Technology and Military Policy in Medieval England, c.1250-1350 was completed at the University of Reading in 2003. For your convenience the chapters etc have been divided into separate links.

Introduction

'Now artillery of all kinds is as common as any other weapons because our minds are quick to learn the very worst.'

Petrarch, *De remediis utriusque fortune*, c. 1360[1]

Few historical topics are as contentious as technology and warfare, especially when combined; any study which attempts to synthesize and contextualize their interaction over a long durèe treads lightly. Yet there is pressing need both for detailed studies of the 'nuts and bolts' of technological development in pre-modern Europe and for a methodology which places these developments within a larger context of European formation. At present the macro-history of Europe and North America, the so-called 'rise of the West' over the past millenium, is the subject of a vast debate centred on two questions. The first asks whether Europe's development was especially unique in world history. The second asks what, if anything, determines a society's growth, and is usually framed as 'Why do some nations grow rich and others poor?'.

Pride-of-place for explaining this remarkable expansion has almost invariably been assigned to one or another of four of its prominent features: war, capitalism, states and science-cum-technology.[2] Recent accounts, however, tend to emphasize the symbiotic and mutually reinforcing relationships of these factors, and tries to acknowledge a range of trends said to characterize Europe's formation.[3] While the sixteenth to eighteenth centuries are still widely considered Europe's coming of age in this regard, in varying degrees historians have drawn attention to a similarly intense phase between c. 1250 and 1350 which also marks a turning point in the balance of East-West relations.[4] A conspicuous feature of this scholarship is the almost overwhelming tendency to conceptualize events as a 'revolution'. A 'military revolution' debate has entered the canon of military history and even if the term is overloaded, a late medieval military revolution or 'renaissance' is gaining credibility.[5] Likewise, the early modern Scientific Revolution is now juxtaposed with the originality of a paradigmatic shift in medieval thought and praxis that brought a more optimistic investigation of nature.[6] As much, if not more, attention has been paid to an elusive transition from 'feudalism' to 'capitalism' which has at least helped to clarify medieval socio-economic conditions.[7] Not surprisingly given the circumstances, the sophistication, vitality and continuity displayed by some medieval governments and their political institutions have led many to view them as the pre-cursor of the modern state.[8] A truly complex event, this macro-revolution of the thirteenth and fourteenth centuries possibly comprised lesser 'revolutions' in agriculture, commerce and mainstream industries such as textiles and ironworking.[9] Furthermore, many extend this timeframe to the eleventh and twelfth centuries to include a social 'revolution' that stabilized society and paved the way for such growth.[10]

That historiography supports the view of world history as a set of distinctive cycles as popularized by Toynbee and Spengler, but consequently the term 'revolution' in this scholarship has become a clichéfor widespread, sweeping and/or radical change in any of a system's components regardless of their level of interaction or extent of influence. When applied to specific events within a system, this term ignores or at least eclipses relationships within a system and the relative importance of the forces acting on them.[11] When applied to change at the systemic level, 'revolution' has confusingly referred to very diverse events sometimes describing a single turn in a series of cycles and at other times a violent change that establishes a new dynamics.[12] Clearly, a more refined method is needed to analyze, gauge and contextualize the dynamics of long-term change especially during these turbulent macro-revolutions.

In the case of military history, historians' efforts have often sought to identify the nature, scale and pace of change in the norms of military activity. In this respect the astonishing changes in the English Crown's warfare during the thirteenth and fourteenth centuries has drawn much attention.(13) With a shrinking domain, internal strife and rising expenses, Henry III faced dim prospects. Edward I's ambitious policies greatly elevated the scope, scale and intensity of an increasingly intra-national conflict. Despite the political instability of Edward II's reign, the English crown continued to develop formidable capabilities. With great political and military ingenuity, Edward III pressed these advantages to what amounted to a splendid culmination of the crown's efforts over the previous century, securing its authority and bringing lucrative gains. Historians now recognize that en route to these victories, epic changes occurred in English government which in practice resembled an imperial system of financing and administration yet national in character and political authority.(14) Pressing matters pertaining to military organization (what broad strategies should be adopted, how to finance military expenditures several fold the crown's annual revenue, how to obtain more military service, how to engage new technologies and techniques) galvanized England's expanding military and political community and required great administrative reform. The recruitment, tactics, equipment and even perceptions of war among the crown's armies can be said to have experienced momentous change.(15) Several historians have even noted what seems to be a major change in England's command of materials and military devices at this time.(16)

During this period of intense conflict and growth, virtually every type of armament from the simple arrowhead to large and complex siege engines underwent rapid development. Petrarch's words quoted above certainly expressed the view that Europe was changing as the result of its devotion to military technology and firearms in particular. Historians, of course, have been all too eager to credit one or another armament with too much influence on medieval warfare: the longbow, plate armours, steel weapons, trebuchets, firearms and various fortification schemes have all been credited with some type of 'revolutionary' effect between c. 1250-1350. We now recognize that not one of these inventions overturned the course of medieval warfare. Yet, it is necessary to ask how European societies coped with the development of such vibrant military devices especially when combined with society's greater capacity for war. In the twelfth century the Latin West was already a technically, economically and intellectually robust society fast outstripping Richard fitz Nigel's maxim that money was the measure of a king's status.(17) Whereas many forms of military organization had previously relied on the individual's obligation to provide service and arms due to the impossibility of large-scale provisions by central agencies, the new amounts of wealth and arms in society can be said to have created an arms race in equipping armies. In the thirteenth century, large quantities of arms began to be commercially produced in most cities and specialist centres particularly in the Low countries. For example, in 1295 Phillip IV's emissary purchased at Bruges a hoard of arms to equp a fleet including 666,258 quarrels, 5067 coats of plates, 14,599 swords and 40 springalds.(18) If England's price trends are indicative of wider conditions in Europe these arms had also become much more affordable. On a broader level which takes into consideration the range of materials and devices needed for war, it can even be argued that between c. 1250-1350 sustained success in European warfare became increasingly dependent on governments' abilities to promote and coordinate an 'industrial' or material-intensive warfare, especially in building an infrastructure capable of handling greater volumes and more technical material of war.

The idea that pre-modern warfare was shaped by industrial forces is not new. William McNeil has repeatedly stressed the importance of industrial capabilities in early societies' development, especially the availability of iron and arms.(19) In fact, were it not for the baggage associated with the term 'military-industrialization' this work could have been titled 'proto-military industrialization in medieval England'.(20) The term 'technology' is only slightly less conceptually problematic. While an abstract 'technology' often took centre stage in Marxist writings on 'feudalism' which continued in the Annals school, the focus on agricultural technologies and labour foundered under hardline philosophical views and the inability to make sense of the highly disparate and localized trends. Subsequently, the study of approaches to technology in medieval society and have languished in deference to attempts which sought to establish a baseline of economic development and focussed on economic indicators such as population, commercial activity, production (especially agriculture and textile), and currency.(21) Although the works of pioneers such as Lynn White, Jr. removed the disdain surrounding medieval technology per se, such early histories had the unfortunate but obvious task to correct previous misapprehensions and consequently, they often suffered from weak links to its intellectual milieu. As such many now hope that these monocausal explanations, such as Christianity, rationality, or the university, can be weaved into a richer tapestry of society and technology.(22) The particular field of medieval military technology is in special need of methodological attention. Basic tools such as the compendia of K. DeVries, *Medieval Military Technology*, D. Nicholle, *Arms and Armour of the Crusading Era* or P. Porter *Medieval Warfare in Manuscripts* have only recently become available.(23) While certain aspects of medieval industrial technology, such as the building of cathedrals and castles have been addressed incidentally, empirical studies of a medieval society's overall industrial capability are almost entirely lacking. Claude Gaier's study of the Low Countries is perhaps the only and yet a very thorough effort, but he eschewed a concerted economic analysis of his material.(24) Historians have assumed that Europe experienced widespread advancements in masonry, carpentry and iron-working from the twelfth century, but many of these changes were poorly documented and are difficult to verify through archaeology.

Theories first expounded to explain 'industrial revolution' of the eighteenth century specialize in charting revolutionary industrial growth on a national and systemic level. Initially presented in a Marxist framework, some economic historians such as J. Schumpeter and W.W. Rostow described industrialization as a progression through a series of distinct stages or modes of production.(25) In a departure, Alexander Gerschenkron eliminated the rhetoric of 'stages' by focussing instead on societies' industrial behaviour and their relative rates of growth.(26) Gerschenkron further opined that rapid industrial growth most often occurred in response to a crisis or 'challenge', amid great tension in society.(27) Several implications of Gerschenkron's model are pertinent here. Gerschenkron and many subsequently found that the demands of large-scale enterprise imparted a cycle in a society's efforts, entailing rapid growth, convergence and finally ossification each occurring at various pace based on the circumstances. That model also revealed the socio-economic complexities of big enterprises: an invention or innovation is only as useful as a society's ability to structure its economy to take advantage of it or to incorporate it in some viable fashion, ie it needed to possess the technical skills, access to resources and the appropriate input from society to support the endeavour.(28) These demanding and high profile technologies therefore also became highly prestigious enterprise even serving as national icons.

Although some may question whether a model of modern industrialization is applicable to medieval Europe, this criticism begs the question about the extent of change in the European system and the fundamental nature of its dynamics.(29) Several other fields in medieval history have already adapted similar models and tools of critique. In an elaboration of Joseph Schumpeter's model, M. Ormrod and R. Bonney have characterized the reform of the English Crown's fiscal organization in the fourteenth century as a shift from a domain state to a tax state which temporarily placed its wealth on a more or less equal footing with French kings.(30) Repeated attempts have even been made to quantify changes in England's productivity as measured by its Gross Domestic Product.(31) World systems studies which prefer a systemic level of analysis often expressed in terms of core-periphery relations have also begun to recommend Gerschenkron's models of modern industrialization.(32) Those works have also benefited greatly by distinguishing between the accumulation of capital and private ownership and acknowledging military works and government infrastructure as capital-intensive enterprises or 'proto-capitalism'.(33) In any case, all or any of these models may ultimately prove more useful for marking *dissimilarities* rather than similarities over this period, but they will allow initial forays and may help to identify changes in dynamics. The very surge of interest in political, economic and military models for the study of the middle ages and the rampant propagation of 'revolutions' are testimony to a need for analysis of the medieval system and its dynamics.

While the economics of technology and industrialization of later periods have been well served, the study of technology's socio-intellectual context especially its relationship with 'science' has encountered numerous setbcks as the field suffered a series of methodological shifts. A common stance which gained currency during the seventeenth century and still prevails today views technology as applied science, which assumes that science encompasses and therefore exceeds or supercedes technology.[(34)] In this vein, 'science' early on was credited with supreme importance in the formation of the modern world, a view which was strengthened in the twentieth century when more abstract sciences co-authored the most powerful technologies indeed.[(35)] Consequently, many hailed the early modern scientific revolution as 'the most important event in Western history', or in H. Butterfield's oft-quoted words, one that 'outshines everything since the rise of Christianity and reduces the Renaissance and Reformation to the rank of mere episodes, mere internal displacements, within the system of medieval Christendom.'[(36)] Subsequently, the study of the histry of science was invigorated but the nature of the early modern scientific revolution came into question as a growing number of people began to speak of medieval intellectual and scientific 'revolutions' that prefigured early modern developments.[(37)] In the second half of the twentieth century the perception of technology as applied science was also steadily unravelling historiographically and philosophically.[(38)] In fact, critical points in the development of scientific activity, especially in abilities to influence technology, have now been proposed for virtually every century from the twelfth to the twentieth.[(39)] Attempts to understand'scientific progress' over the long durèe began to ask questions such as 'What is science or technology?', 'How does science and technology develop?', and 'What is the relationship between science, technology and society?'[(40)] In 1977 E. Layton summarized the state of the debate with harsh criticism: 'Current ideas are often naive and contradictory even in such basic theoretical infrastructures as 'technology and technique', 'invention and innovation' and, above all, in the still mystical relationship between science and technology.'[(41)] In the introduction to the *Handbook of Science and Technology Studies* written nearly two decades after Layton's criticism, the situation was described in equally bemused terms. D. Edge's comments reflect many other contributors' own conclusions that we have not moved beyond methodological confusion, especially in the debate concerning local and systemic influences.[(42)]

Compounding this problem, the desire to locate the rise of the West in its scientific practices seemed to shift its determinism to technology. Technological determinism stresses a technology's natural logic of application or improvement in terms of a more efficient or effective output, thus imparting such devices with an agency or ability to affect change per se or in unforseen or virtually uncontrollable ways.[(43)] At the other end of this philosophical spectrum, advocates of social constructivism adopt a more organic approach and minimize the impact of a technology's 'logic' to emphasize instead its 'grammar', the contemporary conditions or determining factors which stem from society. The conflict of these divergent views has created something of a conundrum for reconciling explanations of long-term technological developments with historical circumstances. This conundrum in turn led to a call for a holistic approach that provided more than a logical analysis of scientific and technological development as can be seen in J. D. Bernal's *Science in History* which viewed science as 'accessory to great social, economic, and political movements'.[(44)] Subsequently, 'Science & Technology Studies' (S&TS) have been'revitalised' by the recognition that there are 'multiple, mutually constitutive, and mutually reinforcing relationships in which science and technology engage with the state' in a 'system of coproduction, in which scientific and political order are simultaneously created and recreated so as to sustain each other through complex rituals of interdependence'.[(45)]

To that end the work of T. Kuhn on long-term change in scientific activity and its intellectual and cultural contexts may be of some aid when applied to the socio-intellectual conditioning of medieval technology. Kuhn's *The Structure of Scientific Revolutions* drew on preclassical mechanics to demonstrate that scientific activity advanced through a series of seemingly irrational, incommensurable transformations that amounted to a shift in belief systems.[(46)] According to Kuhn, the pursuit of science was as much a cultural phenomenon as art or language, complete with an agenda embodied with similar idiosyncratic beliefs, assumptions, and prejudices that rendered such pursuits far less than objective.[47] Indeed, one way historians have distinguished between the strikingly similar medieval and early modern mathematics of motion is by emphasizing each society's reaction to such works and their broader scientific/philosophical frameworks. Although many now prefer the view of the history of science as a more rational pursuit as proposed by Lakatos, Kuhn's model may be more appropriate for the peculiar and highly restrictive conditions of medieval science. The prohibitive religious framework and firmly entrenched Aristotelianism greatly restricted the extent to which logic and reason could direct the pursuit of science or confirm its conclusions; indeed, it may be worthwhile to view this period in the history of science as the growing authority invested in these critical faculties. Nonetheless, we will see that in the thirteenth and fourteenth centuries governments' recourse to scientific knowledge became increasingly important in the European political economy and intellectual superiority came to be associated with politico-cultural preeminence.

The approach taken here is that speaking generally, science and technology are both intellectual investigations of nature, forming the middle band of a spectrum ranging from thought to action. Sciences can be said to utilize formal arguments in a systematic study of nature as a theoretical exercise, even though they may often draw on observation and/or empirical evidence. When scientific activity draws on empirical evidence, often it begins to merge with technology and form bi-directional exchange especially when relying on instrumentation. Caution is further warranted when it is conceded that scientific methods, aims, etc. change over time and need to be viewed in both their cultural and philosophical contexts.[48] Technology would therefore represent the study or appreciation of implementing physical changes in predictable, controlled or systematic ways. However, many disciplines straddle these arbitrary divisions and serve to demonstrate the futility of trying to define exactly where 'science' ends and 'technology' begins even within single disciplines much less for the whole of human experience.[49]

Placing the English crown's perception of technology within the well-studied collapse of a personal and reactive politico-military organization and the rise of a more centralized, autonomous and public one will provide an excellent indication of technology's influence on war and state-formation. Prior to the thirteenth century, English military organization was based on pre-defined obligations which circumvented the problems of a non-cash economy and allowed the mobilization of forces far in excess of kings' immediate wealth. However, such a cumbersome system highly dependent on personal authority and based on surplus extraction tended to retard overall growth and produce inconsistent results.[50] We would expect to see the Crown's interest in technology increase as military organization became more uniform and pro-active in its policies. States are assumed to play dominant roles in international systems due foremost to their relative autonomy, sound infrastructure and command of resources; theoretically, these attributes are conducive for technological development by facilitating the diffusion of materials and knowledge, improving logistics, creativity and understanding of capabilities.[51] The argument that Edward I's reign, for example, witnessed the establishment of a more professional staff and army has a long lineage.[52] A more recent trend in English historiography, however, assigns a similar role to Henry II's household as paid troops became more common with the rise of a money economy.[53] How did the Crown's involvement or interest in technology during the turbulent thirteenth and fourteenth centuries relate to its military organization and with what level of awareness? To what extent should we view England's success up to 1360 as a rather sudden burst achieved through reorganization and introduction of new techniques, or was that success inherently related to longer processes? If real economic growth is defined as growth above that gained from an increase in population etc, then real technological growth is defined here to mean an increase in the interest or application of technology in addition to that gained incidentally through a maturing system. This subject needs a range of methodological treatment to develop an approach better termed 'technology in history', including the philosophy of history for periodization, methodologies of long-term change in pre-modern systems and empirical analysis of societies' military industrialization. Due to the state of research on medieval technology, this work has not been able to achieve much more than a cross-section history of a few of the period's military technologies and therefore takes as premises five features of European formation during this period: 1) the buoyant conditions of Europe during the twelfth and thirteenth centuries increased capacities for war; 2) the synthesis of this growth resulted in a macro-revolution and a new set of dynamics for Europe's political economy; 3) these new dynamics allowed rapid military growth and noticeably greater military capabilities, heightening insecurities; 4) the price scissors affecting the landed classes and the failure of agriculture acted as a further incentive for war; 5) all of these conditions contributed to initiating a virulent arms race conspicuous in its scale, frequency and intensity.

The great majority of this work strives to qualify the English Crown's response to the new warfare and to quantify the mobilization of its most prominent war materials. If Gerschenkron's criteria are applied to medieval warfare, then fortifications, naval craft, siege engines, and personal armaments are the best examples of heavy capital goods. The already substantial and excellent work of specialists devoted to medieval fortifications and naval history has greatly curtailed the attention given here to those prominent aspects except to provide a framework for the Crown's overall efforts and the dynamics of lesser developments related to them, such as siege engines and the equipping of navies. Overall, two broad characteristics can be highlighted in the Crown's management of arms: though England persistently failed to meet the Crown's production requests it nonetheless achieved a high rate of industrial growth between c. 1270 and 1350 (though no gross estimate has been attempted here), aided immensely by the Crown's infrastructure; consequent with this growth, the Crown entered into an experimental phase incorporating these capabilities into its strategies.

A wealth of documentary evidence exists for the English Crown's military efforts raising the need for well-tested theories which aid in the selection, analysis and interpretation of evidence. The Crown's policies can be deduced from the orders issued through its secretarial offices. Details such as their date, location and authority of their issue would allow detailed research into the formation and implementation of the Crown's policies, especially its reliance on county support. These records provide a unique means of gauging the combined effects of the new warfare. At first these expenses were recorded mostly in the Liberate Rolls, but by the fourteenth century that method had largely been replaced by the more detailed particulars of Wardrobe and Exchequer accounts.(54) These records are a rich source for the Crown's industrial efforts, and are extremely helpful for gaining a quick appreciation of Crown's overall capabilities. This particular class of records, however, may present an extreme view of the Crown's *modus operandi* as the most detailed records stem from events which warranted special accounting. Entries of other classes, i.e. Pipe Rolls, Close Rolls and Patent Rolls, while less detailed in their descriptions may prove more representative of routine activities.

The first two chapters examine the importance of the idea that society and nature could be ordered more effectively for the technology and logistics of the new warfare respectively. Chapter One examines one of the most complex science-based technologies of the middle ages, siege engines especially trebuchets and firearms. This effort extends to identifying contemporaries' awareness of changes in philosophy of technology, from writings bordering on political economy to scientific discussions of techniques and praxis. Chapter Two investigates the diffusion of this scientific method into the crown's administration and undertakes a more precise investigation of the crown's reaction to technological development. A review of a range of administrative records provides a unique means of gauging how England coped with the crown's drastically increased demands and demonstrates that the crown's loosely imperial military organization extended to its management of war materials. Although this study gives special consideration to expenditure on arms or to extraordinary efforts when they provide obvious indications of the crown's operations, many routine activities have also been glossed from the mass of documentary evidence to illustrate the crown's management of arms.

Chapters Three and Four trace the importance of technology in the crown's siege and field warfare respectively to note its effects on the equilibrium of attack and defence in those endeavours. This division into types of warfare is noticably artificial for this period, because in actuality the character of war was being overwhelmed by an industrializing landscape wherein greater attempts were made to deploy combinations of forces and more substantial works together, necessitating a far greater range of static military duties. The crown's heavy investments in fortifications and siege warfare peaked in Edward I's reign as it proved over burdensome in the face unpredictable circumstances. In field warfare, the most persistent attempts to raise extremely well equipped armies were initiated in Edward II's reign and persisted until the second half of the fourteenth century when they were gradually abandoned as contact service prevailed.

Chapters Five and Six analyze in succession price trends for iron and personal armaments drawn almost entirely from the crown's records. Iron and steel were crucial for the availability of arms and industrialization in general, but study of their prices is made difficult by many amorphous and ambiguous terms for units of weight in their records. Nonetheless, the acceptable evidence for prices allows us to posit a general price trend for domestic products and foreign imports essential to England's welfare. The range of demands the crown's military efforts placed on these sources is also analyzed for its scale and impact on military organization. This tempting evidence for increased availability of iron and more prolific iron-working is greatly supported by the less ambiguous evidence for the prices of personal armaments. The Crown's ambitious efforts to improve the army's equipment represents one of the best documented and politically charged junctures of technology and policy. Was the English Crown trying to keep pace with changes in the design and availability of armaments in Europe, or was an avant garde attempt being made to create a nation in arms in the early fourteenth century? The question lies at the heart of the transformation of English politico-military structures and yet the costs of armaments has languished under uninspired efforts. Although we can demonstrate a marked decline in arms prices, their adoption stemmed from a range of factors. From the individual's perspective investing in arms had to be viewed in terms of their cost as compared to the benefits of military service; from the government's perspective the desire to field larger and better equipped armies had to be balanced against such factors as their cost, logistics, and tactics. The two appendices also deserve mention here for their overall relevance in this work. Appendix II lists benchmark arms requirements and estimations of their costs, and thus provides a rough index of England's militarization at least regarding the diffusion and availability of personal arms as seen from the crown's perspective. The implications of arms' cost for administration and military organization are discussed in Chapter Two, while the military necessity and significance of the arms requirements follow in Chapter Four. Appendix I contains a price index listing average prices for the most common arms during the period 1294-1347; the methods for compiling the index is explained in Chapter Six which also seeks to place these prices in their long term context. The price index of Appendix II is fundamentally important for the entire work. A price index for each armament provides a much more accurate guide to the arms race and the cost of military service by avoiding the slippery slope of what constitutes an average harness, and will help us avoid the pitfall of blindly accepting the occasional prices found in wills, inventories, and royal expense accounts since these were most often the magnificent armaments of the nobility.

A full index of arms prices will also help put into perspective and serve to qualify and quantify the Crown's logistical efforts. Indeed these records provide us with most arms prices but not always conveniently. During the munitioning of castles, transactions were often made which recorded various arms and materials under all-inclusive sums. At the siege of Stirling (1304) one of many orders simply requested £10 worth of crossbows and quarrels.(55) Likewise, we often see only the total costs for munitioning castles, such as the £219 spent on Glamorgan and Morgannon in 1317, or the nearly 5,000 l.t. spent at Bordeaux during 1324-1325.(56) Conversely, the armaments may be itemized but not their cost, like the 40 crossbows, 12 crossbows *a tour*, 6 springalds, 50 bows, 100 sheaves of arrows, 40 quintals of iron, and 50 targes ordered for the garrison on the Isle of Jersey.(57) Unfortunately these instances offer very little to a study of prices. In contrast, determining the price of each armament will greatly enhance our understanding of industrial and logistical capabilities. For example, what did the £40 for springalds represent to the citizens of Southampton when they were threatened in 1339?(58) Did this provide an impressive battery or a minor addition to the town's defences? When £1200 was set aside to buy arms in 1343, how much equipment would that have purchased?(59) In short, how should we view these figures: as extraordinary measures to prevent catastrophes, or as rather common expenses in providing protection for the realm?

NOTES

1. C.H. Rawski, *Petrarch's Remedies for Fortune Fair and Foul: A Modern English Translation of* de Remediis Utriusque Fortune, 5 vols. (Bloomington, Indiana, 1991), Book 1, dialogue 99, ll 39-40.

2. G. Stokes, 'The Fates of Human Societies: A Review of Recent Macrohistories', AHR 106 (April 2001), pp. 508-25, provides a historiography of Western 'macrohistory'. See also the magnificent series, W. Blockmans and J.-Ph. Genet, gen. eds., *Origins of the Modern State in Europe, 13th to 18th Century*, 7 vols. (Oxford,1995-2000), esp. the first two volumes, *War and Competition between States*, P. Contamine, ed. (Oxford, 2000), and *Economic Systems and State Finance*, R. Bonney, ed. (Oxford, 1995).

3. E.g., a growing importance of economic factors and the emergence of a 'ceaseless' effort to accumulate capital; the prominent role assigned to states rather than individuals; the development of a democratic basis of government; a plurality of authorities and ideologies in domestic and international affairs; a strong tendency to wage war or to exhibit predatory, externalist policies.

4. On this point see J. Abu-Lughod's controversial *Before European Hegemony. The World System A.D. 1250-1350* (Oxford, 1989). World-history has grown rapidly during last quarter of the twentieth century stimulated in no small part by I. Wallerstein, *The Modern World-System: Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century* (New York, 1974); cf. A.G. Frank and B. Gills, eds., *The World System: five hundred years or five thousand?* (London, 1993); C. Chase-Dunn and T.D. Hall, *Rise and Demise. Comparing World Systems* (Boulder, 1997).

5. Historiographies can be found in G. Parker, *The Military Revolution: Military Innovation and the Rise of the West, 1500-1800* (Cambridge, 1988), and C. Rogers, ed., *The Military Revolution Debate: Readings on the Military Transformation of Early Modern Europe* (Boulder, Colorado, 1995). For theories of a medieval military revolution, C. Rogers, 'The Military Revolutions of the Hundred Years War', *The Journal of Military History* 57, no. 2 (1993), pp. 241-278, and idem, *War, Cruel and Sharp. English Strategy under Edward III, 1327-1360* (Woodbridge, 2000), pp. 1-5; A. Ayton and J.L. Price, eds., *The Medieval Military Revolution: State, Society and Military Change in Medieval and Early Modern Europe* (London, 1995); M. Prestwich, *Armies and Warfare in the Middle Ages. The English Experience*. (London, 1996), especially the conclusion, 'A Military Revolution?'.

6. R. Porter, 'The Scientific Revolution: a Spoke in the Wheel?', *Revolutions in History*, pp. 290-316 makes this same point. H.F. Cohen, *The Scientific Revolution: a historiographical inquiry* (Chicago, 1994), thoroughly investigates historians' treatment of medieval and modern science; E. Grant, *The Foundations of Modern Science in the Middle Ages. Their Religious, Institutional and Intellectual Contexts* (Cambridge, 1996), provides an overview of the achievements of medieval science.

7. An insightful review of this debate can be found in S.H. Rigby, *Marxism and History. A Critical Introduction*, second edn. (Manchester, 1998), pp. 160-70; seminal articles for modern scholarship can be found in T.H. Aston and C.H.E. Philpin, eds., *The Brenner Debate: Agrarian Class Structure and Economic Development in Pre-Industrial Europe* (Cambridge, 1985); see also J. Hatcher and M. Bailey, *Modelling the Middle Ages. The History & Theory of England's Economic Development* (Oxford, 2001), pp. 2-3 ff; R.A. Denemark and K.P. Thomas, 'The Brenner-Wallerstein Debate', *International Studies Quarterly* 32 (March, 1988), pp. 47-65, places the Brenner debate in a world- history perspective.

8. Many writers now endorse the medieval origins of the 'modern' state. Q. Skinner, *The Foundations of Modern Political Thought*, 2 vols. (Cambridge, 1978), and idem, 'The State', in T. Ball, J. Farr, and R.L. Hanson, eds., *Political Innovation and Conceptual Change* (Cambridge, 1989), pp. 90-131; see also J.P. Genet, 'Which State Rises', *Historical Research* 65 (1992), pp. 119-33; S. Reynolds, 'The Historiography

of the Medieval State', *Companion to Historiography*, M. Bentley, ed. (London, 1997), pp. 117-38. For the rise of the medieval English state, J.R. Maddicott, and D.M. Palliser, eds., *The Medieval State: Essays presented to James Campbell* (London, 2000).

9. Commerce: R.S. Lopez, *The Commercial Revolution of the Middle Ages, 950-1300* (Cambridge, 1971); a theme picked up in R. Britnell, *The Commercialisation of English Society, 1000-1500* (Cambridge, 1993). Textiles: E.M. Carus-Wilson, 'An Industrial Revolution of the Thirteenth Century', *Economic History Review* 11, first series (1941), pp. 39-60 which has been strongly challenged. Agriculture: G. Astill and J. Langdon, eds., *Medieval Farming and Technology. The Impact of Agricultural Change in Northwest Europe* (New York, 1997). For iron-working see below, Chapter Five.

10. T. Bisson, 'The "'Feudal Revolution"', *Past and Present* 142 (1994), pp. 6-42 and 'Debate: "The Feudal Revolution"', D. Barthélemy and S.D. White, *Past and Present* 152 (1996), pp. 196-223 and T. Reuter, C. Wickham, and T. Bisson, *Past and Present* 155 (1997), pp. 177-225. R.I. Moore, *The First European Revolution, c. 970-1215* (Oxford, 2000).

11. In other words a system's logic. Whether or not the essential or fundamental nature of an international system is subject to change has raised considerable debate especially over the nature of processes such as the development of states or 'capitalism' in the middle ages. One recent attempt to tackle the question of the nature of the medieval system is, M. Fischer, 'Feudal Europe, 800-1300: Communal Discourse and Conflictual Practices', *International Organization* 46 (1992), pp. 427-66.

12. For a discussion of its etymology and historical usage, W. Parker, 'Agrarian and Industrial Revolutions', *Revolutions in History*, R. Porter and M. Teich, eds. (London, 1986), esp. p. 180, n. 1.

13. See for instance Rogers, *War: Cruel and Sharp*, pp. 5-9; A. Ayton, *Knights and Warhorses. Military Service and the English Aristocracy under Edward III* (Woodbridge, paperback edn, 1999), pp. 9-25.

14. See W.M. Ormrod, 'State-Building and State Finance in the reign of Edward I', *England in the Thirteenth Century. Harlaxton Medieval Studies I.* W.M. Ormrod, ed.(Stamford, 1991), pp. 15-35; G. Harriss, *King Parliament and Public Finance in Medieval England to 1369* (Oxford, 1975).

15. A. Ayton, 'English Armies in the Fourteenth Century', *AAF,* pp. 21-38, provides an overview.

16. M. Prestwich, *Edward I* (London, 1988), has brought to light many of Edward I's major engineering works as well as highlighting the change in the scale of war; cf. M. Haskell, 'Breaking the Stalemate: The Scottish Campaign of Edward I, 1303-4', *Thirteenth Century England* VII, M. Prestwich; R. Britnell; R. Frame, eds. (Woodbridge, 1999), p. 223-241; A. Freeman, 'Wall-Breakers and River-Bridgers: Military Engineers in the Scottish Wars of Edward I', *Journal of British Studies* 10 (1971), pp. 1-16.

17. *Dialogus de scaccario by Richard fitz Nigel,* C. Johnson, et al. eds. (Oxford, 1983), p. 1.

18. The entire purchase included 1885 crossbows, 1254 lbs. of hemp for cords, 666,258 quarrels with 1691 quivers, 6309 shields, 2853 helmets, 4511 aketons, 751 pairs of gauntlets, 1374 gorgets, 5067 coats of plates, 13,495 lances, 1989 hatchets, 14,599 swords and daggers and 40 springalds, C. Gaier, *L'Industrie et le Commerce des Armes dans les Anciennes Principautés Belges du XIIIme à la fin du XVme Siècle* (Paris, 1973), p. 118.

19. W. McNeil, *The Pursuit of Power. Technology, Armed Force, and Society since A.D. 1000* (Oxford, 1982).

20. Early modern historians have quite wittingly adopted the term 'proto-industrialization'. S. Ogilvie and

M. Cerman, 'The theories of proto-industrialization', idem, eds., *European Proto-industrialization* (Cambridge, 1996), pp. 1-11. Here the terms 'industry', 'industriousness' and 'industrialization' have been chosen for their simplicity and can usually be equated with 'production', 'productivity', and their processes including the intensification or concentration of material warfare.

21. A recent review of this logic appears in J. Kaye, *Economy and Nature in the Fourteenth Century. Money, Market Exchange, and the Emergence of Scientific Thought* (Cambridge, 1998), pp. 15-16; otherwise see N.J. Mayhew, 'Population, Money Suppy, and the Velocity of Circulation in England, 1300-1700' EcHR 48 (1995), pp, 238-9, and B.F. Harvey, 'Introduction: the Crisis of the Early Fourteenth Century',*Before the Black Death. Studies in the 'Crisis' of the Early Fourteenth Century,* B.M.S. Campbell, ed. (Manchester, 1991), pp. 1-24.

22. E. Whitney, *Paradise Restored. The Mechanical Arts from Antiquity through the Thirteenth Century* (Philadelphia, 1990), pp. 1-22; G. Ovitt, *The Restoration of Perfection: Labor and Technology in Medieval Culture* (New Brunswick, 1987), pp. 1-12.

23. K. DeVries, *Medieval Military Technology* (Peterborough, 1992); P. Porter, *Medieval Warfare in Manuscripts* (Toronto, 2000); D. Nicholle, *Arms and Armour of the Crusading Era, 1050-1350: Western Europe and the Crusader States* (London, 1999).

24. See his dismissal of quantifying aggregate demand for arms, *L'industrie et le Commerce des Armes*, p. 90.

25. J. Schumpeter, *The Theory of Economic Development. An Inquiry into Prolific, Capital, Credit, Interest, an the Business Cycle*, tr. R. Opie (Cambridge, Mass., 1961); W.W. Rostow, *The Stages of Economic Growth: a Non-communist Manifesto* (Cambridge, 1960).

26. A. Gerschenkron, *Economic Backwardness in Historical Perspective* (Cambridge, Mass., 1962), esp. pp. 1-51; his celebrated words are worth quoting: 'The typical situation in a backward country prior to the initiation of considerable industrialization processes may be described as characterized by the tension between the actual state of the economic activities on the one hand, and the great promise inherent in such a development, on the other. [...] Assuming an adequate endowment of usable resources, and assuming that the great blocks to industrialization had been removed, the opportunities inherent in industrialization may be said to vary directly with the backwardness of the country.', ibid, p. 8.

27. Gerschenkron, *Economic Backwardness in Historical Perspective*, p. 11.

28. Otherwise known as technical congruence in reference to the host of factors which must fit together.

29. For criticisms: Hatcher and Bailey, *Modelling the Middle Ages*; E. Ashtor, 'The Factors of Technological and Industrial Progress in the Later Middle Ages', *Journal of European Economic History* 18 (1989), pp. 7-36.

30. R. Bonney and W.M. Ormrod, 'Crises, Revolutions and Self-Sustained Growth: Towards a Conceptual Model of Change in Fiscal History', *Crises, Revolutions and Self-Sustained Growth: Essays in European Fiscal History, 1130-1830,* W.M. Ormrod, R.J. Bonney and M. Bonney, eds (Stamford, 1999), pp. 1-21; cf. R.J. Bonney, ed., *The Rise of the Fiscal State in Europe, c. 1200-1815* (Oxford, 1999), pp. 13-14.

31. R.H. Britnell and B.M.S. Campbell, *A Commercialising Economy: England 1086 to c. 1300* (Manchester, 1995), Appendices.

32. Chase-Dunn and Hall, *Rise and Demise*, pp. 79-81.

33. Frank and Gills, 'The 5,000-Year World System. An Interdisciplinary Introduction', *The World System*, pp. 6-7ff.

34. Cohen, *The Scientific Revolution*, pp. 1-7, 191-5.

35. P. Kroes and M. Bakker, eds., 'Introduction', in *Technological Development and Science in the Industrial Age. New Perspectives on the Science-Technology Relationship* (London, 1992), pp. 1-15; M. Fortun and S. Schweber, 'Scientists and the State: The Legacy of World War II', in K. Gavroglu, J. Christianidis and E. Nicolaidis, eds., *Trends in the Historiography of Science* (London, 1994), pp. 327-54; q.v. above, Introduction.

36. H. Butterfield, *The Origins of Modern Science 1300-1800* (London, 1957), p. vii.

37. See above, n. 5.

38. Cohen, *The Scientific Revolution*, pp. 1-7, 191-95; B. Stock, 'Science, Technology, and Economic Progress in the Early Middle Ages', *Science in the Middle Ages*, D. Lindberg, ed. (London, 1978), pp. 1-51; R. Clarke, *Science and Technology in World Development* (Oxford, 1985), pp. 5 ff., gives an historically grounded account (Industrial Revolution) of technological developments preceding scientific inquiry. A more recent expression of these sentiments can be found in M. Bridgstock, D. Burch, J. Forge, J. Laurent and I. Lowe, eds., *Science, Technology and Society* (Cambridge, 1998), p 4; D. Ihde, *Technics and Praxis* (Boston Studies in the Philosophy of Science, vol. 24, Boston, 1979), pp. xv-xxviii, presents a philosophical argument for technology's precedence.

39. Porter, 'The Scientific Revolution: a spoke in the wheel?', pp. 290-316; S. Shapin, *The Scientific Revolution* (Chicago, 1996); M.J. Osler, ed., *Rethinking the Scientific Revolution* (New York, 2000).

40. Cf. R. Cooter et al, 'What is the History of Science?' *History Today* 35 (April, 1985), pp. 32-40 continued in idem, *History Today* 35 (May, 1985), 46-52, where twelve leading authorities address the question with mixed results; C. Hakfoort, 'The Missing Synthesis in the Historiography of Science' *History of Science* 29 (1991), 207-16; D. Lindberg, *The Beginnings of Western Science. The European Scientific Tradition in the Philosophical, Religious, and Institutional Context, 600 B.C. to A.D. 1450* (London, 1992), pp. 1-4; I. Spiegel-Rösing and D. de Solla Price, eds., *Science, Technology and Society. A Cross-Disciplinary Perspective* (London, 1977).

41. E. Layton, 'Conditions of Technological Development', *Science, Technology and Society. A Cross-Disciplinary Perspective*, p. 217.

42. D. Edge, 'Reinventing the Wheel', *Handbook of Science and Technology Studies* (London, 1995), pp. 1-28; G. Bowden, 'Coming of Age in STS. Some Methodological Musings', in idem, pp. 64-79.

43. On the origins of technology's agency see M.R. Smith and L. Marx, eds., *Does Technology Drive History? The Dilemma of Technological Determinism* (London, 1995), p. xiv, who propose that technological determinism and social constructivism can be reconciled by redefining technological determinism as 'man's willingness to invest great amounts of authority in technology, imparting it with the ability to make change.'

44. J.D. Bernal, *Science in History* (London, 1954), p. 867.

45. S. Jasanoff et al., *Handbook of Science and Technology Studies*, p. 527; cf. T. Kuhn, *Structure of Scientific Revolutions* (Chicago, 2nd edition 1970), pp. 111ff; J.L. Spradley, 'Historical Parallels in Science and Culture' *American Journal of of Physics* 57 (1989), pp. 252-7.

46. Kuhn, *Structure of Scientific Revolutions*.

47. For examples of medieval parallels in science and art, L. White, 'Natural Science and Natural Art in the Middle Ages' *American Historical Review* 52 (1947), pp. 421-35; A.C. Crombie, *Science, Art and Nature in Medieval and Modern Thought* (London, 1996); M. P. Cosman and B. Chandler, eds., *Machaut's World: Science and Art in the Fourteenth Century* (New York, 1987); A.C. Crombie, *Augustine to Galileo* (London, 1952), p. 113.

48. For an excellent but now somewhat dated perspective on the broadening scope required for the study of medieval science J. Murdoch and E. Sylla, eds., *The Cultural Context of Medieval Learning* (Boston Studies in the Philosophy of Science, Boston, 1975), esp. pp. 1-30.

49. On this aspect of premodern science see Lindberg, *Beginnings of Western Science*, pp. 1-20.

50. For limitation to technological development, see Astill and Langdon, *Medieval Farming and Technology*, pp. 1-9; for the power structure, W.M. Ormrod, *Political Life in Medieval England, 1300-1450* (London, 1995), pp. 84-6; R.C. Palmer, *English Law in the Age of the Black Death* (Chapel Hill, North Carolina, 1993), pp. 1-56; G. Duby, ed., *A History of Private Life*, vol. 2: *Revelations of the Medieval World*, A. Goldhammer, tr. (London, 1988), pp. 3-31, ff.

51. J. Goodwin, 'State-Centered Approaches to Social Revolutions: Strengths and Limitations of a Theoretical Tradition' *Theorizing Revolutions*, J. Foran, ed. (London, 1997),pp. 11-37.

52. Tout portrayed Edward I's household as a small standing army of professional administrators/soldiers who formed the core of a new organization that replaced a feudal one, T.F. Tout, *Chapters in the Administrative History of Medieval England*, 6 vols. (Manchester, 1920-33), ii, p. 138.

53. J.O. Prestwich, 'The Military Household of the Norman Kings', reprinted in *Anglo-Norman Warfare. Studies in the Late Anglo-Saxon and Anglo-Norman Military Organization and Warfare*, M. Strickland, ed. (Woodbridge, 1992), pp. 93-127.

