and Ross, most of whom were being criticised for tardy deliveries or poor quality.[76] The picture is one of struggle and, if not of failure, then at best of limited success that causes questions to asked about how effectively the OMGD managed the war-time industry. But it has to be recognised that problems were bound to feature more prominently than successes in these records, and that lack of evidence of success is by no means evidence of its absence. Barr & Stroud, for example, features hardly at all (at least in those sampled) except in relation to its problems with prism acceptances. There is little said about the massive output of rangefinders in Glasgow, although it must be asked whether the OMGD might have paid closer attention had the firm been in London, and provided more information as a result. It would be as unsafe to assume failure in the management of the industry from the records of Esslemont's administrative department as it would be to assume success for Cheshire's efforts on the technical side from his own contemporary claims.

5.9 Conclusion

Whatever the image created by the Weekly Reports, there was no breakdown in the supply of optical munitions throughout the war, even before the Ministry of Munitions was created. Whether or not the OMGD chose the best way to organise the industry is debatable, and a case can be made that Cheshire in particular gave priority to the long-term interests of the country's optical instruments industry over the short-term demands

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[76] PRO MUN 4/5006, Weekly Report 16.8.1917.

to maximise output of munitions products. If he did, his intention was to produce a viable industry that would be able to fill a role analogous to the private pre-war arms makers who had traditionally been expected by the State to make up the shortfall from the national arsenals in time of war, a goal that would in principle have been acceptable to his political masters in the Ministry. It cannot be said that he succeeded in that, largely because the conditions that provided his opportunity also combined to frustrate one of his two strategies and it proved much easier to set up a university programme in optics than it did to let the trade profit financially from its war-work. His own departure from the Ministry (even though he retained an official role in it) meant that his ability to develop any provincial training scheme was largely eliminated, and the centre for excellence in optics remained a metropolitan phenomenon despite the national distribution of key optical munitions producers. As a later chapter shows, most of his efforts had little long-term effect on the optical munitions industry which, after all, had remarkably little in common with the instruments industry.

Much of war-time optical industry can perhaps best be described as hermaphroditic. Those instrument making firms who were conscripted into becoming munitions-makers retained the characteristics of the former while acquiring those of the latter with varying degrees of completeness that subsequently affected their success in the new role. That Esslemont's department was often unable to make sword-smiths from tinsmiths should not have been a surprise; that he was able to get any of them even to make forks was an achievement in itself. But, from the contract records it must be conceded that the bulk of useful output actually came from a small number of firms who were mostly already experienced in optical munitions work before the war began, suggesting that concentrating resources and effort in developing those businesses would have been a more effective route in rapidly expanding optical munitions output than the one chosen. The next chapter examines the degree to which success was achieved in specific and important areas of production and considers to what extent the Ministry played a part in them.

Chapter 6

The industry's war-time performance, 1915 to 1918

6.1 Introduction.

Assessing the optical munitions industry's performance after mid-1915 is not an easy task. War is the critical test of munitions supply, but the Great War so tested production that the choice of criteria by which to evaluate the industry is somewhat problematical. Because optical manufacturing was inextricably linked to the Ministry of Munitions' Optical Munitions and Glassware Department (OMGD) it is impossible to chronicle one without repeated reference to the other, and any assessment of optical munitions makers must also embrace the OMGD. An appropriate way to consider the war-time industry is how well, and by what means, it met the tasks imposed upon it by the exigencies of war, focussing on three particular examples of what Roy and Kay MacLeod called the 'individual optical technologies', and examining them in the context of war conditions.[1] This facilitates the recognition of a distinct and largely temporary war-time industry and the particular problems it encountered. The three examples selected – prismatic binoculars, telescopic rifle sights, and the man-portable single observer rangefinder – represent three distinctive approaches to war-time production and demonstrate different degrees of success. All show an interaction of socially constructive characteristics and technical factors that resists models of explanation that attempt to subordinate either of them to the other.

6.2 The problems of large scale production.

Despite the importance of developing new products in response to the changing nature of warfare, volume production was the chief concern throughout the war and was where the greatest problems were encountered. The need to produce some types of instruments in numbers never previously envisaged led to circumstances where the problems of obtaining sufficient factory capacity – in effect a manufacturing system – were complicated by the emergence of what Thomas Hughes has termed 'reverse salients', a

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[1] Roy and Kay MacLeod, 'Government and the optical industry in Britain 1914-1918' in J. M. Winter, ed. *War and Economic Development* (Cambridge: University Press, 1975) p. 166.

metaphor describing situations where parts of an expanding technological system either fall behind or become out of phase with others.[2] Hughes suggested that in a manufacturing system, an increase in output in one section may result in the need to modify some or all of the other components in the system to ensure optimum performance, these 'lagging' parts remaining reverse salients until a correction has been achieved. The presence of such difficulties, though, need not necessarily bring the system to a halt even though its efficiency may be reduced; in such cases they may be presumed capable of solution, and then by-passed pending that solution in order to permit interim progress on a 'broader front'. Such circumstances were found in all the three areas examined below, but particularly in the ambitious moves to expand prism binocular production. Unlike other applications of optical technologies, this effort was not entirely successful, largely because the reverse salients which, in Hughes' terminology, became 'critical problems' which although identified early were not all adequately addressed until late in the war, demonstrating the dangers inherent in some of the steps that had to be taken to create a substantially new industry at an accelerated rate.

Whether high volume production in the optical munitions industry conformed to current understandings of the true nature 'mass production' is a debatable point. David Hounshell has suggested that the term must embrace not only the manufacture of large quantities, but also the 'basic aspect' of fully interchangeable parts and the absence of hand fitting in their eventual assembly into a completely finished artefact.[3] He pointed out that the incorporation of fully interchangeable components need not ensure high rates of output, nor that the need for adjustments at the assembly stage necessarily precluded the speedy manufacture of very large numbers of a complex product, citing the half million sewing machines produced by the American Singer company in 1880 using hand-fitting methods.[4] That mass production conforming to Hounshell's prescript was found in some areas of British war-time munitions manufacture is beyond doubt – an

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[2] T. P. Hughes, "The Evolution of Large Technological Systems." in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, edited by W. E. Bijker, T. P. Hughes, and T. J. Pinch. (Cambridge, Massachusetts: MIT Press, 1989) pp. 73 to 75.
[3] D. A. Hounshell, *From the American System to Mass Production 1800-1932* (Baltimore: Johns Hopkins University Press, 1984) pp.3 to 7.
[4] Hounshell (1984) p. 6.

excellent example being the Lee-Enfield rifle which was produced at annual rates exceeding a million in three separate factories, using fully interchangeable parts throughout.[5] However, with optical instruments matters were somewhat different and, although some types were made in large numbers, neither the quantities produced nor the methods of manufacture mirrored those for rifles, suggesting that even though production was far higher than ever previously attained, mass production under the strict definition adopted by Hounshell was never actually achieved in optical munitions contracting.

6.3 Prism Binoculars.

The prismatic binocular was needed in far larger quantities than any other item of optical munitions and posed the greatest problem of supply.[6] The War Office had already ordered over 58,000 between August 1914 and June 1915, both at home and in France. That was more than all other optical stores put together and almost twenty times the number ordered in the financial year 1913-1914.[7]

The OMGD inherited a situation in which deliveries were already far behind schedule, where estimated requirements had reached almost three times what had already been ordered, and where output was so small that the shortage could only continue growing. This presented a serious problem whose solution was both protracted and elusive. The difficulty was the lack of capacity. Although binoculars were regularly made in Britain before the war, their manufacture had been on a leisurely and relatively small scale that was far less than presently required. Ross, by far the largest British maker, had taken over fourteen years to produce no more than 25,000, averaging approximately 35 per week.[8] That binoculars could be made on a very large scale had been amply demonstrated by Zeiss at Jena, which had produced almost 433,000 between 1894 and

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[5] Great Britain, Ministry of Munitions, *History of the Ministry of Munitions*, (subsequently *OH*) Vol. XI 'The Supply of Munitions', Part 4 (London: HMSO, 1922) pp. 17 to 31.
[6] *OH* Vol. XI 'The Supply of Munitions', Part 3, p. 133, Appendix III(a).
[7] See Chapter 4 for the details of British firms, PRO MUN 4/745 for samples of French contracts and Great Britain, Ministry of Munitions; *OH* Vol. XI, Part 3. (HMSO London, 1922) p. 133, Appendix III(a) and *OH* Vol. I, Part 1, Appendix II for details of total orders placed.
[8] In the absence of factory records, these figures are based on serial numbers taken from surviving instruments whose dates of manufacture can positively be placed in this period through reference to advertisements and the maker's own catalogues. I am particularly grateful to William Reid for providing data from his own collection.

1914, averaging 50,000 yearly after 1910.[9] However, this was unique, and no other maker anywhere had made anything like that quantity or achieved such high rates of output.[10] The firm was extensively vertically integrated so far as the production of components went, even the optical glass for its lenses and prisms coming from its 'sister company', the adjacent Schott glassworks.[11] It had enjoyed the benefit of patent protection for its binoculars since 1894 and, according to the British optical trade, had been materially assisted by the German government's regular large-scale purchases.[12] With over 5,000 workers in early 1914 it was by far the largest optical manufactory in the world and regarded universally as a *ne plus ultra*. Nevertheless, the way Zeiss made binoculars was no secret; its works were regularly visited by representatives of foreign instrument makers and its production methods described in contemporary scientific and technical journals. Those methods, particularly for assembly, could in fact be replicated on a smaller scale in factories properly set up to perform the work, as Zeiss itself had already demonstrated with small branch works in Austro-Hungary, Russia, and England.[13]

A later claim that 'We knew [in 1915] how to make binoculars, but not … on a great manufacturing scale' was not strictly true.[14] Zeiss produced a thousand binoculars weekly not by employing secret or sophisticated methods, but by employing large numbers of workers to assemble an assured supply of suitable components. The real obstacle in Britain in 1915 was the lack of capacity for optical components and factory space and workers for their assembly. Although Aitchison, Ross, Watson, and the

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[9] These figures are provided partly from data published in H.T. Seeger, *Feldstecher: Fernglaser im Wandel der Zeit* (Borken, Germany: Bresser Optik, 1989) pp. 102 – 104, and from further personal communications from Dr Seeger, as well as information provided by Thomas Antoniades.
[10] H.T. Seeger (1989) Chapter 4, and F. Watson, *Binoculars, Opera Glasses and Field Glasses* (Princes Risborough, Bucks: Shire Books, 1995) pp. 13-19.
[11] F. Auerbach, *The Zeiss Works and the Carl Zeiss Stiftung in Jena*. Translated by F. Cheshire and S. Paul. 2nd edition (London: Marshall Brookes & Chalkely, 1904) describes the factory and its methods in detail..
[12] R. and K. MacLeod, "Government and the Optical Industry in Britain 1914-1918." In *War and Economic Development*, edited by J. M. Winter (Cambridge: Cambridge University Press, 1977) pp. 169 and 170.
[13] Antje Hagen 'Export versus direct investment in the German optical industry' *Business History* No.4, October 1996.
[14] George A. B. Dewar, *The Great Munition Feat 1914-1918* (London: Constable, 1921) p. 217.

London subsidiary of Carl Zeiss Jena had all manufactured binoculars before 1914, none of them had the capacity to handle the volume now needed.[15]

The binocular was not easy to mass produce, even when the methods were familiar. It required great consistency in its optics and, above all, care in final assembly if it were to function correctly.[16] Although its lenses and prisms could be produced by machine tools, the final critical adjustments aligning the two telescopes (collimation) still had to be done individually, which meant using large numbers of workers to avoid a bottleneck and obtain high output rates. In Britain this was seen as skilled work for experienced men who were becoming increasingly hard to find by mid-1915. Many had already joined the Services and, as Cheshire had emphasised, there were no institutions to provide trained optical workers in substantial numbers. The existing makers accordingly had little chance of vastly increasing their output.

Ross and Watson were already heavily committed to both the Army and the Navy.[17] Despite having a 'beautiful factory' Ross was by no means large, employing only 320 workers in 1914 with a binocular capacity limited to around a hundred per week.[18] Matters were little different with Watson which made gun sights, observation telescopes as well as medical and radiological products, and its binocular capability was much the same as Ross'.[19] Aitchison & Co. had even less capacity. Its binoculars were actually made by the Wray Optical Co. Ltd of Bromley, Kent, in which Aitchison held a minority shareholding.[20] Although Wray had built a new factory specially to handle Aitchison's new War Office contracts, its average weekly output was only thirty instruments.[21] It was five miles from the old one and by no means conveniently located for the existing

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[15] See Chapter 4 above.
[16] F. A. Carson, *Basic Optics and Optical Instruments* (Mineola, NY: Dover, 1997) pp. 10-32 to 10-45 explains the intricacies of binocular manufacture and the need for precise collimation..
[17] National Archives, Kew (subsequently PRO) MUN 4/745, Orders placed for Scientific and Optical Instruments, and PRO MUN 4/5305 to 5313, Contract Cancellation files, for details.
[18] Dewar (1921), p. 221., and PRO MUN 4/745, section on Ross Ltd, p. 45.
[19] PRO MUN 4/745, section on W. Watson & Sons Ltd, p. 57.
[20] A. W. Smith, *Wray (Optical Works) Ltd 1850-1971: a short history* (unpublished MS, undated, Bromley Local Archives Collection ref. L37.8/BN 107426), pp. 1-5 provides the source material for this section unless otherwise indicated.
[21] PRO MUN 4/745, section on Aitchison & Co. Ltd, p. 2.

workforce. Built in a small wood 'in fields a long distance from mains electricity cables' it depended for all its power on 'a single 12 horsepower gas engine' whose reliability was uncertain: 'if the gas engine stopped, the [entire] factory stopped'. The works was by no means self sufficient, there was no foundry for casting binocular bodies which consequently had to be bought-in, and despite its recent opening the whole operation was too small to expand its output substantially without large-scale building and extra plant.[22]

Carl Zeiss (London) Ltd, was the British subsidiary of the German company and had been in a kind of commercial limbo since the outbreak of war.[23] Most, if not all, of its German supervisory workers remained at the factory and the War Office had continued placing modest orders, but in early 1915 all the German nationals were interned and the business placed in the hands of a Controller appointed by the Board of Trade, who then engaged Ross to oversee the running of the works. The small size of the operation and its now-fragmented management were quite unsuited to handling any greatly increased workload and, like the other British binocular makers, the business was unable materially to increase overall output.

The main problem was the lack of capacity in an industry that was quantitatively rather than qualitatively inadequate. That difficulty was not unique to British optical munitions manufacture. Even Zeiss, the world's largest optical producer, was unable to keep up with German demands. Although civil production was abandoned and the total workforce increased from 5,200 in 1913 to a war-time peak of 9,800, Zeiss could not maintain the substantive monopoly of government supply it had before the war.[24] Nor could Goerz, the next largest optical munitions producer, make up the shortfall. The German government was forced to draw other companies into the manufacture of binoculars once it became apparent that the peace-time capacity of the specialists was inadequate.[25] From a situation of supposed surplus in August 1915 when, according to

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[22] PRO MUN 4/5006, Reports on Optical Munitions Output, Technical Inspection and Labour Branch, Weekly Reports, 1915-1918: Report 12.7.1917.
[23] see Antje Hagen. 'Export versus direct Investment in the German Optical Industry', *Business History*, October 1996, for background material to this.
[24] F. Auerbach, *The Zeiss Works* (1924,) p. 266.
[25] H. T. Seeger (1996) pp. 83 to 100.

official *History* the German government offered to exchange binoculars and telescopic sights for supplies of rubber, the German optical munitions industry progressively worked harder to keep up with its orders.[26] Despite having the world's largest optical industry, Germany still experienced problems with binocular output, even though they were less severe than in Britain.[27]

Esslemont had to devise a suitable strategy for the British problem. It became clear that a radical approach was needed because substantial short term improvements in deliveries were unlikely. Efforts to purchase French binoculars were hindered because that industry was no better prepared than Britain's to handle huge orders.[28] A promising source of supply in the USA was thwarted because the War Office objected strongly to the design of the instruments being supplied by the Bausch & Lomb company, principally because it did not conform to the constructional details specified for domestic contractors since 1909. Despite achieving a delivery rate averaging 400 hundred a week – then more than the capacity of all the British contractors together – on a contract for 20,000, the Chief Inspector of Optical Stores refused to move from the established technological paradigm and would countenance no further orders, materially adding to the supply problems of the OMGD, which lacked the power to over-rule him.[29] By the end of 1915 the problem was pressing hard and the industry itself was clearly incapable of providing a solution.

The OMGD was in favour of changing how the optical industry worked. Frederick Cheshire was convinced of the need for transformation through economic and educational changes directed at the existing firms which, in his judgement, were held back by a combination of educational and technological inadequacies. Esslemont, however, espoused a different approach, based on the premise that the root of the problem lay less in technological backwardness than in organisational shortcomings that could be overcome far more quickly. The radical solution proposed for 'the supply of

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[26] *OH* Vol. XI, Part 3, p. 42.
[27] H. T. Seeger (1996) pp. 19 to 26, and pp. 83 to 100.
[28] M. E. W. Williams, *The Precision Makers: a History of the Instruments Industry in Britain and France 1870-1939* (London: Routledge, 1994) pp. 72 to 79.
[29] PRO MUN 4/745, section on Bausch & Lomb, p. 7, and PRO MUN 4/5528 letter from A. S. Esslemont to Sherwood, 6.10.1916. See chapter 1 above for comments on the influence of technological paradigms in the British Army.

binoculars under the scheme for development of home supply of these instruments' envisaged creating an entirely new factory in which would be concentrated the vast majority of British binocular production, and its novelty is emphasised because the idea originated neither within the OMGD nor the optical industry itself.[30]

During late 1915 Esslemont began discussions with A. Kershaw & Sons Ltd in Leeds, West Yorkshire, a business that was not in the optical trade at all. The firm had successfully made film projectors for the cinema trade, mechanical components for cameras, and complete camera bodies which were supplied to other companies for sale under their own names, none of which involved optical manufacturing.[31] When the war began, the firm began making gun clinometers for the War Office and phased out civil products to cope with the increasing volume of Government work.[32] By Spring 1915 the business had effectively become a munitions contractor under the Defence of the Realm Act, a status confirmed when the Munitions Act became effective in July. The Ministry of Munitions' classification of products fortuitously brought gun clinometers (which actually had no optically worked parts) under the control of the OMGD, and so introduced Abraham Kershaw to Esslemont. Although Kershaw had clinometer orders of 500 per week, the instrument was of relatively low value (shillings rather than pounds) and could be made by many precision engineering firms, so there was no question of monopoly in supply nor guarantee of an indefinite demand. What Kershaw wanted was a munitions product of substantial unit value which would be required in large numbers, because having been designated a munitions contractor under the Munitions Act his firm was unable to take on commercial work.[33] By late 1915 the binocular supply situation provided exactly the opportunity he wanted.

Kershaw's ideas interested the OMGD. He proposed that high volume binocular production could be attained by applying the principles and methods he had used

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[30] PRO MUN 4/672, Agreement between the Ministry of Munitions and Kershaw, 1916.
[31] N. Channing and M. Dunn, *British Camera Makers; an A-Z Guide to Companies and Products* (Esher: Parkland Designs, 1996) p. 63.
[32] Leeds Industrial Museum Library, Armley Mills, Leeds, W. Yorks, Kershaw material (unclassified): the papers left by Norman Kershaw (subsequently LIM/NK) provide the source material for the rest of this section unless otherwise indicated.
[33] PRO MUN 4/745, section on Kershaw p. 32.

successfully to produce complex articles which combined high precision components with others requiring no especially high standards of manufacture. To make the former he had used machine tooling and enforced rigid standardisation of parts, relying on a relatively small number of skilled machine operators and the elimination of hand fitting. For the assembly of parts he had been able to employ unskilled and semi-skilled female labour which was readily and cheaply available locally. Thus, a relatively small (and inexpensive) labour force of 200 was able to produce complex and precise items at competitive and profitable prices.

Kershaw had a purpose built factory less than four years old and fully equipped with machine tooling, some of which was housed in an 'air conditioned and temperature controlled' environment. He had financed this through selling a 47 percent share in his company to the Marion Co. Ltd., a London photographic wholesaler for whom he already made camera bodies to Marion's own designs.[34] In exchange for transferring some trade names and a monopoly use of some patented designs, Kershaw obtained a substantial cash injection and a guaranteed buyer for those designs whilst retaining control of the business, a deal that seems to have been almost entirely to his own benefit and identified him as very much the man of 'push and go' that typified the then current ethos at the Ministry of Munitions.[35] Despite his enthusiasm for applied technology and his business acumen, Kershaw had no academic background or training of the type being advocated by Cheshire as essential for the advancement of the optical industry, a lack that seems to have been no impediment to his relationship with Esslemont.

Kershaw's combination of character and ideas suited Esslemont's needs, as well as Cheshire's wider aims to improve the optical instrument trade. The key element in Kershaw's plan was the extensive association of women workers and automated methods which he claimed would allow an eventual output of a thousand binoculars every week, equal to the pre-war output of the Zeiss works. His proposal also accorded with the Ministry's desire to side-step labour practices that restricted output and was firmly

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[34] Channing and Dunn (1996) p. 63.
[35] R. J. Q. Adams, *Arms and the Wizard; Lloyd George and the Ministry of Munitions 1915-1916* (London: Cassell, 1978) Chapter 4 'The men of push and go'.

committed to the 'dilution' of labour. One of the main purposes of the Munitions Act had been to secure the agreement of Trade Unions to relax the restrictive practices that excluded unskilled and semi-skilled labour – particularly women – from craft trades, but the largely London-based optical industry was firmly against introducing female workers, arguing that their use would be seriously counterproductive.[36] The OMGD had difficulties overcoming this argument about maintaining output, particularly as Cheshire's pleadings to keep the trade outside control used the same underlying logic of maintaining production at all costs, and its efforts to dilute workforces in London had met little success.[37] As Kershaw was not involved in the optical trade and already used a mixed labour force, his proposals provided the welcome promise of creating a precedent to weaken the general opposition to the widespread introduction of women into the established optical companies.

Kershaw's approach could not have been better timed or structured. Esslemont was willing to move outside the prevailing optical industry paradigm which considered instrument making to be the province of experienced skilled workers, and was happy to follow this new initiative. His thinking was more broadly based than Cheshire's, which remained concentrated on transforming the existing trade rather than creating a new purpose-designed war industry. Esslemont asked Kershaw to 'draw up a schedule' for the construction of an entirely new factory and its necessary tooling, and to define his ideas about how best to employ both the machinery and labour in it. Subsequent events illustrated what could be done when 'The Ministry of Munitions more or less [provided] a 'carte blanche' budget...'.[38] Unlike the Aitchison/Wray expansion in 1914, this venture enjoyed not only the benefit a very large State subsidy, but also had a significantly better location. Kershaw found a suitable site less than a mile from the existing factory (whose workforce would form the nucleus of the new one) in a populous area well served by public transport and already providing a large pool of female workers for nearby large clothing factories.

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[36] *OH* Vol. XI, Part 3, p.18.
[37] see Chapter 6.
[38] LIM/NK, p. 2.

The site purchase was completed on 1st April 1916, and on 3rd May a formal agreement was signed under which the Ministry provided a 'grant' of £20,000 for the project, which carried terms and conditions.[39] Half the money was repayable, and as security a charge was taken on the land as well as the buildings and plant to be erected on it.[40] The conditions included maintaining a 'technical and commercial staff sufficient to ensure the manufacture of binoculars in the most scientific and skilful manner possible' and 'to train and use the service of [British born] unskilled and female labour to the utmost extent possible', both of which were implicit in Kershaw's original proposals. For Kershaw, this was a deal that was potentially even better than the one with Marion in 1910, and which emphasised the symbiotic nature of his relationship with the OMGD. The firm's share of the starting costs could be off-set against high war-time taxation, the expected volume of business was considerable, and when the war ended Kershaw would have a large factory completely equipped for large volume high precision optical and mechanical engineering. In return, the OMGD hoped to obtain a resolution of its binocular problems.