54. Held at Public Record Office (PRO), London.

55. CDS, v, no. 347.

56. CCR 1313-1318, pp. 360, 405; M. Vale, *The Origins of the Hundred Years War. The Angevin Legacy, 1250-1340* (Oxford, 1990), p. 239.

57. CCR 1337-1339,p. 547.

58. CCR 1339-1341, p. 135.

59. Tout, *Chapters in the Administrative History*, iv, p. 427.

ABSTRACT

Technology and Military Policy in England, c. 1250-1350 quantifies and qualifies England's proto military-industrialization and its effect on the conduct and perception of war during a period long recognized as a crucial juncture in the 'rise of the West'. It assesses the extent to which technology, defined as attention to artificial work or the material environment, was supplanting 'men and money' as conventional mechanisms of power. While providing a synthesis of the current scholarship on core areas of medieval English warfare, the thesis draws deeply from published and unpublished government records (mostly E 101) which provide immediate evidence for the scale and direction of England's military industrialization. This industrialization and appreciation for technology is demonstrated in contemporary scientific texts, in the English Crown's strategies, in the material intensification of its warfare (deploying and/or concentrating greater volumes of war materials), in its promotion of state-of-art military hardware ranging from castles to personal arms, and in efforts to integrate more military hardware into the conduct of war, ie combining naval and land forces and more substantial engineering works such as pontoon bridges, peels, bretaches and portable towers in conjunction with more potent weapons (trebuchets, springalds, crossbows, firearms, and personal arms). The thesis seeks to lay the groundwork for better understanding the role of technology in late medieval warfare, and gives special consideration to placing England and its military enterprises within the long durèe of a global political economy. While sustained success in European warfare became more dependent on 'industrial' warfare, this thesis finds that the coordination of these activities and obtaining society's support proved a major part of the struggle to realizing 'revolutionary' growth. Includes chapters on science, the administration of war, sieges, battles, iron-working, and the cost of arms; indices of arms prices and arms requirements; 19 illustrations.

Abbreviations

BIHR	Bulletin of the Institute of Historical Research
CCR	Calendar of the Close Rolls
CDS	*Calendar of Documents Relating to Scotland*.
CIPM	Calendar of Inquisitions Post Mortem
CLR	Calendar of Liberate Rolls
CPR	Calendar of Patent Rolls
De re militari	*The Earliest English Translation of Vegetius'. G. Lester, ed.*
Docs. Illus. Scots.	*Documents Illustrative of the History of Scotland,* J. Stevenson,ed.
EcHR	Economic History Review
EHR	English Historical Review
Foedera	*Foedera, Conventiones, Literae, etc*. T. Rymer, ed.
LQG	*Liber Quotidianus Contrarotulatoris Garderobae.*J.Topham, ed.
Parl. Writs	*Parliamentary Writs and Writs of Military Summons*. 2 F.Palgrave,ed.

CHAPTER ONE

Science and Praxis

'Moreover, the Church should consider the employment of these inventions against unbelievers and rebels, in order that it may spare Christian blood, and especially should it do so because of future perils in the times of Antichrist, which with the grace of God it would be easy to meet if prelates and princes promoted study and investigated the secrets of nature and of art.'

Roger Bacon, *Opus Majus*, c. 1268[(1)]

'For all other animals, nature has prepared food, a covering of hair, teeth, horns, claws as defences, or at least speed for flight. Man, however, is made without any natural provisions of his own, but instead of all these, man is given reason, through which he could procure all these things for himself *officio manuum*.'

Thomas Aquinas, *De Regno*, c. 1267.[(2)]

To begin this study of technology with the history of science is appropriate conceptually and historiographically. Following Pierre Duhem, some historians traced the origins of modern scientific methods to the mathematical studies of motion and force (mechanics) produced at Oxford and Paris in the fourteenth century.[(3)] Over the course of the twentieth century, however, many historians altered their view of 'science' and came to the conclusion that, in a broader sense, the origins of modern science can be traced to the more vigorous approach to nature which emerged in the Latin West in the twelfth century.[(4)]

Though focussing on different aspects of this optimism as can be seen in the above quotations, both Roger Bacon and Thomas Aquinas expressed the utomst confidence that society could improve its condition through reason and many types of labours. There is much evidence which suggests that this ethic prevailed in society and that governments began to incorporate a wide range of 'scientific' advances to affect the new warfare of the thirteenth and fourteenth centuries. Reminiscent of Kuhn=s paradigmatic shift or Gerschenkron=s leap out of backwardness, the Latin West experienced a veritable surge in its desire and ability to investigate nature through acquisition of the rich scientific heritage contained in Greco-Arabic literature most of which appeared in an Aristotelian framework.[(5)] In England, the revival and application of Roman law and political philosophy was apparent as early as John=s reign, gaining greater significance especially after Aristotle=s *Politics* and *Nicomachean Ethics* were translated around 1260.[(6)] During this time economics and a new emphasis on quantification became extremely instrumental in commercialization, financing, taxation, and currency management.[(7)] Far from being isolated developments, several of these pursuits merged in a more thorough investigation of government and what would become the science of political economy.[(8)] As early as the twelfth century *translatio imperii*, and later *translatio studii*, were employed to express the notion that hegemony, intellectual or otherwise, was passing to the West.[(9)] Although virtue, piety and personal military prowess remained crucial in explanations for a society=s success, other factors were considered in detail including good government, economic prosperity and the promotion of arts and learning.[(10)]

Stemming from the same optimism though not possessing as welcoming praxis as those sciences, medieval technologies and >productive arts= also began to benefit from more positive and thorough scientific treatments.[11] A.C. Crombie in particular has credited medieval Europe with a unique predilection for science-based technology, viz., no other civilization >exploited their scientific knowledge technologically on a large scale, and in none [other] did natural science come to dominate their intellectual culture=.[12] This permeation of natural science indeed came to inform several prominent military technologies during the thirteenth and fourteenth centuries. The science of fortifications drew more heavily on the advanced engineering of religious buildings. Alchemy flourished as a 'pseudo-science', becoming a critical aid in gunpowder technology and the production of saltpetre particularly.[13] Metallurgy, though confined to the fringes of theological science, fascinated the likes of Albert the Great whose writings may contain our best literary evidence for a type of blast furnace in the thirteenth century.[14]

It has also been suggested that during the thirteenth century Jordanus de Nemore, a pioneer in the science of weights, drew on trebuchets for inspiration at least.[15] The Jordanus corpus was at the root of Duhem=s theory that medieval churchmen prefigured pre-classical mechanics of the sixteenth century which indeed drew on the visibly magnificent examples of artillery projectiles in mathematical studies of motion.[16] The extent to which the 'new science' of the sixteenth century drew on the language, methods and proofs of medieval natural philosophers is well attested, but the impact of such sciences on medieval technology is virtually unknown. Although these topics concerned many medieval theologians who openly cited various military projectiles as examples of motion and force, our investigation of any practical application is obscured both by religious conventions which favoured the hypothetical and discouraged empirical references, and by the almost complete lack of testimony on the methods of constructing and operating military engines even though churchmen were often involved in these tasks.

The available textual evidence allows to investigate three areas in the philosophy of mechanics for their possible exchange with the technologies of projectile engines during the thirteenth and fourteenth centuries: leverage, gearing, and projectile motion.[17] In tracing the development of these topics in natural philosophy it becomes clear that during the thirteenth century the growing complexity of mechanical siege engines challenged schoolmen's abilities to explain such phenomena, encouraging exploration through the science of weights and later in the fourteenth century in the more refined dynamic and kinematic aspects of motion. We will then conclude by addressing the peculiar development of scientific and technological praxis in the Latin West as it related to these developments.

Weights and Levers

An offshoot of an ancient interest in the balance, the >science of weights= was unique in the Latin West for the amount of scholastic attention given to a mechanical art. Though the mechanical and productive arts were confined to the lowest orders in the classification schemes which flourished in the Latin West during the twelfth and thirteenth centuries, their inclusion indicates a growing appeal and more thorough scientific treatment. Hugh of St. Victor=s very popular *Didascalicon* (c. 1127) contained an extensive scheme which followed Aristotle=s distinction between theoretical and practical knowledge. He adopted Augustine=s inclusion of logic, and per Isidore of Seville provided Latin Christendom with an early branch of the productive arts (*ars mechanica*) subdivided into chapters on fabric-making, arms-making, commerce, agriculture, hunting, medicine, and theatrics.[18] Hugh also made the analogy that the productive arts imitated nature. In this way he compared clothes to the bark of a tree, and arms to a turtle's shell or elephant's tusks- a metaphor illustrated by Villard de Honnecourt a century later (fig.1.1), and adopted almost verbatim by Thomas Aquinas as quoted at the beginning of this chapter .[19] Around 1150

Domingo Gundisalvo=s influential *De Divisione Philosophiae* extended Hugh=s taxonomy of the mechanical arts to include the science of weights and engines (*ingeniorum*), modelled after a tenth-century Arabic treatise *Ibsa' al-'Ulum* by al-Farabi (d. 950) often translated as *De ortu scientiarum* or *De scientiis*.[20] Farabi, who became known in Muslim scholarship as the Second Master (to Aristotle), emphasized mathematics in his division of the natural sciences into logic, medicine, arithmetic, geometry, optics, astrology, astronomy, and the sciences of weights and devices. The science of weights, Farabi explained, is the study of the measure of weights or the things they weigh and their movements. An extension of Euclid=s geometry, the science of machines (*ingeniis*) was described as Adevising ways to make all the things happen whose modes were stated and demonstrated in the sciences (*doctrinis*) such as devices for measuring objects and distances (optics), or the making of bows and military engines". Around 1140 John of Seville also translated Farabi=s *De scientiis* and before 1187 Gerard of Cremona provided a full translation. Hugh of St. Victor also updated his classification in the *Didascalicon* to include a geometry divided into a speculative science based on reason and a practical science involving instruments.[21] Farabi=s treatment of this subject, such as his mathematical description of motion and acceleration through proportions, demonstrated the wealth of the entire heritage and provided the discipline with its distinct form. Farabi=s eminent mathematical and geometric treatment of projectile motion in the Aristotelian fashion was unsurpassed until the Mertonians and may have been the source of Bradwardine's irrational proportion; Farabi's discussion of projectiles= impact and the qualities of stones could later be found in numerous geologies as well as Buridan's discussion of impetus.

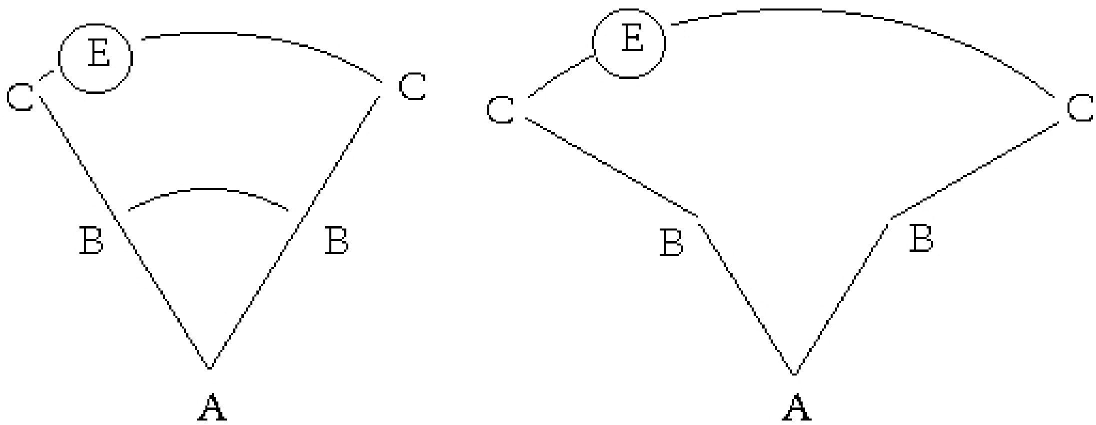
The >science of weights= was invigorated in the Latin West by Jordanus de Nemore=s *Elementa super demonstrationem ponderum* (c. 1230). We know virtually nothing of Jordanus= life except that he probably taught at Toulouse during the second quarter of the thirteenth century, and almost immediately afterwards his mathematical and geometric works were refined into a corpus that was put on a par with Euclid=s.[22] By the beginning of the thirteenth century the Latin west possessed partial translations of works by Aristotle, Archimedes, Euclid, Thabit ibn Qurra and al-Farabi that treated mechanics. In the *Elementa super demonstrationem ponderum*, Jordanus informs us that, >If equal weights are attached to the equal arms by pendants of equal length, but such that one of these pendants can rotate on the lever arm while the other is rigidly attached at right angles to its arm of the balance, then the weight attached to the movable pendant will be positionally heavier than the other weight=.[23] The author goes on to stress that more force is gained by a longer fall and by a weight falling vertically rather than obliquely; consequently, a weight attached to the ascending end of this beam becomes proportionately lighter.

The concept of 'positionally heavier' was further developed in the *Liber Jordani de ponderibus* which provided a more detailed account of its application the author claims to have obtained from an undisclosed source.[24] This concept applies to the amount of force a weight on a beam possessed at various points on the arc of its fall. These ideas probably contained an added significance for contemporaries in that according to Jordanus the motion of levers were violent or unnatural because the movement of the weights on the rotating beam went contrary to their natural tendencies.[25] The displaced arc of the falling weight was a mixture of natural and violent motion, while the propelling a weight upwards was viewed as completely violent.[26] The Jordanus corpus built on these converging traditions to produce the earliest known accurate description of the benefits of leverage as generated by force rather than movement as held by Archimedes and Aristotle.[27] The lever was a pivoting beam with weights attached to one or both of its arms. Jordanus= works are almost wholly concerned with the effects of placing weights at different points on such a beam, and the best methods of obtaining work or force from them. The early Jordanus works concerned themselves with simple operations of the beam and its optimal divisions. Jordanus or a pseudo-Jordanus writes, >If the arms of a balance are proportional to the weights suspended, in such manner that the heavier weight is suspended from the shorter arm, the weights will have equal positional gravity=.[28] Similarly he said, >a weight not suspended at the middle, makes the shorter part heavier, according to the ratio of the longer part to the shorter part=.[29] This principle is then applied to calculate the weights and positions needed to raise weights to certain heights, or to calculate the various arrangements of lengths and weights for producing equilibrium. The germ for calculating projectile motion was expressed in the Elementa and is often paraphrased as >Whatever lifts W to a height H, can lift a weight W@k to a height H/k, or a weight W/k to a height H@k.= Thus the same force can move a heavier object a proportionately shorter distance, or a less heavy object proportionately farther.

Although relevant for the operation of cranes, trebuchets, pile-drivers, etc, a preoccupation with trebuchets becomes evident in the Jordanus corpus in its pursuit of specific mechanical principles and in its adoption of Farabi=s treatment of projectiles. Rather than lifting a weight, the later works in the corpus pursued methods of arranging the beam and its weights to cause great imbalance and violent motion which would discharge projectiles further, faster and with greater force.[30] Altogether five means of achieving a more violent action in the lever were posited in these works: (1) increasing the weight on the descending arm, (2) applying the principle of the bent lever so that the descending weight fell further, (3) optimum placement of descending weights (4) optimum means of attaching the descending weights, (5) extending the projectile=s path in an arc around the throwing arm as if in a sling. The collection of theorems in these works is somewhat eclectic and do not display any overt connection with military engines, but their resemblance to Farabi=s approach and subject matter goes some way in explaining the choice of topics. Of the entire corpus, *De ratione ponderibus* stands out for its ingenuity, accuracy and creativity especially for its correct proofs for forces of the bent lever and on an inclined plane. The work is rather neatly divided into four books: the first repeats seven theorems from the *Elementa super demonstrationem ponderum* and introduces two of its own on the bent lever and one on the inclined plane. The second book treats the Roman balance. The third book is concerned with the beam=s behaviour with different weights set at different angles. The fourth book is more original in that its focus on the kinematic aspects of motion was more pertinent for projectiles of siege engines. All seventeen theorems of the fourth book treat in a successive fashion a moving body ('that which is moved'), the forces the body obtains in motion, the resistance of air or water as a medium, and a projectile=s behaviour on impact.[31] Theorems 4.01 and 4.02 treat respectively the medium=s resistance on a balance with weights and different media=s effect on a moving body. Theorems 4.03-4.05 address the body=s movement in water or other liquids, most probably as they related to the hydraulic devices (hydrostatics) pre-eminent in eastern technology. Theorems 4.06-08 address the forces gained in motion and the effect of the body=s shape on its ability to traverse a medium by minimizing resistance. Theorems 4.06 and 4.08 discuss the Aristotelian concepts of antiperistasis. Theorems 4.09-15 almost certainly describes the series of actions of a projectile engine. Theorems 4.09-4.11 address what can be described as the optimum transference of force to a projectile, ie what actions produce more momentum and what objects are better suited to receiving impetus. Theorem 4.11 and its illustration reproduced in diagram 1.1 seem to make a case for the benefit of a sling

> Again, if (A) remains fixed, and (C) is swung around it, it will give more impulsion than in either of the previous cases where it is not moved; because a thing is moved to a greater degree to the extent that it is longer, in two senses. For if (A)is fixed as an axis and (B) and (C) swung around, they will describe arcs of circles, and (C) the greater one. Since therefore the weight at (C) is greater than at (B), and since (C) is also moved more rapidly, (E) will be impelled much more strongly at (C) than at (B). Also, if (E) is swung around along with (C), it will be given more motion than if (C), being moved first, only strikes (E).
>
> Again, if there should be an axis at (B), of another movement, so that CBA swings around (A), and in addition CB swings around (B), the force of impulsion will be augmented by the double movement; because in an equal time, (C) will be carried around through a much greater arc, as is apparent from the accompanying diagram. [32]

Diagram 1.1



Theorems 4.12-13 address respectively the effects of forces acting on a beam causing it to break or bend. Theorems 4.14-15 report on bodies behaviour when striking unyielding surfaces and follow Farabi=s concept of compression and recoil. Theorem 4.16 demonstrates that falling water gains velocity over the distance of its fall, and theorem 4.17 describes a lopsided projectile=s behaviour in flight. Although historians debate the extent to which Buridan=s concept of impetus depended or derived from the Jordanus corpus, there is little room for doubt that Buridan=s treatment was related in language, subject matter, semiotics and tradition extending back to Jordanus and Farabi.(33) Impulsis for Jordanus often signified an action rather than force, though on two occasions in the *De ratione ponderibus* >impetus= described a force possessed by a moving object.(34) However, such a force was not necessarily equivalent to Buridan=s impetus. An Islamic concept of >mail= described various transferences from motor to mobile including tendency to move, ability to do work, corruption of the stone=s nature or natural inclinations and its other qualities like heat, and furthermore could be intrinsic or extrinsic.

The extent that these works influenced the design and operation of trebuchets is unknown, but in any case they began to be incorporated in secular works addressing military engines by the late thirteenth century. Giles of Rome, when describing the construction and operation of trebuchets in the *Governance of Kings and Princes* (c. 1280), gave the same advice as Jordanus- an indication that formal sciences were beginning to inform other works, and that the mirror for princes genre was incorporating more technical subjects. Giles described three types of trebuchets: one type drawn solely by traction, one possessing counterweights but also powered by traction, and one powered solely by counterweights. The counterweight trebuchets were further defined according to the manner their counterweights were attached. According to Giles, the trebuchets with fixed counterweights throw more evenly or certainly,(35) those with pendulant counterweights threw further,(36) and those with fixed and pendulant counterweights throw evenly and far.(37) All of the trebuchets described by Giles employed slings.(38) In addition to Giles= testimony, in Chapter Three we will see that the Crown=s records reveal that much more substantial trebuchets relying solely on counterweights for their momentum were being constructed by the late thirteenth century- a powerful technology which replaced hundreds of labourers previously necessary for powering each trebuchet. The main obstacle preventing the construction of heavy counterweight trebuchets appears to have been engineers= inability to draw a beam with much counterweight without the benefit of high-torque gearing.

Gearing

The advent of high-torque gearing in the West is often associated with the invention of the mechanical clock during the last quarter of the thirteenth century.(39) An apologetic report by Robert Anglicus in 1271 claimed that their efforts were close to devising a very accurate weight-driven clock the axle and wheel of which would complete one revolution every 24 hours.(40) In Spain, the *Liber del Saber Atronomico* produced for Alfonso X of Castille around 1276 focussed only on water clocks without mentioning any fully mechanical version. Based on this negative evidence and the lack of any conclusive evidence until 1300, it is widely believed that the mechanical clock was invented in France, Italy or England shortly after 1271.

High-torque gearing was more likely to have developed on simpler devices such as winches rather than the more complex clock or bell-works. More than a novel method for marking time, early mechanical clocks were often a grand representation of the universe which in itself betrays the change in perceptions about man's control of nature and time.(41) A profusion of accounts indicate that during the first half of the fourteenth century clockworks became more substantial, grander and precise, acquiring elaborate automata and decorations including the dial or face. By the last quarter of the fourteenth century mechanical clocks and their automata had firmly established themselves in civic, scientific and religious cultures.(42) Writers like Oresme, Bradwardine and Buridan all compared the cosmos and its dynamics to the mechanical clock, a spin on the ancient adage of god as the master architect (fig. 1.2).(43)

Although clocks become grander during first half of the fourteenth century, earlier clocks were still substantial and complex devices (fig. 1.3). Beeson had trouble establishing the date for the invention of the clock because their early records- expense accounts for their construction- failed to register the very slight differences between complex and substantial bell-ringing mechanisms and early mechanical clocks. Such difficulties can be demonstrated by a document which compares with the other earliest examples.(44) A short account of works at Dover castle in 1282/3 begins with the repair of a great bell=s mechanism in Caesar=s Tower and records next the rebuilding of a house next to St. Mary=s church which stored >great engines= (magnis ingeniis). Six men were required to move the great engines 'from the house next to the church' and into a barn while the house and part of a wall were rebuilt for the sum of ,4 10s 5d; the men were also paid for re-assembling the engines in the house after its repairs. Henry III had St. Mary's refurbished on several occasions, including having three bells made in 1252 when the adjacent Pharos tower was converted into a belfry.(45) Other bell-towers at Salisbury and Wells also had large bell-ringing or clock mechanisms mounted in buildings joined to the base of the belfry. Precluding the possibility that very special arrangements were being made to store more ordinary devices, the term 'great engines' appears to have described the heavy machinery of the church's bell or clock-works but providing no further glimpse into their nature.(46)

The earliest mechanical clocks are thought to have relied on the same verge-and-foliot escapement for regulating movement as later clocks (diagram 1.2). This mechanism comprised two pallets pivoting back and forth on the verge to counteract the crown wheel's movement in regular intervals. Because the verge-and-foliot escapement stopped the crown wheel routinely,the speed of the weight's fall was regulated into distinct units demonstrating the Merton theorem. The calculations, design and craftsmanship for clocks were technically demanding, including heavy craftsmanship, 'fine technology', trigonometry, geometry, and astronomy. The earliest complete description of a mechanical clock, and incidentally the first evidence of trigonometry in England, appears in Richard Wallingford's *Tractatus Horologii Astronomici* (c. 1330).[47] Richard rose to become abbott of St. Albans having been received at the age of ten upon the death of his father, a blacksmith. Richard thoroughly described the mechanical clock's construction and illustrated its components in great detail. Here he describes how to construct simple complementary gears:

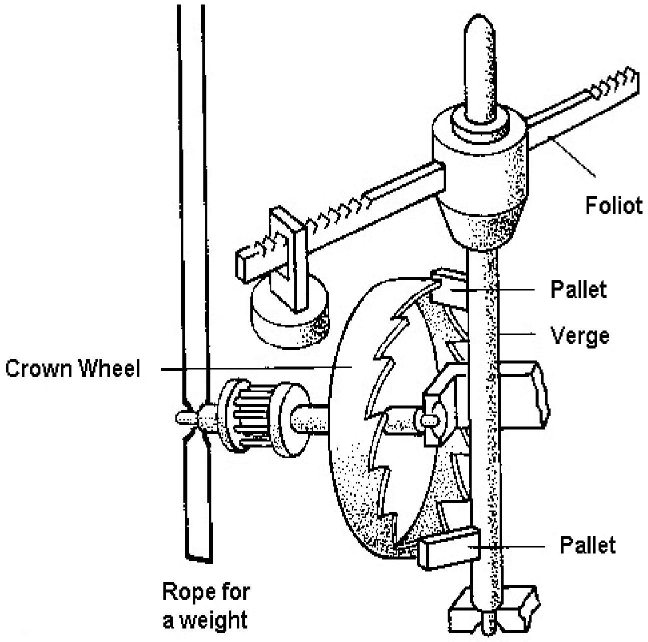


Diagram 1.2: Verge and foliot (after Gies)

> 'Task: Given a wheel of a definite number of equal teeth, find another wheel having any desired number of teeth, [these being] equal in size to the teeth of the given wheel.
>
> Method: Divide the diameter of the given wheel into as many equal parts as there are equal teeth on the circumference, and from these parts of the diameter take as many parts as you wish. Construct a circle with diameter equal to the number of parts chosen, whereupon its circumference will have as many parts equal to the parts of the other circumference as the one diameter has parts equal to those of the other diameter. This is the case, since the ratio of the circle to circle is the ratio of diameter to diameter. And you may proceed in a similar way by producing the diameter as far as you like, and taking as many equal parts as you please.'[48]

The fine teeth of the clock=s gearing were at the basis of its accuracy and timing. Richard=s description of the techniques for calculating the clock=s precise movements demonstrates this: >It must be remembered that the figures given earlier for the lunar movement are very large, and that if they are halved, the same result is obtained, and more conveniently than before. If the larger (solar) wheel, that is to say, is to have 254 teeth, and the Moon=s wheel 19, then a section of 4s 12B 49' 49" will amount to 7 teeth out of the 19'.[49] The precise movement of clocks required trigonometry to calculate highly complex gear ratios and the fine craftsmanship of the astrolabe (fig. 1.4 -5) except executed on a larger scale and in a more difficult medium.

Calculating the exact proportions of gear wheels to obtain precise movements required a much greater grasp of mathematics and geometry than simply designing gears for producing an arbitrary amount of torque. Complementary gears on winches required far less science to construct and the same principles were already present in mills and more rarely on astronomical devices. This pre-existing knowledge of gearing and relatively late invention of high-torque gearing raises the question that iron-working techniques may not have been up to the task of fashioning a durable yet unyielding product capable of sustaining great force.

Direct evidence for the invention of winches for devices such as counterweight trebuchets is equally cryptic. Eastern and western engineers' inability to draw a beam with as much as 10-15 tonnes of counterweight during the thirteenth century was the main obstacle preventing the construction of larger counterweight trebuchets. Tread-wheel cranes were capable of lifting two to four tuns of wine for example, but that mechanism does not seem to have become commonplace on military engines.[(50)] A simple capstan windlass (figs. 1.6 -7) which is normally portrayed serving this purpose until gears and cranks prevail in the fourteenth century, provided at best 10:1 load reduction but this machine is most often seen hauling light loads such as buckets, beams or baskets of materials such as stones.[(51)] Block and tackle pulleys might reduce the load further, but even with the aid of the beam=s 2-3:1 leverage with a windlass only a few tons of counterweight could have been accommodated.

That managing power mechanically was a main challenge to military engineers at the beginning of the thirteenth century is conveyed by a military treatise written for Saladin at Alexandria. The author, al-Tarsusi, purported to describe the latest techniques in constructing many kinds of arms, armour and engines, and in doing so he relates to us the problems encountered in spanning or drawing engines. According to Tarsusi, a crossbow was drawn by placing one or both feet (which was also a designation of their power throughout our period) in the bow or stirrup attached to the bow and straightening the body. The crossbow's cord could be held by the hands or sometimes the cord was attached to the crossbowmen's belt by means of a baldric. Larger crossbows in al-Tarsusi=s treatise were spanned with the aid of a windlass, and the beam of a torsion catapult was also drawn down into place by a windlass. Tarsusi also gave a description of a traction trebuchet, and in some of his other devices we can see early attempts to harness the forces of weight and gravity. He proposed that a large weight such as a net full of stones could be attached to a rope and pulley and lowered to span giant crossbows (fig. 1.8).[(52)] Writing in France in the mid thirteenth century, Villard de Honnecourt compiled his now famous sketchbook which reveals that he obviously lacked knowledge of high-torque gearing. Many of his designs were attempts to transit force through ropes and pulleys (fig. 1.9).[(53)] The sketchbook contains an incomplete yet fairly detailed illustration of how a counterweight trebuchet would operate. He proposed using a hopper full of soil for the counterweight (lead would become preferred), and two wooden tension springs for drawing the beam (fig. 1.10).

With hindsight, the obvious answer to such a problem lies in a winch comprising at least two gears and a pawl for a brake (diagram 1.3). Gearing could reduce the load infinitesimally and enabled its operation by relatively few people, while the pawl gave complete control of the axle when drawing the beam. Without a similar mechanism, drawing a beam with much counterweight would have been potentially dangerous or very haphazard at the least. The earliest illustration of gearing employed on trebuchets for this purpose appears to have been by al-Rammah, a master engineer working in Syria around 1285 (fig. 1.11).[(54)] We will have occasion in Chapter Three to review the development of trebuchets in the Crown's armies which indicates that in all likelihood gearing had been incorporated on them by the 1270s. What is almost surely an early explicit reference to gearing occurs in accounts for the construction of the >Segrave= made to besiege Brechin in 1303. The master smith and 7 associates required 280 stones of iron (c. 3360-4200 lbs.) for making nails, hooks, rings, iron bands, an axle, and *spirellis clickettis*.[(55)]

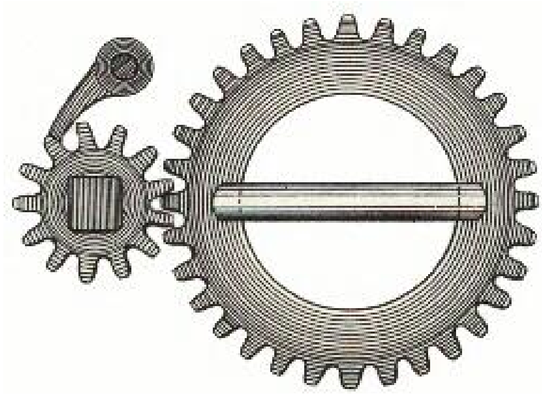


Diagram1.3: Compound Gearing

Projectile Motion

In the fourteenth century the study of motion and force became a vigorous field of enquiry best known for its mathematical treatments which distinguished motion's dynamic and kinematic aspects. We will see that in the fourteenth century mechanical projectile engines and firearms become a common topos in scientific discussions of motion. Farabi established projectile motion and measuring distances and heights as subjects worthy of geometry and optics. Even though the science and technologies for other activities developed during the thirteenth and fourteenth centuries- practices which distinguish early modern scientific involvement with artillery- few clues exist for medieval practices if practised at all (figs. 1.5, 12, 13). The scientific literature linking projectile engines to studies of motion is more insightful. A prominent feature of this discussion is the tendency to refer to stones and stone-throwing engines when an empirical example of projectile motion is needed. Since the fourth century BCE, Zeno=s paradox of the arrow as related in Aristotle's *Physics* provided the most convenient reference in discussions of projectile motion; a status quo probably aided by the arrow's familiarity.(56) The process whereby stones came to complement arrows as a common scientific reference for projectile motion is significant not the least of which for confirming that the Jordanus corpus was perceived as relating to siege engines. The timing and process whereby stones became a common topos is particularly interesting for its connection with firearms which although producing a similar effect to mechanical engines they operated on a radically different type of physics. The earliest gunners in Europe experimented with arrows and shot as projectiles until shot was discovered more efficacious. During this time a set of hypothetical scenarios such as impetus, free-fall and the motion of compound bodies which favoured dense, heavy bodies such as stones where these characteristics were more easily observed became the most popular problems of motion. Whether or not this trend gave preference to stones as examples of motion or arose because of a pre-existing preoccupation with stone projectiles will occupy us now.

That stone projectiles of mechanical siege engines and firearms figured prominently in fourteenth century studies of motion was uniquely addressed by Jean Buridan who made frequent reference to familiar objects and events in expounding his famous concept of impetus. His theory of impetus sought to correct serious flaws in the Aristotelian theory of force and motion which had laboured under the notion that the motor remained in contact with the mobile throughout its movement as with all types of motion. Aristotle explained the apparent lack of contact between the motor and projectile with two possible causes of movement both of which emphasized the air surrounding a projectile for propelling it.(57) In the *Physics,* composed around 1340, Buridan asks how a projectile continues moving: by its surrounding air or by what moved it instead. Buridan=s first point of opposition to the former is reference to the smith=s mill (*mola fabri*) which turns continuously *in situ* with no room for air to rush in behind and propel it forward. Secondly, Buridan says that a lance having both a sharp anterior and posterior would be moved just as quickly as one without a sharp posterior even though the air should not be able to drive the sharp posterior as quickly because the point would divide the air=s force. Buridan accepts that antiperistasis contradicts natural sense, stating that air alone would not be capable of sustaining the flight of a 1000- pound stone as thrown from a sling or machine.(58) Buridan also explained his concept of impetus as follows: >after leaving the arm of the thrower, the projectile would be moved by an impetus given to it by the thrower, and would continue to be moved as long as the impetus remained stronger than the resistance, and would be of infinite duration were it not diminished and corrupted by a contrary force resisting it or by something inclining it to a contrary motion=.(59) In *De caelo*, Buridan says this transference of impetus holds true for a man throwing a stone with his hand, for a bow discharging an arrow or for the machines throwing great stones=.(60) In another instance Buridan asks >utrum lapis projectus vel sagitta emissa ab arcu, ... moveatur a principio intriseco vel a principio extrinsico.=(61) Buridan also noted that projectiles= size, weight and shape have a determining effect on their flight, repeating al-Farabi=s treatment of rebound and recoil due to compression which thus favoured hard, dense stones for artillery shot.

Buridan's uninhibited style produced several direct references to firearms in this context and prompts him to pose the question that mathematicians were trying to solve. In the *Meterology* (1358), while strictly adhering to his concept of impetus, he asks again whether or not the wind has sufficient force to cause motion but this time answers that the wind can contain great force as demonstrated by firearms: Athe force of such wind is manifest in those instruments that are called tubes, from which is emitted, through the wind generated by a little bit of powder, a great arrow or ball of lead with such force that no armor can withstand it.@(62) Given natural science=s previous association with siege engines and the trend whereby more emphasis was placed on observation and experiment, the physics of firearms could hardly have been ignored. Extremely rapid acceleration was evident in bows and many military engines, though some type of tensile force was apparent in those machines. However, the cause of motion and transfer of force in firearms offered less to observe and measure; also the relationship of force to resistance in creating a firearm=s potent expulsion was unique.

Direct references to firearms in this discussion are ostensibly lacking prior to Buridan, but several trends in theories of the cause of movement and acceleration in particular suggest that firearms' unique dynamics contributed to the distinction between the dynamic and kinematic aspects of motion. Separating the cause from the effect of motion allowed consideration of motion's characteristics under theoretical condtions. The Merton school sought a new formula of motion, force and resistance.(63) Throughout the thirteenth century many of the leading figures of science continued to ascribe to the Aristotelian formula of what we would term velocity. This concept of velocity as the simple proportion of force to resistance expressed as the distance traversed produced mathematical impossibilities and inconsistencies such as a velocity of 1 when force is equal to resistance. This fallacy allowed Zeno=s paradox of the arrow by misrepresenting the arrow=s motion as non-velocity at any given moment. In the *Tractatus de proportionibus velocitatum in motibus* (Treatise on the Proportions of Velocity in Motion) written in 1328, Thomas Bradwardine expounded a formula which removed this conundrum.(64) Bradwardine expressed acceleration as an exponential rather than a mathematical function of a motive force exceeding resistance, distinguishing between uniform, difform and uniformly difform acceleration.(65) Bradwardine statement of the theorem has been translated as, >the proportion of the speeds of motions varies in accordance with the proportion of the power of the mover to the power of the thing moved.=(66) Proportions had served as the primary measure in >kinematic geometry= since antiquity, representing constant incremental change geometrically, exponentially, etc.(67) According to Euclid, proportions required a certain magnitude for comparison which precluded incommensurables and the infinitely small or great, but this had been refined in Arabic science to suppose that any two numbers have a ratio or proportion which can be repeated infinitely upwards and downwards. Although incorrect by our understanding, Bradwardine seized on the Arabic irrational proportion to represent extremely fast and powerful acceleration in a fully coherent mathematical treatment. Having shown that a force has a qualitative as well as a quantitative characteristic both of which determine its power, and having shown that motion begins when the total force on an object overcomes all resistance, Bradwardine further explains that this formulation overcame conflicting observations. The irrational proportion could represent different types of acceleration and accommodated the possibility that numerous intangible or incomparable forces could act to produce motion.(68)

Although instantaneous velocity was traditionally associated with Zeno=s arrow, Bradwardine=s work was couched in the tradition of the Jordanus corpus and this tradition may explain why Bradwardine eschewed any reference to firearms regardless of their role in the formulation of his theories. The *Treatise on Proportions* has obvious parallels to the jordanus corpus as a mathematical analysis of the forces required to move objects, and Bradwardine even cites Jordanus when acknowledging that his work had roots in the science of weights especially evident in his consideration of falling bodies.(69) Yet Bradwardine was one of the first to extend the implications of the jordanus corpus into a form more relevant to projectile motion, i.e. >a force can move one object a certain distance and at a certain speed and the same force can move an object half the size of the first twice as far and at a greater speed=.(70) In this pursuit Bradwardine often chose >empirical generalization= rather than referencing actual phenomena but a subtle manner of referencing everyday events is present.(71) In one instance Bradwardine refutes a theory simply because >sense experience teaches the opposite=.(72) Due to its similarities to the Jordanus corpus, it is not surprising that Bradwardine=s very limited empirical references in Proportions focus on mechanical devices. While not mentioning engines specifically, Bradwardine=s hypothetical >column= is reminiscent of Jordanus=s beam. In one instance Bradwardine describes a solid column, fixed on an axis, with cords attached which a man can pull to lever a weight on the opposite end, perhaps in reference to the traction trebuchet.(73) He was not averse to referencing novel technologies; when describing the motion of falling weights, for example, Bradwardine referred to the weights of a clock suspended from a revolving axle.(74) Somewhat strange by his own admission, Bradwardine chose to conclude this new approach with an extended and supposedly original discussion of the motive / resistive forces of the four elements in relation to each other.

All matter was considered by Aristotle to contain inherent properties including motion and force, and thus fire and wind were considered to possess some force and natural movement towards the heavens; heat was considered both a cause and byproduct of motion. The technologies of wind and steam had already begun to receive more attention during the twelfth and thirteenth centuries respectively.(75) The alchemy of gunpowder was therefore viewed as magnifying or creating a great force of fire, wind, and or thunder. Thunder, firearm=s other common comparison, was also assumed to possess great power. Roger Bacon, for example, described his explosive recipe as a means of making thunder and lightning.(76) In the fourteenth century an even greater upsurge of attention focussed on the relative forces of the four elements (air, fire, water, earth). These discussions sought to distinguish rest from motion philosophically and often debated whether motion entailed merely a change of place for the projectile or one of quality and/or nature. Discussion of projectile motion which flourished in natural science during the fourteenth century usually addressed these issues in terms of whether projectile motion was constituted by a flux or transgression through a series of points, or a fluctuation of forms in the projectile=s nature; put another way, these natural scientists asked whether motion was one of a projectile's characteristics or a separate entity. Intertwined with much larger debates on the alteration and corruption of matter or the intension and remission of forms, medieval philosophers addressed these aspects of motion as degrees of quality and expressed as latitude. This technique was borrowed from astronomy and navigation and helped in analyzing spatial and temporal aspects of motion rather than its matter, facilitating the diffusion of efforts such as Nicholas Oresme's in devising a method of graphing motion.

Firearms, to judge by descriptions, constituted a radically different type of weapon but their mechanics were easily accommodated by the aristotelian system and may have supported aristotelian concepts of projectile motion. In addition to firearms' different dynamics at the instant of motion, their dependence on percussion for the transmission of motion and impetus may have prolonged these debates by providing support for aristotelian focus on air as a source of projectile motion. Bradwardine discovered a way to represent acceleration mathematically, and Buridan=s formulation of impetus became the preferred method of characterising projectile motion, but neither of these won agreement on the initial and continuing causes of motion, on the transference of impetus and whether impetus was naturally temporary or permanent. Buridan admitted that impetus was not the ideal term for what he was trying to describe. Oresme also expressed dismay over the debated and vocabulary surrounding 'impetus'.(77) The increasingly refined treatments of projectile motion during the fourteenth century often credited air and 'impetus' in varying degrees as the cause and continuance of projectile motion. We have already noted Buridan=s contradictory remarks on the force of winds as evident with firearms. That the source of motion remained particularly troublesome is indicated by the titles given to later transcriptions of these works. Richard Swinehead=s *De motibus naturalibus*, which contains the earliest statement and perhaps proof of the Merton theorem of acceleration, was transcribed with the title *De primo motore* from its incipit.(78) When this discussion was taken up by Italian scholars later in the fourteenth century, a transcription of the Merton theorem almost verbatim to Swinehead and Heytesbury=s was titled *De motu incerti auctoris*.(79) A fourteenth-century work later printed as an introduction to Bradwardine=s *Proportions of Velocities* also bore the title, *Sumulus de motu incerti auctoris*.(80) Although Clagett translated these titles as >Anonymous= tracts, they may have been referencing the unseen, unknown, or unmeasurable authors of force such as Bradwardine's irrational proportion, Buridan=s impetus or the air of firearms and projectiles in general.

By the sixteenth century the cause of motion had ceased to stir debate and Galileo was able to ask the reverse question: why motion ceases.(81) Within this debate the motive agency of firearms were recognized alongside mechanical engines and had in fact become the exemplary cause of projectile motion. In the Eighth Book of the *Quesiti*, Tartaglia exclaims that through the science of weights Ait is possible to know and to measure by reason the force and strength of all those mechanical instruments that were discovered by the ancients to augment the strength of a man for raising, carrying or driving forward all heavy weights@.(82) Tartaglia gave a similar definition for artillery in the *Nova Scientia*, AAny artificial machine or material is called a motive power that is suited to drive or shoot a uniformly heavy body forcibly through air.@(83) Gunpowder had clearly been equated with the motive force of mechanical engines and Tartaglia had evidently engaged in some research on its nature, or >the origin and nature of guns, salts, oils and distilled waters and of various minerals... relating to the art of fireworks... which of said materials were in agreement and which were not in accordance (so as to burn together).(84) Both Tartaglia and Ubaldo, however, criticized their medieval predecessors for treating the Jordanus corpus as if it described projectile engines.(85) Instead these two sought to confine the Jordanus corpus to the science of statics, i.e. a closed system where the weights remain in contact with the lever and thus excluding consideration projectile motion.

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A fairly clear chronology has been established for these sciences and their involvement with military engines which became a prime technological concern of university science during the thirteenth century. Leverage and several branches of mechanics necessary for producing optimum force were well understood by the mid thirteenth century, decades before these principles were fully actualized in trebuchets. The mathematically more complex science of gearing flourished in the last quarter of the thirteenth century to have an immense impact on trebuchets and other large works including clocks. There is every reason to believe that the science of weights informed the construction and operation of trebuchets during the thirteenth century and that gearing evolved out of its long-standing relationship with time-keeping devices. Perhaps the most theoretically complex science associated with engines, the science of motion did not rise in comparative prominence until the second quarter of the fourteenth century. The science of motion was clearly inspired by projectile engines but no further evidence of involvement has been brought to light. On the fringes of these sciences, limited discussion arose on the geology of stones as projectiles, their behaviour in flight and effect on defences. If these earlier works lacked a clear focus on military applications, they shared the same style, method, content and sentiment, establishing a tradition and framework. Despite the shortcomings of medieval science, Duhem=s impression that fourteenth-century works prefigured the works of Galileo and his contemporaries may have been more accurate in this regard than is recognized.

The history of the sciences involved in engines and projectiles is but one example of the actualization of science-based technologies, but the development of a more mature view of the philosophy of technology was complicated. The problem of natural science being subverted to theology was of course one of great conflicts of the middle ages and this constraint hindered the development of a more positive scientific praxis for the productive arts for several centuries afterwards, directly and indirectly. Indirectly, the Christian mind set of much of the scientific community created a bias against the productive arts. Although science and technology are both inherently intellectual endeavours interwoven in a spectrum which ranges from thought to action, considerable energy was spent in the middle ages to assemble a universal science, or an absolute system which ranked all knowledge according to its relationship with theology. Aristotle had divided knowledge into productive arts, practical science and speculative science, as did Arabic and Islamic scholars and the most popular classifications schemes in the Latin West.(86) The primacy of theology in Christian classifications schemes placed a bias against the merits of the productive arts and the process of their scientific investigation. Although a class of mechanical arts was introduced to the Latin West in Hugh of St. Victor=s *Didascalicon* (c. 1127), they remained among the lowest orders of knowledge in subsequent taxonomies.(87)

A direct influence of this bias has been seen in the tendency to omit direct references to empirical experiences in natural science. Even when scientific principles and religious doctrine found concordance, the abstract arguments of physics as a speculative philosophy were deemed more noble than the other branches of knowledge which dealt directly with physical realities. Directing scientific efforts towards practical affairs such as siege engines may have lowered a work or author=s prestige or worse drawn charges of heresy. This discourse was also conducted within a distinctly Aristotelian framework which was at the heart of theological controversies. The reoccurring condemnations on Aristotelian science during the thirteenth century specifically forbid arguments of natural philosophy which contradicted church doctrine, and although the condemnations were retracted in 1328, references to them can be found throughout most of the fourteenth century indicating that their impact may not have rescinded.(88) One method of circumventing this prohibition was to frame inquiries in an imaginary or hypothetical situation (*secundem imaginatione*) technically devoid of meaning or significance in this universe and therefore incapable of contradicting theology. In this instance the utilization of hypothetical propositions may also have enhanced abilities to theorize about motion and physics in general.(89)

More important than the content of these works, this discussion arose in an optimistic climate that encouraged a synthesis of science and praxis. Attitudes to science or technology were far from consistent throughout society or even in individuals. Some like Roger Bacon vigorously promoted the investigation of specific technologies and assigned the arts a high role in Christendom=s struggle. Others like Aquinas preferred to analyze the roles of productive arts in society and promote their pursuit generally. The new appreciation for technology=s role and benefits for society which developed outside the university worked to obviate strict classification schemes which peaked in popularity in the late thirteenth century. G. Ovitt, for instance, found a barrage of conflicting evidence for the praxis of technology in theological literature; in one line of enquiry he found a range of opinions on the relation between Creator and creation in hexameral literature, including a long-standing and widespread tradition of viewing God as craftsmen or architect. Ovitt demonstrated, however, that although relegated to the lowest orders of knowledge, the concept of work expanded in the twelfth and thirteenth centuries to include various new industries, trades, and opus dei.(90) E. Whitney=s detailed study of the *ars mechanicae* reinforces this view, and suggests that a distinction was emerging between manual labour and the work of the engineer and architect whose physical activities had intellectual foundations or visages.(91) Within select disciplines a more sophisticated philosophy of technology began to form, such as the distinction alchemists began to make in the fourteenth century between artistic crafts and applied sciences, or Robert Kilwardby=s observation that the mechanical arts informed science and vice versa.(92) A wider perspective on this topos also reveals that development of a positive scientific praxis for technology did not depend entirely on the >big science= of universities and ecclesiastics. From the thirteenth century we have sound evidence of the secularization and even militarization of science in patronage and purpose. The advocation of reason and diligence in Vegetius= *De re militari* provided a prime format for addressing military technologies within a scholastic format, as did the mirror of princes genre which also incorporated a scientific advice ranging from analyses of political economy and specific economic matters to the construction of engines. Moreover, though only a fraction of these treatises survive the majority of them were increasingly well illustrated from 1250 onwards.(93) Even more rigorous and no less >scientific= attention to military technologies is to be found in governments= administration and organization of war.

NOTES

1. As translated by R. Burke, Roger Bacon, *Opus majus* (Philadelphia 1928), vol. 7, part 6.

2. 2 >Aliis enim animalibus natura praeparavit cibum, tegumenta pilorum, defensionem, ut dentes, cornua, ungues, vel saltem velocitatem ad fugam. Homo autem institutus est nullo horum sibi a natura praeparato, sed loco omnium data est ratio, per quam sibi haec omnia officio manuum posset praeparare=, *De Regno*, or *De Regimine Principum*, I. 1.

3. Cohen, *Scientific Revolution*, pp. 45ff, 260-7.

4. C.H. Haskins, *The Renaissance of the 12th Century* (Cleveland, OH, 1927), repr. 1957; M.D. Chenu, *Nature, Man and Society in the Twelfth Century. Essays on new Theological Perspectives in the Latin West*, tr. J. Taylor and E. Gilson (Toronto, 1997); Whitney, *Paradise Restored*; G. Ovitt, *The Restoration of Perfection*; R. McKeon, 'The Organization of Sciences and the Relations of Cultures in the Twelfth and Thirteenth Centuries', in *The Cultural Context of Medieval Learning*, pp. 151-92; J. Murdoch, 'The Analytic Character of Late Medieval Learning: Natural Philosophy without Nature', *Approaches to Nature in the Middle Ages*, L.D. Roberts, ed. (Binghamton, 1982), pp. 171-213. See below (Chapter Two) for argument of shift from passive to active military organization.

5. Excellent overviews of translation activity can be found in D. Lindberg, >The Transmission of Greek and

Arabic Learning to the Latin West=, *Science in the Middle Ages*, idem, ed. (Chicago, 1978), pp. 52-90; E. Grant, *Foundations of Modern Science,* pp. 18-32.

6. John, for example, sought to legitimate his actions by adopting from a range of political philosophies, R.V. Turner, >King John=s Concept of Royal Authority= *History of Political Thought* 17 (1996), pp. 157-78; Edward I seems to have been more sceptical about the role of political philosophy in everyday government, M. Prestwich, *Edward I* (London, 1988), pp. 465-8; cf Harriss, *King, Parliament and Public Finance*, pp. 45-74. J.R. Maddicott posits the emergence of a new genre of secular political poetry in fourteenth-century England in response to the heavy demands of war, which adopted ideas for good government such as the importance of justice and the condition of the people, >Poems of Social Protest in Early Fourteenth-Century England=, *England in the Fourteenth Century :Proceedings of the 1985 Harlaxton Symposium*, W. M. Ormrod, ed. (Woodbridge, 1986), p. 144. A. Musson and W. M. Ormrod note that the critique of government in England was extended to the localities in the fourteenth century, especially to address abuse by officials, *The Evolution of English Justice: Law, Politics and Society in the Fourteenth Century* (New York, 1999), p. 163.

7. On medieval quantification in general, Cohen, *Scientific Revolution*, pp. 45f., 260-7. A growing consensus exists for the importance of quantification in economics, Kaye. *Economy and Nature in the Fourteenth Century*; O. Langholm, *Economics in the Medieval Schools. Wealth, Exchange, Value, Money and Usury according to the Paris Theological Tradition 1200-1350* (Leiden, 1992); J.F. McGovern, 'The Rise of New Economic Attitudes-Economic Humanism, Economic Nationalism-during the Later Middle Ages and the Renaissance AD 1200-1550' *Traditio* 26 (1970), pp. 217-53; R. de Roover, *Business, Banking, and Economic Thought in Late Medieval and Early Modern Europe*, ed J. Kirshner (Chicago, 1974).

8. On the medieval science of political economy see, C. Nederman, >Community and the Rise of Commercial Society: Political Economy and Political Theory in Nicholas Oresme=s *De Moneta*=, *History of Political Thought* 21 (2000), pp. 1-15.

9. Chenu, *Nature, Man and Society in the Twelfth Century*, pp. 162-201. Whether studium conveyed an emphasis on scientific temperment and intellectual fruition as opposed to concepts of imperium is difficult to tell. Hugh of St. Victor spoke simply of a *series narrationis*, a series or sequence in the transfer of eminence from East to West, >ut quae in principio temporum gerebantur in oriente, quasi in principio mundi gerentur, ac deinde ad finem profluente tempore usque ad occidentem rerum summa descenderet,= De Arca Noe Morali, iv, 9, as quoted in Chenu, *Nature, Man and Society*, p. 170 n. 19. John of Salisbury attributed rulership and the transfer of power to virtue, Policratus, Book IV, chapter 12. Chretien de Troye substituted chivalry for civilization but maintained the notion that it passed from one society to another, Cligès, Part 1, vv. 1-44.

10. Aided in a large measure by more adept historical methods and the rise of a more practical, secular genre. For historical modelling and methods, A.C. Crombie, *Styles of Scientific Thinking in the European Tradition*, vol. 3 (London, 1994), p. 1554; for secular histories, J.W. Thompson, *A History of Historical Writing*, vol. 1 (Gloucester, Mass., 1967), p. 267f.

11. Whitney, *Paradise Restored*, pp. 9-11; D. Lindberg, however, doubts any sustained exchange between science and technology during the middle ages, >Preface=, *Science in the Middle Ages*, pp. xi-xii.

12. Crombie, *Styles of Scientific Thinking,* vol. 1, p. xxi, 23.

13. Over the course of the thirteenth century, methods of distillation apparently were devised with a serpentine glass apparatus which enhanced the production of alcohol and mineral acids, E.J. Holmyard, *Alchemy* (Dover, 1957), pp. 41-57. This type of experimentation is said to have enabled the

manufacture of saltpetre, Multhauf, >Science of Matter=, p. 381; Crombie, *Augustine to Galileo*, p. 137; J.R. Partington, *A History of Greek Fire and Gunpowder* (Baltimore, reissued 1999), pp. xxv-xxvi. A. Williams, >The Production of Saltpetre in the Middle Ages=, *Ambix* 22 (July, 1975), pp. 125-33; F.S. Taylor, *The Alchemists. Founders of Modern Chemistry* (London, 1951), p. 118; B. Hall, *Weapons and Warfare in Renaissance Europe. Gunpowder, Technology and Tactics* (London, 1997), pp. 41-5, 74-9.

14. N. George, >Albertus Magnus and Clerical Technology in a Time of Transition=, *Albertus Magnus and the Sciences*, J. Weisheipl, ed. (Toronto, 1980), pp. 235-62.

15. P. E. Chevedden, L. Eigenbrod, V. Foley, and W. Soedel, >The Trebuchet=, *Scientific American* 273 (July 1995), pp. 70-1.

16. Note the bare mention of Jordanus in Cohen=s otherwise thorough and fair treatment, *The Scientific Revolution,. A Historiographical Inquiry*, p. 535 n. 70. While recognizing Jordanus= importance in medieval mechanics, Clagett rejected the idea that Jordanus= ideas stimulated the concept of impetus. In a famous exchange, Tartaglia, a sixteenth century mathematician whose works addressed artillery and projectile motion, was accused of plagiarizing Jordanus; in the event both Tartaglia=s >New Science= and Jordanus= 'De ponderibus' were printed together.

17. E.g., J. Forbes and E.J. Dijksterhuis, *A History of Science and Technology. From Ancient Times to the Seventeenth Century* (London, 1963), pp. 140-1.

18. *Didascalicon*, Book II, chapters 20-7.

19. *Didascalicon*, Book I, chapter 9: 'consideravit quod singula quaeque nascentium propria quaedam habeant munimenta quibus naturam suam ab incommodis defendunt. cortex ambit arborem, penna tegit velucrem, piscem squama operit, lana ovem induit, pilus iumenta et feras vestit, concha testudinem excipit, ebur elephantem iacula non timere facit. nec tamen sine causa factum est quod, cum singula animantium naturae suae arma secum nata habeant, solus homo inermis nascitur et nudus. oportuit enim ut illis, quae sibi providere nesciunt, natura consuleret, homini autem ex hoc etiam maior experiendi occasio praestaretur, cum illa, [748B] quae ceteris naturaliter data sunt, propria ratione sibi inveniret. multo enim nunc magis enitet ratio hominis haec eadem inveniendo quam habendo claruisset. nec sine causa proverbium sonat quod: Ingeniosa fames omnes excuderit artes'.

20. Gundisalvo, *De ingeniis*, in E. Grant, *A Source Book for Medieval Science* (Cambridge, Mass., 1974), pp. 59-76; see also P. M. Alonso, *Domingo Gundisalvo. De Scientiis. Compilacion a base principalmente de la ... de al-Farabi* (Madrid, 1954); L. Bauer, *De Divisione Philosophiae Beitraege zur Geschichte der Philosophie und Theologie des Mittelalters* 4 nos. 2-3 (1903), pp. 1-124. For al-Farabi's text, A.G. Palencia, *Catalogo de las Ciencias. Edicion y Traduccion Castellana* (Madrid, 1932; 2d ed. 1954).

21. M. Mahoney, >Mathematics=, *Science in the Middle Ages*, p. 155.

22. On the translations and the scientific context of Jordanus= work, E. Moody and M. Clagett, *The Medieval Science of Weights* [Scientia de Ponderibus]. *Treatises ascribed to Euclid, Archimedes, Thabit ibn Qurra, Jordanus de Nemore and Blasius of Parma* (Madison, WI, 1960), pp. 1-20; M. Clagett, *The Science of Mechanics in the Middle Ages* (Madison, WI, 1959), pp. 69-103; Grant, *Source Book in Medieval Science*, pp. 211-12.

23. Moody and Clagett, *Medieval Science of Weights*, p. 136: >Equis ponderibus in equilibri appensis, si equalia sint appendicula, alterum autem circumvolubile et alterum secundum rectum agnulum fixum, quod in circumvolubili appenditur gravius est secundum situm=.

24. Ibid, pp. 145-7.

25. >The motion of every weight is toward the center of the world=, as translated in Moody and Clagett, *Science of Weights*, p. 129; the Latin text reads, >Omnis ponderosi motum esse ad medium=, p. 128.

26. >Quod quidem grave descendat, hoc est a natura; sed quod per lineam curvam, hoc est contra naturam, et ideo iste descensus est mixtus ex naturali et violento=, ibid, p. 150.

27. Ibid, *Science of Weights*, pp. 121-23.

28. *De ratione ponderis*, 1.06.

29. Ibid, 3.06

30. Jordanus describes this force as '*impulsis*' and very probably meant the same as Buridan but avoided the issue of how this force was transmitted.

31. A crucial distinction in the debate on the nature of motion.

32. Moody and Clagett, *Science of Weights*, pp. 218-21, 'Item, circumactum C, manente A, plus impellet quam utrobique prius non moto; quia motum plus, eo etiam magis quo longius, dupliciter. Fixo enim A in centro, circumacta B et C, describent arcus circulorum, et maiorem C. Cum ergo maius pondus in C quam in B, et velocius quoque motum, multo amplius impelletur E in C, quam in B. Simul etiam circumactum E cum C, magis movebitur quam si C, motum prius, offendat E.

Si, item centrum alterius motus sit in B, ut CBA circa A, et item CB moveatur circa B, augmentabitur virtus impellendi pro duplici motu; quoniam in equali tempore multo maiori circuitu deferetur C, ut in subjecta descriptione patet.

33. Clagett rejected Duhem and Moody=s contention that the idea of impetus spread through the Jordanus corpus and consequently was at pains to find a reason for the discussion of these ideas during the thirteenth century (both Bacon and Aquinas specifically rejected it), Clagett, *Science of Mechanics in the Middle Ages*, pp.514-9.

34. E. Giannetto, G.D. Maccarrone, S. Pappalardo, A. Tinè, >Impulsus and Impetus in the *Liber Jordani de ratione ponderis*=, *Mediaeval Studies* 54 (1992), pp. 162-85.

35. I cite here Trevisa=s translation, C. Briggs, D. Fowler, P. Remley, eds., *Governance of Kings and Princes: John Trevisa's Middle English Translation of the* 'De Regimine Principum' *of Aegidius Romanus*, (London, 1997), pp. 426-27, > þ anne ¥if suche þ rowyng be wi þ oon conterpaise, þ at conterpaise it is ipi¥t o þ er meuable o þ er som del ipi¥t and som del meuable. And it is iseid þ at þ e counterpeyse is ipi¥t whanne in þ e ¥erde is ipi¥t a cassa þ at is fast wi þ |owte meuynge to þ e ¥erd ful of stones o þ er of grauel o þ er of leed o þ er of som o þ er heuye þ ynges. And men in ool tyme clepede þ is manere gyne trabicium. And among gynnes þ is gynne þ rowe þ most euene, for alwey þ e contrepeyse drawe þ ileche.

36. Ibid, p. 427, >Ano þ er manere gyne ha þ contrepayse faste withoute changynge to þ e swengel o þ er to þ e ¥erd of þ e gyne, turnynge aboute suche a ¥erd. And þ e werriours of Rome clepede such a gyne bypha. And þ is gyne is o þ er þ an þ e gyne þ at hatte trabicium, for þ e countrepeyse is fast to þ e ¥erde of þ e gyne. þ ei¥ it drawe þ e more by cause of meuynge, but it drawe þ not so ileche, þ efore it þ rowe þ for þ ere and more but not so euene, so certeynliche.

37. Ibid, p. 427, > þ e þ ridde manere gyne hatte tripantum and ha þ ey þ er countrepayse fast to þ e ¥erd and þ e oon meuable turnyng þ ere aboute. And by cause þ at þ e contrepeyse is fast, þ is manere gyne þ rowe þ more euene þ an þ e gyne þ at hatte bypha. And by cause of þ e peyse þ at moue þ and turne þ aboute, it þ rowe þ for þ ere þ an þ e gyne þ at hatte trabicium.=

38. Ibid, p. 426, >For in eche suche maner gyn is som what þ at drawe þ and rere þ þ e ¥erde of þ e gynne to þ e whiche is iioyned a slenge þ at þ rowe þ stones'.

39. The best evidence for the earliest mechanical clocks is collected in C.F.C. Beeson, *English Church Clocks 1280-1850* (London, 1971); cf. D.S. Landes, *Revolution in Time: Clocks and the Making of the Modern World* (London, 1983), esp. pp. 54-5; E.L. Edwardes, *Weight-Driven Chamber-Clocks of the Middle Ages and Renaissance* (Altrincham 1965). For the mechanical clock=s similarity to trebuchets, L. White, Jr., *Medieval Technology and Social Change* (London, 1962), pp. 102-3, 122-5. For gearing in the West, J. Needham, *Science and Civilisation in China*, vol. 4, part 2: *Mechanical Engineering* (Cambridge, 1965), pp. 440-5; D. Hill, *A History of Engineering in Classical and Medieval Times* (London, 1984, reprinted 1996), pp. 203, 241-7; F. and J. Gies, *Cathedral, Forge, and Waterwheel. Technology and Invention in the Middle Ages* (New York, 1994), pp. 125-9; V. Foley, W. Soedel, J. Turner, and B. Wilhoite, >The Origin of Gearing=, *History of Technology* 7 (1982), pp. 101-31; D. Price, >The Prehistory of the Clock', *Discovery* 17 (1956), pp. 153-7.

40. L. Thorndyke, >Invention of the Mechanical Clock about 1271 AD=, *Speculum* 16 (1941), pp. 242-3.

41. Ie, in combining Judeo-Christian linear time with an increasingly popular concept of cyclical time, often with the result that events experienced intermediate cycles on a longer finite time line. Not surprisingly, these concepts of time matured in relation to and reflected similar concepts expressed in translatio imperii/studii and political economy, with similar tropes also popularized as Catherine Wheels.

42. J.D. North, *Chaucer's Universe* (Oxford, 1988); L. R. Mooney, >The Cock and the Clock: Telling Time in Chaucer=s Day= *Studies in the Age of Chaucer* 15 (1993), pp. 91-109.

43. Kaye, *Economy and Nature*, pp. 224-9.

44. PRO London, E 101/3/25, Account of Stephen de Penecestre, constable of Dover castle and warden of the Cinque Ports, 8 to 16 Edward I.

45. They had been cast at Canterbury.

46. Expenses for the mill=s repair were also listed in this account.

47. J.D. North, ed., *Richard of Wallingford - An edition of his writings with Introduction, English Translation, and Commentary*, 3 vols., (Oxford, 1976).

48. Both the latin and its translation are from North, *Richard of Wallingford*,i, pp. 444-5:

> 'Habita rota certi numeri dencium, unam aliam rotam invenire que habeat quotlibet dentes equales dentibus rote date.
>
> Divide diametrum rote date in tot partes equales quot sunt dentes equales in circumferencia, de quibus partibus diametri accipe quotquot partes volueris; et super illis partibus fac circulum cuius diameter continet omnes partes acceptas, et tunc circumferencia eius habebit tot partes equales alterius circumferencie partibus quot partes equales habet una diameter de partibus diametri alterius. Quia que est proporcio circuli ad circulum, illa est proporcio diametri ad diametrum. Et facere poteris protrahendo diametrum quantumcumque volueris longe, et accipiendo quotlibet partes equales.

49. Ibid, p. 448-9, >Et memorandum quia primi numeri motus lunaris sunt magni valde, ideo si subduplantur idem proveniet, et commodius quam prius; scilicet si maior circulus solaris habeat 254 dentes et circulus Lune habeat 19 dentes, tunc porcio 4 signorum 12 graduum at 49 minutorum et 49 secundorum habebit de illis 19 dntibus 7 dentes=.

50. Capacity: J. Landels, *Engineering in the Ancient World*, 2nd ed. (London, 1997), p. 84.

51. Landels, *Engineering in the Ancient World*,, pp. 89, 104 estimates windlass as !0:1 reduction. P.E. Chevedden,'The Invention of the Counterweight Trebuchet: A Study in Cultural Diffusion', *Dumbarton Oaks Papers* 54 (2000), however, credits the windlass as enabling the advent of the heavy counterweight trebuchet, p. 86f.

52. C. Cahen, =Un Traité d=Armurie Composé pour Saladin=, *Bulletin d'Etudes Orientales* 11 (1945-6), pp. 103-63.

53. *The Sketchbook of Villard de Honnecourt*, T. Bowie, ed. (Bloomington, IN, 1959), pl. 61.

54. D.R. Hill and A.Y. Hassan, *Islamic Technology. An Illustrated History* (Cambridge, 1986), illustration 4.15.

55. CDS, iv, p. 456.

56. Physics VI.9.

57. One possibility, antiperistasis, held that the projectile=s movement forced air out of the way which rushed behind the projectile and propelled it forward; Aristotle=s other suggestion posited that the motor transferred its force to the air around the projectile and that this same air carried the projectile through its motion.

58. Grant, *Source Book in Medieval Science*, p. 276.

59. Physics, XII.9: 73ra.

60. A. Maier, *Zwei Grundprobleme der Scholastischen Naturphilosophie. Das probleme der intensiven grösse die impetustheorie* (Rome, 1951), p. 221, >sicut homo proiciens lapidem movet manum suam cum lapide, et etiam in sagittando corda aliquo tempore movetur cum sagitta pellens sagittam, et ita etiam est de funda proiciente lapidem vel de machinis proicientibus maximos lapides.=

61. Ibid, p. 205.

62. >Vitrus hujusmodi exhalationis apparet in illis instrumentis vocatis canalibus, ex quibus, per exhalationem ex modico pulvere genitam, grossa sagitta vel globus plumbi sic fortiter emittitur quod nulla arma possunt ipsum retinere=, *Quaestiones de libris meteorologicorum Aristotelis* as quoted in Hall, *Weapons and Warfare in Renaissance Europe*, pp. 44-5, n. 23.

63. Thomas Bradwardine, De proportionibus velocitatum (1328), William Heytesbury, Regulae solvendi sophismata (1335), John Dumbleton, Summa logicae et philosophiae naturalis (1349), Richard Swineshead, Liber calculationum (ca. 1350). E. Sylla, >The Oxford Calculators in Context= *Science in Context* 1 (1987), pp. 257-79.

64. *Tractatus de Proportionibus. Its Significance for the Development of Mathematical Physics*, H.L. Crosby, tr. and ed. (Madison, 1955).

65. See Crosby=s comments, *Tractatus de Proportionibus*, p. 16, and J.E. Murdoch, 'The Medieval Language of Proportions: Elements of the Interaction with Greek Foundations and the Development of New Mathematical Techniques', in A.C. Crombie, *Scientific Change. Historical studies in the intellectual, social and technical conditions for scientific discovery and technical invention, form antiquity to the present* (London, 1963), p. 259.

66. *Tractatus de Proportionibus*, p. 110 >proportio velocitatum in motibus sequitur proportionem potentiae motoris ad potentiam rei motae=.

67. Since antiquity the study of >proportions=, which some might consider fractions or functions, were an exclusive domain even among the minority of scholars who were mathematicians, Murdoch, >The Medieval Language of Proportions', pp. 237-71 is still a useful introduction to the subject of medieval proportions.

68. For another of Bradwardine=s works related to this issue, see J.E. Murdoch, 'Thomas Bradwardine: mathematics and continuity in the Fourteenth Century=, E. Grant and J.E. Murdoch, eds., *Mathematics and its Applications to Science and Natural Philosophy in the Middle Ages* (Cambridge, 1987), pp. 103-37.

69. See, *Medieval Science of Weights*, pp. 285-91.

70. Tractatus de Proportionibus, p. 104.

71. Ibid,, p. vii.

72. 'quoniam experimentum sensibile docet huius positionis contrarium=, ibid, p. 98.

73. 'Volvatur igitur sphera seu corpus columnare, super axem quiescentem... Tunc cum ista parte colligetur corda fortiset longa, in cuius extremo alligetur aliquod ponderosum,... si homo traheret illud ponderosum per cordam cum manu', *Tractatus de Proportionibus*, p. 98

74. 'sicut accidit in horologio', *Tractatus de Proportionibus*, p. 98.

75. White, *Medieval Technology*, pp. 90-2.

76. 'Take 7 parts of saltpetre, 5 of young hazelwood (charcoal) and 5 of sulphur, and you shall make thunder and lightning, if you know the trick.' *Epistolae de secretis operibus artis et naturae et de nullitate magiae*.

77. 'dici impetus vel qualitas vel dispositio vel motus, pro nunc non caro, quia bene scio quod in isto capitulo multa satis improprie sunt dicta (sed haec dicta gratia exempli), et etiam quia non habemus nomina bene et proprie imposita', Maier, *Zwei Grundprobleme der Scholastischen Naturphilosophie*, p. 251.

78. MS Paris, BN lat. 16621, Clagett, p. 201.

79. Clagett, *Science of Mechanics in the Middle Ages* did not comment on this title, and referred to it instead by its incipit, >Utrum omins motus uniformiter difformis correspondeat suo gradui medio=, pp. 269, 326.

80. Ibid, pp. 454-62.

81. Which Galileo expressed as V=F-R or velocity equals force of movement minus the resistance.

82. As translated by S. Drake and I. Drabkin, *Mechanics in Sixteenth-Century Italy. Selections from Tartaglia, Benedetti, Guido Ubaldo, & Galileo* (London, 1969), p. 111

83. Ibid, Definition XIII, p. 73.

84. Ibid, p. 68.

85. Ibid, pp. 116, 278-9.

86. J.A. Weisheipl, >The Nature, Scope, and Classification of the Sciences=, *Science in the Middle Ages*, pp. 461-8; G.

Saliba, >The Function of Mechanical Devices in Medieval Islamic Society=, P. Long, ed., *Science and Technology in Medieval Society* (Annals of the New York Academy of Sciences, v. 441, New York, 1985), pp. 141-51.

87. Arbitrarily subdivided into short chapters on fabric-making, arms-making, commerce, agriculture, hunting, medicine, and theatrics, Book II, chapters 20-7.

88. Kaye, *Economy and Nature*, pp. 8ff; J.E. Murdoch, >The Analytic Character of Late Medieval Learning: Natural Philosophy without Nature=, L.D. Roberts, ed., *Approaches to Nature in the Middle Ages* (Binghampton, NY, 1982), pp. 171-213; E.D. Sylla, >Mathematical Physics and Imagination in the Work of the Oxford Calculators: Roger Swineshead=s *On Natural Motions*=, in *Mathematics and its Applications to Science*, pp. 69-101.

89. A. Funkenstein, >Aristotle, Imaginary Experiments, and the Laws of Motion=, in B. Hall, ed., *On Pre-Modern Technology and Science. A Volume of Studies in Honor of Lynn White, Jr.* (Malibu, CA, 1976), pp. 223-33.

90. *Restoration of Perfection*, argument summarized p. 199.

91. E. Whitney, Paradise Restored, esp. pp. 148-9.

92. W. Newman, >Technology and Alchemical Debate in the Late Middle Ages= *Isis* 80 (1989), pp. 423-45, argues that the novelty of these arguments for technology=s importance is not seen in other disciplines until the Scientific Revolution.

93. M. Daumas, and E. Hennessy, eds., *A History of Technology and Invention*, vol. 1: *The Origins of Technological Civilisation* (New York, 1969): 518-519; P. Porter, >The Ways of War in Medieval Manuscript Illumination: Tracing and Assessing the Evidence=, *Armies, Chivalry and Warfare in Britain and France*, M. Strickland, ed. (Woodbridge, 1998), pp. 100-14; also Frances and Joseph Gies, *Cathedral, Forge, and Waterwheel. Technology and Invention in the Middle Ages* (New York, 1994), pp. 205.

CHAPTER TWO

Military Organization and Administration

þ anne for art and science may not be of particuler thinges asigned,
he þ at wol teche art of rewelyng of citees may not ordeyne certeyn nombre of
fitynge men; but suche doynges moot stonde on þ e doom of a wise rector and
rewelere takynge heede of condicions of citeseyns, of manere of þ e contrey,
and circumstance of men þ at ben ny aboute.

John Trevisa, c. 1400[(1)]

The profound changes occurring in European perceptions of nature during the thirteenth and fourteenth centuries were reflected in the transformation of English military organization and administration. Since the twelfth century, the exercise of reason and prudence in government was increasingly expected of kings and their ministers.[(2)] By the end of the fourteenth century, John Trevisa had warned that regard for 'practical' sciences in war and government might come to eclipse the realities of society's condition. England's military success was indeed built on a thorough reordering of society's involvement effected through the same faculties for practical sciences and record-keeping.[(3)] Perhaps the most obvious example of this administrative acumen is to be found in financial reforms and taxation, but military service was also subjected to more precise attention as was the gathering and distribution of supplies all of which truly placed a great burden on society.

During the fourteenth century the Crown began to 'privatize' its acquisition of many foodstuffs and textiles by contracting for the purchase of larger quantities from fewer merchants.[(4)] The Crown's management of war materials is less receptive to neat classifications except to say that its imperialistic method of providing defence was reinforced in its greater efforts to effect a more potent warfare. Lacking the major arms centres which flourished on the continent, England's disperse industries and technical expertise limited economies of scale, and consequently the Crown engaged in a great variety of means to obtain its *guerre necessaria*. The arrangements for obtaining military hardware distributed responsibilities across society in a number of ways: universally through arms requirements, by abdication of such duties to lieutenants of provinces, castellans, etc., and by dividing large orders for goods or labour among several or more regions. The Crown continued to rely on this 'popular' method of obtaining war materials during the increased demands of the new warfare, strengthening royal dependence on society. However, the process required more intensive and extensive attention to mobilizing these goods until more standardized methods were established. Measuring the total volume of goods mobilized by the Crown in these efforts is impossible due to the lacunae in records and the Crown's many methods of obtaining materials, but we have several indications that it struggled in its management of arms due partly to its overburdened administration, partly to England's modest industries, and partly to society's objections to more progressive requests and perhaps to war more generally. We will examine these trends beginning with a general overview of the administrative machinery through which this business was conducted, and then in two broad types of the Crown's activities: the 'sanctions' or legislation aimed at improving the army's equipment, followed by the physical acts of acquisition, maintenance and distribution of common war materials.

PART I

During this period the Crown's management of arms was never isolated to any one administrative department or locale. In what resembled a confederation of administrations, the Crown supported its warfare by directing resources from any of its territories to theatres of war. Finances for this business were issued variously from the Chamber, the Exchequer and the King's Wardrobe, while instructions were commonly issued through the Chancery with the Great Seal but from Edward II's reign more missives were issued with the Privy Seal and later the signet in Edward III's reign. The Crown acquired materials in a variety of ways, viz., it received gifts, commissioned into service, purveyed, confiscated, and 'bought' items with cash and credit, though the latter was not always forthcoming. The Crown also coordinated the manufacture of a high proportion of its armaments (through almost as variable means), ceaselessly engaging in the construction of those items for which it was wholly responsible- missile weapons and large engines- ordering many other common and complex works as occasions demanded.

Even though it is virtually impossible to tally the Crown's expenses on arms or the volume of goods mobilised, some idea of the change in the scale of these activities can be gained by the peculiar evolution of the Royal Wardrobe departments which had a specific responsibility for managing household and army supplies. Tout portrayed the reform of these departments partly as political battle to control the king's prerogative and partly as practical adaptation, but recent historians contend that their evolution was of no real political significance.(5) The Royal Wardrobe appears in the Crown's records as early as John's reign denoting, as one might expect, a storage facility. Over the course of the thirteenth century as the Chancery and Exchequer separated from the household and became residential, other more direct means were required for financing and executing the king and council's policies, especially for matters made urgent by the exigencies of war. This role was performed during Henry III's reign by the Royal Wardrobe which grew into a department with its own staff for organizing household affairs; it was a mobile 'clearing house' handling the recruitment, pay, supply and transport of military forces, negotiating loans and financing allies, conducting diplomatic missions and seeing to the considerable everyday needs of the household.(6) As Tout put it, a Wardrobe clerk was 'a jack of all trades, an administrator, judge, collector, book-keeper, paymaster, store-keeper, auditor, surveyor, scribe, and secretary as occasion demanded'.(7) The key officials of the Wardrobe, from the outset normally a clerk and a merchant acting in tandem, drew upon other clerks, merchants, members of the household, local officials and craftsmen to perform these crucial duties. Not surprisingly men who excelled in managing the Wardrobe often rose to even greater posts later in their careers, such as Robert Burnell or John Langton (Chancellors), and William March or Walter Langton (Treasurers).(8)

As the goods and business of the household multiplied during the thirteenth century, the Great Wardrobe, which had the specific task of managing the household's non-perishable items, also acquired status as a distinct and fairly independent department.(9) The Great Wardrobe referred not only to the staff but also to the goods and the network of store houses. This network was already well-established early in Henry III's reign, but by the later thirteenth century the volume of transactions necessitated formal recognition of the Great Wardrobe and its activities. The growing reliance on such a network can be seen in the Crown's drive for unquestioned control of these residences which constituted a major element in its administrative infrastructure.(10) In a similar manner, in the fourteenth century a Privy Wardrobe emerged largely in conjunction with the Tower of London with specific responsibility for the king's personal armaments and other extraordinary duties in managing arms.(11) Although the refinement of these departments and their clerk's accounting methods indicate a definite attempt to accommodate the growing business of war, it does not appear as if the number of staff within these departments increased significantly, nor was any great specialization of duties in place among them. For example, in 1299-1300 John Droxford could be found buying leather for engine's slings and other minutia.(12) While these household clerks worked to greater capacities, more of the Crown's logistics were handled by officials in the localities, reinforcing the Crown's communal dependence.

Sanctions

We can note several ways in which the Crown attempted, through legislation, to improve the availability of arms in England and enhance its armies' equipment. Arms were consistently excluded in assessments of movable goods for taxation, a tradition stretching back to the Saladin tithe of 1189.(13) This exemption may have been designed to benefit lesser tenants and townsmen whose arms were often their most expensive possessions, but one wonders if the luxurious arms of the gentry and nobility were ever viewed suspiciously or treated differently. From the late thirteenth century the Crown's sanctions also extended to regulation of the crafts and gilds. nscrupulous craftsmen presented a number of problems. In 1327 a complaint was made by the pouch makers in London that foreigners were scraping sheepskin so that it appeared like roe leather, and that the former would not last two days as a protective covering for plate armours.(14) In 1322 complaints arose that old or damaged helmets were being recovered and sold.(15) The noise of legitimate armour makers also required restrictions on their hours and place of work.(16) Exchange was far from one-way and these gilds appear to have been gaining political clout: in London in 1338 a blade-smith was elected to sheriff.(17)

Far from being laissez faire about its arms trade, the Crown placed strict laws preventing the export of arms from England as early as the assize of arms of 1181.(18) Obviously, this situation required more work of the Crown's administration to issue licenses for those travelling with arms legally.(19) Specific orders were also issued when it was suspected that someone was trying to smuggle arms out of England, usually to Scotland where arms were more scarce.(20) When someone was found smuggling arms, the Crown's normally confiscated the arms and processed them with current mobilizations or directed their transport to a place for keeping. For example, in March 1315 merchant ships at Boston were discovered as they were preparing to take arms and victuals to Scotland. The sheriff was directed to confiscate the goods and send them with everything else he could find in the way of armaments to Berwick via Lincoln.(21) The Scots seem to have relied on importing English arms, and the interception of any shipments were serious issue. When a Scottish ship conveying armaments was intercepted by the people of Hartlepool, it enraged Robert Bruce so much that he vouched to destroy the town.(22) Vainly, the English Crown tried to impose an international ban on sales of arms to its enemies.(23) The futility of the situation was commented on in 1305 by Robert, count of Flanders, when he remarked that he had made a proclamation forbidding his subjects from exporting arms to Scotland but the Scots had the right to come engage in trade.(24) When such trade became continual and encouraged, however, it was an indication of collaboration which could not be disguised. One of Edward II's agents in France warned him against coming there because of the obvious support in arms and other war materials being given to the Scots.(25)

The Crown's most comprehensive arms sanctions occurred in the arms requirements which accompanied summons and requests for military service (Appendix II). We will return to the particular arms assigned in relation to the development of English tactics in Chapter Four, and in Chapter Six the costs of individual arms are examined in detail. For the rest of Part I we will be concerned with the Crown's attempts to update society's military obligations *vis a vis* evolving armaments and economic conditions.

Arms requirements were the prime means of detailing the type of military service performed. By adjusting the scale of wealth for assessment and the kinds of arms required, the Crown could tailor its recruiting efforts to match its military needs. Prior to Edward III's reign English armies were criticized for being poorly armed. For comparison, in 1260 the city of Florence required its knights to equip themselves in a hauberk, mail leggings, a steel helmet, and a kind of stiff body armour termed lamières probably akin to an aketon or coat of plates.(26) Those arms were available in England at that time and were in use there by the end of the thirteenth century but comparable arms were not incorporated into national arms requirements until Edward II's reign or later.(27) Integrating increasingly complicated arms into English armies presented one of the most difficult aspects of England's military re-organization. In the wake of the sharp contempt for foreign troops, beginning with Henry III's reign more attention was given to English society's military obligations. Throughout the transition from obligatory to volunteer service, the Crown expected the great majority of its combatants to provide their own arms. This expectation prevailed presumably because the Crown lacked adequate access to commercial industries as were flourishing on the continent, and also because it found that it could not afford the administrative and financial costs, the latter amounting to as much as tens of thousands of pounds per campaign. Whereas recruitment for military service was largely a matter of motivation, attempts to improve the army's equipment depended therefore on arms' availability *and* English society's willingness to invest in them.