The contract issued to Kershaw on 15th June was the largest single binocular order placed by the OMGD during the war, but its wording suggests that it was meant to be the first of a series. It called for 25,000 instruments to be delivered at an escalating weekly rate, reaching at least 600 by 31st October 1916 and running at a thousand 'hereafter'.[41] Ministry records show 'running' contracts regularly followed initial orders, often prolonging the first one for several years.[42] Contract 94/T/1039 also points at a 'reverse salient' condition on whose solution Esslemont was forced to depend for the success of the Kershaw project, which was itself intended to form the major part of a broader scheme to increase binocular supply.

Esslemont's 'broad front' was the increase of binocular output, and his immediate 'reverse salient' the inexperience of Kershaw with optical work. The production of a

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[39] *OH* Vol. XI, Part 3, p. 26 provides source material for the rest of this section unless otherwise indicated.
[40] PRO MUN 4/672, Agreement between the Ministry of Munitions and Kershaw. Unfortunately, only a summary of the actual document survives.
[41] PRO MUN 5/312, Orders for Scientific Instruments &c., Binoculars, Prismatic, p. 5.
[42] PRO MUN 4/745, for examples see sections on Beck, Ross, and Watson.

thousand binoculars required ten thousand individual lens elements and four thousand prisms, besides two thousand individual body castings, four thousand lens cell assemblies and similar numbers of other simpler metal parts.[43] Although the mechanical work was broadly familiar, teething troubles were expected with the lens work which would be new to Kershaw. The OMGD expected pilot work to be begin in the existing factory, and to provide optical sets initially, Esslemont intended to use experienced lens makers who had enough spare capacity to make binocular optics. These would feed Kershaw until its own output built up sufficiently and then carry on supplying lenses to another factory which the OMGD proposed as a second, though smaller, producer of binoculars.

The OMGD identified six potential makers, and the department's technical advisors liased with them in developing satisfactory optical sets.[44] Cooke's of York, The Guaranteed Lens Co., Adam Hilger, the Hummel Optical Co., J. & H. Taylor, and Taylor, Taylor & Hobson were engaged to make standardised eyepiece and objective lenses after June 1916. All of them found it difficult to satisfy the rigorous inspection criteria imposed by the Army's Chief Inspector of Optical Stores at Woolwich (CIOS) and there were delays in obtaining enough even to supply Kershaw's initial requirements. In February 1917 Taylor, Taylor & Hobson were delivering enough sets to allow Kershaw to begin assembling complete instruments in the recently finished factory, but the capacity to make and assemble bodies was far in excess of the supply of optics. By April, just 491 binoculars had been accepted by the CIOS, and Kershaw still had to reach the stage of being able to produce acceptable lenses itself. Only one of the six lens makers had reached an acceptable standard, and the lack of lenses was threatening to cripple the binocular expansion programme.

Esslemont's 'reverse salient' had not been dealt with, for reasons largely to be found within a second problem whose solution was already assumed when the Kershaw project was set in motion. The principal cause of delays lay in the supply of optical glass, whose

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[43] *OH* Vol. XI, Part 3, pp 26 to 28 provides details.
[44] MUN 4/5006, Reports of the Experimental Section, CM6, on optical munitions, various dates in 1917 and 1918.

quality was still by no means assured. The broad issue of optical glass production during the war is too large to be covered in this study, but some salient points must be noted. The official *History* devoted considerable space to glass supply and the MacLeods accepted the *History*'s verdict that early problems were satisfactorily overcome, but this picture is not wholly correct. Despite the progress made through Esslemont's efforts, the quality of certain glass types was particularly difficult to ensure, and during 1917 the inconsistency of those needed for binocular lenses was a constant source of trouble.[45] These problems were mainly responsible for holding back output of binocular lens sets in the first part of 1917, and were only eased by the OMGD's eventual decision to seek alternative glasses from France, and the subsequent improvement in Chance's quality control.[46]

Matters began to improve after May, when a Kershaw trial lens set submitted to the OMGD was judged 'remarkably good and quite up to the standards of any [yet] submitted'. A week later, the OMGD finally passed a similar trial set from Cooke's, noting that this extra source 'should ease the situation so far as Kershaw's troubles are concerned.[47] From then on output began to grow, with increasing numbers of binoculars being assembled using Kershaw's own lenses besides sets from Cooke's and Taylor, Taylor & Hobson. By October the factory was getting into its stride using production methods copied from the former Zeiss works at Mill Hill, as well as numbers of specially built machine tools designed in Kershaw's own drawing office, based on samples obtained from Mill Hill where they had been redundant since Ross bought the works from the Board of Trade earlier in the year.[48] By the autumn of 1918, weekly output had reached 800 and was still increasing when the instructions to scale down production were issued by the Ministry when the war ended as part of the process of industrial demobilisation.[49]

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[45] *OH* Vol. XI, Part 3, pp. 25 to 28, and R. and K. MacLeod (1975) pp. 172-175.
[46] PRO MUN 2/1, Secret Weekly Report 29.3.1917.
[47] PRO MUN 4/5006, Weekly Reports, 24.5.1917.
[48] LIM NK p. 3, and Hagen.A. "Export Versus Direct Investment in the German Optical Industry." *Business History*, no. 4 October 1996, p.7.
[49] LIM NK p. 3.

Although delayed in reaching its goal, the Kershaw binocular project was a successful collaboration between the OMGD and a firm that was innovative and soundly organised. It proved that Kershaw's faith in the transferability of his working methods from movie projectors to binoculars was entirely justified. The delays caused by glass problems were outwith his control, and it is clear that once deliveries improved the factory was able to work up to the high production rates that had been promised at the start. Dilution was achieved on a level not found anywhere else in the optical munitions industry, particularly in women workers. Where Ross employed around 17 percent female labour and Barr & Stroud 16 percent, Kershaw's figure was 80 percent, a substantial proportion of which was 'girl labour' aged under 18, a figure which 'seemed to astound the optical trade at that time'.[50] The earlier claims by London firms that women would create catastrophic wastages in lens making were refuted at Leeds, where 'very young' girls were trained to operate polishing machines within a matter of hours.[51] The cost of a Kershaw binocular was lower than other makers, and by October 1918 the OMGD was proposing to discontinue lens deliveries from Cooke's and Taylor, Taylor & Hobson, partly because of Kershaw's output and partly because costs at Leeds were expected to be 'cheaper than other contractors'.[52]

Kershaw's success was not duplicated elsewhere in war-time binocular manufacture. Only one commercial company was set up during the war especially to manufacture them, but five existing businesses became newly involved in production, and one State-sponsored assembly factory was started.[53] Sherwood & Co. appeared in 1915 in response to War Office demands and continued to produce about fifty binoculars a week until the Armistice, when soon afterwards it ceased trading. The OMGD asked Beck to make binoculars in December 1915, but the contract was subsequently suspended to increase dial-sight output and, according to the firm, none were actually made. Dollond & Co. began production in mid-1916 producing about twenty a week, and the ophthalmic lens makers Theodore Hamblin Ltd. took an order for 2,000 in June 1916 which was

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[50] LIM NK p. 3.
[51] Dewar (1921) p. 222.
[52] PRO MUN 4/5006, Weekly Report 29.10.1918.
[53] PRO MUN 4/745 provides source material for the rest of this section, unless otherwise indicated.

completed by 1918, after which they began making for the Admiralty. H. F. Purser Ltd. began production in February 1916, making around twenty per week until the end of the war. E. R. Watts & Son had an order for a thousand in January in 1916, which were made at only five each week. The amounts these firms added to output were minuscule. Apart from Sherwood, all seem to have been induced to take up production at the time when the OMGD was faced with a very large shortfall in output and when, perhaps, anything was better than nothing. None of them ever had any large potential, but the final newcomer, the State-sponsored factory J. Brimfield & Co., was originally intended to do much better.

Esslemont had intended that the lens makers feeding Kershaw would quickly divert deliveries to another new factory intended to supplement Kershaw's production. This involved a different approach, with the Ministry setting up a new company known as J. Brimfield & Co., not to manufacture parts but to be a central assembly station for binocular components. The costs of 'equipping and fitting' the factory were met by the State, and all its raw materials provided free of charge. Brimfield would subsequently invoice the Ministry for assembly on the basis of labour and overhead costs plus a fixed percentage for profit. Although smaller than the Kershaw, its output was intended to be considerable, and five thousand binoculars were ordered on 28th July 1916, to be delivered at an increasing rate, with a minimum of 100 weekly being attained in less than two months.[54] The surviving records show even that rate was never attained. The plant was dogged by the same lens delivery problems that had affected Kershaw, and poor mechanical quality led to very high rejection rates by the CIOS.[55] Output seems to have been very small, and by the end of the war Brimfield was only taking in enough prisms to make twenty five binoculars a week, a rate similar to many of the private contractors.[56]

Brimfield's failure to live up to expectations was almost an irrelevance by the Armistice. The firm was never intended as a permanent part of what Cheshire hoped would be an improved post-war instruments industry, and Kershaw's increasing efficiency tended to

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[54] *OH* Vol. XI, Part 3, p. 26.
[55] PRO MUN 4/5006, Weekly Reports, 1918.
[56] UGD 295/4/132, Letter Book, H. D. Jackson to Brimfield, 15.3.1919.

make the venture redundant. Binocular production in the war had been something of the proverbial curate's egg, and it is probable that far fewer than the 300,000 binoculars 'demanded' were actually delivered by the Armistice. But, by then a factory to make them on a scale previously unimagined in Britain was running with increasing efficiency and the worst that should be said of binocular production was that high volume production came better late than never.

6.4 The telescopic rifle sight

Volume was not the problem with the telescopic rifle sight. This was an instrument not found in the British Army before 1915 and its mass production was never required. Intended for use by specially selected soldiers on a small scale, it presented a very different manufacturing problem than the binocular.[57] Accounts of its inception and manufacture have been misleading and discredit the ability of the optical munitions industry. Roy and Kay MacLeod asserted that the industry was unsuccessful in producing telescopic sights until the OMGD and the National Physical Laboratory jointly attacked the problem in 1917, but that was not so.[58] The origins of its introduction in early 1915 have been examined by Ian Skennerton who clearly demonstrated that that regular small-scale production actually pre-dated March 1915, but failed to emphasise the achievement that represented.[59] The telescopic rifle sight (riflescope) was one of the most successful applications of optical munitions technology during the war, and showed that the war-time industry was capable of meeting design and production requirements when an appropriate manufacturing infrastructure existed. Unlike binoculars, where the production capacity had to be created, the riflescope was needed in small enough quantities to be manufactured within the available resources.

In late 1914 War Office issued an invitation to tender for a telescopic sight to be used with the Army's service rifle. This was in response to the German employment of

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[57] see Martin Pegler. *The Military Sniper since 1914* (Oxford: Osprey Publishing, 2001) for background information on the employment of snipers.
[58] *OH* Vol. XI Part 3 p. 9ff., and R & K MacLeod (1975), pp. 184-185.
[59] See Ian Skennerton, *The British Sniper*, (Margate, Queensland, Australia:1984) Chapters 2 and 3 for background material.

specially selected marksmen using such sights, which was causing mounting casualties and significantly affecting morale in the absence of any satisfactory means of retaliation. The requirement could hardly have come at a more difficult time for the optical industry, because no such instrument was being made in Britain on a regular and organised basis, and growing demands from the War Office were increasingly occupying its capacity. Imported riflescopes were certainly sold through the gun trade, some with British makers' names on them, but there was no domestic source immediately able to supply in quantity.[60] Although riflescopes were similar in concept to artillery sighting telescopes, the firms making those were pre-occupied with a variety of work and none of the existing patterns were suitable or adaptable to the new requirement. Unlike either binoculars or periscopes, the immediate problem was one of design.

Although all the optical munitions makers were capable of devising a riflescope, only two companies actually submitted designs judged worth adopting by the War Office, and neither had any previous connection with optical munitions. Aldis Brothers of Birmingham made photographic lenses, and the Periscopic Prism Company of Camden Town chiefly made lenses and prisms for the optical instruments trade. Neither had any government orders in late 1914 and unlike most of the industry both were actively seeking optical work. Coincidentally, each had already done sub-contracting for Barr & Stroud, and both had been rejected by that firm because of inadequate quality.[61]

Despite its adverse testimonial from Barr & Stroud, Aldis was well regarded for its camera lenses and appears to have been far distant from Cheshire's depiction of an industry whose workshops were little more than shanties. The business had begun manufacturing in Sparkhill, Birmingham in 1902 and was owned by two brothers who were mathematicians and both graduates of Trinity College, Cambridge. The elder, Lancelot, had worked at the Dallmeyer optical works and was already an accomplished

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[60] Skennerton (1984) p. 34 illustrates examples but leaves their manufacturers uncertain.
[61] UGD 295/4/112, Letter Book, Jackson to Chance Brothers, 7.12.1914, criticises Aldis, and UGD 295/4/110, Letter Book, Jackson to Periscopic Prism Co., 25.8.14, threatens to cancel all orders.

lens designer familiar with the latest in glass technology.[62] His younger brother, Arthur, joined him in partnership soon after being elected to a fellowship at Trinity in 1901, then worked briefly for Dallmeyer before returning to Birmingham where he became interested in automated methods of lens manufacture. He subsequently spent time in Germany studying production methods, which resulted in the partners investing in automatic lens polishing machinery bought from the Ahlberndt company of Berlin. By 1912 the business was doing well enough to start building a factory equipped for both optical and mechanical work at Hall Green, away from the polluted atmosphere that was interfering with lens grinding.[63]

The new works was completed just before the war began, and by 1915 Aldis Brothers' catalogue included twenty seven different photographic lenses and two for photo-micrography, all designed and made wholly in-house.[64] The OMGD was subsequently 'agreeably surprised' to learn that the firm had both a 'large and well equipped lens factory' and a 'scientific staff' able to tackle the problems of optical design.[65] The brothers' design of the riflescope can be seen as endorsing Cheshire's emphasis on the benefits of scientific training in optics and the combination of a thorough grounding in mechanical engineering with a modern well-equipped factory. Within weeks a design (which was certainly not a copy of any existing type) was finished and satisfactory samples provided for the War Office, resulting in an order for a first 'batch' of the 'Pattern No.1' riflescope in January 1915.[66] Two hundred had been supplied and accepted before July when the OMGD took over responsibility for deliveries.[67] By then, Aldis had already suspended photographic lens production and, like Kershaw, become a *de facto* optical munitions contractor. On 7th July the OMGD contracted to take the

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[62] J. S. Carter, *An Historical Analysis of the Development and Application of Visual and Aural Aids in English Education from 1900 to 1970* (unpublished Ph.D Thesis, University of Leeds, 1995) p. 292.
[63] *Aldis Brothers & Their Productions* (Aldis Bros., Sparkhill, Birmingham, undated but probably circa 1920.) p. 3.
[64] *The British Journal Photographic Almanac* (Liverpool: Henry Greenwood & Co., 1914) Aldis advertisement.
[65] *Aldis Brothers*, p. 5.
[66] Skennerton (1984) p. 47.
[67] Skennerton (1984) p. 47.

'entire output' of the works at a minimum rate of 60 weekly, an arrangement that was increased when Aldis later began making other sighting telescopes.[68]

The haste with which the sight was designed, and Aldis' unfamiliarity with weapons may have led to a number of mechanical shortcomings which affected the instrument's durability which caused problems in service. The vibration of firing loosened the range-adjusting mechanism, and penetrating moisture caused fogging; either rendered the sight unusable and the OMGD's Technical Section recognised that re-design was necessary to eliminate them. The Aldis brothers may have been highly competent in computing lens systems, but they had no previous experience of series-producing telescopes and the Pattern No.1 had been put into manufacture without any proper engineering drawings – not through incompetence, but almost certainly because the scale of future demand was not envisaged. In late summer, the likely requirements were far clearer, and OMGD decided to standardise an improved version for larger scale production. By mid-November, prototypes of the revised design had been made by Aldis and accepted, production drawings were finished by the Technical Section less than three weeks later, and manufacture proceeded without further significant technical problems until a decision in 1918 to adopt a completely new design sponsored by the Army itself.

Aldis was an excellent example of how well the war-time optical munitions industry could perform. By building on a base of existing sound scientific and technological practice, and drawing on the resources of the OMGD to bridge gaps in its own pre-war organisation, the firm successfully moved from being a small scale civilian maker of photographic lenses to become a large and highly specialised maker of complex service optics. Its factory was extended twice during the war and by the Armistice it was six times the area of 1914, producing not only riflescopes but derivatives of them for aerial gunnery, as well as large numbers of artillery sighting telescopes. Experience gained with them was used to design a novel electrical Daylight Signalling Lantern (the 'Aldis Lamp') which used a reflector and lens system to create an intensely bright point source of light that could be seen at long range even in the strongest daylight. The lamp needed

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[68] PRO MUN 4/745, section on Aldis Bros., p. 2.

to be aimed precisely to permit the observer to see it, and an inexpensive but durable aiming telescope was designed for it. By late 1917, the firm's capacity was large enough to allow the Aldis brothers to compute new lenses especially for high altitude aerial photography, and to begin production on a substantial scale. The spin-off of munitions contracting provided Aldis with the basis of its post-war civil products; the range of photographic lenses was extended and the Lantern sold widely to both merchant ships and foreign governments.

The second riflescope maker, the Periscopic Prism company, is less well documented. Like Aldis it was quick to produce a design because one of its directors, A. B. Rolfe-Martin, combined optical design skills with an interest in rifle shooting. Even if the quality of its riflescopes was less good than Aldis', it was numerically the larger maker and its products were still adequate for the tasks set. Over 4,400 had been made by April 1917 and production continued until the war's end, by which time the firm had been taken over by the State and was also making sighting telescopes for artillery.[69]

Riflescope production hardly taxed the industry at all. Those used throughout the war were made by just two firms who met the Army's requirements with little trouble and marked a success for the optical munitions industry. Their importance to the psyche of front-line units was out of all proportion to the relatively small numbers made and the value of the contracts. The total of around £70,000 spent on the 10,000 or so purchased during the entire war was less than three-quarters of the first binocular contract placed with Kershaw, and only a twentieth of what the War Office spent on rangefinders with Barr & Stroud, but the instrument was recognised as vital to effective sniping by front line officers and simply had no substitute. In theory, it would have been used most effectively by a team that included a rangefinder to determine distances precisely, but the tactics of trench warfare sniping meant that ranges were relatively short so that precise

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[69] PRO MUN 4/745, section on Periscopic Prism. Co., p. 41 provides contract details, and *OH* Vol. XI, Part 3 p. 23 describes the take-over.

sight settings were not critical, and the need for the portable rangefinder to accompany it never materialised.[70]

6.6 The Rangefinder.

The man-portable rangefinder was by far the most complex item of optical munitions to be mass produced during the war yet, in an apparent paradox, it was the instrument that posed the least problems in supply. And, ironically, it may well have been the least important optical device in the static conditions of the Western Front where the need to determine distances rapidly was highly uncommon. But, unlike the other optical devices used by the services at the start of the war, the capacity to mass produce rangefinders already existed with Barr & Stroud whose records reveal much about its attitude to war-time contracting and the difficulties encountered.

Rangefinder production was the most successful part of the war-time supply of complex optical munitions and neither the Army nor the Navy suffered a shortage of instruments. Barr & Stroud's pre-war capacity was already considerable in August 1914, and the suddenly increased War Office orders then were, to some extent, off-set by the enforced termination of foreign business which enabled output more or less to keep up with growing demand. As orders continued to grow, the company expanded both its premises and workforce and kept pace with demand whilst simultaneously carrying on research and development into new manufacturing processes and instruments, a pattern of activity not found elsewhere in the British industry. Moss and Russell gave an overview of the firm's war-time activities, but they concentrated on its dealings with the Royal Navy and almost totally ignored the company's much greater involvement with Army orders, firstly directly from the War Office and later from the Ministry of Munitions.[71]

Land service business was indeed substantial, being 80 percent more in value than the Admiralty's during the war.[72] Moss and Russell's total of approximately 19,300 rangefinders supplied agrees closely with the official *History*'s figure of 3,730 artillery

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[70] Pegler (2001) p.22.
[71] Moss & Russell (1988) Chapter 3.
[72] These figures have been extracted from Customer Order records in UGD 295/19/2/4, /19/2/5 and 19/2/6.

models and 15,782 infantry ones, a total of 19,512.[73] Prices varied but little during the war despite inflation, with their approximate average values being £80 and £58 respectively.[74] This gives a total value of almost £1,214,000 which compares tolerably well with the £1,362,000 extracted from the company's surviving order records.

The production requirements for each service's orders were quite different and handled separately. The Army's small rangefinders were needed in vastly greater numbers than the large naval ones and posed manufacturing problems similar to the binocular. The rangefinder was far more complex, but most of its components could (in theory at least) be made rapidly, as could those for the binocular. Barr & Stroud's serious problems in getting enough optical parts in the first year of the war have been discussed in Chapter 5, but as its own lens and prism production increased the main factor restricting output became the assembly of completed parts, where large numbers of workers were needed to achieve rapid deliveries of completed instruments. Like the binocular, most of the assembly could be done by semi-skilled workers with relatively little training, but finding enough hands was still a problem and manning shortages grew throughout 1915.

By the end of the year Harold Jackson was complaining that it was difficult 'explaining to athletic young men that ... making tiny prisms is as valuable to the Country as sticking a German with a bayonet'. As in other industries, it was hard to keep men away from the colours, and the OMGD promised to send Barr & Stroud an open letter explaining to the workforce how vital the firm's output really was to the war.[75] But neither the letter nor subsequent posters could persuade the young to eschew the bayonet and by Spring 1916 the shortages, although not critical, were sufficient to require some urgent remedy. The only new source of labour available had never been used previously by Barr & Stroud, to whom the idea of having women in the factory was a somewhat problematical novelty.

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[73] Moss and Russell (1988) p. 80, *OH* Vol. I, Part 1, Appendix II p. 145, and *OH* Vol. XI, Part 3, Appendix III, p. 133.
[74] From UGD 295/19/2/4, /19/2/5 and 19/2/6.
[75] UGD 295/4/625, Letter Book, Jackson to Esslemont 27.12.1915.

Unlike much of the London optical industry, it is clear that the firm had no prejudice against women, but where Kershaw employed them for 80 percent of its workforce, Barr & Stroud never had more than 16 percent on its payroll.[76] Whatever Trade Union opposition existed was dealt with through the mechanism of the Munitions Act, and the relatively small percentage actually employed resulted from the firm's wish to use female workers to the best advantage. Unlike Kershaw, where 'girl labour' was widely employed and where workers were expected to be able to carry out straightforward machine-minding tasks within only hours of starting work, Barr & Stroud intended to employ women on a variety of work including fine and skilled operations such as scale dividing and engraving. Because it planned to draw on those who had either never worked outside the home or had been employed in retail or similar trades, the firm recognised that the first, and possibly greatest, difficulty in employing women would be in their adjustment to a factory environment that was greatly different to anything they had known previously. Those engaged were 'specially selected from a large number of applicants' and were originally required to 'go through a short course of training ... to accustom [them] to factory life' before instruction began in a special Training School teaching skilled operations such as milling, scale dividing and even tool grinding. This was far-removed from the earliest private initiatives to draw in female labour described by Arthur Marwick, when, for example, the Ladies Moir and Cowan had begun training 'leisured ladies' for part-time weekend work at Vickers' Erith works in Kent.[77]

Barr & Stroud saw women as potentially an asset to be directed at specific skills shortages, but they were by no means the first Glasgow munitions makers to adopt such ideas and might possibly have been encouraged by the steps taken in 1915 by William Beardmore & Co. to train women for skilled engineering work.[78] Even though the ambitious training programme had to be curtailed in deference to the Ministry's policy of not delaying the 'introduction of large numbers', women were still given individual instruction in the optical and fitting shops where their performance was judged 'as

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[76] UGD 295/26/1/14, Strang Papers, historical notes concerning women workers 1916-1918, provide the source material for Barr & Stroud in the remainder of this section, unless otherwise indicated.
[77] A. Marwick, *Women at War 1914-1918* (London: Fontana, 1977) p.60.
[78] A. Marwick (1977) p. 60.

efficient as men'. Unlike some Glasgow engineering firms, such as the ordnance makers William Beardmore & Co., which took a considerable time to provide even the most basic facilities for women,[79] Barr & Stroud planned their integration from the outset and went to considerable lengths to provide for it in order to maximise the benefits of the new labour force. Separate 'Cloak room' facilities were provided in 1916 for the 300-plus women workers expected, and a full-time 'Matron' appointed to look after 'the women's welfare and interests in every way' outside the workshops. According to Harold Jackson's post-war summary of the exercise, there were few difficulties in the workshops themselves, and the quality of work done by relatively inexperienced female operatives was generally highly satisfactory and their attitude to their jobs 'more assiduous' than their male colleagues.