Powicke has admirably traced the evolution of these military obligations and found their culmination in Edward II's 'failed experiments' to create a national army through communal arrays. Much has been written about Edward II's 'tyrannical' and 'unconstitutional' military levies but very little has been done to assess the costs of advances in arms requirements.(28) Generations of historians believed that with the addition of mail barding in the early thirteenth century the cost of fielding a fully-equipped knight had outgrown the original value attached to knights fees, leading or at least contributing to a large reduction of *servicia debita* from the beginning of the thirteenth century.(29) The cost of fielding a knight, the continued reduction in *servicia debita* and the eventual abandonment of feudal service in the 1340s are still often linked by historians, usually by including the introduction of 'plate armour' in the equation.(30) One argument against this view contends that the widespread adoption of plate armour in Europe occurred well after the reductions in *servicium debitum* had begun.(31) An additional charge levelled against the high-cost argument contends that the real cost of armaments, especially the hauberk, was actually falling perhaps from the late twelfth century.(32) Regrettably, most estimates for arms prices have concentrated on the cost for an entire 'harness', but that approach fails to reveal the different burdens imposed by scaled obligations and does not take into consideration any variations in the price trends of individual arms.(33) Not surprisingly, that method has produced widely differing estimates for a soldier's outlay on arms, ranging from 5s to £15, with the consensus tending towards the latter.(34) Utilizing the prices presented in Chapter Six, we can determine the changing costs of arms more precisely not only as they related to knightly service of the thirteenth century, but more importantly as they related to the drastic change in military obligations for the greater part of English society in the early fourteenth century. Although we can credit the thirteenth and fourteenth centuries with a marked decline in the costs of arms, the costs of heightened arms requirements may indeed have played some part in the reduction of *servicia debita* and they certainly became a sticking point in negotiations until contract service became the prime means of recruitment sin the 1340s and 50s.

Though accepting or confirming quotas of knights' service, Henry was able to score two key advances in arms requirements. The heavy cavalry provided by these military tenants, vassals and the king's household, the so called backbone of the army, had always been expected to serve in maximum equipment though expressed in vague references such as *armis competentibus*, *potentibus ad arma*, *bene armatum*, *sufficienter armatum*, etc. Mail barding, usually recorded as 'coopteri feri' or 'trappes', which had become much more common in Europe during the late twelfth century, was now required for all knights and men-at-arms' horses, becoming the primary distinction for pay: knights with at least two covered mounts earned 2s per day, men-at-arms serving with one covered mount received 1s per day, and the serjeants and hobelars serving with an uncovered mound received 6-8d per day. Archers and crossbowmen typically received 2-3d or 4-6d per day on uncovered mounts. Based on expenses recorded in the Pipe Rolls, for most of the thirteenth century mail barding often cost £2 or more per set.(35) This addition represented on average as much as a 29% and 33% increase in the minimal outlay for men-at-arms and knights respectively.(36) The true percentage would be slightly lower once riding equipment is factored in, but the additional cost of barding could easily have warranted reappraisal of the service owed especially since the requirement occurred decades before the marked drop in arms prices began.

Henry III's other victory lay in retaining the twenty-pound class as a standard for the knight's fee despite bouts of inflation since 1180s, making approximately one thousand families eligible for distraint by the end of his reign. In addition to military tenants and vassals, military service could be requested of all able bodied freemen between the ages of 16-60, the *jurati ad arma*. The Anglo-Saxon fyrd required the service of one man armed with a helm, hauberk and sword from roughly every five hides of land.(37) At that time those arms might cost ten times a person's annual subsistence.(38) In 1181 Henry II established a more precise formula for requesting service that assigned arms based on individual wealth or income, and thereafter this method remained a viable supplement to military summons.(39) The arms requested of the twenty-pound class in the 1181 assize would have been worth about 60s, only one or two times the cost of a person's annual subsistence. The assize also contained very harsh penalties for failure to muster in these arms, including forfeiture of land or chattel and also threatening loss of limb, but the main concern seems to have been obtaining service rather than punishing disregard for arms: one clause prohibited anyone from keeping *more* arms than required of them. However, these levies failed to impress. Henry II and Richard I both collected scutage to pay for mercenaries rather than deploy the "agrarios milites, nec... burgensium nec rusticorum multitudinem".(40)

Henry III made consistent efforts to reorganize military obligations based on society's changing economic base, relieving the hauberk from the requirements of the sixteen-mark class, and creating two new classes (3-10 marks and £2) required to have only polearms and bows respectively.(41) The events of Henry III's reign, however, demonstrated that the prolonged process of assessment prevented more frequent campaigning. During Henry III's reign some twenty-six distraints of knighthood were issued which theoretically should have addressed what was approaching one thousand families of that income, but this extensive process of negotiating service and surveying wealth was complicated by sheriffs' use of different standards in each locality.(42) The last overseas expedition of Henry III's reign, for example, was preceded by at least two distraints.(43) Bringing the smaller tenants into military assessments widened recruiting options but probably lacked administrative feasability. Whereas 10,000-20,000 families may have possessed an annual income of £5 or more by the end of the century, the two new classes brought some 100,000 smallholders into the process nationwide.(44)

Events unfolded dramatically during Edward I's reign as he sought a radical change to recruiting 'national' armies of wholly paid forces, threatening the lords' privileged status in war cum government. Recruitment over the next few decades often took the form of quasi feudal levies that addressed freemen and military tenants through a scaled rate of pay. Though successful in raising large numbers of lightly armed infantry in addition to the normal cavalry, even if Edward I had wanted to provide arms *en masse* the recruitment of welsh conscripts yielded uncertain numbers and sporadic service, rendering accurate planning impossible. Edward I's attention to arms requirements focussed instead on the gentry. Edward strictly reinforced the emphasis on covered mounts as the prime distinction between the pay of a serjeant and that of man-at-arms. Historians confusion over any supposed terminology associated with a soldier's rank and his arms is entirely misplaced.[(45)] The improved records of Edward I's reign provides an abundance of evidence on this point.[(46)] Those obligated to knighthood were expected to serve with at least two covered mounts, men-at-arms one covered mount and 'serjeants' one uncovered mount.[(47)] Over the course of the thirteenth century mail barding halved in price to 20s or less, but its adoption still varied due to the vagaries of individual assessments. On one of Edward I's campaigns, only 16 of 176 'centenars' served without barding, and despite their title those 16 received only 6d per day as compared to 1s per day for those with covered mounts.[(48)] The assessments of 1277 and 1282 reveal similar vagaries.[(49)] One tenant acknowledged owing two *servientes* one with covered horse and one uncovered. Although clear requirements were issued, assessments tended to vary. In 1282 the £10 class was expected to serve mounted, with a gambeson, iron helm and polearm, while a £30 class was ordered to have barded horses in addition. Again the actual assessments were less clear-cut but do reveal that the aketon and basinet were being adopted in a haphazard manner. Several *servientes* were required to serve with an uncovered mount, an aketon, haubergeon, basinet, lance and sword, though others retained their long-standing obligation of an uncovered mount, pourpoint, iron cap and lance.[(50)] In 1295/6, assessments for the defence of the Isle of Wight and Hampshire revealed more information and wider discrepancies. Assessments for service with one covered mount ranged from £20 to £40; one tenant assessed at £30 owed service with two covered mounts as did one assessed at £70. Others assessed at £30 owed one covered and one uncovered.[(51)] With individual assessments some leeway may have been granted considering the much greater reductions in the *servicia debita* of larger tenants, allowing the corresponding difference in a man-at-arms and serjeants' pay to speak for itself. It also appears that the custom of substituting two men-at-arms for a single knight had expanded into an even broader formula allowing virtually any combination of knights, men-at-arms and serjeants.[(52)] These negotiations cannot have aided planning, and they also offered ample opportunity for a quick-witted tenant to minimize responsibilities that ridiculed obligatory service throughout its duration. As late as 1343, Henry de Grey was required to serve with a horse without a saddle, a bow without a string and an arrow without its head.[(53)]

Edward I's statute of Winchester (1285) which relaxed the knight's fee to £100 was issued largely as a generous peace-time measure and cannot have been intended as a lasting scale of service. The relaxation to £100 may also have been designed to take into consideration the inflation which virtually doubled prices over the course the thirteenth century; in other words, the forty to twenty-pound classes of 1300 expected to provide a knight's service had roughly half the wealth of the same classes in 1200 and much less disposable wealth. The statute of Winchester was more progressive with the requirements of the ten-pound class which saw the hauberk revived in its requirements.[(54)] Society's acceptance of that requirement paved the way for the much heavier requests for durable serjeants/hobelars and mounted archers of later armies. Steps were also taken in the statute of Winchester to provide more of a framework for communal arrays. In 1282, household knights and royal clerks had already complemented sheriffs in this task, and in 1285 commissioners, normally justices, councillors, constables, magnates and bishops, were specially appointed. Centenars and vintenars, commanders of units of 100 and 20 respectively, were drawn from the wealthy peasant class. Arrangements for musters in Yorkshire may have been typical of the multiplication of officials involved: whereas three men were assigned to oversee the process in 1300, in 1303 three men were assigned in each of its four ridings.[(55)] By that time Edward was also beginning to question the feasibility of organising campaigns around such unreliable forces which strained the administration, and instead issued orders for more valiant men to be selected by commissioners of array, limiting future orders for infantry to around 10,000 or less.(56)

Edward II's requests for military service escalated into an ambitious scheme of communal arrays that removed the rigid framework which tied the type of military service performed to personal wealth. Whereas substantial arms had only been requested from those with at least £10 annual income, a much superior force could be raised by drawing more of the realm's resources into equipping an army. By separating the issues of manpower, provision of arms and type of service performed, communities could be assessed for men, their arms and wages, bypassing the heavily negotiated personal assessments. Perhaps, more importantly, the communal array allowed the Crown in theory to choose the exact type and quantities of troops it desired regardless of the distribution of wealth in society. That some freemen owned less than required by arms requirements is evident. The Reading muster of 1311 produced eight men with swords, 33 with bows and knives and 235 with axes and knives, and Bridport's muster in 1319 had similar results.(57)

Following Bannockburn, Edward redoubled his efforts to obtain extremely well armed troops. onceding with the barons in parliament in 1316, Edward began to increase military obligations by making a heavy request of one man from every vill (some 15,000 to 30,000 men), armed and paid by the communities, and after the Treaty of Leake in 1318 towns were brought back into mainstream requests for service. In 1319 the requirement of basinets and gauntlets was extended to the £2 class, and stiff penalties were set for not mustering in these arms. The first time someone failed to appear as required, one-third of his lands or goods were to be confiscated, with the remainder being confiscated on the second time and imprisonment on the third time.(58) The addition of gauntlets to the £2 class, which incidentally begs the question of whether they would continue to serve as archers, raised the costs of their arms to an unconscionable 15-20s each.

Realizing the impossibilities of that method, in 1322 and again in 1324 Edward II applied the communal array on a national scale, requesting thousands rather than hundreds of armoured infantry.(59) In 1324 numerous counties were requested to provide a total of 19,200 infantry, 4,800 of which were to be armed with aketons, haubergeons or coats of plate, basinets, and steel gauntlets. Their armour was to be purchased and maintained by the local commissioners.(60) However, the same type of problems encountered in previous assessments for distraints of knighthood plagued this process but on a larger scale, inviting corruption.(61) Whether or not hese arms could be procured in each county on short notice must also be questioned, and in any event the order was rescinded to arm the men in aketons, basinets, and gauntlets of steel or whalebone. Orders to all counties stated that worthy persons were to be chosen in every town to assess the inhabitants and purchase this armour, still at the cost of the communities, but the campaign was eventually abandoned with only a few hundred of these troops embarking.(62) The drastic attempts to draw more military service from communal arrays made assessments more frequent and intrusive during Edward II's reign, resembling the frequent imposition and collection of unspecified taxes with included military service. The practice of levying unspecified amounts of money for the purchase of these arms- after all, the prices for these arms varied considerably- invited corruption and not surprisingly evoked complaints about injustices. In some cases communities contributed a specific sum for raising troops, but in many other instances the commissioners of array purchased the equipment which greatly varied in cost from community to community, and then assessed the village to pay for the total cost of arms, food, wages, etc. This arbitrary tax and the extortionate manner of some collectors evoked complaints. The communities' also complained about risking life and limb in such numbers and on a regular basis without any voice in the broader elements of war and of the realm's business, and this point was pressed to obtain communal rights in decisions to wage war and other corporate matters.(63)

Edward III faced the monumental challenge of reconciling royal authority with a turbulent and highly politicized society. The strong opposition against the national array led Edward III to return to the method of requesting hundreds of armoured troops from specific communities on a rotary basis. Edward III's attempts to continue even these communal arrays, however, were roundly criticized resulting in periodic requests (1327, 1344, 1346, 1347, 1348, and 1352) for a statutory confirmation of the customs of obligatory service contained in the statute of Winchester, e.g. (in 1327) that men would not be armed at the expense of the community, be forced to serve overseas without pay nor severely penalized for failure to serve as requested.(64) In 1336 a rumour even circulated that Edward III agreed in parliament to provide arms for everyone in military service.(65) Edward III's efforts to revamp the array also suffered from corruption and extortion. Undoubtedly many others pulled the same ploy as the person in 1339 who having been equipped and paid wages from a communal assessment in London fled and sold the arms.(66)

Objecting to the ambiguous assessments in the open-ended process of raising money for levies and methods of collection, in the 1330s and 40s many more communities began to commute their obligation to a cash payment. This disassociation left Edward III few options but to target the gentry and nobility who were accustomed to high arms requirements and pro rata pay since Henry III's reign, reserving communal levies for defence and in this role they proved a valuable asset in responding to Scottish raids.(67) Although Edward III was successful in raising large volunteer forces in 1346 and 1359, he came to employ small, well-armed chevauchée forces drawn from the gentry which adopted the tactical formation of intermingling archers and infantry hammered out in the previous decades. The Crown's recruitment pool was confined to the five-pound class and upwards who could afford substantial investment in horses and armours, though barding was dropped from requirements in the mid fourteenth century. Furthermore, from the 1340s military service was being secured with in advance with contract agreements or indentures, drawing on a practice already in place for certain other arrangements.(68) The adoption of this method on a much larger scale provided a tremendous advantage in allowing more accurate financial and logistical planning, including some alternative method of payment if the king, and hence the Royal Wardrobe, was not going to be present on campaign.(69) Earlier in the fourteenth century when arms were still in a great state of flux, indentures occasionally contained precise instructions about arms. In 1316, an indenture made between Edward II and a Genoese knight stipulated plate armours.(70) In what appears to have been a forerunner of the regard, when the earl of Richmond was made lieutenant of Scotland in 1307, both the arms of his contingent of 60 men-at-arms and the Crown's supplement of 60 men-at-arms were to be maintained in high standards or a deduction would be made in his daily allowance of 10 marks.(71) The precise terms for arms in most later contracts remained subjective (ie, well-armed), perhaps because some standards had been worked out among the diversity of armours, and a number of other incentives- food, gifts, shares of plunder, prests, etc.- were available to maintain standards.

The Crown's emphasis on substantial armours in its arms requirements from 1285 onwards conveys a definite and persistent purpose, yet society was unwilling to meet Edward II's demands and resistance continued under Edward III. Although the cost of living was rising, based on the changing costs of armaments the Crown was entirely justified in increasing arms requirements. The gentry and nobility can hardly have been forced out of their stations by the burdening costs of their armaments. The price for the equipment required of them in the early fourteenth century was about half (a quarter of the real cost) of the basic equipment available in the early thirteenth century, and more often than not they chose to purchase high-priced and luxuriously decorated armaments in order to impress others and proclaim their status. The enhanced arms requirements of the fourteenth century could have been met by the armigerous classes with less outlay than before, but the lower classes would have suffered if held to the most advanced requirements. The £2 to £10 classes, for whom the inflation of the thirteenth century struck more deeply, were actually requested to increase their outlay until assessments were transferred to communal taxes. Politically, the move to burden the counties and towns for the arms of these troops proved disastrous for Edward II by uniting the realm in a common complaint. Given the nature of England's arms industry and the terribly inconsistent communal assessments, the Crown would have had to assume great administrative and political burden to equip armies through a central agency even when arms are obtained in the localities. As taxation was being pushed to its limits in Edward III's reign, reverting back to volunteer service obviated communal assessments for arms and relieved the Crown of any duty for providing personal armaments. Society was willing to provide militias armed according to the statute of Winchester as witnessed in numerous mobilizations even during Edward III's reign. However, both Edward II and

Edward III sought extremely well equipped forces, leading to the employment of smaller forces capable of affording the investment in horses and arms. These chevauchée forces, utilizing the new tactics, were a potent and economical solution to raising well equipped forces.

Although the Crown seems entirely justified in upgrading English arms requirements based on the costs of arms and military necessity, society's strong opposition in the fourteenth century was more likely to have stemmed from objection to compulsory military service especially with the Crown's perilous style of tactics. The transition to paid service sought to overcome a number of obligatory service's ustomary limitations such as duration and locale which greatly restricted English strategies. Arms requirements presented another yet thornier problem that defied a final resolution due to armaments' constant and increasingly rapid evolution. It was natural for the Crown to update arms requirements and the scale through which society was assessed for military service, but the increasing need for well-equipped troops during Edward II and Edward III's reigns necessitated frequent, methodic assessments that pressed society's contributions of money and manpower. Moreover, arms requirements were a way of requesting types of military service. The cost of arming may have been much touted, but performance of more drastic military service may have been at the root of society's complaints. The Crown's tactics were predisposed to lengthy, brutal battles, so that many of the objections to new arms requirements may actually have been objections to the more intense military service they heralded. As the Crown tried to extend arms requirements and hence type of military service performed, society repeatedly sought redress in parliament that limited its obligations and the Crown's means of enforcing them. Society also adopted legal practices and discourse to its own ends as the poignancy of the phrase what touches all should be approved by all makes apparent. Although obligatory service customarily included arms requirements, an implicit responsibility for providing arms lay with king's duty to provide defence and society played this angle to force concessions from the Crown.

PART II

Acquisitions

At the beginning of the thirteenth century only a fraction of the Crown's arms were purchased ready-made, because the Crown was mostly responsible for large works which required special attention and consumables which were routinely manufactured by its own staff. To complement its purchases, the Crown relied on an ancient system whereby tenants holding land by serjeanty paid some minor arm(s) as their rents until most of these were commuted to cash rents in the mid thirteenth century.(72) Arrows, or even parts of arrows were the most common payment.(73) The amount of arrows obtained through each payment was very minimal and rarely amounted to the 6 dozen arrow heads owed annually by one tenant.(74) When set alongside more substantial payments there can be little doubt that this arrangement provided a convenient method of obtaining basic arms, especially when payment was due not yearly but when the king was in the region. For example, a tenant in Nottingham was obligated to provide a dozen barbed arrows without feathers whenever the king passed by on campaign.(75) The countess of Lincoln owed 3 knives and 6 barbed arrows every time the king came to Lincoln castle.(76) For slightly more valuable properties, the tenants contributed more expensive arms or a combination of arrows, quivers, and bows.(77) Agreements with tenants in Lincolnshire often focussed on bows.(78) Both English and Gascon tenants owed one or more lances as rent.(79) Crossbows too were occasionally assigned.(80) Some of the tenants undoubtedly thought of the rent as more than symbolic gesture, especially when they were unable to pay as little as a lance.(81) That the Crown perceived these rents as a convenient method of arms management is confirmed by the wide range of armaments requested. Why else would the agents of Edward II and Edward III have continued to collect a spindle of raw thread to make false cords for crossbows every time the king passed Goodstreet of Chichester in war?(82) Besides, these obligations provided opportunities for obtaining any exceptionally fine armaments owned by its tenants. Upon death, Alexander de Montgomery was supposed to relinquish his best weapon to the Crown.(83)

Confiscation of arms was another of the Crown's ancient methods of acquiring arms. articipants in unauthorized tournaments and the makers of tournament armour during such moratoria were liable to have their arms confiscated, a policy which discouraged these contests and insured that crucial human and material resources would be directed towards war instead.(84) Exact details are rare for how the Crown handled armaments taken as spoils of war. The management of arms taken as spoils of war nly appears to have evoked occasional preparations. or the campaign of 1300-1301, two leather 'baskets' were optimistically readied for the equipment of captives.(85) When Edward III took Caen (1346), 9 coffers of 'arms' taken as spoils were shipped back to the Tower of London- surely a special lot.(86)

The exceptional circumstances surrounding the defeat of rebels at Boroughbridge in 1322 provides a glimpse into Edward II's efforts to recover common arms which the rebels had stolen from armouries in northern England. The month after the battle orders were sent to numerous sheriffs to seize the goods and lands of the rebels.(87) On 13 April the king ordered the sheriff of Lancashire to deliver to the king's clerks the rolls, estreats, memoranda and other evidences so that an account could be made of the lands and goods thus confiscated.(88) Commission was given to Peter de Eyvill and Robert de Cuyners to discover what had been taken by those in the regions of Howden, Ripon, Selby, Knaresborough, Sherburn and York. The return of a warrant dated 15 April described the results of their actions with regard to the recovery of arms.(89) When captured after the battle, most of the rebels wore a minimum of equipment on their persons, usually a haubergeon which would not have been easily discarded. Arms, coats, overcoats and diverse armaments were found scattered in nearby woods, but it was noted that thieves had already taken many of these abandoned arms.(90) From the testimonies that enumerated the arms of prisoners, enough arms to fully equip 22 men, i.e an aketon, haubergeon or coat of plates, basinet, gauntlets, and a variety of leg defences (jambers, poleyns, sabatons, shinbalds) were recovered from roughly 70 rebels, and these seem to have been distributed to local officials and military men. Testimonies usually stated where and with whom the arms had been deposited. The town of Bilton took the liberty of bestowing its captured armaments (a haubergeon, jambers and sabatons) on three local men. The arms held at Bramham, namely 2 pairs of jambers, 2 pairs of sabatons and cuisses, 2 basinets with aventails and a coat of armour, was taken illegally by a pair of men who claimed to be knights of the king's chamber. More reputable men such as John Mignot and William Darell obtained the king's licence keep for themselves a coat of plates, haubergeon, basinet, a pair of gauntlets, and a pair of shinbalds but they were still being held accountable for a third harness.(91)

Purchasing arms and materials was the most convenient method of acquisition. Few munition armours relative to the size of armies, however, were purchased or even passed through the Crown's administration. Occasionally authorization for payments were issued to recompense individuals within the court's scope who had purchased their own arms, but these 'gifts' constituted only a very small fraction of the army's equipment. By the fourteenth century the Crown could turn to the private sector to purchase more of its arms, but its limited provision of personal arms and the special attention required of its larger and more common works greatly curtailed the need to purchase arms in bulk. The larger scale of war in the fourteenth century provides more insight into the Crown's overall purchases and affords some opportunity to place the scale of that activity in perspective, indicating that even its purchase of ready-made goods amounted to a minority of its total acquisitions. For instance, in 1344 the Great Wardrobe's foreign receipts of £1231 were earmarked for arms, but that money could easily have been spent on manufacturing, transport, etc.(92) Many of the Crown's purchases sought raw and semi-raw materials for further manufacturing. In preparation for the War of St. Sardos in 1324, an account of Robert Pippushall contained £578 in purchases of arms and materials including about 1300 crossbows, 50,000 arrows and quarrels, 279 stones of steel, 7 tons of hemp for cords and skeins, 1100 great targets and 400 polearms.(93) In these accounts about half of the arms were purchased ready-made and the other half were fashioned from materials purchased for this task, requiring more payments to craftsmen

Though London and York's capabilities paled in comparison to the industrial giants on the continent, their somewhat impressive capabilities figured prominently in the Crown's orders for arms and armours. That both of these towns established early armourers gilds in the fourteenth century testifies to their lead in English arms industries. A few purchases reveal their capacities. In October 1307, the sheriff of London was requested to send a large amount of material to aid the king in his war in Scotland: 12,000 pieces of iron, 100 garbs of steel, 500 lbs. of threaded rope (*filo canabi*) for crossbow cords, 500 lbs. of hemp, 100 crossbows of 1 foot with 30,000 quarrels and 100 spare nuts, 40 crossbows of 2 foot with 12,000 quarrels and 50 spare nuts, 20 crossbows *a tour* with 2200 quarrels winged with copper and 20 spare nuts. Everything was to be sent to Berwick with all haste.(94) In another instance an order was issued to purchase 1000 lance heads in London.(95) The city of York was certainly able to provide large numbers of arrows. On 22 December 1334 the king inquired about 15,000 arrows bought by the sheriff of York; just the previous May the king had ordered the sheriffs of London and York each to purchase and hold 2000 arrows.(96) Armours were also widely available in York. In 1316 the sheriff of York was directed to purchase all the basinets with visors that he could find in his bailiwick to keep until further notice.(97) In 1336 York's sheriff was ordered to acquire 2 trebuchets, a springald with 100 bolts, 4 crossbows with 400 quarrels, 60 bows with 60 sheaves of arrows, 6 pairs of hand stones, 2000 pieces of Spanish steel, and armour sufficient for 40 men including coats of plates. All of the items were to be delivered to Berwick to be kept by the receiver of victuals until further notice.(98) Again in March 1337 Berwick and other nearby castles were to be supplied with 200 crossbows, 200 baldrics, 500 bows, 20,000 quarrels and 20,000 arrows.(99)

Consumables- bows, arrows and quarrels- were by far the items the Crown purchased and manufactured most frequently. Hundreds of thousands of arrows and quarrels were needed at any one time throughout the realm, but until Edward III's reign these were acquired rather piecemeal.(100) A single workshop at St. Briavel stands out as a notable exception, estimated to have produced a million or so quarrels during the thirteenth century.(101) Between 1241 and 1245, St. Briavel in fact issued some 266,000 quarrels manufactured in six styles based on templates, and the following decade between 25,000 and 50,000 quarrels were produced there annually.(102) The recruitment of large numbers of archers beginning in Edward I's reign amplified the need for such consumables, and the rise of siege warfare placed greater emphasis on crossbows and their ammunition. Keeping archers supplied with their tools of trade meant constantly replacing fragile bows and tensile strings or cords. The clouds and storms of arrows mentioned by chroniclers had to be replaced: one estimate asserts that half a million arrows were shot on the field of Crecy alone.(103) Edward I created relatively enormous stockpiles of these consumables in Wales, perhaps with the intention of making that area a central depot for the Crown's holdings throughout Britain. In 1277, Bristol was set to receive 200,000 quarrels, while 170,000 more were issued to Anglesey. Some 70,000 quarrels and 16,000 arrows were brought from Gascony. By 1286 Caernarvon held 120 crossbows and 104,800 quarrels.(104)

The expansion of industry and the Crown's administrative efficiency is revealed in orders for the national purveyance of bows and arrows issued in 1341, 1346, 1356 and 1359 when Edward III was abroad and therefore unable to accomplish such activities with household and wardrobe staff. To acquire the huge quantities of arrows needed for his corps of archers, orders were issued to sheriffs in some 35 English counties and a few towns for consignments of bows and arrows at set prices. The largest order, that of 1341 requested 8100 bows, 13,400 sheaves of arrows (321,600), 2000 arrowheads and 6000 strings. The price was stipulated by the Crown, and not unfairly, at 14d for sheaves of steeled arrows and 12d for non-steeled. The prices of bows were set at 12d for 'white' or unseasoned, and 18d for 'painted' or seasoned.(105) In 1346 fewer counties were requested to send 5550 sheaves (132,000) of arrows and 2280 bows to London for shipment to Edward III's army after it had ravaged northern France and decided to try to hold its conquests.(106)

The acquisition of sulphur and saltpetre also testify to the emergence of more prolific industries and the integration of trade in acquisitions. During Edward I's reign, small quantities of saltpetre were obtained by very modest means. One instance reveals that saltpetre was cultivated under the watchful eye of a single care-taker paid 2d per day.[(107)] At Stirling as at Brechin the year before, only very small amounts of sulphur (9s) and saltpetre were purchased to be thrown in earth pots.[(108)] By the mid fourteenth century the problems of obtaining the large quantities of quick sulphur and saltpetre needed for gunpowder made the acquisition of these substances a regular occurrence. Accounts from the preparations during 1345-1347reveal the extent to which gunpowder weapons had developed in the first decades of their appearance in Europe: variations like hand guns (*gunn' cum telariis*, *manualia ingenia vocata gunnys*) and larger calibres appear along with more conventional engines such as traction trebuchets (*tractandi ingenii*). Separate barrels of saltpetre, sulphur, charcoal, and of premixed gunpowder (*pullers*) quickly became a logistical regular. Edward III requested 912 lbs. of saltpetre and 886 lbs. of sulphur to take with him on the Crecy campaign, and requested 2,771 lbs. more of saltpetre and 776 lbs. of sulphur while besieging Calais.[(109)] These demands were met by foreign merchants with links to high production centres in Italy, Egypt and farther east. William de Staines, the merchant who became a major financier for Edward III, was particularly instrumental in the first waves of demand. Supplying spices to the Wardrobe on a small scale as early as 1330, Staines soon became a major channel for the import of saltpetre and sulphur.[(110)] By the late fourteenth century, large powder manufacturing centres were emerging in northern Europe which eased such bottlenecks in supply, and a period of intense development in gunpowder weapons ensued.[(111)]

At present whether or not imports provided a substantial source for acquiring other arms is difficult to discern. Arms were regularly imported to England although so little research has been conducted on this trade that the extent of these imports is unknown. In a study of Anglo-Castilian trade, W. Childs noted that some arms such as yew bow staves, crossbows, helmets, swords were imported to England alongside the major shipments of raw and semi-worked iron and steel.[(112)] Armaments frequently appear in the cargo lists of cases involving piracy and smuggling, testifying to a regular trade of some volume.[(113)] For example, in 1317 a ship from Flanders was hijacked on its way to England while carrying £28 worth of maces.[(114)] In the same year the ship of Aymer de Valence was taken near Flanders while loaded with helmets, haubergeons and other armour worth £60.[(115)] Many of the Crown's imports suffered the same fate, such as the ship captured by the coast of Normandy in 1342 which recorded a loss of 24 pairs of plates, 9 basinets with aventails, 12 pairs of plate gauntlets, 13 aketons, and an unspecified amount of bows, crossbows, lances and arms.[(116)] With the growth of international trade and incidents of piracy, the Crown frequently became involved in litigation to regain the merchandise or make compensation. Often merchandise was confiscated from a third party who shared the nationality of the pirates until recompense was formally made. The following example demonstrates the difficulties. In 1302 Flemish thieves stole horses, armour and other goods from a ship of 2 Genoese merchants in the king's service while it was at Sandwich. Letters were sent to the counts of Namur and Flanders asking for compensation of 522 marks. The constable of Dover, where the ship was headed, was ordered to investigate the crime.[(117)] In the meantime licence was granted to arrest and sell similar goods of the same value from Flemish merchants.[(118)] Goods were arrested on two separate occasions in an attempt to remedy the situation, but on neither occasion could it be proved that the confiscated merchandise was Flemish property.[(119)]

As France became the primary theatre of war in Edward III's reign, rather than import materials of war the Crown took advantage of its relations with the Low Countries to establish military depots in one of the most industrialised regions of Europe. Highly productive centres like Bruges, Tournai, Ghent and Antwerp were able to mass produce tremendous amounts of arms.[(120)] Antwerp acted as the hub of this activity, although the purchases in Bruges and Mechelen required wardrobes in those cities as well.[(121)] Accounts such as that of William Cusance in 1340 testify to the ongoing purchase of arms there.[(122)] Some regions were renowned for specialising in the manufacture of particular arms. In fourteenth-century Tournai, for [(123)]

example, armourers outnumbered textile workers by more than two to one. Likewise, the Crown's officers in Gascony had access, via Avignon, to arms from the other major manufacturing centres in northern Italy and southern Germany. The constables and castellans of Gascony were allowed sums to take advantage of these opportunities and make purchases as needed.(124) During 1312-3 an additional £1250 was expended by the constable of Bordeaux for arms and horses.(125) Expenses presented by Bertrand de Goth in September 1315 showed that the equivalent of £2000 worth of horses and arms had been acquired abroad for the war in Scotland.(126) With such a profusion of expertise and industry, it is no wonder that the continent provided England with some of its most influential craftsmen.

'In House' Activities: manufacturing and maintenance

In addition to the ongoing works on fortifications etc, craftsmen were employed *ad tascam* and on a more regular basis to produce a high proportion of the Crown's war materials considering that the great diversity of items needed would not have been available commercially. Though in many instances manufacturing proved no less costly than purchasing, such *ad tascam* work greatly supplemented England's modest arms industries and the limited number of craftsmen under the Crown's full patronage. We have already seen that the Crown's orders for goods treated as 'purchases' above may in some instances have been orders to sheriffs to arrange for their manufacture. Many of the Crown's other purchases in military preparations included semi-raw goods which required further work. Manufacturing *in situ* was a common feature of sieges. For the siege of Stirling (1304), perhaps the Crown's most material-intensive engagement during this period, craftsmen were impressed and tools were gathered as early as the previous autumn.(127) The English camp included some notable craftsmen. Thomas Houghton supervised carpenters and labourers in building a staggering array of engines; Walter of Hereford was in charge of manufacturing stone ammunition.(128) Arrows and quarrels were also manufactured constantly. Ropes, arrows, stone shot, hoardings, engines, and Greek fire were all made on site, and much material like sinew, glue, cords, iron, steel and timber were shipped for repairs and manufactures.(129) A shipment from Newcastle contained trivial but crucial supplies: 420 arrow shafts, 336 goosewings, 360 feathers, 200 arrowheads, 3 quarters of glue, and some string and wax, while wages were paid to at least two groups for turning these raw materials to arrows.(130) Five men from Newcastle were paid between 6d-2½d per day for 8 days to make ropes for engines.(131)

To facilitate these tasks in peace time and war, the Crown took more care to supply materials often giving officials free reign to take as much as needed when basic commodities such as timber, iron, coal, etc were readily available, presumably because these expenses were expected to fall within a modest range. The leeway afforded to officials and craftsmen in these tasks must have contributed to the financial chaos, but the range of unforeseeable tasks and expenses necessary for even relatively simple orders probably mandated as much.

The return of a warrant in 1315 on behalf of the constable of St. Briavel for expenses incurred in making quarrels is indicative of the strenuous and time-consuming efforts required for what appear to be simple orders issued on a frequent basis. In 1282 the constable of St. Briavel was ordered to provide Rhuddlan castle with 30,000 quarrels. Two kinds of axes were made for each of one hundred men who cut timber for the quarrels shafts for a total of 12 days. For fashioning the quarrel heads, attaching them to the shafts and carrying them to Rhuddlan another £21 was spent. Altogether the cost of the 30,000 quarrels came to £47 18s 8d, or about 31 quarrels per shilling.(132) In addition to raw materials and consumables such as bows and arrows which were needed in large quantities, the Crown was responsible for mobilising unusual armaments like siege engines which will be examined in detail in Chapter Three. The details of supplying Dover castle with timber and stone for engines in 1325 conveys the even greater efforts required for these types of activities.(133) A small crew of about 10 men was paid £20 11s 2d in wages (4d per day each) for felling and shaping timber in Tonbridge forest from 9 February to 28 May, resulting in 216 large pieces of timber. These pieces were then dragged 25 leagues to Newenden by teams of oxen, the largest 15 pieces requiring the aid of some sort of cart or axle with two large wheels for a total cost of £12 15s 1d.[(134)] Three scows and a ship were then hired to transport the timber and 32 stones for ammunition to Dover requiring several trips, and 36 carts carried the materials from the shore to the castle, all at a cost of £22 4s 11d. Despite having to pay nothing for the wood itself, £55 11s 2d was still needed for felling and delivering these materials to Dover.[(135)] Then from June to October smiths and carpenters were busy working on engines, and their wages along with purchases of iron amounted to another £58 16s 11⁄2d.[(136)]

In the same way that Edward I nurtured administration of the array in the statute of Winchester, with it he also established a regime of armoury maintenance to be led by specially appointed inspectors. Beforehand he seems to have relied on the discretion of individual castellans for maintaining armouries. The detailed instructions for Gascony made in 1289 are insightful. The constable, or chief financial officer of the territory, was expected to conduct a yearly inspection of the castles in his charge, ordering repairs and provisions of arms as necessary. Additionally, each castellan was ordered to employ an engineer and atillator.[(137)] For those castles which did not have adequate staff, including the Tower of London, men could be requisitioned.[(138)] Political instability in England and the growing threat of Scottish raids probably encouraged Edward II to take a more active stance in maintaining armouries which also conveyed a commitment to the Realm.[(139)] The system for making more regular inspections outlined in the statute of Winchester was followed more faithfully. For instance, in 1318 payment of £10 each was made to two 'masters' to inspect arsenals, and payments of 4d a day each for two serjeants were allowed their care of Windsor castle's armoury.[(140)] Similar arrangements were made at other castles.[(141)] Most royal castles and military residences commonly employed at least a smith and *artillator* to maintain the garrison's arms and make quarrels, arrows, and bows.[(142)] The *artillator* at Windsor castle, Gilbert Pypot, was employed there for over 20 years.[(143)] The family workshop at St. Briavel, Gloucestershire, operated as the Crown's most prolific source for quarrels during the thirteenth and early fourteenth centuries. For the conservation of equipment in these armouries, a *custos* or *ostiarius* employed a variety of treatments. Oil and fat were applied to prevent corrosion, and occasionally these accompanied shipments of iron or steel.[(144)] Orders were also made for fat to be packed in tuns and shipped to John Fleet at the Tower of London.[(145)] Abrasive agents such as lime, emery, parchment, sand, vinegar, sulphur or bran were used to remove rust.[(146)] When rolled, a barrel filled with sand made an excellent abrasive for mail garments, otherwise it would have been an terribly tedious task to clean their thousands of links.[(147)] The inventory in 1344 for the smithy of Dover castle listed such a barrel (*barrele pro armaturis rollendis*) kept in the great hall.[(148)]

Besides craftsmen employed routinely with garrisons etc., specialist armourers were often retained as members of the king's household to manage the king's immediate need for arms.[(149)] Some specialists were recruited from abroad. Edward II and Edward III employed masters from Bruges and Tournai who acted as armourers/merchants.[(150)] Not only were foreign craftsmen recruited to England, armourers were sent abroad on royal orders to learn better manufacturing techniques. David le Hope was sent to Paris by Edward II to learn the arts of sword making.[(151)] This practice in itself suggests an awareness of the value of specialist knowledge, although it may have been geared towards luxurious rather than ordinary equipment. As armours developed in form and function a growing list of specialists could be found in royal employ attending the courts' arms, including an *erubiginator* (polisher), *lanceator* (maker of lances), *galeator* (heaumer), *kisser* (maker of cuisses) and a *broudator* (embroiderer).[(152)] During the fourteenth century these offices, especially the most senior titles of the king's engineer, smith, armourer, and *artillator,* gained authority and formality becoming administrative as well as technical offices. By the 1340s their activities and those of the newly created 'keeper of the king's ships' who was responsible for provisioning royal navies, were sufficiently robust to warrant recognition as a distinct sub-department, the Privy Wardrobe. These 'craftsmen', tended their own accounts and even performed much broader military and administrative duties; combined with the costs of their duties in managing arms their transactions often ran to high amounts. These extensive duties were rewarded with the rank of man-at-arms and its pay of 1s per day.(153) John de Cologne's career in this regard stands out. During the expedition in France in 1338-1339, John de Cologne led a retinue of 9 men-at-arms, and the retinue of another royal armourer, William Standerwick, comprised 8 mounted archers.(154) In another instance John de Cologne could be found disbursing £9 to Edmund Crepin for restoration of 3 horses.(155) For a short time John de Cologne and Peter of Bruges, another armourer, acted as customs collectors.(156) This John de Cologne rented houses in London, and also maintained a house in Cornwall for which he received licence to crenellate which might be seen as pretentious.(157) With regard to his travels and the roles he played, there is little wonder why he was inclined to lofty aspirations.

It made sense that the Crown utilized the people most knowledgeable about armaments to make such purchases, and in addition to repairs, and manufacturing, the accounts of the king's armourers also included purchasing. In combination with the particularly lavish materials involved in their work, these royal craftsmen were often transacting in fairly large sums. During 1322-1323, payments totalling £132 11s 6d were ordered for Hugh de Bungeye, king's armourer, for purchasing and repairing arms at London during in the 10th and 14th years of Edward II's reign.(158) Hugh de Bungeye had been in Edward's service as early as 1302, his bills then amounting to £31 12s 1d of which nearly £6 was spent on 4 war swords and materials to make sheaths; 4 helmets purchased on separate occasions by him cost nearly £12 altogether.(159) In the details of 6 of Edward III's armourers, William Hauberger's account, which one would expect to focus on hauberks, contains most of the mending; that work cost £6 19s 1d for materials and 12s for his employees' wages with another £26 3s 10d due to him for previous work.(160) To put these figures in perspective, Thomas de Copham was the only armourer of these accounts to claim wages for the entire year, £18 5s. His expenses for materials equalled £28 19s 5d, and wages for his employees £33 12s 6d. Another £144 was subcontracted to other armourers in London.

These royal craftsmen/clerks themselves often employed other craftsmen and arranged work involving a range of crafts and industries. Armour linings, coverings and their buckles required tailors, hinges required locksmiths, and lavish decorations required painters, goldsmiths and jewellers. One order for a few particularly colourful pieces of armour kept over 40 painters and tailors employed for weeks.(161) At times royal armourers delivered hundreds of articles to various wardrobes. Thomas Copham provided 300 lances for the king's joust. John de Cologne delivered 100 gambesons in one instance, and 240 in another. Both men employed a dozen or more associates.(162) Tout was surprised to find *broudator* listed with an *armurer, erubiginator* and *artillator*; or when John de Cologne listed *brodaria* as a task.(163) However, aketons, gambesons and jupons were almost entirely composed of textiles. In 1334 John de Cologne was employed to make 100 such garments for soldiers.(164) Before burnished steel armours became fashionable in the second half of the fourteenth century, plate armours were often covered in leather or fine cloths to protect from corrosion, and most royal armourers' accounts list this kind of work.(165) The account from 1337-1341 of Gerard de Tournai, 'heaumer,' contained mostly entries for covering and recovering plate armours.(166) Nicolas de Wight, another of Edward III's armourers, was variously described as an armourer and a tailor.(167)

Provisions

The Crown's real responsibilities in providing arms varied depending on its circumstances. As a consequence of the Crown's reliance on a network of royal and private fortifications, it was also obliged to maintain the fabric and stores of an expanding group of fortifications involved in its wars unless other (168) arrangements were made. The Crown 'farmed out' some profitable holdings ranging from provinces such as Scotland or Gascony to individual castles, and in return these lieutenants often became responsible for part or all works and defensive supplies within their jurisdiction.(169) The number of men its tenants were required to provide were proscribed with surprising thoroughness. In some cases explicit agreements were made for the provision of common materials. For example, in order to munition Carlisle castle, its constable Robert Clifford agreed to place and maintain there two great engines, two springalds, two crossbows *a tour* with winches, and two crossbows for two feet; the bishop of Carlisle was to provide one crossbow *a tour*, two crossbows for two feet and sufficient quarrels for these every year.(170) Of course these arrangements did not always operate smoothly. The constable of Norham castle was disputing what was owed him in 1322.(171) In 1326/7 Dover was still waiting for 700 stones for engines, 500 lbs. of horsehair, 40 lbs. of sulphur, 100 lbs. of hemp for cords, 2 lbs. of tinder, 100 lbs. of cotton, 20 sheaves of steel, 4 oxhides for slings, and 5 lbs. of glue.(172) Nine months after the Crown agreed to provide all munitions for the garrison at Perth, a complaint was made that 1000 eastland boards, 10 sheaves of steel, 400 stones of iron, 200 stones of lead, 200 *chalders* of seacoal, and £20 for equipping a galley were still due.(173) Many other examples of this type could be cited, especially for the arguably more important supply of victuals to these strongholds. The Crowns' first alternative before making provisions was to loan the arms or funds to purchase them. Before William Montagu became steward of the household and a royal favourite, he received £14 in prest for arrows.(174) Other prests more often resembled the £5 received by John Garlot for 10,000 quarrels.(175) In situations when unusual equipment such as siege engines which could not be obtained as easily, loaning them presented the obvious solution. In 1325/6, it was recorded by privy seal that Edward gave 2 springalds to Hugh Despenser.(176) When the inventory was made of the London guildhall in 1339 it was noted that a springald, 80 quarrels with iron heads and latten wings, 2 cords and 1 false cord, several bows of ash and 24 targets with heraldic markings had been loaned to William Haunsard for his expedition to France.(177) Such prests were often acquitted or held in abeyance.(178) Others received ornate and practical armaments as gifts as well as restitutions.(179) The earl of Carrick turned to Edward I when he could not afford to purchase arms for his contingent.(180) In an account providing arms for the earl of Ros we find the same lavish materials worn by kings and princes but his armours appear as rather ordinary pieces of equipment: his basinet cost 8s, a gorget 5s 6d, a pair of jambers and poleyns cost 10s 8d. The hauberk valued at £5 was the only abnormally expensive piece of equipment.(181) Edward of Carnarvon's engineer, Robert of Glasham, received a basinet, aketon, and pair of plates.(182)

The Crown did not normally supply personal arms, relying instead on arms requirements. Only when faced with little or no option did it succumb to the wide scale provisioning expeditionary forces with personal arms. One such scenario arose when the Crown had witnessed a string of defeats and society already felt hard pressed. During his experiments with obligations, Edward II equipped several communal levies so that they could be raised more easily.(183) Thus 20 crossbowmen from the city of York were equipped by the Crown in 1315 to the sum of £33.(184) In 1315 Thomas Chedeworth, chamberlain of Caernarvon, was ordered to buy armour for 20 footmen and 100 crossbowmen at London.(185) The same year 120 crossbowmen of an order for 300 were raised and armed in London at the cost of £178 3s 4d.(186)

Though not provisions in the same sense, the Crown regularly restored private armaments lost in pursuit of its wars and these requests often accompanied requests for *restauratio equorum*.(187) Morris noticed that arms as seemingly trivial as lance heads were restored to persons after the 1283 campaign.(188) The arms of gentry or noblemen resulted in requests for much larger sums. In 1305 Edward Balliol claimed 50 marks compensation for armaments lost in the Crown's service.(189) Failure in many of his military endeavours brought many restorations. After Bannockburn Robert Clifford claimed for horses and armour worth 100 marks, and Edmond de Kendale requested 20 marks just for his armaments.(190) Along with general pardons, Edward II also offered to return criminals' confiscated arms in return for their military service in the summer of 1314.(191) In 1316 a staggering request for £500 was made, of which 500 marks was paid.(192) The Crown even made restoration when for personal armaments lost when castles in its care were taken. When Stirling was surrendered to the Scots in 1299, John Sampson, its constable, made a claim for among other things two aketons (40s), two gambesons (80s), a jupon (20s), a hauberk and haubergeon (15s), a pisan (10s), 'jambers' (8s), a 'chapel de fer' (20s), a 'chapel de nerfs' (40d), gauntlets (5s), a pair of plates (1 mark), a pair of 'treppes' (2 marks), three swords, a misericord and two knives with ivory handles (10s).(193)

Besides garrisons, the only widespread provision of armours appears to have been for naval crews. With the greater scale of operations under Edward I and the rise of siege intensive warfare, access to water-born transport became a crucial factor in logistics placing a greater emphasis on navies that was continued when France became the primary theatre of war. Of course, the cinque ports' obligation of 57 ships was often supplemented by the Crown's construction of more ships, constituting industrial activities of considerable expense and effort. Shipowners and sailors had already been pressed into service, no further obligations such as arms requirements could be pressed on them. As navies became integral to the Crown's warfare, ships were supplied with arms and sometimes an armed cohort for added protection. The equipment Edward I obtained for warships was much more advanced than his requirements for the army. A galley's equipment at Southampton in 1295 included 60 aketons, 20 haubergeons, 60 iron basinets, 30 pairs of iron gauntlets, 60 crossbows and 6000 quarrels, 120 lances, 100 polearms, and 3 iron grapells or grappling hooks.(194) The largest vessels such as the La Phillipe of Edward III's reign, required similar arms for a crew of 150 men.(195) Given the number of ships requisitioned for each campaign, and the repetitive nature of the task due to the Crown's reliance on merchant shipping, the costs of equipping ships for war must have been a constant burden. London seems to have been especially hard-pressed by the Crown's taxes toward this end. Each of the eight wards of London were assessed to provide £1587 8s 7d to outfit 26 ships. It is not clear whether this sum included any structural work or tackle in addition to arms, but at just over £61 per ship would only serve to arm the crews of smaller craft.(196) Moreover, several times orders were issued to equip ships with double the normal equipment. In 1325 Edward II gave instructions for 8 ships to have double equipment to protect merchants on the west coast from raiding.(197) In 1342 Edward III issued similar orders.(198) Even when ship were requisitioned, they were often fitted with military apparatus such as fore and aft castles. Barges were also fitted with safe-guards. When transporting supplies to Lincoln in 1300, 3s 9d was spent to furnish a barge with hoardings (*hurdiciis)* to protect it from the enemies' engines; in the same year at Newcastle, £12 was spent outfitting two barges with hoardings.(199) As these tasks became more common during the fourteenth century, a clerk of the king's ships was established with specific responsibility for the "arms, armour and artillery of the king's ships". The post seems to have been first held by Thomas de Snetesham, whose accounts for arming ships between 1336-1343 reveal some of the largest provisions made by the Crown at the time, including 1572 basinets, 682 pairs of plate gauntlets and 757 pairs of plates most of which occurred during 1338-1339.(200)

An important political development in regard to provisioning was the measure of autonomy gained by the regency council during Edward III's reign in authorizing military expenditure and the provision of arms. In 1338 written instructions known as the Walton ordinances were made to regulate the Crown's largest transactions and flow of payments while Edward III was abroad on campaign.(201) Several attacks threatened the towns of Southampton, Portsmouth and the Isles of Wight and Jersey and the regency council responded by provisioning those towns. At least some of these expenses were quite ordinary as can be seen in the measures taken to bolster the defences at Southampton.(202) Robert atte Barre spent more than £37 on arms for its defences, and John Fleet spent another £40 for more arms in May 1339.(203) After the latter's provisions, the city's arsenal included only 3 springalds with 177 quarrels, 33 crossbows with nearly 2000 quarrels, 31 bows with 49 garbs of arrows, 62 lances, 45 pavises and 19 targets.(204) The control of these arms was subjected to unusually close scrutiny, passing from Nicolas atte Magdalene, receiver of money and victuals of Southampton, to Thomas de Beauchamp, and finally to Phillip de Thame, (205) each time by indenture. Desperate for more funds and faltering in his campaigns on the continent, in 1339 Edward III began interrogating his home administration about their activities and unauthorized expenditure. The regency council responded with resolution, stating that pressing circumstances merited such expenses.(206) Following this incident the king's council became a mainstay of executive government, acquiring the privy seal, chambers at Westminister and the authority to draw on Exchequer funds over the next decades.(207) Whereas the council's efforts did not extend to the wholesale provisioning of personal armaments, its activities greatly strengthened the Crown's attention to military efforts.

Transport

The new warfare saw a tremendous increase in the amount of military duty directed towards guarding works and transporting supplies in hostile territories.(208) These circumstances explain the military status of several Wardrobe clerks and craftsmen responsible for the supervising the transport of materials. The Wardrobe's keeper and controller possessed military retinues and might participate in conflicts. These retinues further served to protect the Wardrobe's accounts which themselves occupied three to five carts on one of Edward I's campaigns.(209) In 1297, the retinues of the Wardrobe's keeper and controller, John Droxford and Benstead respectively, consisted of 5 knights and 41 squires altogether; in 1303-4, their similarly sized company were complemented by 24 crossbowmen and a vintenar.(210)

The heavier scale of war required more transport of course. When troops were raised, equipped, and sent to war, carriage might be provided for their armour. When the 120 crossbowmen were raised and equipped in London, their equipment was packed in cases and tuns and carried to Berwick in 3 carts each drawn by 4 horses.(211) Similarly, indiscriminate charges for carriage of harness (*hernesia, garnisture*) was a constant expense on campaigns.(212) At times transportation merged imperceptibly into duties of storage. Just manoeuvring heavy armaments a short distance was costly: nearly £3 was spent to move springalds from London's walls to the chamber of the guildhall in 1339.(213) The growing complexity of devices place still more demands. In 1301 a 'peil' had to be removed from a springald in Edinburgh castle and sent with a shipment of engines already on its way north because no other 'peil' could be found; a great engine also in this shipment was itself in dubious condition.(214) The tremendous logistics involved in Edward I's efforts to field numerous siege engines for the siege of Stirling in 1304 seems to have overshadowed planning for the gathering of more common materials. Orders for shipments of engines had been issued since January, and in March Edward brashly announced his intention to attack Stirling.(215) The siege began in April and Edward was indeed able to deploy one of the period's largest siege offensives, yet it was not until 20 May that Edward realized that more bows, crossbows, arrows and quarrels would be needed as the siege endured.(216) Perhaps Edward had been too confident that his engines would fell Stirling as quickly as Edinburgh in 1296. Even with this attention on engines their procurement did not go smoothly. The rod (*verge*) from the great engine in the Irish shipment was left behind because there was trouble in finding a cart large enough to transport it.(217) Even worse Robert de Leyburn, constable of Inverkip, was lackadaisical in sending the rest of his shipment and carrying out his orders about purveying other engines, stones, and iron.(218)

Hewitt has shown the usual means by which the Crown arranged for its supplies to be transported.(219) For carriage over a distance, contracts were often arranged by those who had procured the armaments, such as when the king's fletcher arranged for the transportation of crossbows to the Tower of London for 26s 8d.(220) Goods could be shipped, carted or carried by pack animals. The fickle sea naturally took its toll when conveying goods. A ship carrying a great engine for the Crown was wrecked on the coast near Dunbar, losing both the engine and the ship worth £50.(221) A variety of containers and packaging were employed. Baskets, barrels, buckets, casks and coffers had to be purchased or made, and some arms were packed in hay or felt; bows, crossbows and ammunition were also corded together.[222] In several orders baskets held from 300 to 500 quarrels.[223] Casks, coffers and 'buckets' contained as many as 1000 quarrels or arrows, or in one instance, 60 bows and strings.[224] On a hijacked ship of Aymer de Valence a barrel contained £60 worth of armour.[225] The fine armaments of nobles were usually carried in chests and coffers, sometimes especially made for them. Edward of Caernarvon's baggage train in 1302-1303 included some 20 carts to carry among other things, a pair of large trunks for armour (worth 8s), a small coffer of *cuir boulli* and iron for carrying a basinet (3s 4d), and a separate case for the crests (4s 2d).[226] That carts could carry considerable loads is revealed by a shipment to the Tower of London of 6 springalds, 500 quarrels, 24 bows and 24 levers hauled in 8 carts.[227] A load of 80 crossbows, 120 bows, and 200 arrow heads was carried in 4 coffers and a barrel loaded on 3 carts.[228] On another occasion 36 crossbows, 286 bows, 1200 quarrels, and 1200 arrows were carried on 1 cart drawn by 2 horses.[229] Most impressive was the 576 garbs of arrows (13,824 arrows) carried on 2 carts.[230] Carts worked well for heavier loads or general transport, but as the English army sought to disencumber itself in the 1320s, sumpter horses replaced carts.[231] Sumpter horses were able to carry surprising loads, as 3 of them carried 45 crossbows, 12 *costa,* 31 lances and 9 stones (12 lbs. each) of canvas.[232] In 1300 John Droxford sent 41 crossbows, 800 quarrels, cords, baldrics, 4 lbs. of green grease for feathers, 200 lbs. of sinew, and 6 lbs. of glue to Dumfries and Lochmaben- all on 3 hackneys.[233] During the preparations of 1325, 4 horses carried 100 gisarmes, and 11,000 arrow shafts.[234]

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Although the Crown's administrative departments were burdened by all of the demands of war, armaments in particular required special consideration ranging from extensive legislation for arms requirements and the arms trade to the physical management of a diverse range of materials. The Crown's responsibilities increased exponentially: in provisioning an expanding group of castles under its patronage, in providing more ad hoc materials for the defence of towns and communities, in equipping navies and even communal levies in exceptional cases. The range of goods required for its military efforts also expanded, complicating the Crown's task of coordinating its logistics. Whereas in the early thirteenth century intricate arrangements for acquiring arms were made such as payments of arms by tenants with serjeanties or the issuance of liberties as repayments to isolated workshops and craftsmen, by the mid-fourteenth century several more efficient means had been established. Perhaps it is unfair to compare the purchases of Edward I's reign and afterwards with those made during the less frequent wars of Henry III, but the continued evolution of the Crown's methods of acquisition into Edward III's reign reinforces the perception that England's military organization was undergoing a transition to take advantage of a more replete economy and improved industrial base. The Crown's agents increasingly 'purchased' goods directly as more arms could be found in English towns and markets, especially at York and London. The Crown could also rely on its broader administration to handle more complicated logistics autonomously, such as the national orders for arrows or even the general provision of defensive supplies when Edward III was abroad. Furthermore, the division of the realm into territories and distinct administrative provinces governed by lieutenants meant that general policies, such as the regular employment of craftsmen, engineers and inspectors could be implemented systematically. The evolution of administrative departments and the increasing formality of staff assignments also testifies to the emergence of a less personal method of government and a more systematic administration, as does the creation of executive departments such as the king's council.

Burdened by such duties, the Crown continued to elude the potentially enormous responsibility of providing personal armaments and expected the great majority of combatants to provide their own arms throughout the transition from obligatory to volunteer service. Even during the communal arrays, the levying of arms remained a local activity and involved very little correspondence with the central organs of state. From the perspective of creating a national army, the Crown was grievously hampered in not taking responsibility for personal arms, as witnessed in its failure to control the retinues of great magnates in the late fourteenth century and many times afterwards. The status of England's arms industries almost certainly perpetuated obligatory service, and later in conjunction with the Crown's heavy requirements, encouraged retinue-based recruitment. Although pressure grew for the Crown to take on more responsibility in providing arms, England's industrial capabilities meant that complex armaments had to be obtained in comparatively small consignments throughout the localities. ost was clearly a factor in the Crown's refusal to provide personal armaments, but administrative and political burdens may have been equally pressing factors in the Crown's decision to enforce personal arms requirements rather than rely on communal provision, as witnessed in the difficulties of Henry III's distraints or Edward II's arrays. Levying a tax specifically for armaments allowed the Crown to maximise society's contribution, but it compounded the Crown's duties of collecting separate taxes. Moreover, acquiring and distributing armaments in a short time posed additional problems, which would have been compounded by the task of collecting and maintaining the arms afterwards. The Crown strove to keep the armouries of garrisons up to date, but most appear to have sat in poor conditions becoming worthless in a very short time. Creating standing armouries throughout the communities was also unwise, as they could be turned against the Crown in times of civil crisis as happened during 1322. All of these conditions help explain the Crown's somewhat obsessive attention to regulating trade in arms, and its efforts to bolster the availability of arms in England through other sanctions. We can now turn to a more specific examination of the Crown's responsibilities in siege warfare, which might have required the Crown's most strenuous efforts in managing arms.

NOTES

1. Trevisa, *The Governance of Kings and Princes*, book III, pt I, chapter XIV, ll. 19-23.

2. The concept of the divine war-king began to evolve in legal and political discourse to produce in the fourteenth century the articulation of a polity-conscious monarch who pursues the common good, E. Kantorowicz, *The King's Two Bodies. A Study in Medieval Political Theology* (Princeton, 1957), pp. 42-272.

3. Many leading figures in science also held high administrative positions, but lesser officials were also familiar with scientific methods, W. Rüegg, 'Expectations of church, Crown, and municipality' in H. de Ridder-Symoens, *A History of the University in Europe*, vol. 1: *Universities in the Middle Ages* (Cambridge,1992), pp. 14-20; Kaye, *Economy in Nature*, p. 6 f; J. Vale, *Edward III and Chivalry: Chivalric Society and its Context, 1270-1350* (Woodbridge, 1982), pp. 49-50.

4. W.R. Jones, 'Purveyance for War and the Community of the Realm in Late Medieval England' *Albion* 7 (1975), pp. 300-16.

5. Ormrod, *Political Life*, pp. 18-19; M.C. Buck, '*The Reform of the Exchequer, 1316-1326*', EHR 98 (1983), pp. 241-3.

6. Tout, *Chapters in Medieval Administrative History*, is indispensable for study of the Wardrobe departments.

7. T.F. Tout, *The Place of Edward II in English History* (Manchester, 2nd ed., 1936), p. 176.

8. *The Wardrobe Book of William de Norwell, 12 July 1338 to 27 May 1340*, M. Lyon, et al, eds. (Brussels, 1983), p. xxxii.

9. Tout, *Chapters in Administrative History*, iv, pp. 359-64, list six factors in the Great Wardrobe's separation from the Royal Wardrobe, but in essence these six factors are all related to the increased business of managing goods and the necessary arrangements in accounting and storage.

10. By the 1320s refusal to surrender control of a residence was tantamount to treason, cf. J. Bradbury, *The Medieval Siege* (Woodbridge, 1992), p. 130; J. Davies, *The Baronial Opposition to Edward II, its Character and Policy* (London, 1967), p. 106; Tout, *Place of Edward II in English History,* p. 147. For a comparison of the French and English Crowns' abilities to co-ordinate such a system, R. Kaeuper, *War, Justice, and Public Order. England and France in the Later Middle Ages* (Oxford, 1988), pp. 211-25.

11. Tout, *Chapters in Medieval Administrative History*, iv, pp. 351-64; R. Storey, 'The Tower of London and Garderobae Armorum', *Royal Armouries Yearbook* 3 (1998), pp. 176-83.

12. *Liber Quotidianus Contrarotulatoris Garderobae Anno Regni Regis Edwardi Primi Vicesimo Octavo*, J. Topham, ed. (London, 1787), p. 73 [hereafter LQG].

13. E.g., *Rot. Parl.*, i, pp. 239, 240, 270, 443, 446, 452, 458.

14. *Cal. of Plea and Memoranda Rolls of the City of London, 1323-1364*, A.H. Thomas, ed. (London, 1926), i, p. 40.

15. C. Ffoulkes, *The Armourer and His Craft from the XIth to the XVIth Century* (London, 1912), p. 57.

16. Ffoulkes, *Armourer and his Craft,* p. 39.

17. D. Keene, 'Metalworking in Medieval London: An Historiographical Survey', *Journal of Historical Metallurgy* 30 (1996), p. 96; G.H. Lloyd, *The Cutlery Trades. An Historical Essay in the Economics of Small Scale Production* (London, 1968), p. 81.

18. D. Douglas, ed., *English Historical Documents,* ii (London, 1981), pp. 449-51.

19. E.g., CDS*,* v, no. 544.

20. In 1304, CDS*,* ii, no. 1489; in 1307, ibid, no. 1882; in 1311, CDS*,* iii, no. 190; in 1314, CDS*,* v, no. 599; in 1317, CDS*,* iii, no. 568; in 1321, CCR 1318-1323*,* pp. 369-70; in 1326, CCR 1323-1327, p. 545; in 1331 CCR 1330-1333*,* p. 289; in 1340s, CCR 1341-1343*,* pp. 351, 472, 496; CDS*,* iii, no. 1396.

21. CCR 1313-1318*,* p. 259.

22. CDS, iii, no. 602.

23. See the correspondence in CDS*,* iii, nos. 639, 673; and CDS, v, nos. 411, 576.

24. Ibid, no. 411.

25. CDS, v, no. 576.

26. 26 Contamine, *War in the Middle Ages*, p. 67. Verbruggen highlighted the quality of Italian communal militias of that time, noting the well-developed civic administrations which in many cases were instrumental in raising high quality infantries and integrating them with traditional cavalry forces. Verbruggen also drew a correlation between these cities= economic prosperity and financial ability to equip themselves well, J.F. Verbruggen, *The Art of Warfare in Western Europe During the Middle Ages. From the Eighth Century to 1340*, S. Willard and Mrs. R.W. Southern, trans. (Woodbridge, 2nd edn., 1997), pp. 144-7.

27. [27] Coat of plates 1299, *CDS,* ii, no. 1949; iron gauntlets, PRO London, E 101/5/12, Account of John Flemming for expenses of the galley of Southampton, 23 Edward I.

28. For constitutional aspects, W. Stubbs, *The Constitutional History of England*, ii (Oxford, 1906), p. 568; cf. M. Powicke, *Military Obligation in Medieval England. A Study of Liberty and Duty* (Oxford, 1962), pp. 137 f.

29. J. Morris, *The Welsh Wars of Edward I* (Oxford, 1901), pp. 49-54; P. Contamine, *War in the Middle Ages*, trans. M. Jones (Oxford, 1984), pp. 78-82 for 'drastic reduction' and a European-wide description.

30. For instance, F. Lachaud, 'Armour and Military Dress in Thirteenth-and-Early-Fourteenth-Century England', *Armies, Chivalry and Warfare in Medieval Britain and France*, M. Strickland, ed. (Stamford, 1998), pp. 344-345; C. Dyer, *Standards of Living in Later Middle Ages, c. 1200-1520* (Cambridge, 1989), pp. 280-1. Cf. K. Faulkner, 'The Transformation of Knighthood in Early Thirteenth Century England', EHR 111 (1996), pp. 1-23.

31. M. Prestwich, '*Miles in Armis Strenuus*: The Knight at War', *Transactions of the Royal Historical Society,* sixth series, 5 (1995), pp. 207-208.

32. M. Strickland, *War and Chivalry. The Conduct and Perception of War in England and Normandy, 1066-1217* (Cambridge, 1996), p. 170.

33. A. Ayton has made tremendous headway on the cost of mounts in fourteenth-century England, *Knights and Warhorses*.

34. A. Ayton, *Knights and Warhorses,* p. 220, £10-£15 for a 'full outfit of armour in latter 14th century'; Contamine, *War in the Middle Ages*, p. 95, n. 72, £1 for common equipment, £2 10s knightly; Dyer, *Standards of Living*, p. 281, £10 for equipment in early fourteenth century; L. James, 'The Cost and Distribution of Armour in the 14th Century', *Transactions of the Monumental Brass Society* 10 (1967), p. 229, £10-£15 knightly; J.R. Maddicott, 'The English Peasantry and the Demands of the Crown, 1294-1341', *Past & Present Supplement* 1 (1975), p. 41, cost of equipment about 5s temp. Edward I, £2 temp. Edward III; Powicke, *Military Obligation*, p. 145, n. 2, cost of equipment about £1 temp. Edward II; M. Prestwich, *The Three Edwards. War and State in England 1272-1377* (London, 1980), p. 69, 5s temp. Edward I, over £1 temp. Edward II; Rogers, 'The Military Revolution of the Hundred Years War', p. 246, £32 for knight's equipment including horses; Vale, *War and Chivalry*, p. 126, and M. Keen, *Chivalry* (London, 1984), p. 225, several months wages for men-at-arms.

35. See Chapter Six.

36. Barding £2, personal arms=£2, mount=£5, and knight's requirement of two mounts.

37. Powicke, *Military Obligation*, pp. 1-25, esp. p. 18.

38. Chapter Six.

39. Tenants were specifically responsible for providing the arms of their vassals, Douglas, *English Historical Documents*, ii, pp. 449-51.

40. Powicke, *Military Obligation*, p. 49, citing Robert de Torigny, *Chronica*, in *Chroniclers of the Reign of Stephen* (RS), 4, p. 202.

41. Powicke, *Military Obligation*, pp. 88-9.

42. Powicke, *Military Obligation*, pp. 63-82.

43. Powicke, *Military Obligation*, p. 75.

44. Dyer, *Standards of Living in the Middle Ages*, pp. 30, 118-27discusses the estimates.

45. E.g. Morris, *Welsh Wars of Edward I*, pp. 50-2

46. For conditions and similar examples under Edward III, Ayton, *Knights and Warhorses*, p. 101.

47. Ayton, *Knights and Warhorses*, pp. 57-8.

48. PRO, London, E 101/7/2, Account of Walter de Agmondesham of receipts and expenses in the North 26 Edward I.

49. Parl. Writs., i, pp. 197-207, 233.

50. Parl. Writs, i, p. 204.

51. PRO, London, E 101\5\29, Account of military resources for the defence of the Isle of Wight and the coast of Hampshire 24 Edward I.

52. In the assize of 1230, a full coat of mail was required for service of a whole fee, while a haubergellum, or half-hauberk, sufficed for a half fee. In the same writ the service of two men-at-arms was equated with one knight's fee, Powicke, *Military Obligation*, p. 85.

53. *CIPM*, viii, no. 391.

54. [54] In the case of knighthood to ,100, *Statutes of the Realm*, vol. 1 (London, 1810), pp.97-8; Powicke, *Military Obligation*, pp. 85-90. The popularity of these terms may reveal something about the balance of power in some parliaments.

55. M. Prestwich, *War, Politics and Finance Under Edward I* (London, 1972), pp. 99-100.

56. [56] Prestwich, *Edward I*, p. 513.

57. Powicke, *Military Obligation*, pp. 164; cf. the Norfolk muster of 1336, where two vintenars carried bows, arrows and swords while the rest had only knives, axes and the like, ibid, p. 193.

58. M. Powicke, 'Edward II and Military Obligation' *Speculum* 31 (1956), pp. 100-3.

59. Powicke, 'Edward II', pp. 104-105; CPR, 1324-1327, p. 10.

60. *CPR, 1324-1327*, p. 10.

61. E.g., Stephen and Henry de Cobham, Ralph Sauvage and Henry de Goshale raised a large amount of money to purchase armour for the county levy but apparently could not account for its expenditure, CPR 1324-1327, p. 29.

62. Powicke, *Military Obligation in Medieval England*, pp. 148-9.

63. Harriss believes that the procurement of military service was especially influential in provoking

representative government; the phrase 'what touches all should be approved by all' became a common occurrence in the middle decades of Edward II's reign when levies for military service rather than taxes were being sought; qv. 'Nothing testified more clearly to the status of parliament as the voice of the realm than the fact that it became involved in authorizing and regulating these levies', *King, Parliament and Public Finance*, p. 91, 93.

64. *Statutes of the Realm*, i, pp. 255-7.

65. Powicke, *Military Obligation*, pp. 202-3.

66. *Cal of Plea and Memoranda Rolls*, i, p. 105.

67. Powicke, *Military Obligation*, pp. 169, 184.

68. Ayton, *Knights and Warhorses*, pp. 11-12 ff., summarizes the extensive literature on indentures.

69. With contract service, the king reserved the right to campaign personally (which also lessened any political repercussion from military failure) and gained the capability to field armies in more than one theatre. Indentures were especially useful for obtaining service for overseas campaigns, M. Prestwich, 'English Armies in the Early Stages o the Hundred Years War: A Scheme in 1341', *BIHR* 56 (1983), pp. 102-13.

70. *CDS*, iii, no. 519.

71. *CDS*, iv, no. 515c.

72. H. Round, *The King's Serjeants and Officers of State with their Coronation Services,* (London, 2nd imprint, 1971); *Liber foedorum: the Book of Fees, commonly called Testa de Nevill*, 3 vols. (London, 1920-31).

73. E.g., CIPM*, i*v, nos. 404, 418; CIPM, v, no. 615.

74. CIPM, ii, no. 680.

75. CIPM, ii, no. 121.

76. CIPM, ix, no. 107.

77. CIPM, v, no. 607; CIPM, vi, no. 612.

78. CIPM, ii, no. 306; CIPM, v, no. 60; CIPM, vii, no. 531.

79. CIPM, iv, no. 359; *Rôles Gascons 1307-1317,* iv., Y. Renouard, ed. (Paris, 1962), nos. 627-31, 691.

80. CIPM*,* iv, no. 85; CIPM, vi, no. 291; CIPM, iii, no. 423.

81. CIPM, iii, no. 218.

82. CIPM, vi, no. 558; CIPM, vii, no. 353.

83. CIPM, iii, no. 293.

84. E.g. CCR 1318-1323,p. 224.

85. LQG, p. liv.

86. Tout, *Chapters,* iv, p. 478.

87. CCR 1318-1323, p. 538.

88. Ibid, p. 531.

89. *Calendar of Inquisitions Miscellaneous, 1307-1349,* ii (London, 1916), no. 527.

90. Ibid, p. 130.

91. Ibid, p. 133.

92. Tout, *Chapters in Medieval Administrative History, i*v, p. 427.

93. London, PRO E 101/17/6, Account of Robert de Pippishull for fortifications and garrisons in Aquitaine and England 18-20 Edward II.

94. *Feodera,* i, part 4, p. 94.

95. *Cal. of Memoranda Rolls* (*Exchequer*)*, Michaelmas 1326 -Michaelmas 1327* (London, 1968), no. 1578.

96. CCR 1333-1337*,* pp. 224-5, 286.

97. CCR 1313-1318*,* p. 295.

98. CCR 1333-1337, p. 622.

99. CDS, v, no. 767.

100. Storey, 'The Tower of London', pp. 176-7; H.J. Hewitt, *The Organization of War under Edward III, 1338-62* (Manchester, 1966), pp. 63-73; Prestwich, *Armies and Warfare*, pp. 291-2, 299.

101. V. Foley, et al., 'The Crossbow', *Scientific American* 252 (January, 1985), pp. 104-10.

102. CLR 1240-1245, pp. 67, 92, 112, 114, 251, 303, 316, 322, 324; CLR 1251-1260, pp. 373, 415.

103. R. Hardy, *The Longbow,* revised edition (London, 1982)*,* p. 83.

104. Morris, *Welsh Wars*, pp. 91-2.

105. *Foedera*, ii, part 4, p. 98.

106. Ibid, p. 203.

107. Cal. Illus. Scots., ii, pp. 481-2.

108. Ibid, p. 480.

109. T.F. Tout, 'Firearms in England in the Fourteenth Century', EHR 26 (1911), pp. 666-702; J. Hunter, 'Proofs of the Early Use of Gunpowder in the English Army', *Archaeologia* 32 (1847), pp. 381-2.

110. P. Nightingale, *A Medieval Mercantile Community. The Grocers' Company & the Politics & Trade of London, 1000-1485* (London, 1995), pp. 168-70.

111. Hall, *Weapons and Warfare in Renaissance Europe*, pp. 41-5, 74-9.

112. W.R. Childs, 'England's Iron Trade in the Fifteenth Century', EcHR 34, 2nd series (1981), pp. 25-47.

113. For a few examples, CCR 1302-1307, p. 34; CCR 1313-1318, pp. 393, 563, 593-4; CCR 1318-1323, pp. 262-3; *Cal. Plea and Memo. Rolls, 1323-1364,* p. 27; CCR 1333-1337, pp. 125-6; CCR, 1341-1343, pp. 435, 546.

114. CCR 1313-1318, p. 393.

115. CCR 1313-1318, p. 563.

116. CCR 1341-1343, p. 435.

117. CCR 1302-1307, p. 34.

118. CPR 1301-1307, p. 245.

119. CCR 1302-1307, pp. 55, 56-7.

120. See Gaier, *L'industrie et le Commerce des Armes*.

121. Tout, *Chapters,* iv, pp. 103, 106, 396-7.

122. London, PRO E 101/389/8, Part of a counter-roll of daily foreign expenses 14 & 15 Edward III.

123. M. Pfaffenbichler, *Medieval Craftsmen: Armourers* (London, 1992), p. 22.

124. *Rôles Gascons,* iv, nos. 23, 26, 314, 335, 620, 653.

125. Ibid, no. 970.

126. Ibid, no. 1443.

127. CDS, ii, no. 1412, 1414, 1524, 1536 (tools), 1554.

128. H.M. Colvin, *The History of the King's Works* ii, p. 205-6 (Walter of Hereford), 216-17 (Thomas Houghton).

129. CDS, ii, nos. 1556, 1559, 1589, 1599, Cal. Illus. Scot., pp. 481-2; Prestwich, *Armies and Warfare*, p. 300.

130. Wages were paid to 4 men and 2 associates for making arrows from June 2-9, and for Thomas the Archer and 5 associates for the same from 8 June through 21 July, CDS, ii, no. 1589; iv, no. 468.

131. CDS, ii, no. 1589.

132. CCR 1313-1318, pp. 146-7.

133. Cal. Memo. 1326-1327, nos. 604, 1642, 1648, 2121, 2202.

134. The account mentions for this task the hire of 1694 oxen at 11⁄2d each per day, but one wonders whether some form of multiplication was involved in this figure. Perhaps this number represented the sum total of oxen payments rather than actual oxen involved in the task, ie several trips were made using smaller team(s).

135. Cal. Memo. 1326-1327, no. 2202.

136. Cal. Memo, 1326-1327, no. 2202xiii.

137. M. Labarge, *Gascony, England's First Colony, 1204-1453* (London, 1980), pp. 58-60.

138. CCR 1313-1318, p. 265; CDS, iii, p. 72; Tower, CCR 1339-1341, p. 626.

139. E.g. CCR 1313-1318, pp. 6, 10, 113, 115, 153, 186, 187, 237, 245, 264, 360, 405.

140. CCR 1318-1323, p. 39.

141. Dover, *Cal. Memo. 1326-1327,* p. 70; Tower of London, CCR 1318-1323, p. 258.

142. E.g. CCR 1330-1333, p. 78; CCR 1341-1343, p. 42; CDS, ii, nos. 1170-4.

143. CCR 1330-1333, p. 110 and CCR 1346-1349, p. 574.

144. E.g. Cal. of Plea and Memo. 1323-64, p. 149.

145. CCR 1339-1341, p. 500.

146. Gaier, *L'industrie,* p. 299; and Tout, *Chapters in Medieval Administrative History,* iv, p. 475.

147. Estimates for the number of rings in a mail hauberk range between 30,000, D. Edge and M. Paddock, *Arms and Armour of the Medieval Knight* (London, 1988), p. 176, and 200,000 J. Strayer, *Dictionary of the Middle Ages*, vol. 1, p. 533.

148. Ffoulkes, *The Armourer and His Craft,* pp. 25, 79.

149. Tout, *Chapters,* iv, pp. 389 n. 9, 400.

150. Pfaffenbichler, *Armourers,* pp. 20, 22; Gaier, *L'industrie,* p. 121.

151. Ffoulkes, *The Armourer and His Craft*, p. 57.

152. Tout, *Chapters in Medieval Administrative History,* iv, pp. 390-1.

153. *Cal. Memo. 1326-1327,* nos. 2270-1; cf. entries for W. Standerwick, John de Cologne, Nicolas Wight and W. le Hauberger in *The Wardrobe Book*.

154. *The Wardrobe Book,* pp. 350, 361.

155. *The Wardrobe Book*, p. 322.

156. CCR 1339-1341, p. 524; CCR 1318-1323, p. 643; *The Wardrobe Book*, pp. 24, 30-2 (John de Cologne).

157. Tout, *Chapters in Medieval Administrative History,* iv, p. 389; C. Coulson, 'Structural Symbolism in Medieval Castle Architecture', *JBAA* 132 (1979), pp. 78-81.

158. CCR 1318-1323, pp. 439, 643.

159. CDS*,* ii, no. 1413, p. 367.

160. London, PRO E 101/383/19, Expenses of Thomas de Useflete, clerk of the great wardrobe 2 Edward III.

161. G. Williams, *Medieval London, From Commune to Capital* (London, 1970), p. 108.

162. London, PRO E 101/383/19, Expenses of Thomas de Useflete, clerk of the great wardrobe 2 Edward III.

163. Tout,*Chapters in Medieval Administrative History,* iv, pp. 390-1.

164. H.T. Riley, ed. *Memorials of London and London Life in the XIIIth, XIVth and XVth Centuries* (London, 1868), p. 190.

165. Cf. London, PRO E 101/389/4, Expenses of Thomas de Crosse, clerk of the great wardrobe 14 Edward III; and E 101/20/31, Account of William de Standerwyk for arms and equipments 11 & 12 Edward III.

166. H. Dillon, 'An Armourer's Bill, temp. Edward III', *The Antiquary* 22 (1890), p. 150.

167. *Cal. Memo. 1326-1327,* nos. 2270-1; London, PRO E 101/383/19, Expenses of Thomas de Useflete, clerk of the great wardrobe 2 Edward III.

168. Tout, *Chapters in Medieval Administrative History,* ii, p. 137.

169. On farmed constabularies, N.G. Pounds, *The Medieval Castle in England and Wales* (London, 1990), p. 89.

170. *Cal. Illus. Scot.,* ii, pp. 333-5.

171. CDS*,* iii, no. 770.

172. Cal. Memo., 1326-1327, no. 1588.

173. CDS*,* iii, nos. 1283, 1307.

174. CDS*,* v, no. 566(d).

175. *The Wardrobe Book,* p. 219.

176. PRO, London, E 101/17/6, Account of Robert de Pippishull for fortifications and garrisons in Aquitaine and England 18-20 Edward II.

177. Riley, *Memorials,* p. 205.

178. CCR 1302-1307, p. 303.

179. E.g. *LQG,* pp. 164 181; CDS, iii, no. 687; CDS, v, nos. 472(q), 521(d); *The Wardrobe Book,* p. 263.

180. CDS, ii, no. 1495.

181. CDS, ii, no. 1413; cf. N.H. Nicholas, 'Observations on the Institution of the Most Noble Order of the Garter', *Archaeologia* 31 (1846), pp. 1-163; Dillon, 'An Armourer's Bill', pp. 148-50.

182. CDS, ii, no. 1413.

183. See Powicke, 'Edward II and Military Obligation'.

184. CDS, iii, no. 401.

185. CCR 1313-1318, p. 147

186. Riley, *Memorials of London*, pp. 114-5.

187. For *restauratio equorum*, Ayton, *Knights and Warhorses*, pp. 49 ff.

188. Morris, *The Welsh Wars*, pp. 83-4.

189. CDS, v, no. 472(q), cf. 521(d).

190. CDS, v, no. 622.

191. CCR 1313-1318, p. 36.

192. CCR 1313-1318, p. 291.

193. CDS, ii, no. 1949.

194. E 101/5/12, Account of John Flemming for expenses of the galley of Southampton, 23 Edward I.

195. E 101/20/37, Account of Thomas Melcheburn for the galley 'La Phillipe' 11 & 13 Edward III.

196. £61 1s 1d, Riley, *Memorials of London*, p. 140.

197. CCR 1323-1327, p. 432.

198. CCR 1341-1343, p. 442.

199. *LQG*, pp. 50, 60.

200. London, PRO E 101/20/9, Particulars of the account of Thomas de Snetesham of arms and stores for ships 10 to 20 Edward III; Storey, 'Tower of London', pp. 180, 182.

201. For the text, Tout, *Chapters in the Administrative History of Medieval England*, iii, pp. 143-50; otherwise Harris, *King, Parliament and Public Finance*, pp. 224 f.

202. To put these costs in context, between 1338 and 1340 Edward's expenses on campaigns amounted to a staggering £400,000, Prestwich, *Armies and Warfare*, p. 339.

203. CCR 1339-1341, pp. 82, 135.

204. London, PRO E 101/22/6, Warrant and indenture as to delivery of arms at Southampton by the prior of St. John of Jerusalem in England 13 Edward III; for a comparison of other armouries from this time, R. Storey, 'The Tower of London and *Garderobae Armorum*' *Royal Armouries Yearbook* 3 (1998), pp. 176-83.

205. CCR 1339-1341, pp. 83, 161, 185.

206. London, PRO Ancient Petitions, S.C. 8/95 no. 4740, as transcribed in Harriss, *King, Parliament and Public Finance,* p. 244.

207. Ormrod, *Reign of Edward III*, pp. 75-6.

208. Below, Chapter Four.

209. Tout, *Chapters in Medieval Administrative History*, ii, p. 44.

210. Tout, *Chapters in Medieval Administrative History,* ii, p. 47.

211. Riley, *Memorials,* pp. 114-5.

212. E.g., *LQG,* pp. 52, 75, 96-7.

213. Riley, *Memorials,* pp. 206-7.

214. CDS*,* ii, no. 1237.

215. Ibid, no. 1477.

216. CCR, 1302-1307*,* p. 140.

217. Cal. Illus. Scot, pp. 482-3. Stevenson translated 'verge' as 'base', but 'verge' almost always describes the main beam or yard, e.g. CDS, no. 1510.