Labour problems were managed more easily than optical glass. Its shortage and inconsistency was a different sort of problem, and although never so bad as to bring production to a halt it caused difficulties right up to the war's end. In late 1916 Barr & Stroud began small scale production of the most problematical glasses as part of a policy to make the firm increasingly independent of the outside supply of raw materials and components, measures which were so successful that by 1918 almost the only important remaining external requirement was for the most common glasses that were required in bulk. Deliveries of these were still difficult even in late 1918 but, by careful management and complaining vociferously to the OMGD, stocks usually remained high enough to keep production going.[80]

Rangefinder supply ran continuously throughout the war. Both the Army and the Royal Navy were adequately supplied and Barr & Stroud had enough capacity to overhaul large numbers of instruments damaged in service, running and staffing a workshop at Woolwich just to handle Army work. Far from being worn-out in November 1918, the firm was further expanding its works to handle new Admiralty orders and was undertaking optical computation on an increasing scale. Where in 1914 the vast majority

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[79] A. Marwick (1977) pp. 61 – 67.
[80] UGD 295/14/634, Letter Book, Jackson to OMGD agreeing to take on extra contracts.

of optical components were bought in, four years later the business was entirely independent of other sources for grinding and polishing and so well equipped to handle large scale production that it was ready to begin supplying the U.S, forces in Europe.[81]

Despite the success of rangefinder production for both services, it was initially seriously inhibited by the War Office's attitude to the company. The War Office proved a difficult and obstructive buyer, and a crisis in output was averted only by the creation of the Ministry of Munitions which acted as a buffer between maker and user. The subsequent relationship between the company and the OMGD provides an alternative to the picture painted in the official *History*, where the industry is portrayed as the beneficiary of State assistance.

When the War Office began its large orders in the Autumn of 1914, it sought to impose conditions under the provisions of the Defence of the Realm Act that the firm considered irksome and disruptive, and which greatly prejudiced the prospects for output. The War Office demanded priority for its orders over all other work; the Defence Act gave it the legal power to do so, but it seemingly remained oblivious to the problems created by such insistence, particularly when it sought to extend its primacy over Admiralty orders as well. Firstly, it prohibited the export of more than 15 rangefinders each week to France, despite existing orders and that country's urgent need for them. Then in January 1915, the War Office instructed Barr & Stroud to end its efforts to secure the U. S. Navy's future rangefinder business, in order to concentrate on output for the British Army. Objections were fruitless: 'The War Office has even threatened to take over the control of our works' wrote Jackson to his American agents with ill-concealed bad humour.[82] The next month the War Office totally forbade the shipping of any rangefinders to France, disrupting an inter-governmental agreement to obtain French optical glass in exchange for uninterrupted deliveries of rangefinders and bringing

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[81] UGD 295/19/2/6, Customer Order files, CO4000 of 22.8.1918 records an order for 300 artillery rangefinders for U.S. Army.
[82] UGD 295/4/114, Letter Book, Jackson to Keuffel & Esser, New York, 8.1.1915.

repercussions from the French government which temporarily ended all supplies of the optical glass on which rangefinder output largely depended.[83]

To the company, the War Office was a difficult and obdurate customer. It demanded priority in all things, disregarded all the firm's commitments to the Admiralty and Allies alike, frustrated opportunities for new foreign business, and yet failed to take up everything that the firm had available for delivery. By June relations had deteriorated to the point where there was open distrust of the War Office's good faith in Glasgow, and Jackson believed that it intended to buy artillery rangefinders from Bausch & Lomb in the USA rather than in Britain.[84] The War Office was far from an ideal client, and what must have been particularly irksome to Barr & Stroud was that the value of its business since August 1914 was still only two thirds of the Admiralty's in the same period and far less than France's had been in 1913.[85]

The arrival of the OMGD ended this imbroglio and illustrated the pragmatic approach it frequently adopted. Cheshire and Esslemont both understood that irrespective of their duty to organise supplies for the Army, the Navy's need was equally great and could not be obstructed. The OMGD immediately instructed that dealings with the Admiralty should be done directly and independently of contracts for the War Office.[86] This permitted the firm to keep the Navy's business adequately prioritised and doubtless eased problems in proceeding with Admiralty work. Then, in July, Cheshire visited Glasgow, marking the start of what seems to have been an amicable and symbiotic (if asymmetrical) relationship between the firm and the OMGD.[87] So far as control was concerned, the company showed no sign of opposition to it. Jackson had no doubt that *de facto* War Office control had existed since December, so that the prospect of dealing

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[83] PRO BT 66/1/MMW 11, Nature of Demand for Optical Glass: minute from OMGD to Ministry of Munitions, 8.7.1915, warned of a likely embargo on French deliveries if rangefinder deliveries were again suspended.
[84] UGD 295/4/10, Letter Book, Jackson to Major Benson, Royal Artillery, Woolwich,28.6.1915.
[85] Extracted from UGD 295/19/2/3, /19/2/3 and /19/2/4, Customer Order files.
[86] UGD 295/4/625, Letter Book, Jackson to Director General Munitions Supply, 17.7.1915, acknowledging instructions.
[87] UGD 295/4/625, Letter Book, Jackson to Cheshire, 23.7.1915, acknowledging arrangements for visit.

with a new and more accommodating agency was likely to have been an agreeable prospect.[88]

The correspondence between Cheshire and Esslemont and the firm shows that they regarded both the company and its senior staff as their organisational and intellectual equals, rather than seeing them, like the rest of the optical industry, as being in need of assistance and direction. However, this sentiment was by no means wholly reciprocated, and the company's records indicate that it sometimes felt that the OMGD itself required instruction and correction. It may have helped the firm's confidence to know that almost its entire Board had academic credentials better than the OMGD's management and that the business was indisputably the world's most successful maker of optical munitions.

In August, Esslemont asked Barr & Stroud for 'private and confidential' details of its experiences with British optical glass, and Jackson's reply dealt at length with both the commercial and technical difficulties in dealing with Chance Brothers.[89] His strong assertion that unsatisfactory business structure rather than scientific inadequacy was the root of Chance's manufacturing problems went beyond what had been asked for, and was a theme that Esslemont subsequently took up not only with the glass maker but also in his later approach to binocular manufacture. In September, Jackson called for a 'firms' conference' to examine the problems of overcoming the lack of optical glass and skilled optical labour, which Esslemont duly organised.[90] Jackson's summary perhaps made uncomfortable reading for the OMGD. He questioned Esslemont's confidence in guaranteeing adequate glass deliveries and reminded him that increased output at Glasgow depended on Barr & Stroud itself being able to develop 'machines and methods' for the successful use of unskilled labour, in view of which he firmly refused to commit the firm to further increases in production, whatever their importance or urgency.[91]

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[88] UGD 295/4/119, Letter Book, Jackson to Senechal, 12.7.1915 complaining of effects of War Office control after December 1915.
[89] UGD 295/4/625, Letter Book, Jackson to Esslemont,9.8.1915.
[90] UGD 295/4/625, Jackson to Esslemont, 18.9.1915.
[91] UGD 295/4/625, Jackson to Esslemont, 21.9.1915.

At the same time he promised to help Frederick Cheshire to give a lecture on rangefinders by providing background technical information to fill gaps in his knowledge. Jackson sent the material and 'a little model' with the firm's compliments and a gentle reminder that virtually every European army already had both the information and the model, including 'the Technische Militar Komittee [sic.] in Berlin'. In a tactful postscript he added 'If Mr Esslemont is jealous [of the model], I shall be pleased to send him a duplicate'. Jackson perhaps considered that Cheshire just was starting on a steep learning curve. [92]

It is difficult to see any other British firm taking these attitudes. But then Barr & Stroud was in many ways the embodiment of what Cheshire was prescribing for the whole optical industry – a soundly managed, well financed and profitable business that used scientifically trained staff, modern plant and manufacturing methods, employed a motivated and well managed workforce and which was, above all, demonstrably successful against foreign competition. It was therefore ironic that Archibald Barr himself did not see the firm as an optical instrument maker, or indeed any kind of scientific instrument maker; he was absolutely certain it was an engineering company that employed optical components and the war only served to confirm this long-standing conviction.

Barr emphasised this by refusing to connect the firm with other optical manufacturers. He repeatedly turned down invitations to have the firm represented at informal trade gatherings in London early in the war, and declined to join a proposed scientific instrument makers' federation in July 1915 because

> 'honestly (and privately) we do not feel disposed to place ourselves in any way under obligation to abide by decisions made by those who are possibly under very different conditions from our own'. [93]

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[92] For the preceding quotations see UGD 295/4/625, Jackson to Esslemont 9.8.1915. The 'little model' was of an infantry soldier using a Barr & Stroud rangefinder. Cheshire's lecture subsequently won him the Optical Society's Traill-Taylor Memorial Medal for advances in optics. For the learning curve, see UGD 295/4/625, Jackson to Esslemont, 22.10.1915; Jackson to Esslemont and Cheshire, 26.10.1915.
[93] UGD 295/4/118, Letter Book, C. Beck to Barr, 3.6.1915.

Eventually he drew a line under attempts to persuade him join similar bodies by very firmly declining not only the offer of the Vice-Presidency of the newly formed British Optical Instrument Makers' Association but even membership of it. He was not 'disposed to associate' the firm because 'our work is so very different...' from other optical makers.[94] With 1,500 metal workers to just one hundred optical workers both the firm and its work were indeed as different as the way it achieved its success.[95]

6.7 Conclusion

The optical munitions industry's efforts in the three areas examined here embraced degrees of success that differed in their completeness and scale. The binocular and riflescope were both instruments not previously produced in great quantity or at high speed in Britain – indeed, the riflescope had only been made in minuscule amounts. Both were manufactured during the war by firms who had no previous experience with them, the riflescope being made with much more conspicuous success largely because the numbers needed were relatively small and well suited to the sort of optical manufacture typical of British pre-war practice. But that practice was not the skilfully distorted image that Cheshire deliberately fostered to achieve a long-term goal, rather it embodied both scientific training and commercial expertise that could adapt well to a new specialised requirement when that need fitted in with the existing capacity. Aldis in particular built on its inherent skills to become a much larger entity, making a wider variety of instruments than it did before the war; it benefited from its war work and 'span' into its own growth. Success in volume binocular production was harder to find because the lack of any adaptable facility meant everything had to be created from scratch, and although clearly in sight by the end of the war the promised high output rate was still not achieved. The characteristic of the riflescope makers in being strangers to the product was emphasised in Kershaw's manufacturing background, and extended by a considerable degree through his complete unfamiliarity with optical work. But Kershaw showed that his production methodologies could be successfully translated into a

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[94] UGD 295/4/740, Letter Book, Barr to C. Beck, 8.5.1916.
[95] UGD 295/4/625, Letter Book, Jackson to Secretary of Ministry of Munitions, return of workers employed, 20.7.1915.

different field and, had the supporting infrastructure that Esslemont gambled on been in place, the project would have doubtless fulfilled its promise sooner. Unfamiliarity was shown to be no bar to successful manufacture.

The rangefinder was a very different case to the others. Barr & Stroud showed that the transition from peace to war production was still problematical even when the business was both experienced and well equipped to handle large scale output. This was partly because of the unexpected scale of the war, but partly because the firm's incomplete vertical integration left it vulnerable to a supply structure which was much weaker than the body it fed. The scale and organisation of the business allowed a metamorphosis sufficient to eliminate most of its vulnerability and it reached the end of the war in a condition almost universally improved from mid-1914, able to design and manufacture a wider range of more complex instruments with a greater level of efficiency. Barr & Stroud needed little help from the OMGD, except where issues were essentially political such as War Office policy in 1915. If this chapter has said relatively little about problems in rangefinder manufacture for the Army, it is because there is really little to say; even if the job was problematical, the goods were delivered in sufficient numbers to satisfy the immediate demand.

In early November 1918, the British optical munitions industry was working at high speed and full capacity, and in all the cases examined preparing either to further increase output or introduce new and improved instruments; the Armistice on 11th November apparently took all the manufacturers by surprise and created what was little short of chaos. The next chapter examines the reasons why that situation came about and examines how the industry dealt with it.

Chapter 7

Industrial demobilisation and implosion, 1919

7.1 Introduction

For the optical munitions industry, the end of the war came unexpectedly and prematurely. Irrespective of the political desire to end hostilities and the sentiments being voiced in the press, it had been very much 'business as usual' right up to November 10th 1918.[1] There had been no scaling-down of contracts and no warnings from the Ministry of Munitions of any imminent likelihood of cancellations. All the manufacturers were wholly employed in the war effort and had not even begun to consider in practical terms their policies for industrial demobilisation and a return to peace-time trading. The efforts of the Ministry to set the optical industry on a better footing had not yet reached a stage where substantial improvements in organisation or infrastructure had been achieved. The pre-war optical instruments industry had been conscripted and metamorphosised into the war-time optical munitions industry with some considerable success, but nothing had been done to cater for the inevitable end of large-scale government orders. For the hugely expanded industry, the transition back to peace was a difficult process. Its constituent firms had to come to terms with the disappearance of government business and the problems of making up the lost demand from a civilian market which had gone into suspense in 1914. The 'demobilisation' of the war-time industry highlighted the incomplete state of the Ministry of Munitions' efforts to improve the condition of the optical industry, and reflected the companies' collective inability to cope with the organisational and financial problems which the war had generated.

The war had gone a long way towards the creation of an effective (and clearly identifiable) optical munitions industry, or a 'technological system' of manufacture. The widespread changes imposed by the closing-down of war-time demand may be interpreted as being simply a deterministic outcome of returning peace, but they were by no means uniform across the whole industry and the behaviour of Barr & Stroud in particular, suggests that, once again, the 'more flexible mode of interpretation' espoused

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[1] See Lorna S. Jaffe, *The Decision to Disarm Germany* (London: Allen & Unwin, 1985), Chapters 2 and 4.

by Thomas Hughes' most closely accords with events. Even where firms made the transition back to peace with little success and much difficulty, they still had to cope with the 'plethora of variables' mentioned in the introduction to this study, attempting to manage a range of political, economic and social factors besides the scientific and technical ones relating directly to the products of artefacts.

7.2 The problems of total mobilisation

The Great War had drawn into optical munitions manufacture firms which previously had little or no experience in the field. Their pre-war business had come from manufacturing microscopes, survey apparatus, photographic lenses and telescopes, trade which had gradually vanished as the Ministry involved more and more of those businesses in military manufacturing. The result was that these 'conscript suppliers' lost not only their pre-war business, but also close contact with the markets for that business. The Ministry's contract records show that almost all the pre-war 'commercial' optical makers had become so involved with government contracting that by November 1918 they were completely dependent on orders for the armed forces. Mobilisation of the optical instruments industry was, in a sense, complete. Not only had these businesses put aside their familiar products, they had also been forced to adopt changes in their workforce and methods of production. The demand for instruments and components on a scale previously unknown, along with the necessity to use less-skilled labour, had meant that new machinery had been introduced and what often amounted to an entirely new work-force had been created at the Ministry's instigation. This should have placed the makers in a good position to move back into the commercial marketplace, but under guarantees given to Trade Unions in 1915 and 1916, those who had worked in the industry were guaranteed re-employment at the war's end. Those returning from the war were ill-prepared for a changed factory environment, even if there was work for them to do.

Although the optical industry had indeed been transformed by the war,[2] this metamorphosis had been directed to meeting the war's demands, and little or nothing had

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[2] see Chapter 6 above.

been done to develop commercial products. The potential for more efficient manufacture was compromised or negated by four years of stagnation in design and civil product development. Although there was concern in the Ministry for the industry's long-term future, measures to secure that future were still only partly formed by late 1918. The cessation of war-related orders left the 'conscript' makers in a problematical situation where they had neither government business nor commercial trade to rely on.

Two of the three firms which had been most involved in optical munitions manufacture before the war – the 'regular' contractors – had also made commercial products as well. Like the 'conscripts', Ottway &Co. Ltd. and the Ross Optical Company were suddenly faced with the problems of returning to peace-time trading in civilian markets. Barr & Stroud, however, had no civil products before the war and relied entirely on armament related business which had come principally from foreign states. The ending of large scale munitions contracts posed an even greater potential problem for Barr & Stroud than it did for the other war-time makers, all of whom had at least some previous experience of the civil trade in optical goods. For everyone, though, the immediate problem was disengagement from government contracting and securing the best possible financial settlement for cancelled contracts.

7.3 The Ministry of Munitions' plans for demobilisation

The placing of contracts by the Ministry of Munitions had been done under rules which safeguarded both the State and the manufacturers, providing for the amendment of contracts, as well as their early termination. In the event of the latter, there was the right to compensation for the manufacturer, so long as he was not in breach of the contract's terms.[3] Many were very substantial, with lengthy periods for completion. They represented a steady source of business for which payment was never in doubt, and to which firms frequently tailored premises, machinery and workforce. Despite the apparent security and certainty of munitions work, the contractors should have understood that it was by no means immune to curtailment or cancellation, but events after the Armistice

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[3] See Great Britain, Ministry of Munitions, *Official History of the Ministry of Munitions* (London: HMSO, 1922) Vol. III Part 2 pp 112-143 for details of contract termination procedures.

suggest that these eventualities had been disregarded or forgotten. Contract cancellations began on November 12th,[4] and for the Ministry's Contracts Department, it appears that the start of the Armistice was synonymous with the certain end of the war.

This immediate cancellation of optical contracts was in line with the general policy that had been given 'much attention' by the Ministry of Munitions 'for many months before the Armistice'.[5] The greatest problem identified by the Committee on Demobilisation and Reconstruction in connection with the War's eventual end was the cancellation of contracts no longer required 'with minimum disturbance to industry and labour', with the settling-up of contractors' accounts as the next most important matter to be dealt with. Two alternatives for the termination of orders had been considered in depth before a decision was reached that was intended to be applied universally across all munitions production. The first possibility was to begin by slowing down the tempo of output and then to reduce the scale of production so that contracts would go through a gradual process of arrest, spreading the rate and scale of redundancies over enough time to let civil production resume and absorb the munitions workers who would be progressively released from war-work. That process would be helped by what was expected to be high levels of demand for consumer goods after the shortages of the preceding three years. The second, more radical, option was to discontinue munitions contracts 'at the earliest possible moment' whatever the immediate effect on the labour market, in the expectation that rapid freeing-up of capacity for civil products would encourage a quicker reversion to pre-war conditions. The final choice was for the instant discontinuation of war contracts because it was felt that it was 'undesirable that the output of useless munitions should be continued a day longer than was absolutely necessary', a principle the Committee decided could safely be applied once it knew that 'unemployment allowances would be paid to civilian war workers after demobilisation'. The basis on which the Ministry of Munitions then made its plans was that reversion to peace-time production

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[4] National Archives, Kew, (subsequently PRO) MUN 4/5308, Contract Liquidation Records, shows responses to cancellation notices dating from November 13th, i.e. to correspondence which must have been written on the 11th or 12th .

[5] *OH* Vol. II, Part 1, 'Administrative Policy and Organisation', Supplement, p. 16; pp. 15 to 19 provide source material for the rest of this section, unless otherwise indicated, and pp 20 to 42 other background material.

had primacy, and that considerations of the subsequent effects on labour were 'not preponderating'.

It seems that so far as the optical industry at least was concerned, there was no knowledge of this policy, and the Ministry's own historian conceded that 'arrangements for demobilisation were not complete' by the Armistice. However, the plans for immediate contract terminations obviously were in place, and they went into operation without delay, to the consternation of the optical makers.

7.4 Contract cancellations and their effects

The immediate and sharp reactions clearly illustrate the extent of the optical industry's dependency on government orders. R & J Beck, probably the country's second-largest optical munitions contractor, wrote to OMGD on the 13th that the cancellation of their Dial Sight and Trench Periscope contracts would cause 'the immediate lay-off of 1,300 men'.[6] To avoid this, Beck asked for 'an arrangement' whereby the contracts could be run-down rather than cut off short. Six days later, the Ross Optical Company, which shared Dial Sight contracts with Beck as well as having other large orders, told OMGD that the Contracts Department's instruction that all supplies were to be discontinued within three months meant that about half their 700 employees would be thrown out of work.[7] Like Beck, Ross asked for help in avoiding this. E. R. Watts & Co. (one of the many 'conscripts') said their entire working capital of £10,000 was tied up in optical munitions contracts, and they had no civilian orders at all. Adam Hilger Ltd, a much smaller firm, warned that it would immediately have to make thirty redundancies and then progressively to dismiss 'all the optical glass workers . . . engaged by us during the war'.[8] Serious problems were rapidly emerging.

These contract terminations were almost certainly made without prior liaison with OMGD, possibly because of the incomplete state of the Ministry's planning. The optical

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[6] G. A. B. Dewar, *The Great Munition Feat 1914-1918* (London: Constable, 1921) p.222, and PRO MUN 4/5308, , letter R&J Beck to OMGD, 13.11.1918.
[7] PRO MUN 4/5308, letter, Ross Optical Co. to OMGD, 19.11.1918.
[8] PRO MUN 4/5308, letter, Hilger Ltd to OMGD, 21.11.1918.

section, having worked hard towards improving the industry's overall condition, showed immediate concern over the potentially damaging effects of sudden large-scale cancellations.[9] As early as the 15th, there were discussions with the Treasury about whether contracts could be slowed down to allow a transition from war work and minimise redundancies.[10] Whilst insisting that it could not 'deal preferentially with any trade except for a very short period' the Treasury conceded that there was actually no objection in principle as the industry was a 'new one', although a decision needed to be taken quickly about 'the subsequent course' for its future. On the 18th, the Minister of Munitions asked for a schedule of likely redundancies, to which OMGD replied that although it was not possible to produce an exact figure, 'the total number of employees in the whole of the optical and scientific industries is only about 10,000'.[11] The Minster was assured that 'arrangements' would be made to minimise losses, but there was no hint of what these would be.

There was ambivalence in OMGD's response to the question of redundancies. On the one hand was the desire to minimise the effects of cancellations, but on the other was the clear suggestion that the problem was of limited scale. If there were 'only about 10,000' workers involved, then the scale of the problem could be regarded as small by the Government, with the implication that its solution might not be expensive or controversial. This was an echo of Frederick Cheshire's strategy in approaching the question of overhauling the industry in 1915 – the deliberate management and presentation of truth to create an image which would facilitate a desired outcome. A letter from R & J Beck to the Controller of Optical Munitions on November 18th said that the firm had been told to propose a scheme 'to keep a reasonable number of our hands employed and to prevent our disbanding an efficient organisation which might be of service for assisting the reconstruction of the optical industry'.[12] Beck's letter did not say by whom the instruction had been given, but a reasonable assumption is that it came

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[9] Nothing seen in the PRO MUN contract cancellation files has shown any collaboration over cancellations prior to the Armistice.
[10] PRO MUN 4/5308, minute, P. G. Henriques to H A Colefax, OMGD, 15.11.1918.
[11] PRO MUN 4/5308, minute, G. Garnsey to H A Colefax, OMGD, 18.11.1918.
[12] PRO MUN 4/5308, letter R. & J. Beck to Controller Optical Munitions Supply, 18.11.1918.

from OMGD's Administrative Director, and was intended to support a case for holding together as many skilled workers as possible.