218. CDS*,* ii, no. 1519.

219. Hewitt, *Organization of War*, pp. 63-73.

220. CCR 1339-1341*,* p. 140.

221. CCR 1341-1343*,* p. 388.

222. CDS, ii, nos. 1324, 1589.

223. *Cal. Docs. Illus.,* ii, pp. 438-40; CDS, ii, no. 1559.

224. Vale, *Origins of the Hundred Years War*, pp. 209-10.

225. CCR 1313-1318, p. 563.

226. CDS, ii, no. 1413.

227. *Cal. Memo. 1326-1327,* no. 2264.

228. CDS, iv, no. 462.

229. CDS, iv, no. 463.

230. H.R. Schubert, *History of the British Iron and Steel Industry* (London, 1957), p. 118.

231. CCR 1318-1323, p. 708.

232. CDS, ii, no. 1324.

233. *LQG,* p. 129.

234. E 101/165/1, Account of Adam de Lymbergh, appointed to superintend Robert de Pippeshull in providing springalds and other arms in Aquitaine, 18 Edward II.

CHAPTER THREE

The Intensification of Siege Warfare

Caerlaverock was so strong a castle
that it feared no siege before the king came there,
for it would never have had to surrender provided
that it was well supplied when the need arose,
with men, engines and provisions.

Walter of Exeter, C.1300(1)

The Crown's effort to wage war systematically, on a markedly greater scale and within a demanding technological framework is distinctly revealed in its siege warfare. By the thirteenth century, Europe's industrial and economic growth was already manifest in the proliferation of castles, cathedrals and stone works in general; in England the number of 'castles' multiplied from only a few dozen since their inception in the eleventh century to perhaps as many as a thousand.(2) Not surprisingly, stone works consumed large portions of societies' energies, technical resources and capital.(3) The Crown's expenses on its network of fortifications and residences provide some indication of their importance.(4) During Henry III's reign, upwards of £80,000 or as much as ten percent of the Crown's revenue was spent on fortifications, including maintaining around fifty English castles in royal possession.(5) Edward I spent about the same amount in a much shorter time on the series of monumental fortresses in Wales, while at the same time establishing some fifty bastides in Gascony.(6)

Edward I's Welsh castles were pinnacles of medieval military architecture and defensive planning, designed to accommodate a new style of warfare conspicuous for its command of resources and military technology. Although the thirteenth century represented something of an apogee in medieval fortification, historians are less sure about the dynamics of attack and defence in their development.(7) Even though Edward I's defensive system in Wales was a marvel of defensive architecture and planning, in the event it may have been excessive; no comparable attempt was made in the fourteenth or fifteenth centuries during which time most of the Crown's defences suffered in constant need of repair. The discrepancy in views is even more understandable given the paucity of our knowledge concerning the development of siege weaponry. The period c. 1250-1350 witnessed nothing like cannons' impact on fifteenth-century warfare, and no trend in capitulation ratios or duration of sieges has been discerned.

Regardless of the lack of any clear shift in the equilibrium of attack and defence during this period, there is much evidence that contemporaries perceived that the offensive had gained or would soon gain the upper hand. Walter of Exeter's description of the strength of Caerlaverock castle was actually designed to stress the potency of Edward I's army which took the 'fearless' stronghold in a week. Bradbury's pioneering work on medieval siege warfare emphasized late medieval governments' capabilities in terms of deploying men, materials and more potent devices such as trebuchets and firearms.(8) Though much evidence supports the notion that the scale of the Crown's sieges increased from Edward I's reign, ascertaining the level of change based on the mobilization of the most common items of war is difficult due to the vagaries involved in mobilization and accounting as discussed earlier.(9) We can gauge the Crown's developing potency in siege warfare through its control of larger artillery. Although the Crown's largest trebuchets of the fourteenth century have become something of a fascination in recent years, the chronology of its development continues to divide historians.(10) Opinions on the advent of the heavy counterweight trebuchet, or one propelled solely by a falling counterweight instead of traction crews, range from the late twelfth to the early fourteenth century.(11) Most attempts to date its emergence in Europe have relied on the descriptions of chroniclers and clerks even though they seemed to prefer a set of familiar terms such as perrier, magonel, a generic for engine, or in some cases a nom de guerre regardless of the kinds of siege engines involved. Consequently far too many inconsistencies in the use of these terms (even by the same writer let alone across Europe) prevent us from extracting much technical meaning through cognomens alone. The acclaim bestowed on the largest engines and the enormous efforts required to build, maintain and operate them have left a long trail of records that allows to surmise the development of the Crown's arsenal with surprising precision, including the process whereby counterweights supplemented traction crews and eventually replaced them, a labour-saving technology that made fielding these devices a far less complicated and seemingly easier task.

Henry III

Both the mention of a new 'Turkish' engine just prior to Henry III's reign and the 'great engines' of Louis' invasion of England in 1216 have been accepted as evidence for the advent of the heavy counterweight trebuchet in the West. Details of other engines' construction and operation in England during this time indicate that the 'Turkish' engines more likely referred to traction trebuchets.[(12)] In England, expenses were recorded in 1211 for operating two great 'petraries' and two 'Turkish' engines with cords and slings.[(13)] The traction trebuchet was probably known in the West in the ninth century or earlier, and it is widely considered to have become a common feature of western sieges during the twelfth century, particularly after the crusader siege of Lisbon (1147).[(14)] Essentially a large pivoting lever and a sling for discharging shot, the traction trebuchet was powered by hundreds of labourers pulling on ropes attached to the short end of the beam; mostly wood, the traction trebuchet needed no other mechanism or trigger, and did not require much special expertise to construct or operate. Its relative simplicity usually achieved a high rate of fire, and some large, well-built versions are recorded as throwing projectiles weighing many hundredweight. However, the efforts of traction crews were often inconsistent and produced mixed results, and more importantly these crews required extensive efforts to mobilize and maintain in the field.

The greatest material demand for the Crown's engines at this time appears to have been obtaining ropes, presumably for traction labourers. For most of Henry III's reign, large purchases of ropes were a conspicuous feature in accounts of constructing and operating siege engines.[(15)] In 1215 several orders were made to supply Thomas Sampford with cords for drawing engines (*ad trahendi petrarias et magunellos*).[(16)] In 1221 two engineers were sent to Byham with 13 carts of cords to make engines.[(17)] In one account of making engines in 1254, more money was spent on cords than on iron and steel.[(18)] Obtaining the necessary manpower for operating these engines was also problematic. For the siege of Bedford (1224) bishops were supposed to provide one man from every 60 acres of lands to assist with operating the king's engines.[(19)] When labour for operating engines could not be impressed, wages ran high. Wages for operating petraries and mangonels was the only item specifically mentioned in an account for expenses of £1311 18s 2d during a siege in the 1220s.[(20)]

Based on the costs of construction, these engines were of modest size. In 1214, the construction of two Turkish engines cost £38 19s 5 1⁄2d.[(21)] In 1216, the construction of two petraries and three Turkish mangonels and their carriage from Knaresborough forest to the castle cost in all just over £50.[(22)] The very high number of men required to operate traction trebuchets, however, seems to have prevented deploying many of them at any one place. In 1210 the number of throwing engines on John's campaign was probably not very great; only four masons accompanied the army to cut ammunition for engines.[(23)] John's major effort to take Rochester in 1215 included only five engines, one of which was described as a strange contrivance, but mining brought the siege to conclusion.[(24)]

The practice of attaching some kind of small counterweight on traction trebuchets has confused historians in their attempts to date the advent of the true counterweight trebuchet, or one relying solely on counterweight for power. Throughout Henry III's reign depictions of trebuchets often appear with both ropes and some type of counterweight (fig. 3.1-2, 3.3-4). A modest- sized counterweight on a trebuchet would serve to counteract the inertia of its beam, sling and missile, and would store momentum from the labourers' traction. Unlike the expenses of building engines in the first quarter of the century, works conducted later in Henry's reign begin to include quantities of lead purchased or requisitioned specifically for engines. In June 1244 the sheriff of Lincoln was ordered to purchase 20 carts of lead at the fair of Boston for Master Gerard to make engines at Newcastle, but [(25)]

not all of it was intended for counterweight. In September the sheriff of Kent was ordered to receive from Master Gerard three engines, their gear and 17 carts of lead described as *not* part of the engines' counterweights; an order from September 1245 indicates that only 6 carts of lead accompanied 10 horse loads of iron, 4 horse loads of steel and 4 axles (*cavillae*) for the king's engines. (26)

In 1266 the siege of Kenilworth became the Crown's largest siege effort since 1224, in the process consuming the sheriffs' returns from ten nearby counties.(27) Extensive efforts were required. Kenilworth was a very secure castle: a stout central keep stood on a mound of bedrock, protected on its west side by a large artificial lake, and an intricate system of moats, earthworks and concentric curtain walls otherwise.(28) A striking aspect of the mobilisation was the number of requests for materials sent to diverse places. On 28 July some 2500 hurdles (8' x 7' or 10' x 8') were requested of the sheriffs of Oxford, Worcester, and Northampton and in September another request was sent to the sheriffs of six other counties for all the hurdles in their possession.(29) It appears unlikely that all of the Crown's requests were filled entirely. Although 30000 quarrels were requested from the sheriff of Lincoln, in March 1267 he was allowed £8 5s 4d for only 13,200 quarrels he had sent to Kenilworth.(30) The gathering of cords for engines was still a prominent aspect of the Crown's material logistics.(31) In April cords, hides and engines were requested from Bristol.(32) Peter de Neville, marshal of the king's household, supervised the construction and carriage of many siege devices. In early May he was sent to Gloucester with orders to oversee the preparation of some engines and take them to Kenilworth. The sheriff of Gloucestershire claimed £15 for carriage of 7 beams (*virgis*), a nail (*cavilla*) for an axle, cords and weights (*filiis et pendentibis*).(33) In June Peter claimed over £10 for another shipment related to engines, and 30s was spent having three *cavillae* and timber carried to Worcester from the Forest of Dean.(34) Another £11 was spent on cords, cables and hemp for engines, as was 4s of horsehair.(35) Small boats of barges were forwarded by the sheriffs of Worcester and Gloucester.(36) Even though as many as a dozen engines may have been deployed, the king's clerks only gave one engine a cognomen: a belfry called *Ursus* built the previous year for Roger Leyburn's efforts to recapture Sandwich.(37) A second belfry may also have been brought by the sheriff of Gloucester.(38) Portable towers had remained the most common and potent threat to the enceinte since the eleventh century. The Bear's size is unknown, but early crusader towers reached as much as one hundred feet in height and could house hundreds of men and light artillery; by the fourteenth century several accounts suggest the largest belfries might have sheltered as many as one thousand men.(39) We have little evidence of how well the few large artillery performed at Kenilworth. The *Dunstanble Annals* report that Edward's 'new machines' threw incessantly against the castle's walls and wooden towers, and stone shots thrown from engines in both camps kept colliding in mid air. Edward's towers were pushed up to the ditch only to be burned by defenders before any assault could be launched from them.(40) What began ambitiously ended undramatically. The castle survived intact, and typhoid is said to have brought the garrison's surrender.(41) After the siege, the Crown paid only 30s for dismantling the engines and seeing to the lead.(42)

Edward I

The siege of Kenilworth had revealed the limits to which a keep could provide 'cover fire' for the entire enceinte and consequently it has been proposed that a more symmetrically concentric design was adopted at Caerphilly and on a much larger scale in many of Edward I's Welsh castles.(43) In those decades, Edward initiated work on two dozen castles in Wales, almost half of which were new and could easily accommodate a set of important features: these castles incorporated state-of-art defences into a very dense design; several innovations such as multiple accesses to arrow slits sought to maximize defenders' efforts. When possible these castles were built with access to waterways even if constructing a 2 mile canal was necessary such as at Rhuddlan. These castles also began to include larger towers for accommodating cranes or military engines, affording the latter better range.

The integration of artillery and fortifications may have been one of the period's most novel developments in siege warfare. Historians tend to overlook the defensive potential of many siege engines, but the citadel in Cairo appears to have been modified for this purpose during the first half of the thirteenth century. As we have seen, Walter of Exeter's stipulations for Caerlaverock's defencibility included siege engines. A fortress with a powerful artillery often proved dangerous. Artillery duals occurred regularly, and although Giles of Rome must have exaggerated the trebuchet's accuracy, large engines were a constant threat to other engines and ships.(44) Harlech's defences are said to have incorporated a large elevated platform or bay for engines, and a forward tower erected at Criccieth around this time was named the 'Engine Tower'. The mural towers built for Caerphilly's northern dam in the 1280s may also reflect the new desire to sustain large engines, as they were much larger than the mural towers built for the southern dam the previous decade (figs. 3.5-6).

Early in Edward's reign we have several indications that the Crown began to give more emphasis to its siege engines, including constructing much larger devices. Master Bertram's account for building engines at the Tower of London in 1278 demonstrates the new scale of efforts. Under one heading, huge quantities of copper, lead and iron were required including a half ton of copper for an axle; some 248 hundredweights of Spanish iron; and nearly £167 of lead for counterweight which was transported in 61 carts.(45) Altogether the work on engines cost £1021 5s 9d ob. of which about half were wages.(46) There is seemingly no way to tell how many engines were created or repaired in his account, but the expenses and amounts of materials overwhelms efforts made for Kenilworth just a decade earlier.

The Crown's warfare during what may have been the most crucial moment technologically was ill suited for testing any such device. The Welsh strategy of guerilla warfare and lack of major fortifications perhaps removed the need for much siege equipment during Edward I's wars there, and the raw countryside of difficult terrain made mobilizing heavy equipment extremely difficult. At the siege of Dryslwyn (1287) only one engine was constructed for a modest £14 and supplied with ammunition by twenty quarrymen, suggesting a light machine with a high rate of fire.(47) The next year this engine required 40 oxen but only 4 wagons to transport it through the mountainous terrain.(48) Morris writes that the machine was escorted to Emlyn by 20 men-at-arms and 463 infantrymen, and while no doubt these infantry acted as a safeguard, they may have also served as a traction crew. During these same years, when lead was required for a 'great engine' at Bristol, an unspecified amount 'existing' in the village was taken to the castle at a cost of only 4s for transportation, although this amount could have been supplementing other material.(49)

In Aquitaine during the years 1294-1298 both pro English and pro French forces conducted sieges with notable successes but to nether sides' cumulative advantage.(50) Further examination of the records detailing preparations for these conflicts may provide additional insight during this crucial period. The French were clearly engaged in heavy preparations- one account included forty springalds great and small.(51) The term springald (*springard*, *espringal*, etc) begins to appear in French records in the mid thirteenth century and based on cost and description it was the most powerful mechanical 'bow', often requiring a platform or mount.(52) Its closest equivalent in English records is the first mention of a crossbow *ad tour* or *ad turnum* in 1237, a weapon probably spanned with some sort of windlass or perhaps a screw winch.(53) The term springald, clearly signifying a larger weapon than the crossbow *a tour*, is mentioned in English records by 1297 and thereafter rapidly became the Crown's preferred low trajectory weapon until rivalled by small cannon during Edward III's reign. The springald's most interesting aspect for our present purpose is contemporaries' need to distinguish this engine from the crossbow *ad turnum.* A shipment to Gascony in 1297 included 3 springalds and 48 crossbows of which 12 were great crossbows with winding mechanisms.(54) Unlike crossbows which derived their power from a single (composite) bow, springalds may have been torsion-powered as indicated by the copious amounts of hair and cords spun into ropes for them; 56 lbs. of horsehair for springalds was sent to Stirling in 1304, and later accounts contain even more.(55) At a cost of about £5, a springald was often substantial enough to require its own base which was sometimes wheeled for ease of transport. It was also around this time (1303) that Edward of Carnarvon gave his engineer defensive armours consisting of an aketon, a coat of plates and a basinet.(56) It is doubtful that a military engineer's life was ever a safe one, but the gift of armour at that particular time may have been in response to the development of a more powerful anti-personnel device such as the springald.

At the beginning of the fourteenth century, the Crown amassed its largest siege arsenal yet. Edward's invasion of Scotland in 1296 demonstrates a definite change in the way the Crown conducted and perceived sieges.(57) At Edinburgh three engines were set up on the first day and threw a total of 158 stones over three days before surrender was offered. If nothing like a shortage of ammunition impeded these engines then their rate of fire of roughly 17 shots per day was much lower than a traction trebuchet's. One interpretation of the events which followed has Edward declining the offer of surrender, leaving for Stirling and ordering the engines to maintain their volley.(58) We are much more sure that Stirling's surrender was declined in 1304 until construction was completed on the 'lup de guerre', a showpiece among the Crown's biggest military engines.(59) Since Stirling's capture by the Scots in 1299 it had been a thorn in the side of English operations in the north.(60) To manoeuvre around the foreboding castle in 1303, prefabricated bridges complete with drawbridges and springalds were made and brought from King's Lynn to cross the Firth of Forth.(61) Between 1299 and 1304 steady progress was made in establishing a supply line mainly through Newcastle and Berwick.(62) Previously Edward had lacked the strength to attempt a siege of Stirling, but after the sieges of Dunbar (1296), Edinburgh (1296), Caerlaverock (1300), Bothwell (1301), and Brechin (1303), an impressive array of engines had been created which only needed to be brought together to render their combined force on Stirling.

Since January 1304 engines and supplies were being sent to Berwick.[63] The extent to which the Crown relied on Richard de Bremmesgrave, receiver of victuals at Newcastle, to handle many logistical needs is well illustrated by the role that he played in supplying the siege.[64] Newcastle was not subjected to the same attacks as castles farther north, yet it was well positioned to maintain communications with the principal sites of English occupation: Edinburgh, Jedburgh, Roxburgh, Berwick. Engines were routinely shipped from Newcastle to Berwick and thence to their final destination.[65] In March the constable of Edinburgh was requested to send targets to Stirling through this supply route.[66] In April a shipment of lead, iron, crossbows and quarrels were sent to Stirling by Bremmesgrave.[67] In May, 20 crossbows for 1 foot, 4 crossbow for 2 feet, 24 baldrics, 18,000 quarrels of 1 foot and 6050 quarrels of 2 feet arrived from Bremmesgrave in 9 coffers.[68] On 3 July the king ordered Bremmesgrave to send quarrels and repair materials for crossbows.[69] Five days later the clerk at Stirling received his shipment which included 60 sheaves of steel (of 30 pieces each), glue, 2 sacks of horsehair (56 lbs.) for springalds, 400 quarrels a tour and 950 quarrels of 2 feet in 4 baskets, and materials for bowstrings.[70] By 6 April Reginald the engineer had received from Bremmesgrave many springalds, two engines made at Brechin, the Segrave, the Vernay, the Robinett, 16 beams of the Forester and 18 beams of the Aberdeen (perhaps an indication that engines' yards were composite constructions). The Forester and the Aberdeen were made at Berwick in 1298 and supplied with counterweights (*pendula magni ingenii*).[71] In 1304 they were accompanied by 784 stones of lead and 124 stones of iron (15 lbs. each).[72] On 9 April orders were sent for an engine called the 'Linlithgow' to be brought to the sea with more ammunition; twenty-one carts or wagons of stone projectiles and lead for counterweights accompanied it.[73] The 'Bothwell', a belfry, was brought to Stirling in 8 wagons instead of the 30 or so carts which carried it in 1301.[74] One engine was brought from Bridgewater, and more were shipped to Inverkip from Ireland by Robert the Bruce.[75] Robert Glasham brought the 'Prince' from Brechin, and Robert of Bedford brought from St. Andrews an engine called 'Kingston', named after the constable of Edinburgh.[76] A ram was built on site.[77] We also know that in addition to the aforementioned engines, the 'Lincoln', 'Vicar', 'Parson', 'Berefrey', 'Gloucester', 'Dovedale', and the 'Toulemonde' were present at the siege. The 'Warwolf' was constructed on site- the task occupied a work force of five master carpenters, 50 carpenters and 4 pages for most of the siege and Edward was so impressed with one of the 'valets' involved in the project that he rewarded him with £40.[78] Assuming that all of the cognomens indeed referred to different engines, altogether at least 22 major engines were requested or built for the siege as well as an indeterminable amount of springalds and lesser arms.

With such an impressive arsenal the Crown was worried that there would not be enough lead for the trebuchets' counterweights.[79] Already at the siege of Brechin lead had been stripped from a church roof for counterweights.[80] On 12 April 1304 Edward realised he was again lacking enough weight to propel his engines so he ordered the prince to strip lead from the church roofs in Perth and Dumblane being careful not to leave the alters uncovered.[81] The total quantity of lead is hinted at by the payments made. Whereas at Brechin a total of 5 cart loads had been taken at the cost of a half mark per load, for Stirling 75 cart or wagon loads were taken with repayment at 5 marks per load. Both churches received 5s per load as a gift towards damages.[82] Lead was often measured by the cartload or fother which weighed close to a ton and cost £2-3 between 1250-1350, which suggests that as many as 75 tons might have been taken.[83] At least 27 of these cartloads were intended for counterweights.[84]

The array of engines also demanded hoards of ammunition. Ammunition for large engines was usually stone balls sometimes shaped according to templates or moulds provided by the master mason.[85] Stone ammunition was cost effective but marble, lead, even pots containing Greek Fire or similar explosive were used.[86] At Edinburgh (1296) Edward reportedly used lead.[87] In 1303 a master *plumbario* was paid for working 189 lbs. of lead into *puellis et ruellis jactandis*.[88] At Stirling as at Brechin the year before, small amounts of sulphur (9s) and saltpetre were purchased to be thrown in earth pots, a technique first seen in the orient.[89] After suffering terrific bombardment, Stirling's garrison offered unconditional surrender but with the Warwolf nearing completion Edward declined and advised the defenders to take shelter.[90] Once [91] completed, the Warwolf's first shot amazed onlookers by destroying a section of wall. Edward I's stubbornness may seem ridiculous, cruel, or childish, but apparently contemporary chroniclers were not as critical.[92] For someone who had promised to lay the whole country to waste these kinds of actions should have been expected.[93] Edward I's actions may also have stemmed from a desire to demonstrate the full strength of English siege capabilities and the prices paid by garrisons who did not initially surrender.

Edward II

Edward II would have preferred to subdue Scotland per his father's strategy of sieges, infantry armies and their maritime support. The strategy itself has been criticised as has Edward II's maintenance of defences.[94] Contrary to opinion, Edward II paid very close attention to the fabric and armouries of castles, and was able to coordinate massive defence works. Despite a miserable economy and fickle support, Edward II spent more than his father on Scottish fortifications. During his difficulties of raising men and money, Edward II relied on a defensive strategy and continued strengthening artillery in the north, perhaps as his most viable alternative. At the start of Edward II's reign the northern castles were in good repair and several peels with stone foundations and drawbridges were under construction.[95] At Linlithgow an engine, springald and bretache were readied between April and September 1306 costing £953 13s 8d.[96] The vast array of siege equipment created for Stirling was still on hand at Berwick. In December 1306, Berwick's inventory included much of the Warwolf's components, 2 springalds and six crossbow *a tou*r, 24 crossbows of one-foot, and 9 crossbows of two-feet, as well as a number of quarrels for these and materials for their repair.[97] Further work on engines and a bretache at this time amounted to £234 8s 4d for wages alone.**[98]** The sheriffs of London were ordered to send provisions and more engines to Berwick in October 1307.[99] In December 1309 Berwick supplied Henry de Beaumont with a *cavilla*.[100] In the same year a carpenter, mason, engineer, and smith were sent from Northumberland to Stirling.[101] At Dundee 20 quarters of seacoal were purveyed for work on engines in 1310.[102] Reginald the engineer and his team of carpenters were also engaged in repairing engines in the North in 1311.[103]

Despite these preparations Robert Bruce seized the initiative and by 1313 Scottish raids had felled several pro-English castles and extracted high tributes in the process. Edward II still maintained an eye towards munitioning castles. In 1313 Berwick was allowed to retain all its wool customs for the purchase of munitions.[104] Carlisle earned its charter in 1315 by withstanding a siege wherein the Scots employed only one engine which proved no match for the garrison's seven or eight acquired the previous year along with 360 stones of lead.[105] Carlisle's defences had also been strengthened by converting some houses into a belfry and bretache.[106] In 1316 Richard the engineer, an artillator and a smith were to be found at Carnarvon, while at York a serjeant and two associates were making lance heads.[107] The gates and engines at Cokermuth were repaired in 1317.[108] During 1318-1319 work intensified at the king's iron mines at Knaresborough, and the castles' engines and hoardings had recently been renovated for £55 4s 11d.[109] Carlisle's trusty engines also received repairs at this time and another one was constructed to augment the bailey's defences.[110]

Despite possessing numerous pieces of artillery, Edward II appears to have been reluctant to deploy them against Berwick when attempting to regain the wealthy city in 1319.[111] No prearrangements for engines seem to have been made for the siege, though John Barbour's *The Bruce* vividly described how an English sow, or shelter, was crippled by an engine's shot and set on fire by dropping flaming haystacks from a crane. Edward had assembled a powerful army, and perhaps he hoped to receive the city through Robert the Bruce's default, or even better to draw him into battle. Contemporaries were well aware of the long term effects and costs of damage. A decade after its siege by Edward III, Berwick still needed repairs of [112]

£310 6s. Phillip VI often bribed enemy garrisons into submitting, obviously considering their high costs a worthwhile investment. In any case Berwick's garrison agreed to surrender if not rescued. Engines and 100 ditchers were requested only from York on the day after investment, but York was busy preparing its own defences. However, a week later the siege was abandoned when Edward's council could not agree on a course of action following the defeat of York citizens at the battle of Myton.(113)

At Bordeaux in 1324, the threat of attack was being met with massive preparation which better reveals Edward II's grasp of materials war siege. An elaborate set of defences were erected to blockade the Garonne at nearby St. Macaire.(114) The preparations in Bordeaux amply demonstrate the defensive value of engines at this time. After La Reole fell to French forces (22 September) a siege of Bordeaux seemed imminent. A truce was declared until March 1325. In the interim both sides readied themselves for more hostilities.(115) During the accounting year 1323 1324, nearly 5,000 l.t. were spent on preparing Bordeaux for war. Large engines figured prominently in these defences where they were commonly deployed to target shipping. Small arms were purchased, mostly crossbows and quarrels, a belfry was erected inside Bordeaux, and piles were driven into the riverbed to prevent a fleet's approach.(116) Edmund de Martheley was appointed to oversee work on engines inside the city from November 1324 to July 1325.(117) Eight beams were purchased for 16 *l.t.* each.(118) Giant cables, called hawsers, were obtained for holding a great engine's weight, a likely indication of a pivoting counterweight.(119) At the end of the account the expenses were categorized. Wages totalled more than 317*l.t.,* wood cost over 348l.t., some 24 *l.t.* was spent on cables and over 86 *l.t.* was spent on iron. In all the engines cost 961 *l.t.,* although much of the labour and probably materials were impressed or cajoled.(120)

Edward III

The growing emphasis on the war in France presented Edward III with a new challenge. The previous Anglo-French disputes over Aquitaine had demonstrated the futility of fighting a purely defensive war restricted to that area. As we have seen, a strategy relying on siege warfare defensively and offensively required a well coordinated network for handling supplies. Even the war in Gascony required major support from English industries. Furthermore, when support was required in hostile territories it needed protection, creating an extra burden on the Crown's resources.(121) There was little feasability of Edward III maintaining a strategy of conquest in France without establishing supply lines. Consequently much of Edward III's strategy in northern France hinged on challenging cities by blockade with a formidable yet mobile army, perhaps in hopes of drawing battle. Even Calais was taken by blockade, although its marshy surroundings may have prevented a more pressing investment.

Even for the war in Scotland, Edward III had less occasion to deploy a major siege effort. The siege of Berwick in 1333 was probably the largest siege of his reign, and there orders for the construction of engines were only sent two months after the siege began.(122) Barbour mentioned guns at the siege of Berwick (1333), but this reference is not corroborated by any contemporary source. Nonetheless a respectable effort was fielded, including more than six major engines with the aid of John Crabbe. Previously employed by the Scots in prominent roles such as ordering the defence of Berwick in 1319, Crabbe was subsequently captured by Walter Mauny and ransomed by Edward III for 1000 marks so that he could be pressed into service. John turned his talents against Berwick in 1333, and oversaw the construction and operation of engines. In 1338 he supervised the construction of engines for the siege of Dunbar, of which one belfry cost £47 4s 10d.(123) In 1341 he teamed with William Hurel, the king's carpenter, to select wood from the forest at Trent for making engines.(124)

Even though few major sieges occurred during Edward III's reign, works on siege engines became a regular activity. Despite these ongoing developments in conventional engines and the novelty of gunpowder weaponry, the steady increases in England's technical congruence and industriousness provided greater flexibility in the procurement of arms. The orders for engines provide an insight into the rate of diffusion throughout society. Normally the Crown assigned highly novel or difficult projects, such as the Welsh castles, pontoon bridges or major engines, to some engineer(s) or senior master craftsman, aided by administrative official(s) for accounting or financing. As the fourteenth century progressed, orders for projects previously considered difficult began to be directed to just the sheriffs without need of assigning specific master engineers or craftsmen. In 1336 the king ordered the sheriff of York to purvey 2 trebuchets, a springald with 100 bolts, 4 crossbows with 400 quarrels, 60 bows with 60 sheaves of arrows, 6 pairs of hand stones, 2000 pieces of Spanish steel, and armour sufficient for 40 men including coats of plates. All of the items were to be delivered to Berwick to be kept by the receiver of victuals until further notice by the king.[(125)] Presumably the knowledge of building these items, most notably two trebuchets, had become common enough that the sheriff could arrange for their construction through local master craftsmen/engineers.

It appears that the size of the largest engines increased, and still their logistics became more routine. An engine made at Stirling during 1336-1337 required 390 stones of iron, or about 50% more than the largest machines of Edward I.[(126)] When two engines were built for the siege of Berwick (1333), at least 40 oaks were required for their frames.[(127)] More definite evidence for the size of stone shot thrown by these engines is also available. Appropriate stone for projectiles was not always readily available; for the siege of Edinburgh in 1336 stone was carted from 7 leagues away.[(128)] With the advent of the Hundred Years War the quarry at Folkestone in southeast England emerged as a mass production site for ammunition. In 1342 the sheriff of Kent spent £13 10s on 300 stones each cut to weigh either 600, 500 or 400 lbs, and he purchased another 300 stones of various weights for £7 10s.[(129)] In 1343 the receiver at Sandwich was waiting for 300 stones from Folkestone, and stones from there were also sent to Calais.[(130)] Jean Buridan, in his study of movement and projectile motion written in the mid fourteenth century, tells us that engines threw stones of up to 1000 lbs. in weight, and a writer in 1376 claimed projectiles weighed as much as 1200 lbs.[(131)]

Evolving from Greek fire, gunpowder was first used in a type of exploding pot thrown from the larger siege engines and later as a means of throwing projectiles such as darts and stones. The pace of development in gunpowder weapons was astonishing: during the fourteenth century gunpowder weapons diversified into forms ranging from very large cannon to crude hand-held guns. Although guns and cannon were the most notable advancement in military technology during Edward III's reign, their integration into the English siege warfare was a slow process.[(132)] That the Crown still preferred springalds over guns through at least the 1330s and 40s is strong evidence that gunpowder weapons had not assumed any prominent role in its tactics or strategy. French raids on England's southern coasts in the late 1330s stimulated defensive preparations throughout London. Materials for engines were carried to the Tower in July 1339, and in August William le Gyvour was to receive money for making engines.[(133)] A bretache was built for £126 near the Tower and stocked with 7 springalds and nearly 1000 quarrels. The defences along the Thames were strengthened, possibly incorporating guns but relying mostly on springalds.[(134)] Episodes in 1335 and 1336 on England's southern coast reveal similar responses.[(135)]

Experiments with small amounts of gunpowder became more common, and some notable success must have been achieved in Gascony. By the late 1330s the Crown employed a master of cannon there, and small amounts of gunpowder was consistently supplied to a number of castles by Genoese specialists.[(136)] When we afforded a glimpse into these circumstances in England, the same scale was at operation until the well known order for 100 ribalds in 1345-6. In 1327 Dover officials complained of being deprived of among other things 40 lbs. of sulphur (about 2 marks worth); a large amount compared to those seen in the early fourteenth century.[(137)] With no mention of saltpetre and the inclusion of 2 lbs. of tinder and 100 lbs. of cotton in the order, the sulphur may have been intended for Greek fire or some explosive as before.[(138)] In 1334, saltpetre was purchased alongside sulphur but only 5s worth altogether.[(139)] Certainly, Edward III's armies had not mastered gunpowder weapons by 1340. While besieging Tournai, the international force under Edward III paid someone to make explosives promised to force immediate capitulation, but he absconded with most of the money.[(140)]

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During Edward I's reign, English perceptions of siege warfare underwent a transformation. The English Crown's siege capabilities were greatly improved by the ability to keep troops in the field, by its command of resources and new technologies. A major change in the perception of siege warfare also manifested in other ways. The dress and behaviour of the army at the siege of Caerlaverock (1300) were described as colourful and jovial; at Stirling an oriel was erected for the viewing comfort of ladies of the household.[141] Trebuchets were given far more esteem by chroniclers, armies and architects, and Edward I himself was extremely cavalier and confident about employing such devices. The arrogant pride shown by English armies, particularly during Edward I's reign, convey the perception that some novelty had occurred in siege capabilities. It is tempting to look to Edward's crusade as a source for improving siege techniques and devices. Greek fire, which the Crown came to use regularly from the 1290s, had been known in Europe for centuries and appears in English records occasionally like in 1194.[142] By the time of Edward's crusade several types of gunpowder weapons formed the technological vanguard in eastern and near eastern armies; cannon are depicted in China as early as 1180, by which time 'thunderclap fireballs' or exploding bombs were being thrown by traction trebuchets.[143] Although gearing may have enabled a more potent engine and versatile artillery unbound from traction crews, the Crown's ability to deploy larger artillery stemmed from incremental improvements made over the course of the thirteenth century primarily in carpentry, trebuchet technology and the ability to mobilize resources. Edward I harnessed this steady progress into a more intense and ambitious siege warfare, aided by considerable development in other siege devices. Recognizing this offensive potential, Edward I's programme of castle building appears to have been in response to the perception that offensive capabilities had improved markedly.

Edward II sought to rely on a strategyof siege warfare, initiating a regime of constant siege works to maintain the impressive artillery but in the event England's defences were ill prepared for the Scots' hit-and-run strategy and few offensive sieges could be launched. When facing an equally potent system in France, Edward III was much more reticent to mobilize such large artilleries but his threats had to be taken seriously: when the occasion demanded Edward III could still mobilize efforts as impressive as Calais. Several factors in addition to the desire for mobile armies may have worked towards this policy. Despite much advancement in siege capabilities, in many ways the advice of Pierre Dubois held true: sieges were costly and unpredictable.[144] The untimely and unpredictable nature of campaigns may have deterred large-scale preparations for a siege unless it was the primary objective of a campaign as had happened at Kenilworth in 1266 and Stirling in 1304. The chance that a stronghold might surrender very quickly also removed the need for large artilleries in every army, and the desire to take cities intact further deterred bombardment. Perhaps just as important, sieges could be entered into with less of the king's attention and could therefore be threatened with greater effect especially in conjunction with proven increases in capabilities. The king's administration which had been absolutely necessary for financing and directing labour-intensive sieges was hardly needed for the operation of siege engines involving relatively few men as at Ediburgh in 1296. Even if these weapons did not bring quick surrender from the defenders, the task of defence became much more harried requiring a greater expense of resources and energies including precious calories. In this context, more efficient and more powerful fortifications would have afforded vital protection against attacks, minimized liabilities against ploys and half-hearted threats or at least bought more time for any relief. Far more fortifications were less competent, and the combined improvements in the offensive may have shifted the equilibrium of siege warfare by altering the basic question from whether or not a site could be taken to how long fortifications or supplies would hold out. It is probably due to these changing perceptions and dynamics that northern Europe witnessed an unprecedented spate of battles in the first half of the fourteenth century often involving a relieving force being drawn into battle.[145]

NOTES

1. *The Siege of Caerlaverock...,* N.H. Nicolas, ed., (London, 1828), p. 60.

2. Some argue for an earlier date for the diffusion of stone fortifications, B. Bachrach, 'On Roman Rampart 300-1300', *The Cambridge Illustrated History of Warfare*, G. Parker , ed. (Cambridge, 1995), pp. 64-91. Bradbury, *The Medieval Siege*, p. 67, places the number of English fortifications at 'several hundred' by 1200; Pounds, *The Medieval Castle in England and Wales*, p. 68, posits 900 English castles by 1154. Cf. Vale, *Origins of the Hundred Years War*, esp. map 1 for dense pattern of fortifications in Aquitaine.

3. Colvin, *History of the King's Works*, provides an 'industrial' perspective of the castle's evolution as does Pounds, *The Medieval Castle in England and Wales*; see also L.F. Salzman, *Building in England down to 1540* (Oxford, 1952).

4. For an overview see Pounds, *The Medieval Castle in England and Wales*, pp. 75-83.

5. Pounds, *The Medieval Castle in England and Wales*, p. 82.

6. A.J. Taylor, *The Welsh Castles of Edward I* (London, 1986); bastides, Prestwich, *Edward I*, pp. 308-11.

7. C. Allmand, 'New Weapons, New Tactics 1300-1500', *Cambridge Illustrated History of Warfare*, pp. 96-7, describes a seesaw effect until a decisive swing in favour of cannon in the second quarter of the fifteenth century; Bachrach, 'On Roman Rampart 300-1300', pp. 87-8, agrees that siege costs and techniques increased in the twelfth century but the 'art of defence more than kept pace with the technology'; G. Parker, 'The Gunpowder Revolution 1300-1500', *Cambridge Illustrated History of Warfare*, pp. 106-7, sees no major change in siege warfare until the second quarter of fifteenth century. Bradbury, *The Medieval Siege*, pp. 128 f, and Prestwich, *Armies and Warfare in the Middle Ages*, pp. 280-1, both posit a major change in offensive capabilities in the early to mid thirteenth century. Contamine, *Warfare in the Middle Ages*, pp. 200-1, C. Oman, *A History of the Art of War in the Middle Ages*, ii (London, 1924), pp. 52-4, and M. Vale, 'New Techniques and Old Ideals: The Impact of Artillery on War and Chivalry at the End of the Hundred Years War', *War, Literature and Politics in the Late Middle Ages*, C. Allmand, ed. (Liverpool, 1976), p. 58, extend defensive supremacy until at least the early fourteenth century.

8. Bradbury, *The Medieval Siege*, pp. 128f.

9. Above, Introduction.

10. An engine closely related to the structure of cranes, windmills, ships and later the clock's mechanism, White, *Medieval Technology*, pp. 102-3. An excellent bibliography can be found in Chevedden, 'The Invention of the Counterweight Trebuchet'.

11. For 1199, D. Hill, 'Trebuchets', *Viator* 4 (1973), pp. 95-114; White, *Medieval Technology*, p. 102. For other dates, see Bradbury, *The Medieval Siege*, pp. 254, 263-4, and Prestwich, *Armies and Warfare in the Middle Ages*, p. 289, who argue for an early thirteenth century invention; Contamine, *War in the Middle Ages,* p. 194, believes the counterweight trebuchet was still a novelty in the West c. 1300. J. Needham believes the counterweight trebuchet was first used in the Near East in the 1260s, *Science and Civilisation in China*, vol. 5, part 6: *Military Technology: Missiles and Sieges* (Cambridge, 1994), p. 221.

12. J. Liebel, *Springalds and Great Crossbows*, J. Vale, tr. (Leeds, 1998), pp. 2-3, however, suggests that the Turkish engines were torsion- powered springalds.

13. Pipe Roll 13 John, p. 39; cf. CDS, i, p. 93 (1212).

14. Current scholarship places the advent of the traction trebuchet in China around the beginning of the first millennium, after which it spread across Asia and possibly to Europe by the ninth century, P. Chevedden, Z. Shiller, S.R. Gilbert, D.R. Kagay, 'The Traction Trebuchet: A Triumph of Four Civilizations', *Viator* 31 (2000), pp. 433-486; C. Gillmor, 'The Introduction of the Traction Trebuchet into the Latin West', *Viator* 12 (1981), pp. 1-8; Needham, *Science and Civilisation in China*, vol. 5, part 6, p. 204. White, *Medieval Technology and Social Change*, p. 102, f; Bradbury, *Medieval Siege*, p. 260; Prestwich, *Armies and Warfare*, p. 289.

15. Pipe Roll 16 John, p.97; For. Accts. Henry III 1219-34, pp. 17-18; Pipe Roll 5 Henry III, p. 99.

16. Memoranda Roll 10 John, pp. 139, 141.

17. Pipe Roll 5 Henry III, p. 99.

18. CLR 1251-60, p. 217.

19. Bradbury, *The Medieval Siege*, p. 140.

20. For. Accts. Henry III, 1219-1234, p. 52.

21. Pipe Roll 6 John, p. 156; for a comparison of other engines' costs see below.

22. Pipe Roll 17 John and Prests 14-18 John, p. 13.

23. One master mason and three others, Prestwich, *Armies and Warfare in the Middle Ages*, pp. 285-6.

24. Bradbury, *The Medieval Siege*, p. 139.

25. Lead was occasionally worked onto towers and other shelters as protection against flammables, or onto rams to increase their impact or even as projectiles.

26. CLR 1240-1245, pp. 245, 323.

27. Prestwich, *Armies and Warfare in the Middle Ages*, p. 300. The 'Baron's War' in general had worked to reduced returns until the early 1270s, Powicke, *King Henry III and Lord Edward*, ii, p. 506.