It was apparent that the vast quantity of optical munitions on order for Britain and her Allies was no longer needed and that almost all contracts would have to be ended prematurely. Although the industry was bound to be adversely affected, there were safeguards which provided for compensation payments when a contract was terminated by the State.[13] An 'Optical Munitions Liquidation Committee' was set up to manage the cancellations, and by the end of November it had delivered a report.[14] Its responsibilities were to decide which contracts to close, which, if any, to maintain, and to scrutinise the performance of companies which might be eligible for payments under the termination provisions. To qualify for compensation payments or 'liquidation amounts', a maker not only had to have suffered a contract's premature ending, but also must not have been in default of its terms. A series of 'preliminary investigations' was started to assess whether, from the State's point of view, contactors had actually complied with the terms and conditions of the orders placed.[15]

This may have been sound practice, but because of the often confused placing and revision of orders, any rapid and accurate assessment of compliance was likely to be extremely difficult. OMGD appreciated the situation many of the contractors found themselves in, and had what might loosely be termed a 'vested interest' in their survival and future prosperity. There was an inclination towards supporting the makers in their appeals for financial assistance, although as will be shown, OMGD was by no means blind to the failings of some of them. The Liquidation Committee, on the other hand, was looking for evidence of non-compliance, and had no brief to assist the contractors.

The first to be scrutinised in detail were Beck and Ross. Other firms had been subjected to 'preliminary reports for liquidation [of contracts]', but on November 29th the

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[13] *OH,* Vol. I, section 2 details these safeguards.
[14] PRO MUN 4/5313, Contract liquidations, summary of decisions made by Optical Munitions Liquidation Committee, 29.11.1918.
[15] PRO MUN 4/5313, summary of decisions.

Liquidation Committee decided that 'Special Investigations should be made on Ross and Beck . . . at the earliest possible date', probably because of their large contracts for the expensive artillery 'Dial Sight No. 7', whose liquidation involved very considerable sums of money.[16] The Controller of Optical Munitions advised that the Ministry was 'obliged under outstanding contracts' to take an additional 4,550 sights at a cost of £230,000, whether it wanted them or not.[17] After rangefinders, dial sight contracts had been the largest in value and were the Ministry's greatest liability. They had been numerous, subject to much amendment, and were a mixture of 'running' ones (calling for minimum delivery rates over an indefinite period) and those for a specified quantity (not always with a delivery deadline).[18] For Beck and Ross, this was valuable long-term business, and its premature ending must have been viewed with great concern. Compensation provisions gave less than the full value of the contract, and a 'War Break Clause' allowed the Ministry to escape from the contract altogether under certain circumstances; evidence of default in particular would absolve the Ministry from any liability for payment.

If the Liquidation Committee was hoping for a verdict against the contractors, it must have been greatly disappointed by the findings of the 'Special Investigations'. The investigators reported in less than three weeks, not just on Beck and Ross but on all the other firms that had been subjected to 'preliminary investigations'. The Liquidator commented that

> . . . practically none of our contractors have been able to maintain the contracted rates of delivery in view of the pressures put upon them by this department – investigation clearly shows that default has not been due to negligence or circumstances within the control of the contractor.[19]

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[16] MUN 4/5308, Contract liquidations, sundry correspondence and MUN 4/5313, Liquidation Committee minute, 29.11.1918.
[17] MUN 4/5308, Controller OM to Sir W. Graham Greene, 4.12.1918.
[18] PRO MUN 4/745, Orders Placed for Scientific and Optical instruments etc, provides examples of such contracts and their delivery terms.
[19] MUN 4/5308, Liquidator's note to Liquidation Committee, 20.12.1918.

It is tempting to think that the Special Investigators examined the sheaves of contracts and alterations held by the manufacturers, shook their heads in disbelief, and then went back to write a diplomatically worded report that exonerated the trade whilst not specifically blaming any one party at the Ministry. To establish a case for default would have required detailed and necessarily long investigation of each individual contract. The report simply pointed out what everyone connected with optical munitions supply already knew – that the process of procurement and supply during the war had been characterised by pressure and confusion, had been immensely complicated by shortages of capacity, raw materials and labour, and not infrequently exacerbated by delays in acceptance by the Army through squabbles over the minutiae of quality control.[20]

The report may have been made more acceptable, or even encouraged, because by then 'the labour situation was so difficult' that the Minister of Labour was asking Liquidation Officers 'to avoid any action which might result in violent dislocation'.[21] Arrangements for paying unemployment allowances were still not in place, and there was a belated recognition that, as the Armistice was still no guarantee that hostilities were finally over, it would be imprudent to disperse 'the means of production' prematurely. Those fears had disappeared by the start of 1919, and the process of termination resumed after a brief but important check that bought some small measure of relief to the optical industry.

Having accepted, for whatever reasons, that there were no general grounds to escape paying for prematurely terminated contracts, the Liquidator of Optical Munitions Contracts told OMGD in early January that 'the general policy is [now] to close down contracts for [all] stores not required by mid-March [1919]'.[22] The Army's drastic reduction meant the ending of practically all War Office orders as demands rapidly fell to pre-war levels. The policy from March was to be one of ordering 'commercial articles' instead in order to aid civilian industry. For the 'regular' optical munitions makers, this was hardly a blessing. Although the War Office might support civilian industry by

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[20] see Chapters 6 and 7 above.
[21] *OH,* Vol. II, Part 1, Supplement, p. 17.
[22] PRO MUN 4/5308, Edmund Batty to T. Knowles, OMGD, 10.1.1919 supplies this and the following quotation.

ordering off-the-shelf products, the amount of 'commercial articles' the War Office would need for its optical inventory was virtually nil. Specialised optical munitions were held in very large quantities and requirements would be minimal for the foreseeable future, so that the specialist capability of the firms drawn into optical munitions work was now redundant. It required little prescience to recognise that British military contracting would support none of the war-time 'conscript industry' and by no means all of the 'regulars'.

Although compensation payments had been virtually guaranteed by the Liquidation Committee's findings, the instructions to cease production meant that skilled operatives would be without work until new business was found, and employers were unable and unwilling to pay an idle workforce out of limited and dwindling resources. Firms urgently needed some means to keep trained workers productively employed whilst attempts were made to recover their pre-war business and slowing down contracts would have been helped to do this. In fact, the Controller of Munitions Supply had told OMGD on December 16th that although all contracts extending beyond eight weeks were to be terminated he now had authority to slow down optical contracts 'instead of using the guillotine'.[23] As his remit extended far beyond optics, this suggests that the industry's need for some special treatment had already been recognised. However, on January 10th 1919, the Liquidator's announcement about closing-down contracts showed the policy had been revised and replaced by one of making cash payments instead, an alteration that compromised earlier intentions to nurture a 'new industry'.

The extreme situation of some firms is shown in surviving contract liquidation correspondence.[24] R. & J. Beck had no new designs for commercial markets; their technical design staff had been 'entirely engaged' on war work since 1915, and development of civil lines had been precluded. E. R. Watts & Son had become totally dedicated to war production and, having no free capital, was now 'financially embarrassed' with the loss of Ministry orders. The Ross Optical Company reported on

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[23] PRO MUN 4/5308 Minute, Controller to T. Knowles, 16.12.1918.
[24] PRO MUN 4/5308 and 4/5309, Contract Liquidation papers provides the source material for this section unless otherwise indicated.

January 20th 1919 that 'All our contracts are now cancelled and all manufacture thereon has been stopped.' Adam Hilger Ltd was in such a state that the firm's directors had applied to the Ministry of Munitions for 'relief in respect of hardship through cancellation of contracts . . .'. Dollond & Co. Ltd was 'totally engaged on government contracts' with over 4,000 prism binoculars in process of manufacture which were no longer required. These had prominent government ownership marks that were 'impossible to remove', eliminating any chance of selling them commercially even if buyers could be found. W. Ottway & Co Ltd summed up the generally depressing situation in mid-January, writing that since the Armistice their efforts to get orders 'all over the place', had produced orders totalling scarcely £100. Hard times had rapidly come on the optical industry.

The war-time optical munitions makers had not generally been extensively involved in government contracting before 1915. All the firms, excepting Barr & Stroud, had relied on commercial sales to some extent and all had particular areas of expertise.[25] For these firms, the problem was twofold; there was the matter of surviving until business could be recovered, and the need to scale-down both capacity and workforces from the levels generated by the war. Overlaid onto this need for transition were both staffing and financial difficulties rooted in the measures taken during 1915 to direct labour and control both profits and wages.[26]

Despite the business it had received, the industry was by no means cash-rich at the end of 1918. War-time profits had been geared to 1913/1914 levels which were taxed at increasingly higher rates and Excess Profit Duty levied on surpluses severely eroded retained earnings. The production of accounts during the chaotic conditions after 1915 was generally delayed, meaning that provision had to be made for still-uncertain but expectedly large amounts of taxation. Operating costs had risen steeply from 1914 levels, and the increasing rate of inflation, particularly in 1917 and 1918,[27] meant that many

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[25] See Appendix: List of Manufacturers.
[26] see *OH* Vol. I, part 2 for background details of this aspect of the control of industry.
[27] R. Twigger, *Inflation: The Value of the Pound 1750-1998* (London: House of Commons Library, Economics Policy and Statistics Section, 1999).

contracts had been far less profitable than expected when they were signed. Expensive additions to premises and plant had not always been funded by the Ministry of Munitions, and were financed either from cash reserves or with borrowed money bearing interest. Although the State sought to limit contractors' profits, it did not indemnify them against loss nor guarantee their liquidity.

The Ministry's now-incomplete contract records indicate that the scale of compensation payments was substantial.[28] Those seen show that Beck was due to over £180,000, the Ross Optical Company due to almost £83,000, and Sir Howard Grubb & Co. was owed £20,500 for parts and optical tools alone. E. R. Watts & Son asked for an advance of £6,500 to cover their immediate needs which was paid immediately and without demur, suggesting that the total owing was substantially more. There had also been many contracts placed independently by the Admiralty up to November 1918. Submarine periscopes, complex prismatic gun sights for warship turrets, and naval rangefinders were never ordered through the Ministry, even after it formally assumed responsibility for Admiralty requirements in July 1917. Barr & Stroud's records show its Admiralty orders by 1918 were considerably greater than War Office ones,[29] so it is reasonable to assume that Grubb, Ottway and Ross were also due to substantial amounts for Navy business.

These amounts became important in the process of withdrawal from large-scale government contracting because they represented palliative redundancy payments for almost the entirety of the war-time industry. They also marked the departure of all the 'conscripts' and some of the old 'regulars' from optical munitions work. But, large as the liquidation payments might have been, they were far from unencumbered. Their value was eroded by inflation since the time prices had been originally agreed, and by the need to make provision for still-uncertain taxation and profits duty. But the subsequent story

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[28] PRO MUN 4/5305 to /5313, Contract liquidation records contain much information. These figures are taken from /5308.

[29] University of Glasgow, records of Barr & Stroud Ltd, (subsequently UGD) 295/19/6/3, London Office papers, Admiralty Contract Cancellation file.

of those departed manufacturers is not within the boundary of this account and must be sought elsewhere .

7.4 Barr & Stroud *versus* the War Office and the Admiralty

Given the extent of the difficulties being faced by the more broadly based firms, it might be expected that Barr & Stroud would have been seriously concerned by its prospects as it had no civil business to fall back on, and the large-scale termination of contracts represented the loss of most of its work. The company was in a somewhat curious position in 1919. During the war it had extended its competencies and skills and become self-sufficient in virtually all aspects of the design and production of rangefinders so it was potentially even stronger and more competitive than it had been in 1914. Expansion and vertical integration into glass production and optical computation had removed the two main pre-war weaknesses, and, in theory at least, equipped the firm to move into optical work outside munitions contracting. On the other hand, the extended factory was set up entirely for ordnance manufacture and the company's expertise was wholly in making munitions related instruments which were marketed through processes quite unlike civil products. Although, as already described, Barr & Stroud was largely insulated from many of the immediate problems facing almost all of the optical industry, the firm was by no means immune to the difficulties of adjusting to a peace that was very different to that of 1914.

However, both its treatment and reactions were quite unlike those of the others, most of whom had signalled immediate and pressing problems. On November 15th, a meeting was held between Barr & Stroud's Harold Jackson, OMGD's administrative head, Mr Knowles, and a Captain Johnson who was presumably from the Ministry's Contracts Department.[30] Jackson was asked to give 'a considered statement' on the question of rangefinder manufacture and uncompleted orders. His summary indicates the complexity and confusion surrounding optical munitions ordering. Only a month before, it had been agreed that a large rangefinder contract be reduced from 2,000 to 1,500, but it was then decided that another 500 were actually needed to cover the 'immediate needs' of Britain,

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[30] UGD 295/4/635, Letter Book, H D Jackson to Controller of Optical Munitions Supply 20.11.1918, provides material for the rest of this paragraph.

Greece and the USA. The first contract was already being delivered, and uncompleted instruments were in such an advanced state of assembly that Jackson stated it would be 'inadvisable' to terminate manufacture. As for the other 500, he thought that the Ministry should agree to their completion, work having already started and the firm's costing methods not providing for 'an accurate estimate of accounts' until the entire order was completed. Barr & Stroud's opinion was that the Ministry should pay in full for whatever it had ordered, but unlike other makers, there is no evidence of desperation or embarrassment. On the 18th, Jackson indicated that the directors were happy to have the contract for a very large (and expensive) experimental coast-defence rangefinder cancelled, so long as the Ministry paid for all 'out of pocket expenses' incurred.[31] The company gave every impression of being in control of its affairs, although lay-offs were already starting.

The first were the female workers that Barr & Stroud had begun recruiting once the need for dilution became pressing in 1917.[32] Despite detailed planning for their training and integration, it was always clear that they were there only for the war's duration. On November 19th Jackson warned that redundancies were imminent and inevitable, advising them to seek alternative work before large numbers of other redundant women swamped the existing vacancies in traditional areas of female employment.[33] The next day he informed the local Employment Exchange of the first of a series of redundancies in the male workforce which would begin on November 30th. The women numbered approximately 400 out of a total payroll of about 2,000, but there is no surviving record of the rate at which they were released. Presumably their dispersal was rapid, because by December 31st, only 112 men out of 1,600 had been given notice,[34] which was a much smaller proportion of the workforce than the London firms had threatened to dismiss at short notice.

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[31] UGD 295/4/617, Letter Book, Jackson to OMGD, 19.11.1918.
[32] see Chapter 7 for details about female workers
[33] UGD 295/16/1/58, Personal Papers of Dr W. Strang: works notices.
[34] UGD 295/16/1/58, Personal Papers of Dr W. Strang: works notices.

This may have been because Barr & Stroud still had a considerable amount of Admiralty rangefinder and submarine periscope work. Over £140,000 of orders were placed during the first ten months of 1918, besides work in progress from the previous year's total of £264,000, and earlier contracts from 1916.[35] These were not affected in the same way as War Office orders, because they related to ship construction programmes rather than immediate issues to troops. Warships already fitting-out were in no danger of cancellation, even though the urgency of completion had disappeared, and would still need their outfits of rangefinders. Besides these, large numbers of anti-aircraft rangefinders were also on order for ships in commission as well as submarine periscopes for boats nearing completion, none of which seemed threatened with premature conclusion. In addition, the Admiralty had ordered a number of experimental long-base rangefinders and mountings for trials in an effort to solve the gunnery problems disclosed at the Battle of Jutland in 1916.[36] Although difficult to assess precisely, the total value of Barr & Stroud's Admiralty business in November 1918 must have been substantially in excess of half a million pounds, with a good proportion of it looking safe from cancellation.[37]

There was also a considerable amount of War Office work, not all of which was expected to terminate prematurely. Before allowing for cancellations and consolidations, some £292,000-worth of orders had been placed by the Ministry between March and October 1918, (excluding contracts to repair rangefinders) which meant that a proportion of the workforce could be kept employed, at least in the short-term.[38] Scarcely a week after the armistice, the company decided to extend the lease on its Woolwich Arsenal premises (where instruments for repair were prepared for shipment to Glasgow) for a year, clearly signalling it had no immediate fears of War Office business vanishing overnight.[39]

Nevertheless, there were still the problems of diminished government trade. The rangefinder contract discussed in November, for example, was worth over £100,000 and

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[35] Extracted from UGD 295/19/2/5 and /6, Customer Order files 1916-1919.
[36] UGD 295/19/2/5 and /6, Customer Order files 1918-1919.
[37] Estimated from figures extracted from UGD 295/19/2/6 and /7, Customer Order files.
[38] Extracted from UGD 295/19/2/6, Customer Order files 1916-1919.
[39] UGD 295/4/634, Letter Book, Jackson to R. T. Lacey at Woolwich, 19.11.1918

its early termination involved a substantial loss of profit even after compensation. In the meantime, deliveries continued and there was the question of payment for them. Established practice was for payment only after goods had been inspected and accepted at Woolwich Arsenal, a procedure which had always been subject to delays.[40] The Ministry had been persuaded (or bullied) into paying a monthly 'standard advance of £12,500' for instruments delivered and waiting inspection, but in January 1919 it proposed to terminate the arrangement.[41] The firm would have none of this, pointing out that dealing with the Ministry caused a 'very unsatisfactory' cash position, illustrated by a December debit balance to the Ministry of £37,921, plus another £50,000 for work in progress. Rather than terminating the advance, said Jackson, the Munitions' Accounts Office should increase it to £35,000. The Ministry would not accept Jackson's exhortation to be more generous, but it did maintain the existing arrangement until the final liquidation payment in May 1919.

Pressure on Barr & Stroud to accept cancellations on the Ministry's terms evidently grew. By the end of January, Jackson had refused to agree that no further deliveries would be accepted after certain dates, as well giving clear notice of Barr & Stroud's stance on the subject as a whole:

> We cannot . . . accept cancellation of contracts without compensation, more especially as the reason for non-adherence to original delivery dates has arisen from causes entirely beyond our control. If therefore any of our contracts are deemed to be cancelled . . . we reserve the right to claim full compensation.[42]

Jackson was quoting almost verbatim from the Special Investigator's report.

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[40] see Chapters 6 and 7 above.
[41] UGD 295/4/634, Letter Book, Jackson to Director Munitions Accounts, 21.1.1919, provides the source material for the rest of this paragraph.
[42] UGD 295/4/634. Letter book, Jackson to Liquidator of Optical Contracts, 27.1.1919, and UGD 295/4/634, Letter Book, Jackson to Liquidator, Optical Munitions & Glassware Supply, 31.1.1919.

The skirmishing continued, particularly over the large order for 2,000 rangefinders. In early March, Jackson told the Liquidator that if the Ministry had not 'interfered' then '. . . the full number of instruments would have been delivered, and presumably the full profit would have been made'.[43] The 'fair way' was for the Ministry to pay for all materials and labour used, plus the previously agreed 'oncost' factor of 70 percent, plus ten percent of that total for profit, and another ten percent on the grand total for 'royalty'. To show the firm's reasonable attitude to burdening the War Office with unwanted instruments, Barr & Stroud would then buy 'the balance of the undelivered rangefinders at an agreed price'.

The firm was asking compensation for some 650 instruments at the rate of £44.20 each, and its offer to buy them back amounted to £5,790, or less than £9 per rangefinder.[44] Even though far less than the cost price, it was no trifling sum, implying either that Barr & Stroud could easily afford the purchase, or that there was some client in mind for them. [If there was, no sale followed; many of them were still in store in the late 1980s when the company finally left Anniesland when they were given *gratis* to any employee who wanted one.[45]] By the 29th, the Liquidator had agreed to almost all the company's terms, except that he offered only 5 percent for 'royalty'.[46] Jackson stuck to the firm's guns; 'We think we are entitled to some special consideration', he said, as they had been 'inconvenienced' and in any case it was now 'very hard' to sell rangefinders. As a parting shot, he reminded the Liquidator of a Government notice following the Armistice saying that 'Contractors for war materials would be liberally [sic] dealt with'. By May 2nd, the Liquidator had apparently given way, and almost all the negotiations over War Office contracts were ended. Jackson then wrote that £21,377 had been agreed upon for the rangefinders and 'Everything is now settled I think, except for our claim for . . . binocular prisms'.[47]

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[43] UGD 295/4/634, Letter Book, Jackson to Liquidator, Optical Munitions & Glassware Supply, 4.3.1919.
[44] UGD 295/19/8/3, War Office file, papers on liquidation of rangefinder contracts 1919, Jackson to Liquidator, 8.4.1919 and 29.4.1919.
[45] Personal communication from Mr David Carson, head of Barr & Stroud's periscope department at the time of the move.
[46] UGD 295/4/634, Letter book, Jackson to Liquidator, Optical Munitions & Glassware Supply, 29.3.1919.
[47] UGD 295/4/634, Letter book, Jackson to Liquidator, Optical Munitions & Glassware Supply, 2.5.1919.

Although the Ministry had officially taken over responsibility for Admiralty supplies on June 30th 1917, Barr & Stroud continued to deal directly with the Navy over rangefinder contracts. Sorting out those cancellations was more protracted and difficult than for War Office ones, and only concluded in 1925 after much negotiation and not a few threats on both sides. Discussions began with the Director of Admiralty Contracts in August 1919 and displayed the firm's willingness to exploit its *de facto* monopoly position.[48]

Prices for war-time Admiralty contracts had generally been calculated on the same basis as for the Ministry of Munitions, the formula being 'labour costs + materials costs + oncost factor + profit + royalty'. During the war the profit and royalty elements were standardised at 10 percent each, with materials and labour being calculated being the actual prices. The 'oncost factor', devised in the 1890s to cover overheads and background expenses, was normally set at 70 percent. The firm remained content with this formula when negotiating settlements with the Ministry, but things went differently with the Admiralty.

Contracts made in 1917 and 1918 had sometimes departed from the usual arrangement, being made on the basis of a fixed sum to cover both the 'oncost', and 'profit and royalty' elements. In 1919, when these came under scrutiny for liquidation, Barr & Stroud became concerned that compensation payments would not – from the firm's point of view – fairly reflect the value of lost business. In August, Jackson pointed out that when made 'there was an expectation of a long period of continuous work' and that both wage and commodity costs had been lower.[49] Rising costs had 'rendered quite inadequate the sums originally considered fair and reasonable to cover oncost plus profit' so that some fixed-price contracts were already showing a loss, and others only a 'bare margin of profit' making it 'imperative' for the firm to ask for a revision of the prices.

The money involved was considerable, Jackson estimating in mid-September 1919 that the amount already owing on them was 'considerably over £50,000'. There were also a

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[48] UGD 295/19/6/3, Admiralty file, papers on liquidated and cancelled contracts, provides the source material for the following section, unless otherwise indicated.
[49] UGD 295/19/6/3, Jackson to Director of Contracts, 8.8.1919.

large number where even the basis for payment was still to be fixed. The company requested that all terminated contracts be settled on one basis irrespective of previous agreements, amounting to a retrospective increase in prices. To do this took no little nerve and showed considerable self-confidence because the fixed-sum contracts had been freely entered into, there was no legal ground for renegotiation, and by leaving open the matter of final profits the company had put itself in a weak position. As the client no longer urgently needed the instruments, Barr & Stroud's position might be considered to have been somewhat weak.

The initial response from the Contracts Department certainly showed no inclination to help, peremptorily demanding a full list of the contracts involved and the full disclosure of profit and loss accounts from 1913 to 1918.[50] In addition, the Director wrote that he was prepared to send the matter to the Treasury Contracts Committee which had the power to make a final decision against which there could be no appeal, implying that the firm might consequently find itself even worse off. Quite unshaken, Jackson sent only the list which information, he pointed out, the Director already had, and refused to provide accounts or balance sheets, saying 'We do not see that they can furnish any useful information'.[51] In fact, there were as yet no results for 1917 and 1918; like other firms, Barr & Stroud had found the war's chaotic trading conditions meant that accounts were not only difficult to prepare but largely meaningless without some means to disentangle the involvement of the Ministry of Munitions in day-to-day business and to allow for inflation.[52] As for the threat to refer matters to the Treasury, he urged the Director of Contracts to do that 'with the least possible delay', probably confident that the threat was hollow. (Having lit the touch-paper, the firm then had to watch it burn – a slow process which continued well beyond the boundaries of this study, lasting for six years before the Admiralty eventually settled all the claims virtually in full, paying out £356,808.)