28. A large tower protected the mechanisms for controlling the flow of water, Powicke, *King Henry III and Lord Edward* (Oxford, 1947), ii, p. 431; cf. Bradbury, *The Medieval Siege*, p. 142; Prestwich, *Edward I*, pp. 56-7; Prestwich, *Armies and Warfare in the Middle Ages*, pp. 299-300.

29. Buckingham, Bedford, Gloucester, Worcester, Warwick and Leicester, CLR 1260-1267, pp. 221-2, 225-6, 230, 232-3.

30. CLR 1260-1267, p. 263.

31. Ibid, pp 229, 231; CLR 1267-1272, pp. 269,

32. CCR 1264-1268, p. 188.

33. CLR 1267-1272, no. 999.

34. CLR 1260-1267, pp. 219, 221.

35. For horsehair, Ibid,, p. 229-30; others, CLR 1260-1267, p. 231.

36. CLR 1260-1267, pp. 253, 289; CLR 1267-1272, p. 269.

37. It remained at his disposal during the 'pacification' of southern England, A. Lewis, 'Roger Leyburn and the Pacification of England, 1265-7', EHR 54 (1939), p. 200.

38. CLR 1260-1267, p. 223.

39. In the mid fourteenth century these structures are said to have been capable of housing one thousand men, Bradbury, *The Medieval Siege*, pp. 241-50, esp. 244, 248.

40. 'Annales Prioratus de Dunstaplia, AD 1-1297', *Annales Monastici*, H.R. Luard, ed. (Rolls Series, 1864-9), p. 242.

41. Powicke, *King Henry III and Lord Edward*, ii, p. 531; Bradbury, *The Medieval Siege*, p. 142.

42. CLR 1260-1267, p. 294.

43. A design that would have been made apparent to Edward during his crusade.

44. E.g., his claim that a trebuchet could strike a needle, *Governance of Kings and Princes*, pp. 426-8.

45. London, PRO, E 101/467/7(3), Account of expenses for works at London and Westminster 2 to 6 Edward I.

46. £444 16s 2d for wages.

47. Above we saw how two traction trebuchets cost over £38 in 1214.

48. Morris, *Welsh Wars*, pp. 213-16.

49. London, PRO E 101/4/12, Account of Richard Lovel, constable of Bristol castle 14-15 Edward I.

50. Vale, *Origins of Hundred Years War*, pp. 200-15.

51. *Compte Royaux (1285-1314)*, ii, no. 25393.

52. Liebel, *Springalds and Great Crossbows*, pp. 3-5.

53. CLR 1226-1240, p. 274; see also CLR, 1240-1245, p. 61.

54. Vale, *Origins of Hundred Years War*, p. 209.

55. CDS, ii, no. 1559; and infra.

56. Ibid, no. 1413.

57. For brief discussions of these events and attitude see, M. Vale, 'Edward I and the French: Rivalry and Chivalry', *Thirteenth Century England* II (Woodbridge, 1987), pp. 165-176, especially p. 165; Prestwich, *Armies and Warfare*, pp. 2 f.

58. Docs. Illus. Scot., ii, p. 27.

59. PRO, London, E 101/10/18, particulars of Richard de Bremmesgrave, keeper of stores at Berwick, 30-32 Edward I.

60. G.W.S. Barrow, *Robert Bruce and the Community of the Realm of Scotland* (Edinburgh, 1988), pp. 120-31.

61. Colvin, *History of King's Works*, i, pp. 416-7; infra, Chapter Four.

62. For the English position during the early 1300's, Barrow, *Robert Bruce,* pp. 191-2.

63. CDS, iv, no. 1797.

64. For food CDS, ii, nos. 1458, 1482, 1497, 1527, 1542.

65. Ibid, nos. 1230, 1234, 1237.

66. CDS, v, no. 356.

67. CDS*,* ii, no. 1491.

68. Ibid, no. 1539.

69. Ibid, no. 1556.

70. Ibid, no. 1559.

71. Docs. Illus. Scotland, ii, p. 320.

72. CDS, ii, no. 1500. The remaining items were 2 great ropes and 2 smaller ropes for drawing these, 2 hawsers, 5 little ropes and an old one, 600 throwing stones, 4 ropes called hawsers and a long rope of 72 toyses, 6 white horse hides and 10 pieces of canvas.

73. Ibid, no. 363; CDS*,* iv, p. 467.

74. Docs. Illus. Scot., ii, pp. 449-50; Prestwich, *Edward I,* p. 493.

75. Prestwich, *Armies and Warfare in the Middle Ages*, p. 300; CDS*,* ii, no. 1510.

76. Colvin, *History of the King's Works*, i, p. 417.

77. Prestwich, *Edward I*, p. 502.

78. CDS, ii, no. 1599; reward CDS*,* iv, p. 477.

79. Docs. Illus. Scot., ii, p. 481.

80. CDS, ii, no. 1687.

81. Docs. Illus. Scot., ii, p. 481.

82. CDS*,* ii, no. 1687.

83. Measurements of lead, F.B. Andrews, *The Medieval Builder and His Methods* (New York, 1993), p. 78; cost of fother, Salzman, *Building in England*, p. 263.

84. CDS, ii, no. 1513.

85. J. Harvey, *English Medieval Architects. A Biographical Dictionary Down to 1550* (Gloucester, 1984), p. 115.

86. For marble shot, cf. Hill, 'Trebuchets', p. 106.

87. CDS*,* v, no. 472; Bradbury, *The Medieval Siege,* p. 257.

88. CDS*,* iv, p. 456.

89. Docs. Illus. Scot., ii, p. 480. For 'thunderclap fireball' in eastern warfare, S. Turnbull, 'Chinese influence

on Japanese siege warfare', *Royal Armouries Yearbook* 3 (1998), pp. 145-58; Hill and Hassan, *Islamic Technology*, p. 111.

90. CDS, ii, no. 1560.

91. Prestwich, *Edward I*, p. 502.

92. CDS, ii, no. 1560; see Prestwich, *Edward I,* p. 502 and idem, *Armies and Warfare in the Middle Ages*, p. 300.

93. H. T. Riley, ed., *Chronica Willelmi Rishanger, Rolls Series* 47 (London, 1865), p. 447.

94. C. McNamee, *The Wars of the Bruces. Scotland, England and Ireland 1306-1328* (East Linton, 1997), p. 123.

95. Prestwich, *Edward I*, pp. 497-8.

96. CDS, v, no. 5??.

97. CDS, ii, no. 1863.

98. CDS, v, no. 492.

99. CDS, iii, no. 20.

100. Ibid, no. 121.

101. Ibid, no. 72.

102. Ibid, no. 210.

103. CDS, v, no. 562 (b).

104. CCR 1313-1318, p. 10.

105. Lead that was stripped from a chapel, London, PRO, E 101/14/36, Military expenses of Gilbert of Tyneden, 8-9 Edward II.

106. CDS, iii, no. 464.

107. CCR 1313-1318, pp. 265, 363.

108. Ibid, pp. 496-7.

109. CCR 1318-1323, engines and hoardings, p. 160; mines, pp. 43, 171.

110. Ibid,, pp. 160-1.

111. Prestwich, *Armies and Warfare in the Middle Ages*, p. 284

112. CDS, iii, no. 1434.

113. Ibid, no. 663; Prestwich, *Armies,* p. 284; Barrow, *Robert Bruce,* pp. 239-40.

114. Vale, *Origins of the Hundred Years War*, pp. 238-9. See also infra, chapter 4.

115. J. Sumption, *The Hundred Years War*: *Trial by Battle*, vol. 1 (London, 1990), pp. 92-6; Vale, *Origins of the Hundred Years War*, pp. 237-8.

116. Ibid, pp. 238-9.

117. London, PRO E 101/165/2 Account book of Edmund de Martheley for works at Bordeaux 18 and 19 Edward II; see also Vale, *The Angevin Legacy,* pp. 238-9.

118. London, PRO E 101/165/2, fol. $19^{v,}$.

119. *ad tendens magna ingen pond*, E 101/165/2, fol. 20^{V}.

120. Ibid, ff. 17^{r}, 19^{V}, 20^{v}, 21^{v}, 23^{r}.

121. Infra, chapter four.

122. CCR 1333-1337*,* pp. 24, 38.

123. Prestwich, *Armies and Warfare in the Middle Ages*, p. 288; CCR 1339-1341, p. 11.

124. CCR 1341-1343, p. 27.

125. CCR 1333-1337, p. 622.

126. CDS, iii, pp. 366-7.

127. CCR 1333-1337*,* pp. 24, 38.

128. CDS*,* iii, p. 366-7.

129. L. F. Salzman, *English Industries of the Middle Ages* (London, 1913), p. 80.

130. CCR 1343-1346, p. 77; Hewitt, *Organization of War,* p. 72.

131. Buridan: Grant, *Source Book in Medieval Science*, p. 277; 1376: Ralph Payne-Gallwey, *The Book of the Crossbow* (London, reprint, 1995), p. 314.

132. For an overview of gunpowder weapons' development in Europe at this time, Hall, *Weapons and Warfare in Renaissance Europe*.

133. CCR 1339-1341, pp. 163, 179, 542.

134. Riley, *Memorials of London*, pp. 204-7; *Cal. Plea and Memo. Rolls*, pp. 102, 176.

135. Infra, Chapter Four.

136. Vale, *Origins of the Hundred Years War*, p. 261.

137. At Stirling (1304) 9s of sulphur was purchased.

138. Cal. Memo. 1326-1327, no. 1588.

139. Tout, 'Firearms in England', p. 689.

140. Sumption, *The Hundred Years War*, i, p. 351.

141. For Caerlaverock, Prestwich, *Edward I*, p. 487; *Siege of Caerlaverock*, pp. 2-4. For Stirling, Prestwich, *Edward I*, p. 501; CDS, iv, no. 466.

142. Pipe Roll, 6 Richard I, p. 175 (igne greco), p. 212 (112s spent on pitch and sulphur).

143. S. Turnbull, 'War, trade and piracy', *Royal Armouries Yearbook* 2 (1997), pp. 150-1.

144. As mentioned by Vale, *Origins of the Hundred Years War*, p. 203.

145. A similar argument has been put forward for Europe's response to gunpowder artillery in the period 1450-1530, Ayton and Price, *Medieval Military Revolution*, p. 7.

CHAPTER FOUR

The 'Industrialization' of Field Warfare

But smythes, carpunteres, bocheres,
hunteres for þe herte and þe wylde boor,
þese mowe abliche be chosen to chyualrye,
for hereynne stonde þal þe helþe and profit of þe commonalty...

anonymous English translation of Vegetius, c.1408[(1)]

The outcomes of battles have often mistakenly been equated with decisive military and political victory.[(2)] While not decisive in themselves, battles often provided sombre opportunities to strike a devastating blow against an opponent's regime and to achieve fame and wealth. As such, 'battle' was much esteemed throughout the middle ages and still figures prominently in theories of military revolutions due to its demonstration of capabilities and objectives.[(3)] Battles were widely believed to signify a natural and divine judgement of a ruler's worthiness.[(4)] Winning battles or at least leading armies gloriously was considered one of the king's primary duties.[(5)] A representation of the kingdom's total might, armies might be led into enemy lands for political, economic and military reasons, challenging rivals' ability to provide defence, and ultimately their authority and legitimacy to rule.

These time-honoured conventions survived the major transformations in late medieval warfare, but not entirely intact or without proviso. If not eclipsed, battle and the knight's preeminence were being engulfed by an 'industrializing' warfare as can be seen in three ways. Firstly, battle figured less prominently in the Crown's strategy as more attention and acclaim was given to siege warfare. The investments in fortifications, entrenchments and building in general transformed the landscape and influenced armies' movements and tactics, forcing commanders to seek out places 'undisturbed by rivers, fortifications or other obstructions'.[(6)]

Secondly, as the thirteenth and fourteenth centuries progressed, chivalry and the knight's preeminence was increasingly at variance to the realities of military life.[(7)] The higher frequency and greater scale of war required more efforts of transportation and protection to mobilize supplies and slow-moving equipment, and it involved more activities of guarding or even engaging in the Crown's increasingly substantial works. Consequently, armies were involved in more patrolling, protecting and raiding. They began to be composed of more diverse kinds of troops of varied occupations and social backgrounds, and they became more dependent on competent administrations for coordinating and sustaining multifaceted forces in simultaneous campaigns.

Thirdly, the risk combatants faced in battle may have been greater in the late middle ages. Maurice Keen portrayed the knight's risk in battle as being limited by three general conditions: the rarity of battle, the noble custom of ransoming prisoners, and the heavy armour for himself and steed.[(8)] The first two need not occupy us here save to note that in contrast to previous lulls, more battles were being fought in the thirteenth and fourteenth centuries drawing combatants from more elements of society.[(9)] During this spate of battles, infantries began to have remarkable successes over notable cavalries.[(10)] Due to these factors and others which undermined the aristocratic monopoly on war, the potential for safe capture may have waned.[(11)] The third factor in Keen's formula requires more thorough investigation, especially in the context of what is referred to here as the industrialization of field warfare. We will therefore explore how society's growing technical, economic and administrative capacities affected field warfare, first by revealing the Crown's efforts to deploy larger works and heavier firepower with expeditionary forces, and then through the symbiotic relationship of armaments and tactics which became a crucial element in army performanceto judge by the emphasis placed on arms requirements during the reorganization of military service.

The 'industrialized' landscape of war

By the beginning of the fourteenth century, English field warfare resembled the descriptions and advice found in Vegetius' fourth-century military handbook which had become enormously popular during the twelfth and thirteenth centuries.[(12)] At the peak of their power, ancient Roman armies waged an industrial warfare that integrated engineering and profuse crafts into the army's equipment, performance and consequently its strategies. Julius Caesar's bridgeworks to cross the Rhine, for example, are still inspiring. According to Vegetius the army should be self-sufficient as far as possible,possessing all the skills of a fortified city.[(13)] In many instances Vegetius praised industriousness for troops, stressing the need to recruit craftsmen and farmers who were accustomed to the work of the spade, carrying burdens and building.[(14)] Even the army's ministers, according to Vegetius, should be of the proper physique and disposition for war.[(15)] Vegetius clearly recognized the importance of the army's equipment: 'The legion owes its success to its arms and machines, as well as to the number and bravery of its soldiers' (every legion carried with it 55 carrobalistae or mounted springalds, and 10 onagers or small stone-throwing machines).[(16)] Besides large engines of war, Vegetius recommended the army carry small boats, timber and iron chains for making pontoon bridges and palisades, even describing how the bridges, troops and naval forces should be deployed together.[(17)] Wherever the army camped, it was to erect a timber fort reinforced with earthworks.[(18)]

Edward I is known to have owned a copy of *De re militari*, and it is tempting to see a correlation in England's military reforms from the use of engines in field warfare to the organization of the army.[(19)] Vegetius was adamant about the importance of craftsmen in the army. We know that the composition of the Crown's armies altered from the late thirteenth century in terms of its social character, its tactics and organization of units, but assessing subtle changes in the recruitment of certain occupations would prove more difficult. As Prestwich noted, Edward I's practice of impressing thousands of workmen had precedents; John conscripted 8000 labourers in 1212.[(20)] Edward I's larger, more ambitious works undertaken during the Welsh wars required thousands of woodsmen, carpenters, diggers and masons. These were often closely guarded by armed forces and navies when possible. At Rhuddlan, for example, specialist diggers were recruited from Holland for building the canal which finally engaged more than 1800 labourers.[(21)] In 1282, three dozen horse and 2600 archers were assigned to accompany and protect the thousand workmen restoring Hope castle.[(22)] Works undertaken in hostile territories sometimes led to combined duties. We have already mentioned the military experiences of several wardrobe officials and the king's armourers.[(23)] In 1355 Edward III had to restrain armourers from campaigning on the basis that their skills were needed in London.[(24)] Masons were equipped with arms when improving the fortifications in the vicinity of Calais after its capture by Edward III.[(25)] Garrisons, of course, included craftsmen and the record of their pay might allow some prosopography. For example, in 1298 Edinburgh's garrison included 5 carpenters, 3 smiths and 2 masons under Thomas Houghton's direction; in 1301 sixteen men in that garrison served dual roles as mason/crossbowmen, and archer/masons at Berwick in 1302 received 2d extra pay per day.[(26)] Given the predilection for drawing reinforcements for field armies from nearby garrisons, it is conceivable that the Crown's policy of maintaining such craftsmen in its garrisons gradually elevated field armies' engineering skills.

More definite information regarding the industrialization of English field warfare can be observed in the events of several campaigns. Rivers, bridges and fords often played key roles in campaigns especially when armies were ill-equipped to prepare a crossing. During 1264-1265, Edward I's army appears to have enjoyed a mastery in bridgeworks that Montfort lacked. Bridges were routinely destroyed to inhibit Montfort's movements, yet the same ploy failed on Edward I: royalist forces repaired a bridge over the Severn on their approach to Gloucester, and the following year several more were built in the pursuit of routed foes.[(27)] These bridges might well have been small, makeshift works. In 1282 a much more substantial bridge was begun on the Menai Strait when Edward ordered Luke de Tany, seneschal of Gascony, to build a pontoon bridge linking Anglesey to the mainland at Bangor. This was probably a substantial undertaking possibly employing large pile drivers like the one Thomas Houghton created in 1292.[(28)] Similar machines drove piles as defensive measures into the waters surrounding Bordeaux in 1324, and in the Thames in 1339. Portions of the bridge for Anglesey in 1282 proved too heavy to be transported by ships in the immediate vicinity, requiring special help from Chester. Manpower and materials were sent from Rhuddlan, and at one time some 200 carpenters were engaged in its construction, the works being guarded by the crews of forty pontoon boats, two galleys, a small number of horse and 350 archers. Although Edward's forces were technically capable of constructing such an impressive bridge, its incorporation into military practice was not as successful. Not long after the bridge's completion, a small English force rashly raided the mainland but their harassed return over the bridge caused it to collapse with horrific consequences.[(29)]

Edward I's war in Scotland required similar works. Stirling castle's control of a geographical bottleneck gave it prime strategic value in Anglo-Scottish conflicts. Understandably anxious about crossing of the Firth of Forth, in 1303 Edward I returned to the idea of a pontoon bridge. Having learned lessons from Bangor in 1282 and Stirling Bridge in 1297, Edward did not want to risk an unsupported crossing, and clearly something had failed in the design of the bridge in 1282. Richard the engineer was called to Windsor where plans for a new bridge were hatched. Bringing carpenters and smiths from Chester and Norfolk to King's Lynn, in January Richard began construction on three pontoon bridges furnished with pennons, bretaches, drawbridges, and two springalds. The king was kept informed of progress, and once completed in May, 32 ships transported its components along with 30 carpenters and 5 smiths to the site. By 20 June the pontoon was erected on the Forth, costing a total of £938 9s 6d.(30) The bridges remained in place until August when they were shipped to Berwick for storage, and in December the parts for the largest of the three accompanied forces to Blacknesse, but all the bridges were eventually recycled into the construction of a new peel at Selkirk two years later.(31) In fact by the end of Edward I's reign, numerous wooden peels, the medieval equivalent of the Roman fort, had been erected in the area as stop gap measures of defence.(32)

By Edward II's reign these techniques had been improved upon by greatly increasing the firepower attached to temporary field works and expeditionary forces. Edward II was clearly impressed with the performance of springalds, deploying them in larger groups. Orders for sets of them, such as the five requested of the Tower of London in 1313, were becoming more commonplace.(33) Preparations to defend Bordeaux from siege in 1324 and 1325 reveal a matrix of defences in and around the city trailing up the Garonne to prevent the French from conveying an attack or supplies by waterway. In November 1324 a pro-English engineer surveyed the Garonne up to St. Macaire and Langon and devised a plan to erect a pontoon bridge linking the two towns and blocking the river.(34) The defences were also designed to be aided by scores springalds- a great improvement in the few accompanying Edward I's pontoon bridges. In December 1324 an order was issued in England requiring 60 springalds and 7,000 quarrels to be made by 2 February for transport to Gascony. The order is precise about the size of quarrels: roughly half of the engines were to use bolts of three-quarters of a yard in length, and the others five-eights of a yard in length; York and Nottingham were to provide false cords and 8 gross of cords between them. The order was originally sent to Richard de Museley of Conisborough with the intention that the springalds would be constructed on two sites, but the scale of the task made that unfeasible, and the order was redistributed as contained in Table 2.1.(35) Robert Pippushall supervised the project which continued until May 1325.(36) Indentures were made for each subcontract.(37) Where possible timber was requested ex gratia: 120 oak and ash trees were requested from the abbots of Westmінister and Waltham.(38) Ships were requisitioned for their transport.(39) Of those regions which shipped their engines from Hull (York, Lincoln, Nottingham, Conisborough and Pontefract), only 24 of 34 springalds and 2700 of 4000 quarrels were ready by 2 April.(40) The Tower of London produced 18 of its allocated 20.(41) The remaining springalds were acquired in some other way and a total expense of £1,023 for construction and carriage of 60 springalds and 7000 quarrels to Gascony was submitted, with each springald costing on average about £5 to manufacture, and each quarrel 4d.(42) Several thousands of arrows and quarrels along with hundreds of crossbows and numerous polearms accompanied the shipment.(43)

Table 4.1 Allocation of Springald Construction (1324-1325)

	Springalds	Quarrels

Nottingham91000 York91000 Lincoln61000 Warwick6500 London202500 Conisborough4300 Pontefract6700

The trend towards engineering and heavy firepower in the field increased in Edward III=s reign. Bridging rivers was a constant concern for Edward III when campaigning in northern France. In a what was becoming a common ploy, Phillip VI attempted to trap Edward III's army at Antwerp in 1338 by destroying all nearby bridges.(44) The Crecy campaign of 1346 consisted of an perpetual series of attempts to cross rivers during which no less than two bridges were rebuilt virtually overnight by the English army; their French opponents were impressed even though they were equally adept at fortifying rivers with pontoon bridges.(45)

Edward III's reign witnessed a more novel development in the concentration of firepower afforded by the implementation of firearms into its field tactics. Very little is known about firearms' early development in England until the 1340s when a profusion of evidence appears. In 1339 a single gun was listed among the stores in London's guildhall.(46) Tout's meticulous search of exchequer records revealed that many small guns and large amounts of saltpetre, sulphur and charcoal were being prepared in 1345. That year ,128 19s 3d was spent at the Tower of London on manufacturing 100 lesser guns (*minutis ingeniis vocatis ribaldis*) and 1,000 iron lances for their ammunition. The 'ribaldquins' were fixed to a cart, and several sources place them at the battle of Crecy. The evidence for firearms advent elsewhere in Europe begins in the second and third decades of the fourteenth century. In 1313 part of Ghent=s military stores appears to have included cannon and gunpowder.(47) Cannon were almost certainly used at Metz in 1324.(48) Though the Milemete treatise of c. 1326 provides one of the earliest illustrations of guns in Europe, firearms do not appear to have been part of England's arsenal at that
(49)

time.

Edward III's heavy reliance on springalds in the late 1330s suggests that England's experiments with firearms occurred abruptly in the decade or even just years before Crecy. In June 1335 people near England's southern coast anxiously feared a Franco-Scottish attack which was gathering in Normandy, and by July Edward III's spies confirmed imminent invasion.(50) For defending the coast Edward ordered the construction of 40 crossbows, a great engine and 100 springalds.(51) The raids indeed came and although the damage was relatively slight, the implications of a Franco-Scottish alliance were much more discomforting. When more raids threatened the following summer, the construction of 30 springalds was contracted with Nicholas the engineer.(52) Such large orders for springalds as late as 1336 suggests that they were still the Crown's preferred low-trajectory artillery.

Early firearms seem have been employed for psychological effects as much as their physical effectiveness, but the promise inherent in these devices, their very cheap cost of manufacture compared to other engines, and their prestige value encouraged investment.(53) Discounting any differences in rates of fire between guns and springalds, the compact formation possible with guns must have represented an astonishing increase in the concentration of firepower. The promise of more powerful and manoeuvrable weapons at less cost provided another incentive for firearms development. By the 1340s the manufacture of ribalds cost as little as one-fifth as springalds. Later in the fourteenth century, the Crown paid 2-4d per pound for the manufacture of cannon weighing only several hundred pounds, which meant that a 400-pound cannon cost on average £5 or about the same as a springald and far less than comparable mechanical artillery. These differences must be set against the cost of operating the machines, but the high cost of gunpowder before the 1380s might have been matched by the high maintenance costs of mechanical engines and was certainly surpassed by the wages for traction trebuchets. The adoption of firearms was also aided by several customs initiated to accommodate conventional weapons. Administrations were prepared for the logistics of larger guns and cannon due to trebuchets, and the manufacture of both darts and stones for ammunition had been subjected to standardization since the early thirteenth century. The deployment and tactics of low-trajectory weapons in the field had been developed for springalds and heavy crossbows, as did construction techniques in that attaching the firearm to its stock followed techniques developed for crossbows and polearms.(54) The relative manoeuvrability of guns and cannons led to their use at sea in a way that was impossible for springalds or other engines. Efforts to incorporate guns into defences and navies outpaced field warfare during the fourteenth century, but firearms nonetheless became a familiar feature in field warfare almost as quickly: firearms have even been credited with playing a pivotal role in battles by the late fourteenth century.(55)

Arms, armour and tactics

Under ideal circumstances, a society's armaments and tactics evolved hand in hand. Ancient Rome=s arms >factories=, for example, were instructed to make several minor modifications to infantry helmets when the crouched position became the preferred method of facing cavalry charges.(56) Medieval England's infrastructure was far less sophisticated nor capable of such control of arms manufacturing, but detailed attempts were made in the Crown's arms requirements which addressed the need for better arms and armours. We have already reviewed the Crown's efforts to make arms available and promote the careers of specialist craftsmen. The Crown had considerable problems convincing society to invest in better arms despite the fact that it was in society's best interest. Although arms requirements provide a convenient tariff and fairly standardized terminology, they were not an accurate reflection of ownership in society and they certainly do not convey the complexities of arms evolution. The military necessity for more and better armour in English armies arose in at least three ways one of which we have already discussed, ie the trend towards a more >static= warfare which required heavy infantry. The other two ways will now occupy us, namely, the generic dynamics between arms and armours during the period, and the Crown=s choice to rely on infantry formations in its battlefield tactics.

The generic dynamics which contributed to the widespread adoption of plate armours during the fourteenth century are easily summarized. Obviously, a distinction needs to be made between the need or availability of armours and their widespread adoption. Some 'plate armours' were available throughout the middle ages as many kinds of helmet demonstrate. Charlemagne=s biographer surely exaggerated in claiming that his soldiers clad their chests, shoulders and thighs in iron, wore iron helmets, gloves and greaves and carried iron shields, but the point remains that these items were conceivable and desirable as early as the ninth century.(57) The adoption of 'plate armours= from the late twelfth century was actually a very subtle process where existing garments began to incorporate harder materials such as bone, baleyn, cuir boulli, iron, steel etc. The earliest consistent evidence of 'plate armours' in England occurs during the late twelfth and early thirteenth century when iron leg defences (caligulis ferreis, greaves and cuisses) were recorded in the pipe rolls among expenses for other armours, (58) notably mail barding which was adopted at the same time. Iron boots, one can reasonably assume, meant leather boots reinforced with iron, and all of these armours appear to have been intended for cavalry whose legs would have been very much exposed to infantry attacks. The adoption of horse armour and leg defences late in the twelfth century begs a number of questions about styles of cavalry warfare beforehand. Had high costs hindered the widespread adoption of these armours and mail barding in particular? Were calvaries unaccustomed to much melée before the couched-lance charge became commonplace?

Europe's seemingly rapid adoption of other armours incorporating iron and steel between c. 1275 and 1350, notably the coat of plates and more articulate armours for the legs and arms, has captured historians' attention and prompted a number of explanations, especially improved hand weapons,(59) or the penetrating power of bows.(60) More simply, others suggest these plate armours were adopted as a natural desire for protection rather than responding to any specific cause.(61) As will be seen in Chapter Six, decreasing costs of materials and production costs may have been a major factor in the adoption of iron and steel into more armours. A general need for improved armours can also be posited. Both arrows/quarrels and bladed weapons benefited from a wider availability of steel in the thirteenth century, both in terms of its international supply and lower costs.(62) A steel is much harder than most irons, giving it an advantage in piercing or cutting. Whereas the techniques of incorporating steel into weapons had been practised for centuries or even millennia, mail was made from iron (drawn into wire, stamped or cut) which may or may not have been heat treated afterwards to improve its hardness. While techniques for incorporating steel into weapons had long been practised, techniques for fashioning iron and steel into relatively thin plates capable of withstanding violent blows continued to trouble craftsmen into the fifteenth century.(63) Whereas the Crown's preference for steel arrows and quarrels can be seen as early as the 1220s, the prescription of steel armours did not begin until Edward II's reign.(64) During this interim, plate armours made from durable materials would have provided sound additions to mail before becoming sufficiently sound in their own right to replace mail altogether as a lighter and more protective armour from the mid fourteenth century.

The need for better armours throughout the entire English army became manifest as the crown sought to rely on infantry formations in its battles. Vegetius' advised that infantry including bowmen should be well armed in cuirass and helmet even when travelling so as not to be caught by surprise. Men fight better or stand like a wall, Vegetius informed us, when their chests, necks and heads are protected; when unprotected troops are likely to flee.(65) The fifteenth-century translation goes further: it suggests breastplates, basinets, swords, bows and arrows.(66) Keen also reckoned that the knight=s preeminence on the battlefield was largely due to his heavy armour which provided him with a physical and psychological edge in battle. Obviously, the physical benefits derived from better armours would have been far from negligible in combat, especially in the lengthy and lethal conflicts of the Crown's style of infantry warfare. A well equipped force might also gain a psychological benefit such as courage. Courage, long equated with the cardinal virtue fortitude, was often said to be a most important element of warfare and battles particularly. Perhaps in a reinforcement of the chivalrous class, medieval writers often proclaimed that a few courageous men were more valuable than large, uninspired armies.(67)

Although Edward I initiated a trend towards recruiting massive infantries no significant advancement was made in their arms requirements. Edward I raised massive infantries of mostly unarmoured archers, paying little or no attention to their requirements. Perhaps Edward was wary of arming the thousands of Welsh archers and slingers, did not perceive any great need for it, or realized that he lacked the authority to impose any arms requirements. One request sought to raise as many as 60,000 troops, although nothing of this size had been deployed in the West since the Roman imperial armies of the fourth or fifth century.(68) The request may not have been an arbitrary figure, as that was the number of 'knights' (in the sense of fighting men) owing service in the reign of William the Conqueror as recorded by Orderic Vitallis.(69) Edward I was in fact successful in raising armies of nearly 30,000, a 'very significant increase' over the Crown's previous armies.(70) Edward I initiated experiments of supplementing perhaps three to four thousand cavalry with mostly Welsh infantries as large as 15,000 in 1277, around 25,000 in 1294, 1296 and 1298.(71) Whether or not these Welshmen brought the longbow into English service remains unknown, but in either case these troops were under no arms requirements and probably remained unarmoured. In the course of these campaigns the Crown began to learn the value of archers and the strong defensive possibilities of infantry, albeit most often demonstrated by Scottish forces. Although the archers proved their worth at Falkirk (1298) in breaking up the Scottish schiltroms with their missiles, they were not fully integrated into more reliable defensive formations where heavier armours would have been needed most.(72)

Desperate politically and financially, Edward II's sought to raise heavy infantries through arms requirements and provision. As early as 1310 the Irish foot levies were required to have hauberks. The occasional muster during Edward I=s reign revealed that some crossbowmen were armed with aketons, basinets, crossbows, swords and knives.(73) Under Edward II this practice of enlisting crossbowmen and archers with substantial armours becomes common. In 1310 London provided 100 armoured crossbowmen for the campaign in Scotland.(74) In 1314, crossbowmen from London were equipped in aketons, mail and (75) basinets at the Crown=s expense. In practice, the deployment of these troops was less than satisfactory. Lack of leadership at the highest levels inevitably induced disorder and disagreement, leading to impromptu and vain attempts among the nobility in several instances to demonstrate their valour and worth as cavalry. At Loudon Hill (1307) and Bannockburn (1314), English cavalry made rash and unsuccessful charges against Scottish lines of well-equipped infantry. At Bannockburn, the lack of integration of the English archers left them unprotected and they were soon scattered from the field by a small force of Scottish cavalry.(76) In both cases the Scots gained an advantage by choosing their formation carefully according to topography and further preparing the field with pits. Following the defeat at Bannockburn, Edward II redoubled efforts to obtain better equipped infantry. In November 1314 orders went out to York, Lincoln, Northampton and London to provide a total of 400 crossbowmen armed with aketons, coats of plates, and basinets.(77) London actually produced 120 crossbowmen armed at a cost of ,178 3s 4d, nearly 30s per man.(78) York provided 20 crossbowmen who were equipped for the sum of ,33.(79) Thomas Chedeworth, chamberlain of Caernarvon, was also ordered to buy armour for 20 footmen and 100 crossbowmen at London.(80) In 1316 and again in 1318, infantry from Lincoln and Cambridge were armed with aketons, basinets and swords, and a few obtained hauberks.(81) Progressive requests were continued in 1319 with the requirement of basinets and gauntlets extending all the way down to the ,2 class, the traditional recruiting pool for archers.(82) In 1322 some 12,000 armoured infantry were raised successfully but badly managed in the field the campaign in Scotland floundered.(83) Rather than marching in their armour as suggested by Vegetius, carriage was provided for some of these troops' arms. The 120 crossbowmen raised in London had their equipment packed in cases and tuns and carried to Berwick in 3 carts each drawn by 4 horses.(84)

Following the battle of Boroughbridge (1322), both Edward II=s confidence in infantry and his authority to request more from the communities was strengthened. Though archers played no great role there, effectiveness of well armed infantry was made more clear to England's military elite.(85) The purchase of equipment by Thomas Chederworth to raise 500 armed men in Surrey and Sussex in 1322 resulted in purchases of 300 sets of aketons, basinets and plate gauntlets, plus another 100 basinets.(86) In 1323, 454 troops arrayed in Norfolk were armed in aketons, basinets, iron gauntlets and swords, and the justiciar of Ireland contributed 1000 hobelars and 600 infantry armed similarly.(87) The request eventually abandoned in 1324 made Edward II=s intentions clear: to summon 19,200 infantry from shire levies, of which 4,800 were armed with either a hauberk, aketon or coat of plates, basinets and steel gauntlets. These were superior armaments: by this time the aketon was virtually equated with the coat of plates and the specification of steel gauntlets indicating that armour's increasing importance.

Under the rule of Queen Isabella and Roger Mortimer, Edward III=s reign began with an inglorious campaign against the elusive Scots who were adept at avoiding battle. The campaign is remarkable for the orders that everyone in the English army should be prepared to fight on foot, and a warning that a charge contrary to orders was punishable by death.(88) At Dupplin Moor (1332) and Halidon Hill (1333) the need for well-armoured infantry became apparent in these particularly intense and protracted engagements. The Chronicle of Lanercost, which provides one of the best accounts for both of these battles, tells us that at Dupplin Moor the arrows from the English army blinded the Scots due to their unvisorsed helmets.(89) Again at Halidon Hill the Crown=s archers and infantry were somehow intermingled so that the archers could not be cut-off from the rest of the army and driven from the field, and their arrows inflicted heavy injuries against the Scot=s uphill charges.(90)

Following these campaigns we see a determined effort to maximize the recruitment base for well armed hobelars/serjeants and mounted archers armed in aketons and basinets. Though society's repeated appeal to the statute of Winchester prevented the enforcement of these assessments on a national scale, the Crown was able to mobilize an almost constant rota of forces with detailed arms requirements, allowing for greater specialisation among troops. Edward III favoured modestly armed archers, usually assessing the five-pound tenant to horse and aketon and basinet, while heavier arms requirements fell to the ten-pound serjeant and upwards to the men-at-arms assessed variously between £15-30. As Powicke noted, during this recruitment the term >hobelar= began to be used interchangeably with serjeant or valet, and their already substantial requirements of the statute of Winchester were improved upon.(91) In 1332 a select group of 'hobelars' from Lancashire had already been asked to serve with iron gauntlets in addition to their hauberk and basinet, and in 1335 a ,15 class was ordered to serve mounted with an aketon or coat of plates, basinet or palet, gorget, iron gauntlets, sword, knife and lance.(92) Some infantry classes were also assessed to more armours. During the late 1330s foot archers drawn from a ,2 to ,5 class were required to have an aketon and a burnished, meaning steel, basinet.(93) Later in 1345, a ,5 class of archers was required to serve mounted, and stiffer arms requirements were placed on a £10 class.(94) Again some leeway was afforded in assessments, including allowing a combination of troops to fulfil obligations.

Even though Edward III led armies of around 10,000 combatants into the centre of the French domain, the tactics hammered out between 1314 and 1333 made the much more economical chevauchée forces a potent and viable alternative to large armies. The exact arrangements of the forces that brought famous victories remains debatable, but our conception of a thorough intermingling of archers and dismounted men-at-arms is reinforced by the compositions of mixed retinues. From the 1350s, the Crown sought to deploy retinues containing nearly an equal ratio of archers to men-at-arms, coming to favour archers two or three to one man-at-arms by the century's close.[95] If the archers were deployed to form distinct groups separate from dismounted men-at-arms either on their flanks or elsewhere, there would have been little incentive to recruit them together with men-at-arms and hobelars and even less reason to improve their armours, as without support from heavier infantry they risked quick dispersal by enemy forces as happened numerous times during Edward I and Edward II's reigns. There were numerous benefits for deploying as a unit men who knew each other and possibly had trained together: loyalty, familiarity, trustworthiness, common cause, peer pressure and pride would all work to their advantage. Due to tactics of taking a defensive formation, these archers would need to be able to withstand a range of missile assaults, and could not escape any melée which followed a cavalry charge into the compact English formations. Archers would need sufficient equipment namely some helm such as the basinet which afforded superior protection but allowed mobility and visibility, preferably a light but effective body armour and some hand weapons. Since the proportion of archers to men-at-arms in armies rose later in the fourteenth century, it suggests that these 'archers' would be expected to remain with the men-at-arms when receiving cavalry charges. In this case the need to equip the archers had become virtually as important as the traditionally chivalrous classes: anything less would have seriously weakened the defensive quality of the army. If the aketon is equated with the coat of plates then archers only lacked the men-at-arms and hobelars' gauntlets. Though not required to serve in aventails, vambraces, rerebraces etc, one wonders how often archers in English armies, men drawn mostly from gentry classes who could afford such armours, wore them because of their tactics and the realities of hard fought engagements.

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Despite the fluctuation of chivalric enthusiasm during this period, battle still possessed great allure which encouraged its prosecution and attracted participants. As with many elements in the late medieval military revolution, trends in tactics and the deployment of various kinds of troops predate the thirteenth and fourteenth centuries. However, during the thirteenth and fourteenth centuries a number of factors worked to alter perceptions of battle and its dynamics. We have already discussed the ascendancy of siege warfare in the Crown's strategy. Battle was also enveloped by the emergence of a much broader-based field warfare over the course of the thirteenth and fourteenth centuries which both arose from and necessitated a more 'scientific' approach. Much logical analysis, reason and forethought was needed to transform the army: in the politics and economics of its recruitment and arms requirements, in its regimentation, composition, and tactics, and in meeting logistical needs. By the fourteenth century due to these reforms we see more diverse 'national' armies and greater diversity of troops within armies. Unlike the bipolar character of Edward I=s armies of elite cavalry and poor quality infantry, Edward III=s armies incorporated many kinds of troops: hobelars, heavy infantry, archers foot and mounted, and heavy cavalry all of which were expected to be well armed. English forces became more specialized, relying heavily on integrated techniques and more extensive equipment. English armies also became multifaceted- in the multiplication of duties to include more guard, transport and marine activities, and in combining military service with other labours and craft-work. All of these factors worked to reinforce the conception of an army as a self-sufficient city or organic whole, thus consciously inculcating technological elements into perceptions of armies and battles.

Battles of the fourteenth century were in themselves distinctive in at least three ways: in the number of them fought within the space of 60 years, in infantry's consistent and widespread effectiveness, and in the immense influence society's infrastructure and technical congruence imparted on the quality of armies. While the first two of these characteristics have long been recognised as constituting a turning point in medieval warfare, the last has gone relatively unnoticed even though it had the most far-reaching implications. The unusually high incidence of battle was in part brought about by the period's wider developments. The growing populations, strategic points and expanding economic interests heightened defensive responsibilities, and when combined with societies' abilities to exert political influence on their governments worked to compel many rulers into accepting battle even when not trapped in the field. The industrializing landscape and mode of warfare also seems to have combined with the growing advantages of field warfare to produce the unusually high incidence of battles. While not all armies desired the risky engagement of battle, they found their movements increasingly hindered by the prevalence of fortifications, entrenchments, and other ad hoc works. While the industrializing landscape constrained manoeuvring, the possession of adequate skills improved armies' chances to overcome such obstacles in either escaping or pursuing their foes.

Against this backdrop, we may say that just as military strategies underwent an intense development during the late middle ages, so too did the awareness of tactical possibilities. The relatively fluid transmission of tactical techniques and ideologies as opposed to methods of siege warfare meant that emulation of battle tactics occurred much more easily and quickly than possible with siege warfare, leading to more intense and rapid-paced innovations in field warfare as seen in personal armaments and tactics. Unlike sieges, each battle was influenced much more heavily by local circumstances and opposing forces' characteristics, removing to some degree the great advantages a strong state might hold over a lesser one. The logistical and technical difficulties of mounting a siege, for instance, can also be juxtaposed against those involved in fielding an army and for these reasons outmatched or backwards societies may have preferred battle rather than in siege warfare. The precise development of English tactics and their relationship to personal armaments is obscured by several factors, not the least of which is almost total reliance on chroniclers for such evidence- historians' disagreement over the intermingling of archers and men-at-arms is a paramount example. Battles were, after all, emotive and disturbing circumstances which to some extent defy rational treatment, and the deployment and actions of troops may or may not have conformed to what was planned. In this respect, predefined tactics and the regimentation provided by reorganisation of the army into more coherent units may have alleviated some of the confusion inherent to battle.