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[50] UGD 295/19/6/3, Letter Book, Admiralty to Barr & Stroud 12.8.1919.
[51] UGD 295/19/6/3, Letter Book, Jackson to Admiralty, 18.8.1919.
[52] UGD 295/11/1, Balance sheets, profit and loss accounts, Jackson's working papers.

These apparently fraught negotiations with the Contracts Department had no immediate effect on work in hand although, as will be seen in the following chapter, the whole relationship between the Royal Navy and the firm came under scrutiny at the Admiralty and the nature of that association began to change. New orders in 1919 totalled scarcely £10,000 but there was still a substantial amount of other work from earlier orders in progress, submarine periscope and anti-aircraft rangefinder development was proceeding steadily and a set of experimental rangefinders for trials nearing completion.[53] Besides all this, the company was examining and reporting on war-time German instruments as they came into the Navy's possession, so that both technical staff and production workers were being kept busy for the moment.[54]

Although prepared to fight for as much as possible from its cancelled contracts, and although certain that a reduced level of Admiralty business would continue, Barr & Stroud – like all the other demobilised optical munitions contractors – was faced with a pressing need to secure additional work to avoid further contraction. Some of this might come from foreign navies which had been starved of up-to-date instruments during the war, but in early 1919 this was uncertain and hedged about with political considerations as the recent combatants considered their post-war positions. Diversification into civilian markets was one way for Barr & Stroud to hold its plant and workforce together.

Michael Moss and Iain Russell have given a useful 'broad-brush' picture of the firm's efforts at extending its product base immediately after the Armistice, and William Reid has described its attempts to manufacture and market binoculars.[55] These accounts point out the company's lack of experience in selling to non-government customers, indicate a lack of adept direction, and imply failure by suggesting that the resulting financial benefits were at best minimal and sometimes non-existent. However, scrutiny of the firm's records indicates that these attempts were never expected greatly to support the business, and that the concept of failure in commercial marketing is actually

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[53] Extracted from UGD 295/19/2/6 and /7, Customer Order files 1919.
[54] UGD 295/4/132, Letter Book, J. W. French to Archibald Barr, 3.5.1919.
[55] Moss & Russell (1988) Chapter 4, and William Reid, *We're certainly not afraid of Zeiss: Barr & Stroud Binoculars and the Royal Navy* (Edinburgh: National Museums of Scotland, 2001) Chapter 1.

inappropriate. The evidence strongly suggests that Barr & Stroud never saw any substantial future for itself outside optical munitions manufacture and that the apparent attempts at diversification were really efforts at internally-generating subsidies to support core activities in the lean times anticipated following the war's end.

William Reid considered that the decision in 1919 to start production of binoculars was not propitiously chosen. He maintained that this was 'the worst period in history to launch such a venture', as large quantities of war-surplus glasses came onto the market as soldiers returned home with improperly retained Army-issued instruments and War Office surplus stocks started to be sold off.[56] However, an official decision on the large-scale disposal of stores was not even made until 23rd September 1919, when the intention put before the Cabinet was that

> All Government Stores in the UK, and in every theatre of war and all ports whatsoever to be declared surplus forthwith and sold as soon as possible, excepting only sufficient to provide for the peacetime requirements of the Fighting Services and such duly authorised reserves as prudence may require in the interests of safety. . .[57]

The Government's desire was clearly to be rid of as much as possible in the shortest possible time, without regard to prices fetched:

> The intention is to release storage and circulate stores and materials without delay and for this reason sales should be effected even at reduced prices, rather than hold out for better results which would entail the retention of storage accommodation which the commerce of this country so badly needs, and which is hindering trade.[58]

Although there was the possibility of binoculars being put onto the market at very low prices in late 1919, this could hardly have been known by the company earlier in the

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[56] William Reid (2001) p. 22.
[57] PRO WO 32/4947, minute, Secretary, War Cabinet to Secretary, War Office, 23 .9.1919.
[58] PRO WO 32/4947, minute, Secretary, War Cabinet to Secretary, War Office, 23 .9.1919.

year. And, given the continual shortages of such instruments being complained about in the Ministry's own war-time weekly reports, the high war-time attrition rates, and the large quantities retained by the Admiralty, the notion of an avalanche of very cheap binoculars swamping the domestic market after 1919 cannot readily be sustained.[59]

Reid went on to account for the firm's decision partly through the expectation that the substantial pre-war German export trade in optical goods would not be resumed, and partly through 'restless ambition marinated in optimism'.[60] Neither of these suggestions stands close examination. In early 1919 there had been no indications from the victorious Allies that any peace settlement would restrict pre-war German trading activities and so embargo the manufacture or export of optical goods.[61] What was certain, though, was that the disruption of pre-war distribution and marketing structures suffered by the more important German firms in Britain meant at least a temporary lack of optical imports. Antje Hagen has described the extent of their pre-war activities and how the problems they faced subsequent to the Armistice in recovering lost assets and rebuilding their operations delayed the return of German-made instruments to the British market.[62] Far from being 'the worst period in history' to begin manufacturing binoculars, from Barr & Stroud's position the timing was not only good but even imperative. The decision to start in early 1919 had nothing to do with ambition or optimism but was rather the result of the firm's realistic assessment of its immediate needs and opportunities, combined with a piece of sharp commercial opportunism.

One of Barr & Stroud's biggest problems was the retention of its optical workers. Building a self-sufficient optical department had been difficult because precision optical working in Glasgow was unknown before the company set up its own glass-working shop. Unlike the London-based optical companies, which were concentrated geographically and effectively provided themselves with a pool of skilled labour, Barr & Stroud had never been able to recruit experienced workers locally. Before the war the

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[59] PRO MUN 4/165, MUN 4/166 and MUN 4/167, Weekly and Monthly Reports.
[60] William Reid (2001) p. 22.
[61] see Jaffe (1985) Chapter 4.
[62] Antje Hagen, 'Export versus Direct investment in the German Optical Industry' *Business History,* Number 4 October 1996.

business either had to entice workers from far afield or train new ones from scratch. In 1919, for the first time Barr & Stroud had a full complement of optical workers carrying out all the processes needed to make even the most complex rangefinders. Loosing them would put the business back to the unsatisfactory pre-war state when it depended on outside contractors who were frequently unable to work to the required standards. The only commercial optical product with sophisticated lens and prism systems similar to those of the rangefinder – and which had any prospect of being sold in substantial numbers – was the prismatic binocular.[63] It alone offered the chance of keeping the experienced optical workforce employed in the face of uncertain prospects for Government orders.

During the war, Barr & Stroud had contracted to make 120,000 prisms for the Army's 'Binocular No. 3'.[64] This was the first time they had been mass produced in Britain, and the firm had acquired considerable expertise in making the most expensive optical component of the binocular. When the war ended, the contract was incomplete, and a large number of prisms were still at Glasgow in various stages of completion. The rough-moulded glass blocks for them had been supplied, at the Ministry's expense, by Chance Brothers Ltd. When the prism contract was 'closed down', Barr & Stroud not only claimed compensation but also offered to buy the blocks still at Glasgow at well below cost, as well as tendering to buy a large number of binocular 'optical sets' (spherical lenses) from the Liquidator of Munitions Contracts.[65] With all the optical components to hand, the firm then needed only to provide the mechanical body parts and assemble everything. Binocular manufacture would thus initially be done mainly using components bought far cheaper than normal costs.

The decision to start production was not to satisfy any 'restless ambition' or even to enhance the firm's profitability, but to safeguard the future of the optical workshop and its skilled staff; as one of the firm's directors later wrote, 'something had to be done

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[63] H T. Seeger, *Feldstecher: Fernglaser Im Wandel Der Zeit* (Borken, Germany: Bresser-Optik, 1989), and F. Watson, *Binoculars, Opera Glasses and Field Glasses* (Princes Risborough, Bucks: Shire Books, 1995) gives background information.
[64] see Chapter 7 above.
[65] UGD 295/4/635, Letter Book, Jackson to Controller of Optical Munitions Supply, 4.3.1919.

immediately for the sake of the optical workers . . . one of the objects of the decision was to keep at least some of the [optical shop] machines in operation'.[66] The binocular project was the product of what was, for Barr & Stroud, a typical combination of altruism and pragmatism. The desire to provide employment for the optical shop went beyond a philanthropic ideal in wanting to do something simply for the sake of the workers. Disbanding a large proportion of the skilled optical hands would have severely weakened the ability to handle future munitions contracts and the venture was conceived principally as a way of holding together skilled operatives who would subsequently have been almost impossible to replace. The directors, through shrewd recognition of the potential utility of newly-surplus prisms and lenses, set about creating what amounted to an internally generated subsidy to keep the optical shop in existence.

The company also began making 'Kinematograph' machines.[67] These cinema film projectors were by no means alien to Barr & Stroud's munitions products. Besides an optical system, they used geared driving and other mechanical components which were related to the mechanisms in the rangefinders already being made at the factory. The firm's machine tools and its workers' skills could readily be applied to their production, and it was expected that demand for them would quickly begin to increase substantially.[68] The Ross Optical Company and A. Kershaw & Sons Ltd., both optical munitions makers during the war, also made similar machines, and Kershaw in particular had considerable experience with them that dated back to before the war.[69] By April 1919, Barr & Stroud had a contract for 530 machines, and work began on them during June.[70]

The profits to be made were, however, substantially less than those from military and naval work. The contract had a gross value of £26,500, but Jackson regarded it as unprofitable compared to Government work. Each machine sold at £50, apparently based

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[66] UGD 295 Unlisted material: J. M. Strang manuscript *The History of Barr & Stroud* .p.124.
[67] Moss & Russell (1988) p. 103.
[68] Moss & Russell (1988) p. 104.
[69] Leeds Industrial Museum Library, Kershaw material (unclassified), 'A Kershaw & Sons, Leeds: A brief history based on notes by Mr. Cecil Kershaw'.
[70] UGD 295/19/2/7, Customer Order File 1919-1920, 11.6.1919.

on the actual costs of labour and materials and influenced by other makers' prices, whereas using the established formula for optical munitions work the figure would have been at least double. Unlike optical munitions, the movie projector market was well supplied and competitive, with neither demand nor need for innovation or technical superiority, and price the over-riding consideration. Jackson believed that the return was inadequate in relation to the margins the firm had always enjoyed on its munitions contracting and was only prepared to accept it because he felt it was essential to keep the plant employed for the company's immediate welfare.[71] Although there might be some future profit, the principal motivation was again to retain as many skilled workers as possible. As with the binocular optics, even relatively rudimentary work at a reduced profit was better than losing highly experienced fitters whose value was largely in their 'savoir-faire'.

The other moves towards diversification taken in 1919 and mentioned by Moss and Russell were never likely to generate significant income.[72] Substantial profits were again less important than actually doing work. The simple 'Impactor' golf practice device, made for another company to sell, kept some of the apprentices busy and retained them at minimal cost to the business. It was only ever made in small numbers and eventually abandoned when its parent company failed. The 'Optophone' was a complex electrical instrument intended to convert printed words in books into sounds by which the blind would be able to 'read books by ear', and really was an expression of Archibald Barr's philanthropic character.[73] It never proved successful and was eventually allowed to fade away, once again having shown a loss to the business. A plan to manufacture motor cycle engines (which employed some of the mechanical techniques used in making rangefinders) was also taken up in 1919, but it developed slowly and the decision to start production was not taken until the end of 1920. Eventually, after both technical and marketing difficulties, it too was terminated without any financial benefit to the firm.

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[71] UGD 295/4/315, Letter Book, Jackson to Barr, 9.9.1919.
[72] Moss and Russell (1988) pp.104-106.
[73] Moss & Russell (1988) bring out some aspects of this side of Barr's character in Chapters 1 to 4.

None of these 'great efforts'[74] to move into commercial lines generated much in the way of profits, and emphasise the extent to which the company's expertise and success was connected with optical munitions. Diversification for Barr & Stroud was not intended to move into new territory, but was a means of holding together as much of the workforce as possible until munitions work established a new equilibrium. The months following the war's end were characterised by uncertainty about the future for the whole of the optical industry, but Barr & Stroud alone of the optical munitions makers made the decision to remain wedded to that now unpredictable speciality. Where all the other firms saw their futures in the civil market, Barr & Stroud banked on its core activity returning to a level great enough to sustain the business, recognising that it lacked the expertise or infrastructure to move quickly and successfully into large-scale new activities which might substantially replace optical munitions work. Although accepting the need for short-term amendments to its product range, there was no doubt that rangefinders would continue as the mainstay of the business.

7.5 Conclusion

1919 was a significant year for optical munitions manufacturing in Great Britain. It saw the large and specialised war-time industry vanish completely within a few months as the need for its existence disappeared. In one way, this was in accord with what the Ministry of Munitions had planned for. When Frederick Cheshire was its Joint Head, he had worked to cultivate a climate in which the whole of optical instrument making in Britain would be brought up to a level where sophisticated apparatus could be designed and made economically on a scale large enough to let the industry compete profitably with foreign makers in peace-time, and to meet all the country's needs in the event of war. The notion of a separate optical munitions industry had no place in Cheshire's philosophy, and much of his efforts had gone into creating what he saw as the essential underpinnings of scientific training which would benefit technical optics generally. That his ideas for reform were incomplete when the war ended was unfortunate, and the sudden, premature casting loose of the industry from government work was bound to have serious implications for the future of the optical trade. The vicissitudes suffered by

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[74] Moss and Russell (1988) p. 108.

the makers of civil optics after 1919 are really separate to this account, and have yet to be examined and analysed. What is relevant here is that for practical purposes the optical munitions industry actually reverted to its pre-war state leaving only one substantial maker which had to struggle to keep its capabilities intact. The problems encountered by Barr & Stroud were analogous to those suffered by specialist armaments makers, and heighten the case for considering optical munitions production as a distinctly separate activity to instrument making in general. The weakness of Cheshire's ideas lay in failing to recognise this and put in place in any mechanism by which the capacity could be maintained. The result was that the nation's capability for optical munitions production, after four years of trial and effort was left in no better state than it had been in August 1914, with only one company retaining either the inclination or ability to stay in the game. Over the next four years, Barr & Stroud was to become, to all intents and purposes, the British optical munitions industry, as the following chapter relates.

Chapter 8

Adaptation and survival, 1919 to 1923

8.1 Introduction

The period from 1919 to 1923 was extremely difficult for the optical munitions industry. The peace brought new political attitudes to armaments, and the resulting shift to arms limitation and reduction contrasted sharply to the pre-war years which had been characterised by the willingness of governments to spend heavily on military technologies. Budgets shrank, and the War Office found itself with surplus optical munitions which would not need replacing for a considerable time. This practically eliminated demand for land service instruments and for most pre-war producers, military optics ceased to be viable business. Matters were different with sophisticated naval instruments such as large rangefinders and submarine periscopes, where demand did not vanish because progress in related weapons technologies sustained the need for improvements, even though the quantities required were relatively small. Diminished requirements meant that by 1923 only one British company was still substantially involved in complex optical munitions, and of the other makers mentioned earlier, only three continued occasionally to manufacture less complex optics for the forces. Frederick Cheshire's gloomy assessment of optical munitions manufacture in 1915 perhaps came closer to the truth in 1923 than when he originally made it; fewer firms were involved and the capacity for mass production even less than before the war. This chapter examines the policies and strategies devised by the major participants and examines the extent to which they were successful, providing another reminder of how the optical industry was faced with further difficulties interacting with a range of external factors which crossed social, economic and political dimensions and added to the internal problems relating to the technical aspects of instrument design and production. The ability of Barr & Stroud to attain a significant degree of success in resisting the tendency of external factors to force it onto a new path suggests that they had, in Thomas Hughes'

words, become 'systems builders', successfully evolving strategies to enable them to cope successfully with maintaining their products in the 'enduring whole'.[1]

8.2 The problems facing the makers

Optical munitions producers have previously been seen as part of general instruments manufacturing rather than the armaments industry, and it has been assumed their problems were those of the makers of civil optical goods. Mari Williams illustrated a number of difficulties faced by British precision instruments producers, and Anita McConnell described the problems facing Thomas Cooke's of York.[2] Williams identified problems of inadequate research and development, difficulties of providing appropriate education and training, and the threat from foreign competition which benefited significantly from exchange rate advantages. McConnell dealt generally with the commercial problems facing Cooke's trying to regain its pre-war commercial trade, but gave little attention to its munitions activities after 1919. The instruments trade certainly had its share of difficulties, but they were by no means the same as those facing the manufacturers of military or naval optics. The weaknesses identified by Williams were not always found in the munitions makers, and even where they were, their correction would not necessarily have benefited individual companies.

The principal difficulty for makers of complex service optics was not any of those touched on by Williams and McConnell. Scientific training was not lacking at Barr & Stroud, for example, nor were research and development departments absent there or at Cooke's. The increasing complexity of the most important optical munitions made them the province of a very small number of manufacturers who certainly did not lack the necessary expertise to design and manufacture them, and because of the insistence of domestic supply by the armed forces, questions of foreign competition were irrelevant. Rather, the difficulty was that the massive reduction in post-war arms budgets made

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[1] J. Law, 'Technology and Heterogenous Engineering: The Case of Portuguese Expansion' in Bijker et al (1989) p. 112.

[2] Roy and Kay MacLeod, 'Government and the Optical Industry in Britain, 1914-18' in J. M. Winter, ed. *War and Economic Development* (Cambridge: University Press, 1975), Mari E. W. Williams, *The Precision Makers: a History of the Instruments Industry in Britain and France, 1870-1939* (London: Routledge, 1994), Chapters 5 and 6, and Anita McConnell, *Instrument Makers to the World: a History of Cooke, Troughton & Simms* (York, England: William Sessions Ltd, 1997) pp 76-80.

successful involvement difficult because of the paucity of orders. Adding to the problem was the peculiar nature of naval rangefinders and submarine periscopes compared to civil instruments like microscopes and spectrometers, which almost wholly precluded the possibility of spin-off that could have aided other commercial production. These key munitions instruments needed technologies and manufacturing facilities unlike those normally employed in civil instrument making. Although precision devices requiring tolerances similar to laboratory instruments, naval rangefinders and periscopes were massive objects requiring welding torches and 30-foot lathes in their manufacture, as well as heavy lifting gear to move around workshops. Their lenses and prisms, although often weighing less than an ounce, were buried in massively complex frameworks that frequently weighed nearly a ton and whose construction required specialised tooling and abilities that were unknown in the precision instruments industry. To move between one field and the other was not a straightforward exercise.

Because of falling demand and the trade's idiosyncratic nature, few firms showed the inclination and ability to remain substantially in optical munitions production. Sir Howard Grubb & Company never resumed munitions activities after the Armistice and ceased entirely to be involved, whilst Thomas Cooke & Sons Ltd, whose activities had always been broadly based, struggled for several years to remain active in military optics. Barr & Stroud, whose specialised business had no previous commercial lines, found it easier to remain in optical munitions than to diversify into civil products. Their differing degrees of success illustrate how difficult it was to make headway with optical munitions in the early 1920s. Of the other pre-1919 optical munitions makers, all returned to their civil activities and continued substantially as before, with a handful occasionally making sighting telescopes or prism binoculars when the War Office placed small orders for them. Only A. Kershaw & Sons Ltd of Leeds and two London companies – W. Ottway & Co. Ltd, and the Ross Optical Company Ltd – received any War Office business up to the end of 1923.[3] They all regarded military contracting as

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[3] National Archives, Kew, London (subsequently PRO) WO 395/4, Annual Reports of the Director of Army Contracts, 1920-1921 to 1923-1924.

only a very small part of their business, picking up and developing pre-war activities as best they could.

8.3 Sir Howard Grubb & Company

The one important company that failed to make the transition back to its pre-war status was the original maker of submarine periscopes, Sir Howard Grubb & Company. The firm had made them right from the introduction of submarines in the Royal Navy in 1901[4] and had been the sole British maker until the Great War, when Kelvin Bottomley & Baird of Glasgow started production.[5] The company shared some of the monopoly characteristics of Barr & Stroud, but with important differences that had an important bearing on its ultimate fate. In 1917, Sir Howard, the firm's sole proprietor, had been forced by the Admiralty to shift periscope production from Rathmines near Dublin to St Albans in Hertfordshire, partly to reduce the risks from U-boats when shipping completed instruments across the Irish Sea, and partly through security fears over political unrest in Ireland.[6] The choice of site was the Admiralty's, relocation was slow and still far from complete when the war ended, leaving the business in a difficult situation from which it never really recovered.

Grubb's post-war problems were probably worse than for any other long-established firm recently engaged in optical munitions. The disruption of the move had interfered with both periscope production and contracts for less complex instruments, which the Ministry of Munitions had largely been able to terminate without paying substantial compensation.[7] The narrow interpretation of performance clauses to the Ministry's benefit, despite the situation having been forced on the company, denied the business the useful injections of cash that helped many others to ride out the difficulties of translating their manufacturing back to pre-war commercial activities.[8] As late as March 1919, although work on small instruments was still being carried out in Dublin, the St Albans

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[4] See Chapter 4 above.
[5] University of Glasgow Archives, Records of Kelvin & Hughes Ltd, UGD 33/4/2 , Inventories and valuations, 1919.
[6] I. S. Glass, *Victorian Telescope Makers, The Lives and Letters of Thomas and Howard Grubb* (Bristol: Institute of Physics Publishing) p. 213.
[7] Williams (1994) p. 106, and PRO MUN 4/5306 Contract cancellations and liquidation advances.
[8] see Chapter 8 above.

factory remained incomplete and yet to start production.[9] This was not really the result of any failure on the company's part, and it is hard not to feel some sympathy for Sir Howard's subsequent plight.

He had not volunteered to make the move, which had been forced on him through the powers of the Admiralty under the Munitions of War Act. If possible he would have preferred to abandon it once the war ended, but 'the arrangements . . . had gone so far when the Armistice occurred that it was impossible to go back',[10] and in any case neither the Admiralty nor the Ministry of Munitions were eager to relinquish war-time controls. The Dublin works were under military guard to protect government stores from expected civil unrest, and he believed his business would not be free 'for some time yet'. This, along with the Rathmines works' partially dismantled condition and the unfinished state of the St Albans site meant that he could neither take up unfinished pre-war contracts for astronomical telescopes nor complete whatever government work there was on hand.[11] Adding to these woes was widespread industrial unrest in Ireland which prevented the shipping of 'three hundred tons of machinery' still missing from the new works and interfered with operations at the already disrupted Irish factory. The choice of the new factory had been entirely the Admiralty's, and there seems to have been little enthusiasm for the whole project within the company. With some prescience, Sir Howard noted in 1919 that 'I am afraid we are in for a bad time'.[12]

He was quite right. By August 1921, even with the transfer to St Albans finally complete, things were going badly. The recession had set in, and Grubb was in low spirits; he wrote to an overseas client who was still awaiting a large astronomical telescope ordered before the war that 'It is very difficult for an outsider to understand the state of things in this country just now . . . factories closing or closed all around, everyone trying to realize, no one buying . . .'.[13] His business was by then in straitened circumstances. Periscope manufacture, the mainstay of Grubb's optical munitions work, had stopped once the

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[9] Glass (1998) p. 214.
[10] Glass (1998) p.214, Grubb to Innes, 27.3.1919.
[11] see PRO MUN 4/5306, Contract Cancellations and Liquidation Advances.
[12] Glass (1998) p.215.
[13] Glass (1998) p.215, 19.8.1921, Grubb to Innes.

move from Dublin began and never restarted. Almost no new civil astro-telescope work had come in, and existing orders were very much behind schedule. The business was barely surviving.

The loss of the periscope business was critical and contributed substantially to the firm's dire condition in the early 1920s. Grubb was by inclination a telescope maker who had been drawn into optical munitions around the time of the Boer War through an association with the armaments firm of Vickers, and the production of submarine periscopes had almost certainly helped the business financially before 1914.[14] Astronomical telescopes were never renowned for producing high profits, and payment for them frequently protracted.[15] Both McConnell and Glass illustrated the uncertain economics of that business, and Grubb had benefited from the regular substantial payments that periscope manufacture and servicing brought in.[16] Although he had enjoyed a monopoly of supply, its nature was significantly different to Barr & Stroud's position with rangefinders. Unlike Barr & Stroud, Grubb had never dealt directly with the Admiralty, either individually or as a business, and consequently failed to establish the same rapport that Barr & Stroud enjoyed. His relationship with Vickers, established when they first became involved with submarines, evolved into that of sub-contractor, and his periscopes were supplied direct to Vickers (for many years the monopoly builder of submarines) who delivered the boats fitted with them. The Navy's technical requirements for periscopes went to Vickers, who then passed them to Grubb. In consequence of this separation, Sir Howard was unable to build up the connections that Barr & Stroud enjoyed with the Navy, and this ultimately contributed to his loss of periscope manufacture.

In 1915, the Admiralty had approached Barr & Stroud to see if a rangefinder could be incorporated into its existing periscopes. That proved impossible, but the company

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[14] Glass (1998) p.206.
[15] H. C. King, *The History of the Telescope* (London: Charles Griffin & Co. Ltd, 1955), Chapters XV and XVII provide background material.
[16] Cambridge University Library, Vickers Collection (subsequently CUL/VC): Document 739, Periscopes – correspondence with Sir Howard Grubb 1908-1908: Document 1003, Electric Boat Company correspondence 1901-1907.

offered to make an entirely new type incorporating a specially designed rangefinder that would readily replace the instruments in boats already in service.[17] The proposal was accepted and a contract placed in 1917 not only for it, but also trial models of conventional types.[18] This involvement of Barr & Stroud in periscope design and manufacture came at a most inopportune moment for Grubb. At the same time that the Admiralty was insisting periscope manufacture be shifted to England unavoidably interrupting deliveries, setting up an additional supplier would have made sense, but that was not the principal motive for the Navy's involving Barr & Stroud. Neither was there any complaint about Grubb's periscopes. They were generally satisfactory by contemporary standards, and were also being made by Kelvin Bottomley & Baird at Glasgow, presumably to ensure sufficient output during the war.[19] But, the Royal Navy was minded to have a combined rangefinder-periscope and Grubb had no background in rangefinder design which was even more complex and problematical than the periscope's. It made more sense to approach Barr & Stroud for the novel instrument because, unlike Grubb, that firm not only had wide rangefinder experience, but also a large design department, a secure factory, and – most importantly – had come to command the confidence of the Navy. The anticipated interruption of Grubb's output in the planned move to England added to the Navy's inclination to draw Barr & Stroud into periscope manufacture. Grubb's vulnerability was unfortunate, and in large measure neither his own creation nor the result of ineptitude. Nevertheless, this combination of circumstances completely removed Grubb's primacy in periscope making and transferred that role to Barr & Stroud which not only replaced Grubb as the Navy's preferred supplier but eventually attained a monopoly.

Grubb's company struggled unsuccessfully after 1918, and the St Albans works never became fully operational. In 1920 Sir Howard tried to 're-organise [the] business on a very much enlarged basis' for astro-telescope work, but this was never carried through.[20]

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[17] Michael Moss & Iain Russell, *Range & Vision: The First Hundred Years of Barr & Stroud* (Edinburgh: Mainstream Publishing, 1988) pp. 83 and 84.
[18] UGD 295/19/2/5, Customer Order records 1917.
[19] Norman Friedman, *U.S. Submarines through 1945* (Annapolis, Maryland: Naval Institute Press, 1995), Appendix B provides background material.
[20] Glass (1998) p. 215, Grubb to Innes, 26.5.1921.

By October 1922, the company was 'weak financially and probably in the hands of their bankers'[21] and in 1923 there were still 'confused heaps of material . . . lying on the new workshop floors' including parts for submarine periscopes whose contracts had been terminated in 1919.[22] The relocation of the business had a catastrophic effect on its ability and efficiency; it ceased entirely to produce optical munitions, continued to decline as a builder of large astro-telescopes and eventually, in January 1925, went into liquidation.[23]

Grubb's failure as an optical munitions maker resulted principally from being compelled to relocate to England. A second, but inseparable, cause was the coincidental decision of the Admiralty to bring Barr & Stroud into periscope manufacture, which opened an opportunity for that firm to assume Grubb's previous role. The massive disruption that followed the move was entirely predictable, but although Grubb was opposed to moving he lacked the ability to dissuade either the Admiralty or the Ministry of Munitions from the idea. The inability to resolve the chaos once the war ended and the income from munitions contracts ceased, reflected Grubb's financial weakness and compromised his ability to take up his pre-war commercial work; it also crippled his prospects of continuing to be competitive with his conventional periscopes which were not immediately superseded and continued satisfactorily in service for many years afterwards.[24] For Sir Howard Grubb, the war had brought no lasting benefits. His business, more than any other in optical munitions, suffered through serving the State. The firm's subsequent failure as an instrument maker stemmed from the harmful effects of Admiralty enforced policies during the war rather than the shortcomings identified by Mari Williams in the civil precision instruments industries.

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[21] Glass (1998) p. 216, Innes to Secretary of State, Pretoria, 19.5.1923.
[22] Glass (1998) p. 215, Frank Robbins report.
[23] Glass (1998) p. 225.
[24] Cumbria Archives, Barrow-in-Furness: Vickers Material BDB 16/500, handbooks, and specifications, various dates, 1918 to 1927.

8.4 Thomas Cooke & Sons Ltd (Cooke, Troughton & Simms Ltd from 1922).[25]

The fate of Cooke, Troughton & Simms in 1923 had many similarities with Sir Howard Grubb's business, but its route there was very different. Cooke's had a broader base in optical work – including service optics – than Grubb, although its earlier importance to the British service was far less. The company had ceased to be independent when Vickers acquired 70 percent of its shares in 1915,[26] a circumstance that bore heavily on its post-war course. The wider involvement in ordnance products and the support of the massive armaments company should have placed the business in a stronger position to compete in optical munitions work, but Cooke's struggled to make headway after the war, losing money until eventually its parent withdrew support and, like Grubb, it went into liquidation. As with Grubb, the company lacked any close rapport with the Royal Navy, and despite the connections its parent company already had with the Department of Naval Ordnance, it never built up the kind of relationship that had always worked in Barr & Stroud's favour.

The relationship between Vickers and Cooke's is not easy to understand, and even the reason for buying such a large stake in the firm is unclear. J. D. Scott considered it was 'to bring a particular product more directly under control', meaning the mechanical fire control instruments that Cooke's were already supplying.[27] This may be correct, but Vickers was probably more interested in the connections Cooke's had with the Argo Co. Ltd., which was the marketing agency for the Pollen system of naval gunnery control that had been rejected by the Admiralty in 1914.[28] Not only did Cooke's make all its mechanical elements, the firm had also introduced a sophisticated long-base rangefinder for it that was radically different from the Barr & Stroud pattern and promised to be superior.[29] Cooke's had a majority interest in Argo, so that by acquiring the one, Vickers acquired the other as well. Cooke's was the only other British company to have constructed a large naval rangefinder before the war, it was highly competent in optical

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[25] The term 'Cooke's' is used to describe both.
[26] J. D. Scott, *Vickers, A History* (London: Weidenfeld & Nicolson, 1962) p. 132.
[27] Scott (1962), p. 132.
[28] J. T. Sumida *In Defence of Naval Supremacy; Finance, Technology, and British Naval Policy 1889-1914* (London: Routledge, 1993), Chapter 6 provides a full account of these events.
[29] McConnell (1992) p. 74.

design, and offered Vickers an opportunity to integrate optical munitions capability into its other armaments operations. Cooke's importance to Vickers lay partly in its optical expertise and partly in its ability to tackle the specialised optical and mechanical engineering needed for complex optical munitions. What Vickers did not do, though, was to take over the day to day running of the firm, nor even to establish a strong presence on its board.[30] Instead, the business was left very much to its own devices, with its munitions department coming under Cooke's general management and accounting structure.

Although there was much to commend the idea of integrating Cooke's into Vickers armaments operation as a base for optical munitions manufacture, the exercise ultimately proved costly and problematical. Cooke's had not been asked to make sophisticated optics for either the War Office or Admiralty during the war, all its production being for relatively simple sighting telescopes, none of which were the company's monopoly. Nor had it actually sold any rangefinders to either British or foreign governments because all the deals that were in progress before the war were frozen by the hostilities.[31] As a result, Vickers owned an optical instruments company with no proven record in complex armaments optics, which had no programme to develop new products – civil or military – and which was also in a weak financial condition. Unlike Barr & Stroud, Cooke's had no experience in selling to foreign armed forces, and its name lacked sufficient *cachet* to command the attention of prospective buyers. All the potential for optical munitions sales actually lay in the firm's ability to design and manufacture instruments nominated by Vickers as a result of its own armaments experience. The failure by Vickers' management to separate civil and military optical products meant that the parent company found itself propping up a business that struggled to overcome the problems of post-war re-adjustment, whilst the munitions products that were developed under Vickers' aegis failed to find markets either at home or abroad.

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[30] No mention of any such steps occurs in CUL/VC Document 1366, Directors' Minute Book, entries 1920 to 1924, and University of York, Borthwick Institute, Vickers Instruments Archive (subsequently VIA) AJB 030/1.1.1, Cooke Directors' Minute Book, entries 1915 onwards.
[31] McConnell (1992) p.74.

Cooke's had never been a particularly profitable business and although its accounting records have not survived, by late 1922 the company was clearly struggling despite its recent acquisition of one of its instrument-making rivals, Troughton & Simms Ltd. of London.[32] This had actually been done with Vickers' encouragement and money, but it is unclear how Vickers might have benefited from it.[33] Troughton & Simms was a smaller firm which had little expertise in optical munitions, its war-time activities had been on a smaller scale than Cooke's, and its design capabilities virtually non-existent. Anita McConnell suggested that Vickers were persuaded into the acquisition because Troughton & Simms' management was better than Cooke's, producing 'competitive goods at lower prices'.[34] This is doubtful: the London firm was also financially weak and Elinor Mennim showed that after 1920 there was a crucial lack of effective direction and management, with strong disagreement between the two principal family shareholders whose chief desire was to be rid of the responsibility of running the business in increasingly difficult conditions.[35] Whatever the underlying reasons for the purchase, the result was a further weakening of Cooke's overall condition and the merged company continued to decline.

Cooke, Troughton & Simms was not actually selling any optical munitions, although it had prepared designs and built prototypes of instruments that Vickers hoped subsequently to market. Vickers' aviation interests led to a 'Prismatic Bomb sight' being manufactured in 1919, as well as an 'Aeroplane Periscope' that allowed a pilot to see the ground directly under his aircraft.[36] The following year, Vickers' naval interests led to new designs of large naval rangefinders for Admiralty trials to decide on future standard types, and in 1920 and 1921 a number of rangefinders and range-and-heightfinders were constructed for both surface and anti-aircraft use.[37] This must have been an additional drain on Cooke's resources. The Admiralty was accustomed to having trial instruments

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[32] McConnell (1992) p.77.
[33] CUL/VC Document 1366, Directors' Minute Book, entry 30.9.1920.
[34] McConnell (1992) p.77.
[35] VIA AJB 050/1.2.3,Troughton & Simms Balance Sheets 1914-1919, Income Tax Papers and Stock Figures provide financial details, and E. Mennim, *Reid's Heirs: a Biography of James Simms Wilson* (Braunton, Devon: Merlin Books, 1990) p.127 describes family relationships.
[36] VIA AJB 070/1.3, Index to Optical Munitions Drawings, references 3524 and 3677.
[37] VIA AJB 070/1.3, Index to Optical Munitions Drawings, references 3434 to 3492, and 3860.

supplied *gratis*, and the costs of developing them were expected to be borne by the submitting company, which may explain both why the Vickers' Board was starting to register concerns over Cooke's finances and why it was prepared to keep underwriting the losses.[38]

The Vickers finance committee had forecast in September 1920 that Cooke's bank overdraft would exceed £58,000 by the following June. Cooke's bankers (who were not Vickers') were obviously uneasy, having recently refused to raise the existing overdraft ceiling of £45,000, and in consequence Vickers had to lend Cooke's £15,000 to meet immediate needs. In addition, another £75,000 was needed to cover liabilities for Excess Profits Duty. By February 1921 Vickers' loans stood at £39,000, and Cooke's bankers were asking for the overdraft to be guaranteed, a further indication of their doubts over the firm's finances. The deterioration continued with a trading loss of £10,000 for the financial year ended 30th September 1922. The now-guaranteed overdraft's ceiling was increased, with Vickers' support, first to £60,000 and then to £80,000 in the following January. The trading loss for 1922-1923 worsened to £16,183 with unpaid Excess Profits Duty of over £22,000 still to find besides, and by then it was clear that Cooke's was no longer a viable business.[39] Vickers finally 'grew tired of pumping cash into an ailing company' late in 1923 and liquidated the firm in the following Spring.[40]

The only optical munitions designs recorded at York from 1921, when Cooke's position was seriously worsening, until the close of 1923 were some observation periscopes for naval gun turrets and a prismatic sight for the Vickers-Berthier light machine gun which Vickers hoped to sell to the War Office and the Indian Army.[41] Like the earlier rangefinders and aeroplane instruments, these came to nothing. The observation periscopes, for some unexplained reason, were actually made by Barr & Stroud,[42] and the machine gun sight languished because neither prospective client made its mind up about

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[38] see Barr & Stroud's previous experiences described in earlier chapters above.
[39] CUL/VC Document 1366, Directors' Minute Book, entries 30.9.1920, 24.2.1921, 19.7.1922, 28.9.1922, 23.1.1923, 28.3.1924 and 2.5.1924.
[40] McConnell (1992) p.79.
[41] VIA AJB 070/1.3, Index to Optical Munitions Drawings, references 3905 and 3906.
[42] UGD 295/4/336, Letter Book, Harold Jackson to Vickers, 12.7.1922.

the Vickers-Berthier gun. The rangefinders produced for the Admiralty trials in 1921 failed to convince the Royal Navy of their superiority (although Barr & Stroud saw them as a serious threat and worried about prospects until May 1922),[43] and the aeroplane instruments apparently never went into production. Not a single Cooke-Vickers optical project successfully generated orders between 1919 and the end of 1923.

The difficulty in understanding Vickers' relationship with Cooke's is illustrated by the acquisition of marketing rights for Barr & Stroud products in Spain in 1921 and the willingness to have Cooke observation-periscope designs made by Barr & Stroud.[44] The marketing rights included both naval and land-service rangefinders, both types which Cooke's was already able to make. One possible answer for the agency acquisition is that Vickers was then working hard to sell the Spanish government an entire coast-defence gunnery system, and it may be that the client had shown a preference for the proven and familiar Barr & Stroud instruments, rather than because Vickers doubted Cooke's ability eventually to manufacture a competitive product.[45] It would have made no sense for Vickers to prejudice a very large project through a refusal to supply something the customer preferred or demanded. Whatever the reasoning, Spain bought sixteen Barr & Stroud field-artillery rangefinders worth £2,000 through Vickers in 1922 and £9,837 of larger models the following year, and afterwards no more attempts to promote Cooke-Vickers rangefinders were made.[46] A satisfactory explanation for out-sourcing the periscopes is harder to find, but whatever the reason, Vickers chose to go outside its own organisation for a product which it could have made itself. This was scarcely an expression of confidence in Cooke, Troughton & Simms, and possibly by the time Barr & Stroud were given the order the Vickers Board had already written-off the idea of using Cooke's for optical munitions production.

Vickers' attempts to capitalise on the integration of optical capacity into its armaments business did not fail because of the difficulties Cooke's had in marketing its civil

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[43] UGD 295/4/334, Letter Book, Harold Jackson to F. Morrison, 2.5.1922.
[44] Vickers CUL/VC 1367, Directors' Minute Book 9, 27.10.1921.
[45] CUL/VC 1367, Directors' Minute Book 9, 27.10.1921.
[46] UGD 295/19/2/11, Customer Order files 1923.

products. The lack of success was firstly because the amount of new munitions business available at home and abroad was small and secondly because all the advantages lay with the established and demonstrably successful competition. Even if Cooke's had been a profitable instruments company, Vickers' efforts at developing a range of optical munitions would still not have succeeded up to 1923. That failure was almost inevitable, given the scarcity of government business and Cooke's previous lack of success in selling ordnance products in competition with rivals. Faced with a dominant and proven domestic competitor, and in the absence of either demonstrable functional failure in the Navy's rangefinding instruments or being able to demonstrate any presumptive anomaly, Vickers had little chance of displacing Barr & Stroud as the Admiralty's preferred supplier. Cooke's failure as an instrument maker and Vickers' failure as an optical munitions supplier were quite separate issues.

Left alone, Cooke's would probably not have continued with optical munitions after the war. Its earlier efforts had brought no financial rewards, and the firm probably felt it had suffered through its association with the vexatious Arthur Pollen's dealings with the Admiralty.[47] War-time munitions profits had been small as a result of State taxation policies, and like almost every other maker Cooke's finished in a weaker state than when it began as a munitions conscript. That the firm was a reluctant player in 1919 does not necessarily mean it would have survived solely as an instrument maker – the vicissitudes of the British instruments industry described by Mari Williams were felt as keenly by Cooke's as by anyone else. The company's potential utility to Vickers justified continued support only until it eventually became clear that no substantial optical munitions work was likely in the foreseeable future, and that matters relating to Cooke's civil manufacturing should not be allowed to drift further. Any hope of profits from civil instruments in 1920 were long gone by 1923 and it then made sense for Vickers to let the ailing company go to the liquidator, apparently relinquishing all involvement with optical munitions. However, Cooke's story did not end there; Vickers eventually bought the company's assets and re-floated it under their own direct control, so that they kept some

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[47] Anthony Pollen, *The Great Gunnery Scandal* (London: William Collins & Co. Ltd, 1980) Chapters I to V provide background material on Pollen and his association with Cooke's.

capacity for fine mechanical and optical engineering as well as running the instruments business on a more or less profitable footing until the re-armament programmes of the late 1930s pulled Cooke's once again into optical munitions contracting.[48] For Cooke Troughton & Simms Ltd, 1923 marked not so much the end of optical munitions manufacture, but the start of a period of hibernation.

8.5 Barr & Stroud

Unlike Grubb and Cooke's, Barr & Stroud not only stayed in business but remained almost entirely dedicated to optical munitions. It had the benefits of a continuing domestic monopoly, an effective and tightly controlled management structure, and both the determination and ability to continue exploiting its previous success. However, success is a relative term, and Barr & Stroud sometimes found that it amounted to little more than simply remaining in business. Despite its corporate assets, the problems of maintaining the firm's existence were often considerable and frequently outside the Directors' control. One critically important – though intangible – asset that Barr & Stroud possessed, uniquely amongst British optical munitions makers, was a relationship with the Admiralty that had continued unbroken since 1892. This association, which both brought benefits and obligations to each party, was a very significant factor in Barr & Stroud's survival in the difficult times of the early 1920s, despite some fundamental alterations in its nature.

The relationship was, nevertheless, not something that could be taken for granted by the company. The war had imposed strains on it, and in particular on the firm's earlier ability to set prices for Admiralty work as it alone thought fit. That had been overturned by the provisions of the Munitions of War Act which had imposed a series of controls intended to bring war-work firmly under the State's governance.[49] Almost immediately after the Armistice, Barr & Stroud sought to be rid of those controls, causing the Admiralty to look closely at how it saw the nature of post-war dealings. The firm wanted to be able to

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[48] McConnell (1992) pp. 86-88.
[49] Great Britain, Ministry of Munitions, *Official History of the Ministry of Munitions* (London: HMSO, 1922) Vol. 1 Part IV, Sections 1 to 5 describes these controls.

negotiate freely over prices, to pursue whatever markets seemed opportune, and be rid of the war-time controls that, like Sir Howard Grubb, it felt to be restrictive and irksome.[50] This request to be released had an effect on the Admiralty which Barr & Stroud may not have anticipated and which apparently remained unknown to the company.[51] Before replying, the Admiralty set out to consider the merits of control from the Navy's viewpoint, and opinions were sought within the service as to the future. The responses illustrate that there was by no means unanimity about how the firm was regarded within the Navy.[52]

The Naval Contracts Department favoured keeping Barr & Stroud permanently under Admiralty control by extending the war-time arrangements. There would be 'great advantage' in keeping the firm's skills and technical facilities available on demand, although difficulties were seen in arranging what amounted to a takeover. State business would not be sufficient to keep the firm going, and Government ownership would preclude not only foreign work but also commercial production because 'the Private Trade would not appreciate Government competition'. A subsidy would therefore be needed, which the Director saw as being problematical to arrange. Nevertheless, the Contracts Department favoured bringing the company into the Navy's hierarchical structure, so that prices might be controlled and contractual arguments avoided.

Those arguments were not welcomed by the Director of Naval Ordnance (DNO) who saw Barr & Stroud in a different light. His response illustrates the service's internal tensions about taking over the company.[53] The DNO said that because the firm was the only British maker of naval rangefinders it was 'imperative' to keep it going both for peace-time needs and future requirements in time of war. That would better be done by maintaining the *status quo*. The idea of outright control disturbed the Ordnance Department because it threatened the nature of the relationship that had grown up with

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[50] UGD 295/4/146, Letter Book, Jackson to Secretary of the Admiralty, 6.12.1918.
[51] Nothing in the contemporary letter books examined shows any knowledge of it.
[52] Ministry of Defence, Naval Library. *Monthly Record of Principal questions Dealt with by the Director of Naval Ordnance* (subsequently *PQ*), July to December 1918. Minute No. 192, 17.12. 1918. Other minutes provide the source material for the rest of this section, unless otherwise indicated.
[53] *PQ*, July to December 1918, Director of Naval Ordnance to Director of Navy Contracts, 21.12.1918.

the company, and the Department was perfectly happy to have an independent Barr & Stroud acting virtually as its consultant. The tendency of service hierarchies to resist change, as described by William McBride,[54] is not necessarily confined to their internal structures. As with ordnance, where the commercial development of weapons had long been accepted as working to the Navy's advantage, so the design and supply of optical munitions was established as an external but inseparable adjunct. The firms supplying both had become so closely identified with the Navy's own interest that they were seen as inseparable from its functional framework. With Barr & Stroud, the Gunnery Branch strongly resisted any change in the relationship, seeking to maintain the familiar and satisfactory arrangement that had evolved in the preceding twenty five years .

Even worse than unwelcome structural change was the chance that the firm might fail completely. For the Gunnery Branch, the solution was to let the firm again sustain itself with foreign business. The hierarchical structure again resisted change, not through conservatism or prejudice but through a justifiable fear of a future functional failure in design and supply. The DNO insisted State control was neither 'advisable nor necessary' and urged that 'no other restrictions' should be imposed beyond those already in place, stressing that it would take until 'well into 1920' to complete current orders. In his judgement there was 'no other firm in the country who can be compared with Barr & Stroud in respect of their experience and facilities . . .'. and urged an immediate meeting to settle what work should be regarded as 'specially confidential'. That would clear the way for Barr & Stroud to seek new foreign business and make up any shortfall in Admiralty orders to ensure its survival.

The idea of perpetuating control was abandoned by the end of February 1919, probably without the firm ever having any inkling of it.[55] The advantages in preserving the *status quo*, where the Navy obtained rangefinder research virtually free of charge, were massively in the Admiralty's favour, and the Contracts Department was disregarded.

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[54] William McBride, *Technological Change and the U.S. Navy1865-1945* (Baltimore: Johns Hopkins University Press, 2000) pp. 4 and 5.

[55] UGD 295/4/146, Letter Book, Jackson to Secretary of the Admiralty, re. conference with Barr & Stroud, 26.2.1919.

However, the war-time controls were not immediately rescinded, a situation that Barr & Stroud was temporarily, if unwillingly, obliged to accept.

The question of finding new business was pressing. Contracts were disappearing and work to replace them was urgently needed. Orders were most likely from foreign navies which had been starved of rangefinder deliveries since 1914, but some of the war-time controls – particularly those relating to secrecy – stood firmly in the way. In a typically studied approach to the Admiralty, Harold Jackson first assured their Lordships that 'nothing can give us greater satisfaction' than continuing to work for the Royal Navy, and that the firm would continue all the security precautions 'maintained during the war', including not soliciting foreign sales without specific consent. Then, almost certainly with clients already waiting, he blandly asked whether, without further special applications, he could supply France, Italy, Japan and the U.S.A. with 'any instruments actually in use by H. M. Fleet' at the date of the Armistice. Jackson presumably got his way, because there were no further letters of protest from him, but the problem of foreign sales for the new instruments being developed for the Royal Navy was less easily solved. He agreed to defer the matter until questions of limiting the spread of armaments 'attaching to the proposed League of Nations have been formulated and agreed by the Powers'. There were now constraints on business that were unknown in 1914. [56]

They went far beyond those imposed by the Admiralty and were likely to be an even greater problem. Jackson touched on the nature of future difficulties when he mentioned the limiting of armaments and the embryonic League of Nations, implying that opportunities were likely to be governed by factors outside the firm's control. Much of its pre-war prosperity had come from supplying Europe's large conscript armies, none of whom were now in the market for instruments as they shrank rapidly leaving enormous surpluses of optical munitions. The neutral states which had been denied deliveries after late 1914 generally maintained only small armies, and even if they offered some opportunity for business the value of their likely trade was small.

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[56] UGD 295/4/146, Letter Book, Jackson to Secretary of the Admiralty, 3.3.1919, is the source for this paragraph.

If the prospects of foreign land-service business were discouraging in early 1919, there was greater optimism over naval orders. Even the Allied navies had been starved of rangefinders since 1914, and war experience emphasising the need for effective gunnery control systems, suggested there was a reasonable expectation of foreign business when navies sought to modernise. Jackson must have had orders pending when he wrote to the Admiralty in March that year, and there were actually still some rangefinders for foreign governments held in store from 1914 when deliveries had been embargoed.[57] As an antidote for excess optimism though, there was virtually no new foreign warship construction outside Japan and the United States. New ships had always been the prime movers for high-value orders, because with rangefinders went their associated mountings and data transmission systems. The U.S. Navy had a large programme of capital-ship building, but Barr & Stroud had never captured its business as it had done with France or Japan before 1914, and after 1915 the British government had prevented the firm pursuing American sales. By 1919, the U.S. optical company of Bausch & Lomb had advanced so far that it was unlikely that Barr & Stroud could win major orders, but Japan still lacked any sophisticated optical industry and its navy had so many earlier ties with the company that Barr & Stroud must have seen the Imperial Navy as the main chance of foreign sales.

However, to Michael Moss and Iain Russell, 'Barr & Stroud's immediate future looked bleak' in 1919, with the directors 'resigned to the fact that there was no prospect of a revival in [munitions] orders . . . in the near future'.[58] This was by no means the case, and their opinion paints a gloomier picture than the evidence warrants. The company was still busy; turnover for the year was a substantial ££369,279, 1,200 of the workforce still employed in the autumn working a 47-hour week, and – most importantly – the order book was by no means empty.[59] The value of those uncompleted orders is not easy to assess as the firm's financial records are not always easy to interpret, but the sums

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[57] UGD 295/4/315 Letter Book, Jackson to Satiolas, 10.9.1919.
[58] Moss and Russell (1988) pp. 101, 102, 103.
[59] UGD 295 unclassified, Strang Material, financial papers, UGD 295/4/315, Letter Book, Jackson to the Federation of British Industries, 11.10.1919, and UGD 295/4/131, Letter Book, Jackson to Conrad Beck, 23.1.1919.

involved were certainly very considerable, probably exceeding half a million pounds, even if the future of some of the contracts was uncertain.[60] Ordnance work was certainly not about to evaporate and the Board was definitely not in despair. In fact, by November 1919, the directors had agreed unanimously that they could not 'consider any abandonment of our armament business' and that it must be maintained if at all possible.[61] As for them being 'resigned' to the prospect of no new munitions orders, in October Jackson asked the Admiralty to confirm there was no objection to quoting the Imperial Japanese Navy for new rangefinders, and began negotiations with the Coventry Ordnance Company for a 'complete fire control system'.[62] In November the Admiralty asked for a design for a new rangefinder for large submarines, as well as additional fire control instruments for the torpedo directing rangefinders on large surface ships.[63] And in December negotiations began with the Dutch Army for 600 infantry and artillery rangefinders, to make up for the dearth of deliveries since 1914.[64] Although these negotiations were all in the early stages, prospects were by no means lacking and confidence certainly not absent.

Even if prospects were far from barren, there was still the problem of managing the present. Inflation and reduced margins had greatly eroded the firm's profitability.[65] Turnover was actually lower than the last year before the war after allowing for inflation – only £166,000 against £188,000 in adjusted figures.[66] Manufacturing profit was down from 55 percent to 26 percent, which with higher operating costs resulted in a recorded pre-tax loss of £530. Bank overdrafts were £62,402, the highest recorded since the limited company's creation. Against this, the year's new orders received were only just

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[60] I am grateful to Paul Hodgson ...
[61] UGD 295/4/316, Letter Book, Jackson to Francis Morrison, London office, summarising recent board meeting.
[62] UGD 295/4/148, Letter Book, Jackson to Admiralty, 27.10.1919, and UGD 295/4/316, Letter Book, Jackson to Coventry Ordnance Co. Ltd., 30.10.1919.
[63] UGD 295/4/148, Letter Book, Jackson to Admiralty, 13.11.1919, and UGD 295/4/148, Letter Book, Jackson to Director of Admiralty Contracts, 25.11.1919.
[64] UGD 295/4/316, Letter Book, Jackson to W. H . Martin (Dutch Agent), 2.12.1919.
[65] Robert Twigger, *Inflation: the Value of the Pound 1750-1998* (London: House of Commons Library Research Paper 99/20, Economic Policy and Statistics Section, 1999) provides the data for this and other inflation references.
[66] UGD 295/11/1 Balance sheets, profit and loss accounts. Audited accounts for 1919 and later supply the data for this section.

over £39,000 which meant that the value of work on the books was declining. Overall, the situation was far from ideal, although a long way from crisis.

However, 1920 saw a marked deterioration in the firm's position. Recorded turnover declined to £310,822, manufacturing profits fell to only 12 percent, and the year-end showed a very large pre-tax loss of £80,497. Although orders had increased to £91,114, this was insufficient to sustain the business, and after allowing for inflation, new work was only one eighth of that received in 1913. Borrowings had increased to £129,497 by the end of December, and it appeared that without some radical change of circumstances the business would be heading towards insolvency. The firm sought to achieve this through reforming its relationship with the Admiralty.

In the autumn of 1920, Barr & Stroud requested an annual subsidy. This marked a major change in the way the firm saw its relationship with the Admiralty and prompted the latter to reconsider its own role in the association. The company asked for £50,000 yearly 'for the purpose of continuing their Experimental and Research work and also for maintaining in a state of efficiency their own plant as well as the plant and factory put up by the Admiralty [during the war]'.[67] In essence, the company wanted the State to guarantee the costs of running the business, a circumstance inconceivable in 1914.

There can be no doubt that Barr & Stroud's position was far from satisfactory. This stemmed partly from diminishing business and partly from the twin burdens of maintaining an expensive research and development section whilst carrying a substantial amount of Admiralty debt. The research facility, which worked almost entirely on Admiralty projects, was the firm's largest standing charge and its salary costs had risen from 5.23 percent of turnover in 1913 to 18.05 percent in 1919.[68] Manufacturing wages fluctuated with output, but the cost of scientific staff had continued to grow irrespective of current production, and sustaining research and design was Barr & Stroud's heaviest single expense. A guarantee of £50,000 would cover it and many of the company's other

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[67] PRO ADM 212/46, Barr & Stroud correspondence.
[68] UGD 295/11/1 Balance sheets, profit and loss accounts. Extracted from annual accounts 1913 to 1923, trading account section.

standing costs as well. However, such a subsidy would not help with the question of outstanding bills.

There were substantial Admiralty debts for war-time contracts where Barr & Stroud had financed the work's progress. Their total is now difficult to assess, and it appears to have been a problem even at the time. In October 1919 Jackson reckoned that the sum owing for finished and invoiced jobs alone was 'not less than' £58,663.[69] To complicate matters, invoices had not been submitted for many completed contracts because the basis for charging was still not agreed.[70] There were 73 of these still to be settled in August 1919, whose value is not recorded in the surviving records.[71] And there were frequently long delays in payments for pre-priced contracts which forced the firm to press hard for settlement on several occasions, more than once even telegraphing requests for money.[72] Because materials and labour costs were paid by Barr & Stroud as contracts progressed, the burden of financing Admiralty orders continued to grow, even as the total value of work on hand was falling.

At the beginning of 1920, these pressures were showing. Jackson was in discussions with the Department of Naval Ordnance about a large project involving the development of a new 30-foot rangefinder intended to become standard for capital ships, and on 22nd January he wrote that unless relations with the Contracts Department improved 'we shall ask for our name to be removed from the Admiralty list [of approved contractors] – if indeed it is not automatically removed by proceedings in the Bankruptcy Court ! [sic]'[73]

This illustrates Jackson's willingness to play one section of the Admiralty against another. The frustration with the Contracts Department is clear, but it was the Ordnance Department that stood to suffer most from the possible loss of Barr & Stroud and it was to them that he made both threat and complaint. The threat was delivered with a light

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[69] UGD 295/4/147, Letter Book, Jackson to Admiralty, Advisor of Costs of Production, 20.10.1919.
[70] see Chapter 8 above.
[71] UGD 295/4/147, Letter Book, Jackson to Director of Naval Contracts, 18.8.1919.
[72] UGD 295/4/145, Letter Book, Jackson to Director of Naval Contracts, 29.10.1918, and UGD 295/4/148, Letter Book, Jackson to Accountant General, 11.11.1919.
[73] UGD 295/4/148: Jackson to Commander Ardill, DNO, 22.1.1920.

touch (and a delayed action fuze), but the complaint about the Contracts Department's shortcomings was justified as many of the firm's immediate difficulties could be laid at its door. What the business needed was not only orders, but also prompt payment for them. In early 1920, Barr & Stroud's greatest difficulty was to match income to outgoings, and having to borrow large sums at interest to finance the Admiralty was expensive and clearly frustrating.[74] Jackson's complaint was part of his continuing efforts to extract the money due from the Admiralty.

By the Autumn of 1920, those efforts had seemingly had little effect. Faced with the subsidy request implying that the company was in difficulties, the Admiralty once again looked at the relationship. It passed the question to the Director of Scientific Research (DSR) for an opinion on the cost of maintaining a research department to handle rangefinder design and construction, as well as optical glass research.[75] The question was not whether the sum requested was reasonable, but whether the research could be done cheaper by the service itself. The DSR made a general examination of rangefinder procurement and his report illustrated the position the Admiralty thought the Navy to be in *vis-à-vis* the company, strongly suggesting that Barr & Stroud had succeeded in colouring the Admiralty's perceptions very much to the firm's benefit.

He accepted that Barr & Stroud was 'in financial difficulties' and that the consequences of its failure would be serious. There were no substantial new British orders likely 'for some time' to come and the firm's foreign business would only last for about two years. Without assistance, Barr & Stroud would have to convert to commercial instrument making, and subsequently '. . . close the rangefinder business down completely' in order to handle the new work. That would put the fighting services 'in a most dangerous position' as there was no other firm to step in. 'We must have rangefinders' he said, neatly summing up the Admiralty's predicament.[76]

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[74] UGD 295 unclassified material, Russell research notes, Barr & Stroud Board Meeting 19.2.1919.
[75] PRO ADM 212/46, Correspondence between Admiralty and Director of Scientific Research, December 1920, supplies the material for the rest of this section.
[76] PRO ADM 212/46, undated memorandum.

If Barr & Stroud discontinued rangefinder operations, the creation of an Admiralty research and experimental department would be essential, as no other firm 'would be in the position to make [rangefinders] without assistance'. The DSR estimated its annual costs as between £17,500 and £22,500 for research into the mechanical aspects of rangefinder design, and suggested either setting up a government factory to produce entire instruments, or a state-owned assembly shop to assemble parts made by other instrument firms. His preferred plan however, was for the Admiralty to take over the large new premises it had built at Glasgow during the war, then progressively transfer both plant and personnel from Barr & Stroud as the company dropped out of rangefinder manufacture. This would avoid any 'dangerous hiatus during which the supply of rangefinders would be completely stopped'. Almost as an afterthought, he suggested that the State might buy a controlling interest in Barr & Stroud 'and then run the firm in the way they wanted'.

The Director of Scientific Research was perhaps unclear about what should actually be done, but an opinion dated 16th December 1920 from the Admiralty Research Laboratory at Teddington was much more decisive. This acknowledged that the question of subsidy was problematical, but in the present circumstances there was simply 'no choice': there was no State rangefinder factory and it would take 'some years' to create an effective one, so 'some Agreement with [Barr & Stroud] must, in the public interest, be arrived at...' This was very much to the point and in line with the Admiralty's eventual conclusion.[77]

The decision was that a subsidy would be the most effective and simplest way to assure the supply of rangefinders and the Admiralty then approached the War Office for its co-operation in securing funds from the Treasury. The War Office, doubtless remembering its unsuccessful pre-war attempts to buy rangefinders elsewhere, agreed to the overtures, and the Director of Army Contracts subsequently recorded that ' . . . in view of the probable smallness of orders in the near future, the Admiralty and War Office have conjointly made application for Treasury sanction to subsidise Barr & Stroud to enable

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[77] PRO ADM 212/46, Memorandum from Director of Scientific Research to Admiralty, December 1920.

that firm to keep in being its existing facilities for manufacturing'.[78] The paucity of current War Office orders could hardly be disputed, just £75 having been spent with the firm in year April 1st 1920 to March 31st 1921, out of a total outlay on optics of only £2,347.[79]

The application was vetoed by the Treasury, which refused to provide funds because in its judgement the current warship building programme would provide enough work to keep the firm going.[80] Exactly how this conclusion was arrived at is hard to see, given the absence of major warships then being built in Britain, but the decision stood, leaving the Services facing the prospect of Barr & Stroud withdrawing from rangefinder building. However, the course of subsequent events turned out to be very much different from what might have been expected.

When the Director of Army Contracts wrote his annual report in March 1921, he noted the Treasury's refusal but observed that it had not been possible to take any further action on Barr & Stroud's behalf, as the firm had made no further appeal for assistance.[81] Given that scarcely six months earlier the company had been predicting great difficulty in staying in optical munitions, the lack of subsequent calls for succour raises questions as to what had happened in the meantime. 1920 had continued to be difficult. In mid-September, Barr & Stroud reminded the Naval Staff's Director of Gunnery that although the Navy was calling for lots of new designs, there was still 'no real work' coming in.[82] Admiralty orders for new instruments and servicing contracts for the year came to just over £17,888, or just 19.6 percent of the year's new equipment business.[83] Without Japanese orders totalling £71,953, the year would have been catastrophic.

The new year marked a sudden upturn in the company's attitude and its fortunes. January's orders came to £37,900, which apart from 1915, was the largest ever for that

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[78] PRO WO 395/4, Report of the Director of Army Contracts 1920-1921; 31.3.1921, p. 14.
[79] PRO WO 395/4, Report of the Director of Army Contracts 1920-1921, p. 91.
[80] PRO WO 395/4, Report of the Director of Army Contracts 1920-1921; 31.3.1921, p. 14.
[81] PRO WO 395/4, Report of the Director of Army Contracts 1920-1921; 31.3.1921, p. 14.
[82] UGD 295/4/149, Letter Book, J. W. French to Capt. F. C. Dreyer, 15.9.1920.
[83] UGD 295/19/2/7 and /7, Customer Order files 1920 and 1921.

month.[84] In late February the bank overdraft was down from almost £100,000 at the end of December to only £54,000, 'without any Excess Profits duty repayment' and 'two or three large accounts still to be paid',[85] and Jackson observed that Japan's recent decision not to accept any reduction of armaments 'may be sad from the humanitarian point of view, but it is not likely to cause much sorrow with Barr & Stroud Ltd'.[86] The Admiralty had pronounced the new 30-foot FX rangefinder model 'excellent', and was asking about an even larger one.[87] Armaments business was now encouraging, unlike the civil ventures started soon after the war's end and mentioned in the preceding chapter, none of which seemed likely to be profitable. The Optophone device was uncertain of making even a 'small return' on its investment, the cinema projector programme was mired because the single client could not pay for the machines already delivered, and the motor cycle engine project was demanding such large sums that the Directors had been obliged to talk 'solemnly about costs'.[88] Despite all these difficulties, Jackson was able to tell a correspondent 'Don't think I'm not cheerful . . .'[89] a sentiment which probably summed up the firm's overall attitude in early 1921.

There were indeed some changes for the better that year. Despite the prediction in late 1920 that the Royal Navy would have little business for Barr & Stroud in the near future, the Admiralty ordered almost £60,000-worth of equipment, making it the largest client in 1921.[90] The Imperial Japanese Navy was the next largest, with orders of nearly £53,000. The total value of new business that year was £125,610, an increase of 38 percent on 1920's figure of £91,114. Although this was an encouraging trend, the state of new business was not so much getting better as becoming less bad.

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[84] UGD 295/ M11 Jackson to Barr 16.2.21.
[85] UGD 295/ M 11 Jackson to Barr 16.2.21.
[86] UGD 295/4/325, Letter Book, Jackson to Barr, 16.2.1921.
[87] UGD 295/4/325, Letter Book, Jackson to Barr, 25.2.1921.
[88] UGD 295/4/325, Letter Book, Jackson to C. P. McCarthy, 16.2.1921, UGD 295/4/325, Letter Book, 25.2.21 J to Tongue & Co., and 25.2.1921. UGD 295/4/325, Letter Book, 25.2.21 Jackson to Barr, 25.2.1921.
[89] UGD 295/4/325, Letter Book, 16.2.21 Jackson to C. P. McCarthy, 16.2.1921.
[90] UGD 295/19/2/8 and /9, Customer Order files 1919 to 1922 provide data for the rest of this paragraph.

Nevertheless, the underlying condition of the business was improving. Manufacturing profit increased to £98,629, up from 12 percent to 36 percent of output, and there was a small pre-tax profit of £4,406 compared to the previous loss of £80,497. Even more importantly, the accounts in December 1921 showed the borrowings at the end of 1920 had been discharged, and even after paying £26,000 of dividends there was still £10,765 cash in the bank, plus another £2,335 in French National Bonds. A fall in turnover, from £310,822 to £259,226 represented the working-through of older contracts before payments for newer ones began, and continued the expected trend in sales.[91] There had clearly been a major turnaround, but it was not accounted for by either an increase in sales or a massive reduction in operating costs. The transformation probably resulted from refunds for earlier overpayments of Excess Profits Duty. These large war-time payments (on top of income tax) totalling at least £225,000 according to Jackson's working papers, must have harmed liquidity, and their progressive repayment, which according to Moss and Russell began in 1918, must have been instrumental in restoring the balance sheet to a satisfactory condition.

This welcome trend continued as prospects for munitions business began to improve during 1921, enhanced by the Government's belated, and reluctant, decision in December 1920 to restart capital-ship building which had finally come to a halt with the completion of the battlecruiser *Hood* in May 1920.[92] None other had been planned after 1916, partly because the fleet action at Jutland that year had raised questions about what types of ships and armament were actually needed.[93] The post-war elimination of the German High Seas Fleet as a threat had been countered by the apparent willingness of the United States to complete its very large war-time construction programme that would have challenged the superiority of the Royal Navy, and which was the subject of much political and naval debate.[94] In January 1920, the Admiralty had urged that four new ships be started in the financial year 1921-1922, with four more the year after. In

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[91] UGD 295/11/1, Balance sheets, profit and loss accounts 1912-1928: audited accounts and working papers.
[92] Alan Raven & John Roberts, *British Battleships of World War Two* (London: Arms & Armour Press, 1976) p.75.
[93] Raven & Roberts (1976) Chapters 1 to 5.
[94] Phillips Payson O'Brien, *British and American Naval Power: Politics and Policy 1900-1936* (Westport, Connecticut: Praeger, 1998) chapters 6 and 7 provide background material.

December 1920, the Committee for Imperial Defence agreed that whilst diplomatic efforts would be made to check the USA's naval programme, the Admiralty could begin planning the ships it had advocated. In fact, design studies had been progressing since 1919, and thirteen different designs had been examined by early 1921,[95] so that plans for the first four ships were approved as early as August 1921, invitations to tender issued on 3rd September, and orders placed on 26th October.

To Barr & Stroud, this must have been welcome news. In March 1921 the Admiralty had approached the firm about a rangefinder of over 40-foot base,[96] and by June discussions were taking place with shipbuilders Armstrong Whitworth over the necessary turret installation.[97] The new ships were to reflect all the lessons of the war as well as more recent progress in design, which meant rangefinders that were larger, more sophisticated in design and more complex in construction to give more accurate readings. Barr & Stroud's 'duplex' design incorporating two instruments in a common housing, provided an increase in the rate at which readings could be fed into the newest range and bearing computers and was accompanied by a new height-finding rangefinder was intended for both anti-aircraft and surface use, providing information for gun direction and fuse-delay settings.[98] These were all vastly more expensive than those in battleships during the Great War, and were also to be provided on a much larger scale. The four battlecruisers were to carry at least three 41-foot instruments each for the main armament as well as sets of 15-foot duplex instruments for the other guns and torpedo armament, all requiring associated sighting telescopes, periscopes and fire-control equipment, and representing a substantial amount of business.

Any optimism felt by Barr & Stroud at the ordering of these ships was to be of short duration. There had been considerable political reluctance to embark on a costly capital ship programme in Britain, and a similar desire in the USA to disengage from its own programme. In July 1921, the USA had called a conference of major naval powers to

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[95] Raven & Roberts (1976) p.98 provides the source for order dates.
[96] UGD 295/4/315. Letter Book, Letter Book, Jackson to Barr, 2.3.1921.
[97] UGD 295/4/150, Letter Book, J. W. French to Secretary of the Admiralty, 25.6.1921.
[98] UGD 295/4/150, Letter Book, J. W. French to Secretary of the Admiralty, 29.6.1921.

discuss the whole question of naval armaments, and this met in Washington during the November. The resulting Washington Treaty limited new building and fixed relative strengths between the navies of the signatories. Welcome as this may have been to the politicians, it had serious implications for Barr & Stroud because one of the key clauses was 'a ten-year capital ship building holiday'[99] which ended British plans to build the eight new warships for which the firm had been going to supply all the optical fire control apparatus, as well as curtailing the Japanese programme that would also have brought it considerable new business.[100] The only immediate consolation was that the Royal Navy was to be allowed to construct two new battleships requiring similar outfits of optical instruments, so that there was still to be some business for Barr & Stroud.

None of the rangefinders for the subsequently cancelled ships had been ordered by the end of 1921, but design work was progressing and the firm's research and development department was fully employed, even if manufacturing work was still insufficient for the entire work force. In September, Jackson told a naval officer enquiring about joining the firm that although Barr & Stroud was 'having a pretty thin time at present' and had laid off shop-floor workers, there was no intention of letting any of the design staff go.[101] When the Admiralty Research Laboratory approached Jackson in December, asking if he could help them find a skilled optical designer, he replied that he made every effort to keep them and had not let even a single one go.[102] This emphasised the company's policy of maintaining its strategy of adherence to optical munitions production, despite the high costs of research and design – nearly all the salaries of £29,347 in 1921 went to it – and the difficulty of finding new business to keep it going.[103]

Orders for 1921 came to £125,610, and even with the ship cancellations resulting from the Washington Treaty, new contracts in the next twelve months increased by 41 percent to £177,399. However, Admiralty orders fell to £23,000 and War Office orders for anti-

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[99] O'Brien (1998) p.166.
[100] Raven & Roberts (1976) p. 108.
[101] UGD 295/4/151, Letter Book, Jackson to Commander F. Bennett, RN, 18.9.1921.
[102] UGD 295/4/151, Letter Book, Jackson to T. Y. Baker, 13.12.1921.
[103] The data for this and the following section has been extracted from UGD 295/11/1 Balance sheets, profit and loss accounts and working papers 1912-1928, and UGD 295/19/2/8, /9 and /10, Customer Order files 1920 to 1922.

aircraft rangefinders were just £25,835 so that had the company been forced to rely on British trade alone, the consequences would certainly have been dire: even with commercial orders for rangefinders from shipping companies the total of home orders was less than £55,000 and insufficient to maintain the business. The trading account for 1921 showed an actual expenditure of £85,800 on operating costs, excluding manufacturing wages, and for 1922 the figure was £71,350. The average gross (manufacturing) profit margin between 1902 and 1922 was 51 percent, with 1921 at 38 percent and 1922 at 52 percent; using this as an approximate guide to the level of business needed to sustain the company, relying on British orders alone in 1921 and 1922 would have resulted in massive and crippling losses. As it was, foreign government contracts enabled the firm to remain solvent and hold a substantial proportion of its skilled workforce together.

Improvement continued in 1923. Turnover increased by 7.33 percent to £194,901. Orders rose more substantially, by 22.94 percent to £218,091, of which civil products amounted to only 3.9 percent. Barr & Stroud was still almost entirely an optical munitions business, with the vast majority of that work – 82 percent – coming from rangefinders. This was a remarkable state of affairs. No other manufacturer demonstrated such an ability to sustain itself on sales of military or naval optics in the early 1920s. In Britain, by 1923 every other optical company had ceased to be involved. The German makers were forbidden to engage in optical munitions production because of the provisions of the Versailles Treaty, and although Zeiss had set up a Dutch company to circumvent this proscription it was still not operational.[104] In the USA, Bausch & Lomb ran its ordnance products within the framework of a large business with substantial involvement in ophthalmic and scientific instruments manufacturing, and made little progress in foreign munitions sales.[105] Notable as this achievement was, Barr & Stroud was still in a far from ideal position.

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[104] Reid, W. "Military Binoculars from Venlo." In *A Farewell to Arms: Liber Amicorum in Honour of Jan Piet Puype, Former Senior Curator of the Army Museum Delft*, edited by G. Groenendijk. (Delft: Legersmuseum, 2004) pp. 82 and 83.

[105] Bausch & Lomb Archives, Rochester New York, Unclassified material (subsequently B&LA), G. S. Saegmuller, letters to Bausch & Lomb from Jena, Germany, various dates during 1920 supplies the source material for this paragraph.

British service orders for 1923 totalled £114,994, which on their own would not have sustained the business. It was only foreign sales that made it viable. But, some 87 percent of that business came from the Imperial Japanese Navy, leaving Barr & Stroud largely dependent on one foreign client. Japan had always been the firm's largest overseas buyer of naval instruments, and in 1922 and 1923 had ordered rangefinders and commissioned a prototype mechanical analogue fire-control computer.[106] Japan still lacked an optical industry that could make rangefinders as well as the precision mechanical engineering capability necessary for the analogue computer, but this was not something Barr & Stroud expected to continue indefinitely. For several years the Japanese Navy had had resident inspectors at the Glasgow works, and by mid-1922 the company knew that two of them who had already returned home were designing rangefinders and submarine periscopes intended to be built in Japan.[107] The firm was also well aware that Zeiss had set up a Dutch subsidiary to build optical munitions, and may have known that Zeiss had already established connections both with Bausch & Lomb in the USA and the Tokyo firm Nippon Kogaku.[108] The anticipated growth in Japan's optical self-sufficiency may account for Barr & Stroud's subsequent willingness to keep the Admiralty informed about the Japanese fire-control contract, although in July 1923 the firm hoped for at least one substantial order following the successful demonstration of the prototype.[109] A major problem for the evolving Japanese industry came with the earthquake of September 1923 when the Nippon Kogaku works were destroyed, causing delays on its route to self-sufficiency and prolonging the connection with Barr & Stroud.[110]

The Admiralty's orders for 1923 included only part of the rangefinder outfits for the two battleships built as a result of the Washington Treaty. Only the smaller instruments for the secondary armament were ordered during 1923, at a cost of £24,820, with the bulk of Naval orders that year coming through £72,000 worth of contracts for similar

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[106] UGD 295/4/637, Letter Book, J. W. French to Col. Alison, Royal Artillery College, Woolwich, 4.7.1923.
[107] Moss & Russell (1988) pp. 110, 111, and UGD 295/4/334, Letter Book, Jackson to French, 31.5.1922
[108] B&LA, Saegmuller letters, and J. Alexander, 'Nikon and the Sponsorship of Japan's Optical Industry by the Imperial Japanese Navy, 1917-1945', Department of History, University of British Columbia.
[109] UGD 295/4/154, Letter Book, J. W. French to Commander Bruce Fraser, RN, 16.7.1923.
[110] Moss & Russell (1988) p. 111 – more orders were received in 1924.

rangefinders intended for cruisers. The very large main-armament outfits, worth £40,813, were in fact officially ordered early the next year, although work on them had begun during 1923.[111] These were significant because they were the last orders for such enormous and complex rangefinders until the late 1930s, and marked the suspension of this activity for almost fifteen years until the resumption of capital-ship building.

The close of 1923 saw Barr and Stroud in far better shape than three years previously. 1920 must be considered as the low point for Barr & Stroud. Even though Moss and Russell considered 1924 to have been the firm's 'lowest ebb,'[112] the earlier date marked a more critical situation. Manufacturing profit as a percentage of output reached its lowest at only 12 percent and the pre-tax trading loss of £80,497 was the greatest ever recorded by the company. In addition, although in earlier years the company had borrowed money from its own members to save bank charges and interest,[113] during 1920 it paid interest at 2 percent over bank base rate to them and was prepared to take up £75,000 in loans, suggesting that its bankers were unwilling or unable to extend as much credit as the business anticipated needing. This principally reflected a problem of liquidity rather than anything else, and it was solved in 1921 through massive tax refunds which wiped out the heavy deficit. After 1920, things were never so bad again, and by 1923 the point had been reached where the percentage of profit on manufacturing output had returned to pre-war levels and orders were again at a level that would let the business survive.

8.6 Into suspense

By 1923, the British optical munitions industry was quantitatively, if not qualitatively, inferior to its condition in 1914, with only one business actively engaged in producing instruments on a significant scale. This was not the result of inadequacies in technological ability, nor any lack of business acumen, but came about because the demand for military and naval equipment had fallen internationally to a level where armaments products of all kinds were hard pressed to find adequately remunerative

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[111] UGD 295/19/2/10, Customer Order file 1922-1923.
[112] Moss & Russell (1988) p. 114
[113] UGD, unclassified material, Iain Russell research notes, Barr & Stroud Directors' Minute Book, Board minute 19.2.1920.

markets. Optical munitions makers fared little different to those making weapons after the war and were generally forced to diversify in order to survive, Barr & Stroud alone successfully maintaining its status as a speciality producer, albeit on a smaller scale than before the war. Capacity had adjusted to current demand, and the industry was at the start of what can be described as a period of hibernation during which the ability to produce all kinds of optical munitions would be sustained, even though output remained at a low level for the remainder of the 1920s. The disposition to limit armaments constricted the British optical munitions industry but failed to bring its elimination, leaving enough of a nucleus to build on when the shift to re-armament eventually arrived.

Conclusion

The story of optical munitions manufacture in Britain between 1888 and 1923 involves a successful technological manufacturing community that is not always easy to categorise and which runs counter to perceptions of general relative decline in British scientific and technological industries during this period. Its small size and comparative obscurity when set beside other sectors engaged in manufacturing either weapons or scientific instruments has led to its being almost wholly overlooked, and to misidentification and misunderstanding by the few historians who have previously stumbled upon it. It was a peculiar industry whose progress was as much governed by the State's defence policies as commercial ability, and which despite its comparatively small size came to assume an importance of strategic significance.

The introduction to this thesis made the point that the industry's story was diverse and complicated, suggesting that its interpretation and understanding could be aided by reference to one or more of the models which seek to explain the nature of change over time in the study of history. The necessarily brief summary of their chief characteristics indicated that although all of them might be appropriately applied to different phases in the industry's evolution, the one best suited to be a general model here was Thomas Hughes' 'systems approach', with its emphasis on considering together both the technological and social factors that bore on the evolution of events. This model of explanation has indeed fitted well with the story of the progress of optical munitions production in Great Britain in the review period, even though at times it has become apparent that certain events outside this specialised field had a deterministic effect that eventually carried through to the industry itself. At the start of the story, for example, recent advances in the technology of gun propellants can be understood to have caused directly a rapid and unprecedented progress in the design of weapons, enabling their ranges to became so greatly extended as to trigger a demand for some means to measure distances on the battlefield. The process that led to the emergence of the new propellants may well itself have been driven by a series of complex and interacting social and technical forces, but the result of that process – 'nitro powder' was the catalyst, the

determining factor in the next stage in weapons technology. To this extent, 'hard determinism' does have its place in the study, but the subsequent evolution of optical munitions manufacture can only be explained through a highly involved process that places the technical, the scientific, the social, the political, and the economic in a shifting but ever present juxtaposition. By the end of the account, there is again a condition that can be seen as deterministic, where the cost of armaments (in political, economic and social terms) was seen as so prohibitive that there was an over-riding political imperative to curtail both their development and proliferation. Again, a complex and socially driven process led to a deterministic outcome which then caused those managing the industry to react in a similarly complex way to evolve strategies for survival.

This study of a highly specialised and relatively small scale industry tends to support the use of the approach taken by Hughes, if only because his model has a broader compass than the others considered at the outset. If the others are less satisfactory, it is because they do not encompass all the elements of this story and their relevance is, to a greater or lesser extent, only partial. They may be reconciled with each other and with this story to some extent; certainly none (not even hard determinism) can be dismissed as irrelevant or flawed but their capacity to make sense of the subject is less than the systems approach. Whether or not the optical munitions industry fits perfectly with Hughes' model, that is the one which best facilitates its understanding. The purpose of the exercise was, after all, to document and explain the industry, rather than to provide a detailed critical assessment of a range of theories and models in the history of technology or the evolution of businesses.

Those historians who have touched on this idiosyncratic industry assumed without question that optical munitions production was a component of the scientific instruments industry. Optical instruments for warfare were taken to be little more than variations of those for civil applications; it was taken for granted that the makers of, say, microscopes or survey instruments could – and did – adapt both their products and manufacturing techniques to supply whatever the British Army and Royal Navy required in optical instrumentation. As the preceding account has indicated, such an understanding is far

from correct, firstly because most of the instruments used as optical munitions came to be far-removed from civil patterns and secondly because the nature of the market for them was quite unlike any commercial one. The evolution of the optical munitions industry can only be understood by locating it within the framework of the larger armaments industry, although in a tantalising paradox its constituent businesses were never actually part of the arms manufacturing community. The British optical munitions makers functioned in a demand-led market which was based on evolving weapons technologies and heavily influenced by both domestic and foreign political considerations, whilst depending on the civil instrument producing community for many of its optical techniques, raw materials, and skilled workers.

At a time when much of British technological industry can be shown as fitting well with notions of relative decline, this one showed a pattern of financial and technological growth right up to the start of the Great War, flourishing in a climate of lavish spending on armaments and increasingly dominated by one company, Barr & Stroud, that by deliberately choosing to specialise in what became a particularly important type of optical munitions – the rangefinder – created for itself a dominant place in the world market for them. It would be misleading to say that Barr & Stroud competed successfully against a German optical industry that was acknowledged by contemporary commentators as being the world's largest and which represented the very highest levels of optical design and manufacturing skills, because the reality is that the German companies were forced to compete (almost always unsuccessfully) against Barr & Stroud for markets other than their domestic one.

Archibald Barr & William Stroud became 'first-movers' in rangefinder manufacture and established an early lead, not because they recognised a marketing opportunity and exploited it – as William Armstrong did with his breech loading artillery weapon after 1854 – but because they were serendipitously drawn as academics to a military problem that awaited a solution, and because of their willingness to persevere in finding an answer, even though the commercial rewards were not immediately quantifiable. Had they not been discouraged by the slow progress of their earlier joint academic research

project in 1888, they would never have taken up rangefinder design, and had they been entrepreneurs by profession they would almost certainly have been so deterred by the difficulties they met in their rangefinder experiments that they would have abandoned the idea after their failure in the 1889 trials. The question of chance in theories and models of explanation in history may be resistant to scientific employment but sometimes, as in this case, it cannot be ignored. Unlike Armstrong, who first identified a market and then, stimulated by motives that were as much patriotic as business-like, invented a novel product through the application of engineering techniques that were familiar to him, the Professors Barr and Stroud stumbled accidentally across rangefinders and taught themselves as they went along. Their rapid progress up the learning curve came from the application of scientific methodology which enabled them to become 'first-movers' in the field and build up a lead that competitors found extremely difficult to overcome before the outbreak of war in 1914.

Barr & Stroud's performance as a business can be interpreted in two ways. One is that it was a success, running counter to notions of a general under-performance in British technological industries before 1914, and exploiting the benefits that first-mover status conveyed to secure both market share and profitability. The other is that weaknesses in management caused a failure to employ adequately the strategies of vertical integration that were needed to ensure it obtained all the facilities it required along its chain of production, which inhibited its development and limited its capacity for diversification out of a highly specialised and narrow market. Both of these interpretations contain elements of truth. The company was indeed profitable, and it undeniably had a hegemonical market position in 1914, but at the same time it did fail to integrate fully into lens and prism manufacture, a condition whose causes and implications must be understood before a judgement can be reached.

Alfred Chandler proposed a number of reasons why firms might carry out vertical integration, suggesting that the most common was 'to ensure a steady supply of

materials' for production processes.[1] That certainly applied to Barr & Stroud, and its problems obtaining adequate quantities of high quality optical components were manifest right from its formation, tending to worsen as the level of business grew more rapidly after 1912, and reaching a peak in the first two years of war when the inability to procure optical materials and parts at times threatened to halt production altogether. That failure, which might also be described as limited success, came from two causes. Firstly, as Chandler suggested, the 'personal ties and relationships' typified by those with Adam Hilger & Co., 'helped to assure' the fulfilment of contracts and diverted attention towards improving the relationship rather than replacing it with another, more satisfactory, arrangement. But where Chandler said that such arrangements tended to divert businesses away from investing in production facilities and that most makers 'preferred other routes to growth' Barr & Stroud were actually prepared to make the investment but were restrained from developing a substantial optical manufacturing capacity by factors that were largely beyond their control and that reflected the condition of British optical manufacturing in general, and in particular the lack of structures for scientific education and technical training that had already been identified by the instruments industry itself. It was not that Barr & Stroud did not want, or could not afford, to make such a move, but that there was no means to obtain the necessary skilled labour except from other optical businesses, all of whom were geographically remote. Once that *impasse* was ended by changes created during the Great War, then the firm moved quickly into large-scale optical production and integrated even further into optical glass design and manufacture.

The apparent success of Barr & Stroud combined with its uniquely extensive surviving archive tends to skew attention towards it and emphasises an unfortunate – though unavoidable – reduction of attention on the other pre-war optical munitions makers, most of whom have left little in the way of records. This is regrettable, particularly in the case of Sir Howard Grubb & Co. who had a British monopoly of submarine periscope manufacture until well after the start of the Great War and may well have exported them

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[1] A. D. Chandler, Jnr. *Scale and Scope: The Dynamics of Industrial Capitalism* (Cambridge Massachusetts: Harvard University Press, 1994) p. 38.

successfully in competition with the German Goerz company. For most of these lesser players, all that can be said is that they met the requirements of the British armed forces adequately and provided a source of supply that, contrary to previous suggestions, did make Britain independent of foreign supplies after the Boer War. The importance of these relatively small-scale manufacturers was that they provided a base on which to build much of the massively expanded war-time industry, a stage for which much more is known about them thanks to the surviving records of the Ministry of Munitions.

That archive material allows the opportunity to judge how well the optical munitions industry responded to the challenges of the Great War, and provides a large body of data about what happened from mid-1915 to late 1918. Unfortunately, the printed *History* reflects only what the Ministry chose to record of what it saw as its main achievements, and the remaining manuscript material was heavily 'weeded-out' in an apparently arbitrary manner during the closing down of the Ministry in the early 1920s. Nevertheless, much unpublished confidential material remains to show the 'coupled agendas' that ran within the Ministry's Optical Section and which represented largely unofficial efforts to inject State aid, not into optical munitions manufacture, but into the peace-time framework of the civil instruments industry in an effort to bring it to a level of parity with its German counterpart. What emerges is a picture showing the diversion of the short-term energies needed to complete industrial mobilisation and accelerate war output into a longer-term effort to create a strong, science and technology oriented instruments industry that could quickly and effectively adapt to large-scale munitions production in the event of a future war. That philosophy reflected governmental pre-war attitudes to the structure of armaments production which had envisaged private manufacturers supplementing the State arsenals to achieve adequate output, but in the case of the optical industry the notion ignored the essential difference that there was no State-owned capacity for manufacture. Cheshire's plan to secure future optical munitions supplies through a rejuvenated civil industry also contained the flaw of making no provision for keeping that sector of activity alive in peace-time when demand might be minimal.

One inference from that, and one which is very hard to resist, is that despite what he had already seen since the late spring of 1915, Cheshire was still failing to grasp the fundamental differences between almost all optical munitions and civil instruments in mid-1916 when his efforts to create a new infrastructure for advanced education in optics were well under way. Most of his plans were rooted in the entrenched pre-war attitudes and desires of the instrument making community that had become virtually an intellectual paradigm and built up enough momentum to keep attention firmly focused on the need to create an optical industry closely modelled on the German one that had long been regarded as intrinsically superior. Neither Cheshire nor his colleagues recognised that, so far as optical munitions were concerned, there was no critical inferiority in the British model. None of that means that his emphasis on technical training was misplaced; far from it, it was the lack of it before the war that had prevented Barr & Stroud from successfully integrating into lens and prism manufacture and its provision was long overdue. His misjudgement was in not understanding how very different not just the instruments were, but also the circumstances surrounding their marketing and sale.

It was ironic that Cheshire's success in pushing for university-level training in optical design should lead to him leaving the Ministry in 1917, before the rest of his ideas had matured to a point where results were likely. His departure caused much of the momentum he had built up to dissipate, and little was done to set up the network of technical-school teaching that he had envisaged. The end of the war, which seems to have come much sooner than anyone in the Optical Section expected, brought all those developments to a halt and created chaos throughout the war-time optical munitions makers.

Peace found the industry fully adapted to war work after a lengthy process of industrial mobilisation, and both unprepared and ill-equipped to abandon munitions work and resume making civil products. All Alfred Esslemont's war-time energies had been used to create capacity for war products, and the end of new orders together with the almost immediate and total cancellation of government contracts meant that the war-time conscript industry quickly found itself redundant and disbanded, having to resurrect civil

product lines and seek out old clients. Of the pre-war optical munitions makers, only Barr and Stroud had been a total specialist, and it was the specialisation that had brought its earlier prosperity that now threatened it with collapse; Barr & Stroud never had commercial products and almost all its old clients were either fully stocked or closed-down by the war. The return to peace was a bigger trial than the war itself.

The problems Barr & Stroud faced in 1919 would almost certainly have occurred to some lesser extent even there had been no conflict. By 1914, most of the benefits it had enjoyed as a first-mover were ending, not because it had fallen behind in the technology of what it produced nor because of its inadequate integration in optical production, but because most of its foreign clients were approaching self-sufficiency in optical manufacture. The firm's profits since 1905 had increasingly come from overseas armed forces in countries which either lacked the ability to produce complex optics or which were prevented from making particular types, such as the rangefinder, through international patent protection. In 1912, for example, neither Austro-Hungary nor Russia had advanced optical industries and Barr & Stroud had been able to start negotiations to supply both countries with rangefinders, parts of whose designs were still covered by patents. Two years later, as war began, technology transfer *via* foreign firms who had established factories there meant that both countries could consider the production of sophisticated instruments, and the patents' lives were running out. Once the earlier contracts were complete, Barr & Stroud's chances of finding fresh orders would be diminished, although not necessarily eliminated. The same applied in France and Italy, as well as the USA, and the only other country likely to be a large buyer of military rangefinders was Japan, whose optical industry was still relatively backward. The momentum of Barr & Stroud's success was starting to dissipate, not because of superior competition but through a combination of growing foreign self-sufficiency, market saturation and the absence of any demonstrably superior rangefinder to replace expensive instruments whose service lives were likely last a goodly number of years. In 1914 the firm was reaching a condition that, but for the war, would soon have demanded attention to the question of alternative products.

For Barr & Stroud, then, the problem after 1918 was how to convert to peace in order to survive. The development stimulated by the war meant that, unlike in 1914, the firm was now largely self sufficient in everything except large quantities of the simpler optical glasses, and could undertake to manufacture every item of optical munitions required either by the Army or the Royal Navy. It was the antithesis of Cheshire's prescription for an optical munitions industry – a business that made only optical devices for warfare and lacked the ability to manufacture a range of civil products in order to sustain itself in peace-time, demonstrating its characteristics as an armaments manufacturer. Faced with the evaporation of such business, the firm's management turned to a two-pronged strategy for survival which embraced diversification and state subsidy.

The problems of war industries in adapting to peace through diversification were examined by Alfred Chandler, who observed that armaments firms frequently lacked the relevant managerial and technical skills needed to move into unfamiliar markets.[2] That this condition applied to Barr & Stroud seems demonstrated by the lack of success in attempts to diversify into motor cycle engines and cinema projectors, but in fact the firm's philosophy in these efforts was quite different to other, much larger, arms businesses who sought to replace one activity with another. To Barr & Stroud, the issue was of what could be made using existing capacity, which might be sold commercially to provide a bridge until enough government business came in to keep the firm employed in optical munitions manufacture. As early as 1919, the Board was convinced that the future lay in doing what the business had always done, despite the problems confronting them. The correctness of that judgement, based on instinct rather than a detailed study of options, was shown by the subsequent success in getting the Admiralty to believe that the symbiotic relationship that had evolved between them over the previous thirty years was balanced in favour of the Royal Navy, and that the company had to be kept alive for the benefit of the service rather than the firm. Survival was not always a matter of making a demonstrably superior product. Although the Admiralty, or rather the Treasury, balked at an outright subsidy, the willingness of the Admiralty to guarantee a substantial level of profit on a reduced volume of business enabled Barr & Stroud to retain enough of their

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[2] Chandler (1994) p. 342.

skilled workforce to keep going in the munitions business, and to be able to abandon its relatively un-remunerative civil ventures. By 1923, irrespective of the reduced levels of business, Barr & Stroud was tacitly recognised as 'an essential arm' of the Admiralty's establishment.[3] It also remained, as in 1914, the world's only manufacturer devoted wholly to the production of optical munitions.

For the British optical munitions industry in the early 1920s, success had become synonymous with survival. In 1888 there had been no industry, it had emerged after then in the wake of evolving armaments technologies and its products only became taken seriously by the British Army and the Royal Navy in the first years of the 20th century. By 1914, still led by the evolution of military science, optical munitions were an integral part of strategic weapons systems and the importance of their makers to the state starting to become apparent. The Great War provided a totally unprecedented scale of demand and created a vastly expanded and vital industry that suffered an inevitable implosion with the Armistice of 1918, threatening to leave the State without any means of producing the now-essential instrumentation of warfare. Such a simple summary implies a deterministic nature to the shaping of the industry, but as the preceding narrative has shown, much of that shaping was done under social and cultural influences that were no less important than the technology that framed them. Under those influences the optical munitions industry equipped not only Britain's armed forces but also most of the world's navies before 1914, provided profits for its members, adapted to the needs of the greatest war yet experienced, and emerged from it in a drastically truncated but still capable form. That it was effectively reduced to only one company was not so much evidence of failure but an unavoidable adaptation to vastly changed circumstances. Faced with a major shift of international political attitudes towards armaments that looked likely to eliminate any large future demand for optical munitions, Barr & Stroud not only survived the transition from war to peace, but through adhering to a policy of austere specialisation continued until the re-armament programmes of the 1930s simultaneously resurrected optical munitions and stimulated the development of the electronic range and targeting systems

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[3] Chandler (1994) p. 345.

that would eventually make them obsolete. 1923 marked not the end of the British optical munitions industry, but the start of a period of hibernation.

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