That the Crown's evolution of tactics required more armours of its combatants is clear. Even though Edward I sought large (c. 20,000) infantries, efforts to improve their equipment only began during Edward II's reign especially following Bannockburn, but such slow-moving forces could not keep pace with lighter elusive armies. During these years, the practice of deploying archers in tandem with more substantially armed infantry was worked out, and glimpses of techniques can be gained such as the instructions before the battles of Orewin Bridge and Dupplin Moor to place one's body weight on the lance when receiving cavalry charges. However, while efforts were first made to limit baggage trains which may have carried these infantries heavy armours, the emergence of wholly mounted forces during Edward III's reign provided mobility and increased flexibility. By the mid fourteenth century, equal ratios of mounted archers and men-at-arms were recruited for chevauchée forces, all of whom dismounted to fight. This powerful defensive formation allowed English armies to fight on its terms, preparing the battlefield with rows of ditches, stakes, caltrops or other diversionary ploys. The discovery of this tactical method ignited a strategical solution for an outmatched and overstretched England in the raiding chevauchée forces which saved money and manpower, lessened logistics and could meet the Crown's arms requirements. While maintaining previous administrative strengths such as the nobility=s close participation and a strong household element, the army changed considerably in its outward appearance and function, not the least of which was the quality and quantity of their arms. We have noted the physical and psychological benefits of heavy armour as proposed by Keen which would have been far from negligible in the lengthy and lethal conflicts of the Crown's style of infantry warfare. Thirdly, as Vegetius noted, while fighting on foot in heavy armour, flight becomes much more difficult especially given the English practice of deploying in tighter quarters, viz. next to woods, rivers, marshes and on hills, leaving little option for English armies but to fight determinedly. In addition to those theoretical inducements we can also note more direct evidence of a real or at least perceived need for superior arms as the thirteenth and fourteenth centuries progressed: the intense development and proliferation of armours, the preference for iron and especially steel in their construction, and the Crown's efforts to implement better armaments into its armies despite the political repercussions and costs. Although the evolution of armaments was undoubtedly related to fighting styles, many other factors were also involved, such as cost, knowledge of manufacturing techniques, and even fashion. Greater diversity in arms would also have been fostered by the condition that most combatants in English armies providing their own arms, a great diversity in their arms was probably present. Many changes in armaments depended on exchange between craftsmen and combatants- a condition which no doubt improved as more armourers and craftsmen accompanied or even served in armies. We will now examine the prerequisite developments in the iron industry which allowed the industrialization of medieval field warfare to assess whether or not the Crown's efforts to raise arms requirements and alter its tactics coincided with any changes in the arms industries.

NOTES

1. *The Earliest English Translation of Vegetius'* De Re Militari, G. Lester, ed. (Heidelberg, 1988), I.7; p. 55 [hereafter *De Re Militari*].

2. On this point see K. DeVries, *Infantry Warfare in the Early Fourteenth Century. Discipline, Tactics, and Technology* (Woodbridge, 1996), pp. 1-4; M. Bennet, 'The Development of Battle Tactics in the Hundred Years War', *Arms, Armies and Fortifications in the Hundred Years War*, A. Curry and M. Hughes, eds. (Woodbridge, 1994), pp. 1-5.

3. A recent attempt to place 'battle' within the context of the Crown's overall strategy during the peak of English power is Rogers, *War: Cruel and Sharp.*

4. On the former theme, K. DeVries, 'God and Defeat in Medieval Warfare: Some Preliminary Thoughts', *The Circle of War in the Middle Ages*, D. Kagay and L. Villalon, eds. (Woodbridge, 1999), pp. 89-99.

5. Kaeuper, *War, Justice and Public Order*. For an interesting discussion of the martial pedigree of the aristocracy, Strickland, *War and Chivalry*, pp. 142-9.

6. As requested by the French in 1339, Sumption, *Trial by Battle*, p. 285; Rogers, *War Cruel and Sharp*, pp. 168-9; for an overview of fortifications and field warfare, Contamine, *War in the Middle Ages*, pp. 220-2.

7. The knight's supremacy in war has become a matter of some debate, M. Bennet, 'The Myth of the Military Supremacy of Knightly Cavalry', *Armies, Chivalry and Warfare*, pp. 304-16.

8. Keen, *Chivalry*, pp. 220-24.

9. DeVries, *Infantry Warfare*;Contamine, *War in the Middle Ages*, p. 66.

10. For the 'infantry revolution', Oman, *A History of the Art of War*, ii; Verbruggen, *The Art of Warfare in Europe*, pp. 111ff; DeVries, *Infantry Warfare*; Rogers, 'The Military Revolutions of the Hundred Years War'.

11. Infantry warfare left little room for consideration of formal or sentimental values, and common armies were not obliged to take prisoners, Keen, *Chivalry*, p. 221. Also, the new warfare waged under the banner of statehood gave greater emphasis to treason, leading to the imposition of harsh conventions over older, more personal chivalric customs, M. Strickland, 'A Law of Arms or a Law of Treason? Conduct in War on Edward I's Campaigns in Scotland, 1296-1307', *Violence in Medieval Society*, R. Kaeuper, ed.(Woodbridge, 2000), pp. 39-78.

12. C. Shrader, 'A Handlist of Extant Manuscripts Containing the *De Re Militari* of Flavius Vegetius Renatus', *Scriptorium* 33 (1979), pp. 282; C. Allmand, 'The Fifteenth-Century English Version of Vegetius' De Re Militari', *Armies, Chivalry and Warfare*, pp. 30-40.

13. *De Re Militari*, I.7, p. 55-6; II.22, p.98; II.23, p. 100; III.10, p. 129; II.11, pp. 86-7.

14. Ibid, I.1-2.

15. Ibid, II.19

16. Ibid, II.20

17. Ibid, II.24, p. 101; III.7, p. 120-1.

18. *De Re Militari*, I.21-25, pp.69-72.

19. Prestwich, *Edward I*, pp. 123-4.

20. Prestwich, *Edward I*, p. 228.

21. Taylor, *Welsh Castles of Edward I*, pp. 26-34; Morris, *Welsh Wars*, pp. 129 ff.

22. Morris, *Welsh Wars*, p. 161.

23. Above, Chapter Two.

24. Cal. Letter-books, G, p. 44.

25. Colvin, *History of King's Works*, i, p. 428.

26. Colvin, *History of King's Works*, i, p. 409; PRO London, E 101/9/25, Supplies for Scotland, 29 Edward I.

27. Prestwich, *Edward I*, pp. 42-55.

28. For Thomas Houghton's pile driver, Colvin, *History of King's Works*, i, p. 217.

29. Prestwich, *Edward I*, pp. 190-2; Morris, *Welsh Wars*, pp. 176-80.

30. CDS, ii, no. 1375; Prestwich, *Edward I*, p. 499.

31. Colvin, *History of the King's Works*, i, pp. 416-8.

32. Prestwich, *Edward I*, p. 498.

33. Colvin, *History of the King's Works*, ii, pp. 598, 724 n. 1.

34. Vale, *The Origins of the Hundred Years War*, p. 239.

35. CCR 1323-1327, pp. 246-8, 262.

36. E 101/165/1, Account of Adam de Lymbergh, appointed to superintend Robert de Pippeshull in providing springalds and other arms in Aquitaine, 18 Edward II.

37. London, PRO E 101/16/34, Particulars of customs collectors at Hull for springalds and arms, 18 Edward II.

38. CCR 1323-1327, p. 248; Vale, *Origins of the Hundred Years War*, p. 237.

39. CCR 1323-1327, pp. 248, 302.

40. London, PRO E 101/16/34, Particulars of customs collectors at Hull for springalds and arms 18 Edward II.

41. E 101/165/1, Account of Adam de Lymbergh, appointed to superintend Robert de Pippeshull in providing springalds and other arms in Aquitaine, 18 Edward II.

42. PRO, London, E 101/17/39, Military operations in Gascony, temp. Edward II.

43. PRO, London, E 101/165/1, Account of Adam de Lymbergh, appointed to superintend Robert de Pippeshull in providing springalds and other arms in Aquitaine, 18 Edward II.

44. Sumption, *Trial by Battle*, p. 368.

45. Ibid, pp. 504, 506, 523-4; for French bridgeworks, p. 256.

46. Riley, *Memorials of London*, pp. 206-7.

47. Bradbury, *The Medieval Siege*, p. 284.

48. Contamine, *War in the Middle Ages*, p. 139.

49. *The Treatise of Walter de Milemete De nobilitatibus, sapientiis, et prudentiis regum*, M.R. James, ed. (Oxford, 1913).

50. Ibid, p. 147.

51. CCR 1339-1341, p. 518.

52. For the springalds, CCR 1333-1337*,* p. 724; otherwise Sumption, *Trial by Battle,* pp. 154-67.

53. M. Vale, >New Techniques and Old Ideals: The Impact of Artillery on War and Chivalry at the End of the Hundred Years War=, *War, Literature and Politics in the Late Middle Ages*, C.T. Allmand, ed. (Liverpool, 1976), pp. 57-62.

54. Tout, 'Firearms in England'.

55. K. DeVries, >The Forgotten Battle of Bevershoutsveld, May 3, 1382: Technological Innovation and Military Significance=, *Armies, Chivalry and Warfare*, M. Strickland, ed. (Stamford, 1998), pp. 280-94; Contamine *War in the Middle Ages*, pp. 137-50; Hall, *Weapons and Warfare*, pp. 45-55.

56. J. Eadie, 'The Development of Roman Mailed Cavalry', *Journal of Roman Studies* 57 (1967), pp. 161-73.

57. Before the battle of Pavia (774), as quoted in Gies, *Chathedral, Forge and Waterwheel*, p. 57.

58. E.g., Pipe Roll 30 Henry II, p. 135; Pipe Roll 32 Henry II, p. 199; Pipe Roll 3 Henry III, pp.80, 195; see also below, chapter 6.

59. Ffoulkes, *Armourer and His Craft,* p. 1; C. Blair, *European Armour, circa 1066 to circa 1700* (London, 1958), pp. 38-9, 54-5.

60. C. Allmand, *The Hundred Years War. England and France at War, c.1300-1450* (Cambridge, 1989), p. 61; DeVries, *Medieval Military Technology,* p. 76; Prestwich, *The Three Edwards*, pp. 59, 70; T. Richardson, 'The Introduction of Plate Armour in Medieval Europe', *Royal Armouries Yearbook* 2 (1997), pp. 40-5; C. Singer et al., eds., *A History of Technology*, vol. ii: *The Mediterranean Civilisations and the Middle Ages, c. 700 B.C. to c. A.D. 1500* (London, 1957), p. 721; Strayer, *Dictionary of the Middle Ages,* i, pp. 525, 532.

61. Strickland, *War and Chivalry*, p. 170f.

62. R.F. Tylecote, *The Early History of Metallurgy in Europe* (London, 1987), p. 269, 278-9; Idem, >The Medieval Smith and His Methods', *Medieval Industry*, D. Crossley, ed. (London, 1981), p. 48; Schubert, *History of the British Iron and Steel Industry*, p. 117.

63. A. Williams' has collated much of the evidence available from the few artefacts surviving: A. Williams, 'Slag Inclusions in Armour', *Historical Metallurgy* 24 (1991), pp. 69-80; idem, 'The Blast Furnace and Mass Production of Armour Plate', *History of Technology* 16 (1994), 98-138; idem, 'Four Helms of the Fourteenth Century Compared', *Journal of the Arms and Armour Society* 10.3 (June, 1981), pp. 80-4, 89-96, 101-2; idem, 'Medieval Metalworking: Armour Plate and the Advance of Metallurgy', *Chartered Mechanical Engineer* (September, 1978), pp. 109-14; idem, 'Medieval Armour and the Mass Production of Iron', *Proceedings from the Conference on Medieval Europe* (York, 1992), pp. 191-6.

64. For quarrels with steel heads, CLR 1226-1240, p. 31.

65. De Re Militari, I.20.

66. De Re Militari, pp. 67, 69, 91.

67. Contamine, *War in the Middle Ages*, pp. 250-9.

68. Prestwich, *War, Politics and Finance*, p. 94.

69. *The Gesta Normannorum ducum of William of Jumieges, Orderic Vitalis, and Robert of Torigni*, E.M. van Houts, ed. and tr. (Oxford, 1995), ii, p. 168.

70. Prestwich, *Armies and Warfare in the Middle Ages*, p. 336.

71. Prestwich, *Edward I*, p. 180.

72. Morris, *Welsh Wars*, pp. 246-8, discusses early English attempts to integrate archers and men-at-arms.

73. PRO London, E 101/13/39, Muster of London, temp. Edward I.

74. McNamee, *Wars of the Bruces*, p. 49.

75. Riley, *Memorials of London*, p. 114-5.

76. Bannockburn received substantial attention from chroniclers. One of the fullest accounts was Thomas Gray's *Scalachronica*, J. Stevenson, ed. (Edinburgh, 1836), pp. 140-3; otherwise see Barrow, *Robert Bruce*, pp. 203-32.

77. The distribution was York (40), Northampton (20), Lincoln (40) and London (300), CCR 1313-1318, pp. 122, 201.

78. Riley, *Memorials of London*, pp. 114-5.

79. CDS, iii, no. 401.

80. CCR 1313-1318, p. 147

81. PRO, London, E 101/15/10, Inquisitions for supplies for war in Scotland, 9 & 11 Edward II.

82. Powicke, >Edward II=, pp. 100-3.

83. Powicke, *Military Obligations*, pp. 152-3.

84. Riley, *Memorials of London*, pp. 114-5.

85. *Chronicon de Lanercost*, J. Stevenson, ed. (Edinburgh, 1839), pp. 242-4, and *Vita Edwardi Secundi*, N. Denolm Young, ed. and tr. (London, 1957), pp. 121-4 are the two principle accounts of the battle. Otherwise see J.E. Morris, >Mounted Infantry in Mediaeval Warfare=, TRHS 8, 3rd series (1914), pp. 86-91.

86. Cal. Letter-books, E, pp. 170-1. Assuming this produced a levy of only 300, the average cost per person was 15s though only armours had been provided.

87. PRO London, E 101/16/15, Names of Norfolk men raised for war in Scotland, 16 Edward II; E 101/16/16, Accounts of expenses of Irish soldiers for war in Scotland, 16 Edward II.

88. Prestwich, *Armies and Warfare in the Middle Ages*, p. 318.

89. One of the best contemporary accounts of Dupplin Moor is the *Chronicon de Lanercost*, p. 268; see also *Anonimalle Chronicle*, J. Taylor and W. Childs, eds and trs. (Leeds, 1991), pp. 148-51; otherwise R. Nicholson, *Edward III and the Scots. The Formative Years of a Military Career, 1327-1335* (London, 1965), pp. 84-90.

90. The *Lanercost Chronicle*, p. 273-4; *Chronicles of the Reigns of Edward I and Edward II*, W. Stubbs, ed. (RS, 1883), ii, p. 116; see also, Nicholson, *Edward III and the Scots*, pp. 132-8.

91. Powicke, *Military Obligations*, pp. 148-9.

92. Ibid, p. 192.

93. Ibid, pp. 190, 192-3.

94. Ibid, p. 192.

95. Ayton, >English Armies=, p. 31.

CHAPTER FIVE

Iron: Supply and Demand

'In many ways iron is more useful than gold'.
Bartholomew of England, c.1260[(1)]

In exclaiming iron's importance, Bartholomew was drawing on a long tradition. Quoting Isidore of Seville, Bartholomew informs us that iron's name comes from *ferrendum*, that which beats and smites all other metals into submission.[(2)] In an eqully forthright manner, iron's pre-eminence among industries was voiced in an eleventh-century poem when the smith claimed that all the other crafts ranked below his because they depended on him to provide them with tools. The other craftsmen replied impishly that the ploughman's bread and ale were dearer to their hearts![(3)]

A cornerstone of industrialization and militarization, the use of iron has been credited with a pivotal role in many periods of history.[(4)] Regardless of whether a chronicler was highlighting the power of Charlemagne's army, a crusading army, or fourteenth-century English armies, the possession of an abundance of iron arms was a preferred topos.[(5)] Although the availability of iron is recognized as largely determining the availability of arms in pre-modern societies, the military and political repercussions are the more debated. W. McNeil suggests that the discovery of iron-working around 500 BCE led to a 'democratization of war' whereby the availability of such formidable weapons radically altered the balance of military and political power.[(6)] Lynn White Jr., alongside his more famous theory of the stirrup and feudalism, drew an immediate correlation between the diffusion of ironmills, the availability of iron and Europe's predilection for heavily armed cavalry.[(7)] Less technologically deterministic, C. Rogers nonetheless posits a connection between the availability of arms, the military strength of non-feudal armies and the redistribution of political authority in the late middle ages.[(8)] A similar trend has been attributed to England. Scammel draws a strong connection between the increased availability of arms and the shifting concept of knighthood in the twelfth century, proposing that beforehand 'knighthood was in the arms not the man'.[(9)] As discussed in Chapter Two, the lack of arms conditioned England's military organization by limiting the Crown's provisions and perpetuating arms requirements, but by the fourteenth century arms' availability enabled the Crown to request service from more of society with direct and far-reaching political consequences.

Many discussions of iron's availability in medieval England, however, tend to emphasize the civil needs of the wealthy as the predominant influence on the industry's organization.[(10)] The conditions of the industry's development should provide another indication of the extent to which the Crown fostered technical and industrial growth. Since the consumption of iron provides an excellent indication of both civil and military industrialization, analyzing its supply and demand can help to clarify the relationship between military and economic development, a prime indicator of a pre-modern political economy's character. We will review the evidence for the changing levels of iron production in Europe to gain an idea of England's status as a consumer, before turning to assess changes in England's annual aggregate consumption of iron for military purposes, paying special attention to connections between the diffusion of iron, industriousness and/or technical competence. We can then conclude by relating this structural evidence for the availability of iron to the prices of iron and steel in England during the thirteenth and fourteenth centuries.

Supply

It is unfortunate but understandable that so few attempts have been made to ascertain aggregate levels of iron production and consumption in Europe. Most historians agree that in general the production of iron and steel increased at least in proportion to population growth during the high middle ages, and that the rise of international trade in the thirteenth century made the product available to much of Europe.[(11)] Major production centres emerged in the Basque provinces of Spain, in Styria in Austria and Westphalia in central Germany, and their export figures provide the most valuable evidence for Europe's aggregate production. Wendy Childs study of the Basque provinces indicates that as much as 10,000 to 15,000 tons of high grade iron were produced there annually in the fourteenth and fifteenth centuries when Westphalia and Styria are each estimated to have been producing annually around 2000 tons of high grade iron or steel.(12) Such figures accord well with Sprandel's estimate that Western Europe's annual production of iron rose from around 25,000 tons in the fourteenth century to 40,000 tons in the late fifteenth century.(13)

The causes for this increase were multifarious and difficult to isolate. The supply of iron and steel depended on the types of ore present in a region, the techniques available for converting the ore, and the distribution of the final product. The production of iron and steel occurred primarily in the countryside where ore, fuel and water were readily available or could be supplied with a minimum of transportation. Converting iron ore into a workable product required extensive processing which in effect meant that iron or steel traded as a semi-raw good. An initial step in removing crude impurities involved either washing the ore, or roasting it at a low temperature in a small pit with simple stone or clay insulation. Next the ore was smelted: placed in a furnace with charcoal and fired to reduce the entire charge into a relatively compact mass or bloom. The bloom was often reheated and hammered extensively to drive out more slag, creating a denser material which finally could be cut and shaped ready for sale. Renowned areas of iron production were densely peppered with these conglomerate works often described as '*fabrica*' regardless of their exact role in the production process.(14) Commercial transport of a good as densely heavy as iron was heavily dependent on waterways, and England was well positioned to receive imports from Spain and also the specialized products from Germany and the Low Countries.(15) Thus for imports to have been competitive with domestic products they must either have been produced and transported at less cost or possessed some other advantage. Spanish iron for example was considered much tougher than most English products and was therefore preferred even though we will see below that it cost two to three times as much as most English iron.

The rise in output could have been the result of increased productivity at individual sites, an increase in the number of iron-working sites or a combination of both. For England we have several indications that the number of ironworks in operation multiplied perhaps fivefold between 1086 and 1300.(16) Schubert was able to document 350 ironworks operating in Britain between 1250-1350, but as we shall see that number should be taken as a minimum. Such small scale works, which accounted for the majority of production in Britain at least, could have been established and abandoned with rapidity and are notoriously difficult to date through archaeology alone.(17) The size of the bloom also appears to have steadily increased since the early middle ages.(18) The surviving evidence is scant, but blooms from Roman Britain ranged from less than a pound to 17 lbs., whereas by the fourteenth century blooms of 30 lbs. were common even without waterpower, and some works such as those at Tudeley, Kent, were producing blooms of 200 lbs or more.(19)

The application of waterpower is often credited with this increased output. Over time waterpower was harnessed for the successive stages in production: for washing and crushing ore, for powering bellows at the furnace and trip hammers during refining.(20) The application of waterpower became the most potent means of improving the process, but its involvement is highly debated especially in relation to powering the bellows in what is known as a blast furnace. The ancients employed horizontal and vertical waterwheels in various industrial activities, but waterpower's application in the medieval iron industry seems to have emerged only in the late eleventh or early twelfth century.(21) A concomitant advancement occurred in the production of silver and iron at this time wherein the two exchanged techniques including the use of waterpower.(22) By that time watermills were employed in a host of other industries producing cloth, timber, paper, pigments, and non-ferric metals.(23) The four mills recorded in Domesday as paying iron as rent are often cited as the earliest evidence for ironmills in Europe, but it is not known what part of the process involved these mills. Discounting such circumstantial evidence, Reynolds compared the linguistic evidence and concluded that some type of ironmill most likely originated near the Alps, spreading rapidly during the twelfth century; a date supported by D. Hill in his analysis of similar types of evidence for Islam and Europe.(24) Evidence that waterpower was indeed harnessed for the purpose of driving bellows was found during the excavation of an unusually well preserved furnace in Sweden dating to the twelfth century with bellows powered by an overshot waterwheel and complex damming.(25)

The blast furnace comprised two or more bellows operated mechanically to create a much more constant and hotter blast for the furnace. There were several advantages to this method. The higher temperatures enabled the smelting of relatively poor ores.(26) Secondly, this furnace was capable of producing much larger blooms, as much as 200 lbs., representing a fivefold increase over conventional methods using the same amounts of fuel.(27) The cost of the production process could also have been greatly reduced by waterpower. The cost of fuel was major factor in operating expenses and therefore the final price of iron or steel. If the Tudeley forges in Kent were representative of medieval smelting operations, then charcoal constituted half of a furnace's operating cost, while wages amounted to 33% most of which (20%) was for blowers or bellows operators.(28) Thirdly, this furnace may have increased the production of steel. The higher temperatures of powered bellows allowed the bloom to absorb more carbon, either through simple surface carburization and/or as small droplets of cast iron formed due to carbon-rich pockets and then dispersed across the forming bloom, raising its overall carbon content.(29) A mill's hammers could further improve the consistency of a bloom by better removing slag and being capable of handling the larger blooms.(30) The benefit of the mill's hammers can be gauged by an estimate of their power. Hammers weighing 500 to 1600 kg were capable of forging the larger blooms produced by blast furnaces, refined afterwards by a 300 kg hammer making 60-120 strokes a minute.(31) Lastly, the more efficient process reduced the amount of bloom smithing required, preventing waste.

However, Europe's aggregate iron production would not have spiked dramatically as the benefits of waterpower became known. The production of iron depended on many local factors, preventing any simple correlation between the appearance of industrial milling and a boom in the production of iron everywhere. The composition of iron ore in each locale differed, often requiring a certain type of furnace best suited to its smelting. For this reason iron and steel were usually distinguished by province of manufacture. Iron ore is actually a mixture of earth and iron compounds containing 'impurities' such as silica, manganese or phosphorous. Whereas carbon free iron liquefies at 1540 °C, the minimum temperature for smelting is thought to have been about 1200 °C when some of the ore's impurities would form into slag and melt away.(32) These impurities affected the bloom's absorption of carbon and final qualities. A phosphorous rich bloom, for example, resulted in a rigid iron resembling steel. Manganese rich bloom produced tough iron that did not give easily and yet did not break as steel was apt to do. The simple bowl furnace, such as the Catalan type, was well suited to phosphorous rich ores, producing smaller but tougher blooms than tall furnaces. On the other hand the Stuckhofen furnaces with towering shafts of up to 30 feet in height, were precursors of the blast furnace and were able to produce larger blooms of hard iron resembling or constituting steel. Even when an ore suitable to the blast furnace was available, it required a minimum current to power the waterwheel as with other milling activities. The high costs of erecting and running watermills also limited their diffusion.(33)

English Demand

On the other side of the equation it is equally difficult to be exact about minor trends in the aggregate consumption of iron and steel in England. As with cloths, iron was traded on an international market that determined viability at the regional and local levels. Iron and steel were imported in large quantities to augment domestic supplies, enhancing opportunities for industrial and military growth. This relatively open trade in iron brought more competition in quality and price.(34) The direct sea route to the Basque provinces in Spain made its rich product ideal for importing to England, and in the second half of the thirteenth century England began to consume vast quantities of Spanish iron.(35) In the most thorough study of this trade to date, Childs speculated backwards from English customs accounts of the fifteenth century to virtually concur with Schubert and Sprandel that England imported around 1000 tons of Spanish iron annually in the fourteenth century, rising to 3000 tons by the late fifteenth century.(36) The customs accounts for the late thirteenth and early fourteenth centuries are notoriously deficient, and we should take such figures as the basis not the ceiling of our estimates.(37) Childs' estimate, reveals some large shipments at the turn of the thirteenth and fourteenth centuries. In 1294, one shipment of Spanish iron coming into Sandwich contained roughly 250 tons, and that port alone received in Spanish iron at least 275 tons in 1325-6, 317 tons in 1327-9, and 214 tons in 1344-1345.(38) Similar levels of Spanish iron was imported to Winchelsea, Southampton, Sandwich, Bristol, Plymouth and London. Smaller but steady imports came from Port-Audemer and St. Omer, Normandy as early as 1235.(39) The more steely Osmund and Westphalian products were also imported, on a much smaller but significant scale given the quality and price. One shipment in 1320 contained 34 casks of Westphalian steel.(40) Altogether, we should probably place English imports of iron and steel from at a volume closer to 2000 tons annually between c. 1250 and 1350.

During the second half of the thirteenth century the volume of England's domestic iron production also appears to have increased. Schubert estimated that Britain produced on average 900 tons annually between 1250 and 1350.(41) Even though we have less reliable figures for the Weald, by the fourteenth century its productivity rivalled the Forest of Dean. Many lesser forges doubtless went undeclared to escape paying rent. In fact a very fine line separated smelting operations and smithing, and numerous works may have existed on the same site. Many of the forge owners in the Forest of Dean were described as lorimers, bladers, nailers etc. Various iron working activities, ranging from ore extraction to smelting, forging and smithing were described using similar terms, hindering identification of specific activities from documentary evidence alone.(42)

The increased consumption was probably the result of several demands. A marked increase in English consumption should have occurred during the twelfth and thirteenth centuries from the surge in land cultivation, building, and war before the economy and population faltered in the fourteenth century.(43) This hypothesis is supported by our best evidence for building trends which demonstrate that by the late thirteenth century religious houses beginning and undergoing (44) construction had dipped to pre twelfth century levels. However, the demand for iron was related to living standards which varied from one region to the next. For instance, the amount of land under cultivation grew steadily during the twelfth and thirteenth centuries to support Europe's growing population, but this does not necessarily mean that the amount of iron used in the process increased commensurately. Similarly, the number of peasant dwellings did not always correspond to changes in population.[45] Additionally, local material resources and the region's prevailing economic activities and styles often determined the area's industries, building types and hence consumption of iron.[46]

There is much circumstantial evidence for increased iron consumption and specialization in the twelfth and thirteenth centuries. There is no need to doubt that ironworking formed a reasonably common occupation during the early middle ages.[47] The smallest landholders often worked at many occupations either seasonally or simultaneously, incorporating their families in these various endeavours to augment their incomes.[48] Some rents comprised iron goods or ironworking services, suggesting that ironworking formed a part of their livelihood and a regular feature of the local economy. Not only iron but arms and armour were paid as rents from this time from small tenants and mills.[49] We may add that smiths were commonly employed in royal castles at the least.[50] Hilton sees specialization and diversification in handicrafts like ironworking as marking one of the most important economic developments between the eleventh and thirteenth centuries. For Hilton specialization allowed a more advanced organization of raw material production and better products for the buyer, while also indicating that demand had deepened and widened.[51] Already by the twelfth century several areas in England had become locally renowned production centres. Obtaining numerous mining rights and serving as an important source of iron for the Crown, the Cistercians did much to revitalise iron working in the north.[52] The Forest of Dean in Gloucestershire, the areas around York and Durham, and the Weald in Kent were all capable of filling large consignments of iron and iron goods for royal and ecclesiastical patrons.[53] In London, guilds based on ironworking multiplied from six specialist occupations in 1300 to fourteen by 1422.[54] The largest estates contained so many industries and economic activities that one writer drew an analogy with modern factories.[55]

The archaeological evidence for the development of medieval smithies is less indicative of major growth as G. Astill has made apparent, as England's village smithies appear to have become more substantial during the fourteenth century rather than earlier. Of the eleven permanent medieval English smithies which have been excavated, only three were located in villages and all of those dated from the later fourteenth century, [56] One conclusion from these preliminary statistics is that the demand for iron-working only became sufficient in the fourteenth century to warrant larger smithies at the village level, or that these iron-workers had benefited from the relative wealth per capita in the plague's aftermath. However, others have proposed that the iron industry also became more commercialized in the fourteenth century.[57] According to this view, before the growth of markets in the thirteenth century, the iron industry would have been largely substantiated by ad hoc demand, and consequently, the scarcity of surplus iron and lack of market forces on production would have hindered overall productivity, specialization and experimentation and maintained artificial prices.

Indirect evidence for increased specialization comes from the archaeology of tools and craft techniques. During the twelfth century basic tools such as files, chisels, hammers, saws and anvils diversified to serve more specialized purposes, resulting in more intricate 'fine technologies' such as locks, dyes, stamps and astronomical equipment in the thirteenth century.[58] From the late twelfth century more complex joinery is to be found which could only be accomplished with the advent of better saws and chisels instead of the crude adze which was best suited to rough work. The enhanced strength of this new joinery enabled many of the advancements in heavy machinery evident on windmills, cranes, siege engines and ship building. Similar improvements to masonry tools allowed more complex stone work in dwarf stone walls, padstones, bridges, manor houses, quays and harbours, in military works such as castles, towers, fortified bridges and city walls, and in the intricate sculpture and architecture of religious and artistic endeavours.[59]

We can see several ways in which the Crown managed the industry including sustaining major iron works itself. Throughout the thirteenth century the Crown's need for cheap iron was offset by competitively priced imports and the need to conserve wood resources (either due to scarcity or high cost). The rise of European trade in the thirteenth century enabled the Crown to be prudent in maintaining its own forges as high quality grades were being supplied from Sweden, Germany and Spain at competitive prices. Purveyance could also be relied upon to provide the Crown with immediate supplies. As a further safeguard, the Crown forbade exporting iron and armaments as frequent notifications testify.

In addition to the royal works in the Forest of Dean, repeated references were made during Edward II's reign to the king's iron mines and watermills at Knaresborough.[60] Consequently, the Crown was constantly reviewing the production of iron on its lands as seen in the management of ironworks in the Forest of Dean.[61] Royal forges had been present there at least as early as Henry II's reign, and by 1246 the Crown reviewed the situation and found that the great forge at St. Briavel cost more to operate than it generated in revenue. Despite this inhibition, the number of 'forges' operating in the Forest of Dean rose for most of the thirteenth century. In 1217 only six private forges in the forest were allowed to operate, whereas by 1250 up to 30 forges were in operation there. This number rose to 43 in 1270, 60 by 1282 before dropping back down to 45 the following year. Private iron-working may have been more productive. By the thirteenth century, many prominent iron-working communities such as the Forest of Dean had earned the right to engage in their trade more freely in terms of being allowed to gather more fuel and ore from local resources.[62] Fixed rents rather than percentages of production were established for many tenants, and the right to trade directly with merchants further facilitated commercialization.

The Crown maintained an impressive corps of forest officials to protect its rights. The Forest of Dean was teeming with these officials. Under the constable of St. Briavel were landowning officials such as the nine greater foresters in charge of specific bailiwicks, or the ten or so sergeants who had full jurisdiction of the forest. Among the greater foresters' perquisites were iron working and charcoal making. Additionally, many lesser foresters were responsible for maintaining the forest more intimately. In royal employ were the sheriff, verderer and regarder who kept a watchful eye on the king's interests.[63]

A commodity as heavy as iron which demands large amounts of other heavy goods such as timber and charcoal for its production was heavily dependent on waterways for production and trade. Canals were opened in some regions to ease the burden of transporting such heavy goods, allowing bulk shipments to major markets. From the twelfth century several quays and loading sites in the Severn estuary provided waterborne access to ores produced in the Forest of Dean.[64] The areas around Glamorgan and Monmouthshire began producing charcoal for outlying areas, which may have been a response to a shortage of wood but in any case resulted in a large-scale division of labour.[65] The amount of charcoal required for these forges brings home the scale of these operations. In 1282 around 900 charcoal hearths were operating in just four of the demesne woods in the Forest of Dean. The task of providing charcoal for the furnaces was an enormous industry in itself, threatening to reduce woodlands to barren. Current estimates suggest that around 2 acres of woodland were required for each ton of iron produced, or to put it another way, that twelve pounds of charcoal were needed to smelt one pound of iron.[66] In the survey of ironworks in the Forest of Dean made in 1270, the depletion of forest raised real concerns. Some 9,000 oaks had been felled on the bishop of Hereford's lands for ironworks in Dean.[67]

Previous historians have emphasized the role of royal demands as a main factor in the domestic iron industry.[68] We would expect to see transactions predominantly in the form of *ad tascam* if most ironwork stemmed from seigneurial or ecclesiastical patrons. Instead, in addition to contract work these patrons seem to have purchased and purveyed iron from the same 'market' that supplied the smallest landholder or craftsmen with iron. When we recall that fulfilling orders such as 30,000 horseshoes and 60,000 nails requested in 1254 would have required roughly 50% more iron than contained in the final product, we may surmise that around 15 tons of iron were required. However, even the purchase of 50,000 horseshoes for Richard I's crusading effort were gathered from markets in much the same way as a few hundred nails.[69] Over the course of the thirteenth century, not only do these orders grow larger but the amount of iron becomes more liberal. One study of horseshoes excavated from London indicate that before 1250 an average horseshoe weighed less than 130g and was fixed with six nails, whereas in the early fourteenth century horseshoes commonly weighed 250g and were fixed by eight nails.[70] In the early 1250s the sheriff of Gloucester purchased on different occasions 16 hundredweight, 200 pieces, and a thousandweight of iron seemingly as conveniently as his purchase of 6 hauberks.[71] At this time large amounts of iron was being purveyed from Spanish merchants, in one instance £30 5s 1d (probably 7-8 tons) worth was taken.[72] In 1225 trade in iron at Gloucester was so prolific that the bishop of Chichester was advised to obtain iron from there rather than his own lands.[73]

Works on fortifications became a constant activity requiring large amounts of iron as framework, stanchion and glazing bars of windows, accessories such as hinges, rods, clamps, and locks, for nails, tools etc. From the Crown's disbursements of iron we can tell that on average the garrison and simple maintenance of a lesser fortification might consume between one and two tons of iron annually during our period, while major strongholds might require 5 tons or more per year. For example, as part of its agreement to supply the garrison at Perth the Crown was expected to deliver 10 sheaves of steel and 400 stones of iron.[74] In 1303-4, £15 2s 6d worth of iron, some 4-8 tons, remained between Chester, Flint and Ruddlan castles.[75] Twenty years later the Crown's castles in north Wales contained 11,279 pieces of iron, 24 seams and 10 bindings; the meanings of these terms varied but the sheer number of 'pieces' implies a respectable store if only significant of pounds.[76] In an account which uncommonly equated the piece of iron with a stone in weight, 1301 pieces of iron (7-9 tonnes), were listed as part of Berwick's stores during 1297-1298.[77] Projects such as building siege engines consumed huge quantities, especially from the late thirteenth century when heavy counterweight trebuchets became common. One account covering the expenses at Berwick between the years 1294-1296, recorded £28 2s 8d ob. spent on iron for one engine out of a total of £129 13s 5d spent on iron for more general purposes.[78] In 1303, 280 stones of iron were consumed in making the engine 'Segrave'.[79] At Stirling in 1336 another engine's essentials used 390 stones of iron.[80] For making springalds in 1326-1327, Robert [81]

Pippushall was supplied with half a ton of iron. We have seen that the largest trebuchets each contained several tons. Arrows and quarrels, expended by the tens of thousands, represented tons of iron. Hoardings, ladders, and towers and repairing the same would have consumed more. John de Malemort supplied £15 19s 4d of quarrels and nails for the siege of Kenilworth (1266).[82] At the siege of Dunbar 34 masons required a quintal of iron and 5 garbs of steel for repairing their tools.[83] Substantial amounts of iron were needed just to maintain these men in the field. While campaigning in Scotland in 1307, Edward I sent orders for 12,000 'pieces' of iron and 100 'garbs' of steel.[84] As the importance of maritime forces grew during the fourteenth century, fleets represented hundreds of tons of iron, if not a few thousand tons. In one instance, constructing a galley required 937 stones of iron, some 6 or 7 tonnes.[85] Although many ships were impressed, the Crown habitually built and equipped galleys and barges.

From these figures we may gather that by 1300 an impressive siege effort may require one hundred tons of iron including expendables and repair of tools and personal armaments. R. Bartlett has stressed the great amounts of iron required for armies, and taking 50 lbs. (22.7 kg) as an average amount needed to equip each knight and mount, he concluded that an army of 5000 knights contained 125 tons of iron.[86] J. Fino's estimates of 70 kg per knight or men-at-arms and 25-30 kg for a heavily armed infantryman, however, are probably much closer to the actual amounts.[87] The less well equipped serjeant with an uncovered mount might therefore have needed just under 25 kg, while the average footman might only wear a few kilograms of iron. Therefore, a more realistic estimate for 3000 heavy cavalry and 7000 footmen armed according to Henry III's assizes would have contained 180,682 kg, or nearly 178 tons of iron. Excluding the fleet, the Crown's armies might contain 500 tons of iron including arrows, equipment, siege engines and personal armaments, but the amount of iron obtained for creating these arms may have been twice that depending on rates of loss. Including stores at castles, and supplies for works on fortifications, the Crown's military system may have contained as much as 1000 tons at any one time, with an annual need of 500 tons.

Prices

Prices serve as the best indication of the regional supply and demand of iron. Dyer presents the received view that the prices of manufactured articles, giving shingles, solder and nails as examples, increased by 50% or less between 1220 and 1300, before virtually doubling between the 1320s and the late fifteenth century.[88] Tylecote posited that the price of steel dropped in relation to iron over the course of the thirteenth and fourteenth centuries, but his estimate of £3 for a ton of steel and 12s for a ton of iron in 1300 are far from typical.[89] Childs followed Thorold Roger's findings to conclude that the price of iron remained at around 3s per hundredweight of common English iron until after the Black Death.[90]

The study of medieval iron prices is made treacherous by the inconsistent terminology and methods of attainment. The great variations in the size and quality of most iron articles have led some such as Postan to dismiss their study altogether. In a robust study, Salzman braved the minefield, perusing some two thousand manuscripts to catalogue transactions covering purchases of goods and services involved in building. Devoting a chapter to ironwork, he revealed the bewildering terminology that confronts any such study. Just nails for example, encompassed over 20 terms describing their size, make and quality.[91] Several studies have focussed on royal orders for goods such as horseshoes, as in the 50,000 purchased for £33 18s for Richard I's army in 1199.[92] However, the purchase of iron artefacts contain the value of the smith's labour in addition to the material's worth, and due to the differences in manufacturing techniques and loss, it would be difficult to make consistently accurate estimates of the amounts of iron involved. Smiths were often hired for contract work, or *ad tascam*, screening from our view the prices of his materials.

Even focussing on the basic units of iron and steel, a multitude of terms arise, few of which represented the same amount over space or time. Schubert was under the impression that a 'garb', literally a bundle, described an amount similar to the hundredweight; but he may have been confused as to what the hundredweight meant.[93] We also encounter the 'quintal', which Childs posits as a synonym for the hundredweight.[94] Beside the more familiar *duodena* (dozen), *centum* (hundred), *quarta* (quarter), *mille* (thousand), *summa* (seam or horseload), *petra* (stone), and *pondus* (pound), appear more general terms such as *pecia* or *frustum* (piece), *bendus* (band), *endus* (end), *garb* (bundle), *schef* or *glavettus* (sheaf), *esperditus* (bar), *kivillus* (rod), and *blome* (bloom), along with dialectical *gadde*, *cuellus*, *jucud*, *quintal*, and many variants thereof. Due to the variability of meanings associated with these units, it is not possible to make straightforward comparisons of prices, nor of volumes of transactions.[95]

Late in Edward I's reign an assize of weights and measures sought to remedy this situation by regulating terminilogies and weights of iron goods. The hundred of iron, we are assured, should contain five score, while the sheaf of steel was defined as

30 pieces, the dozen of iron contains six pieces, and the stone should weigh 12 and a half pounds.[(96)] Realities at market were far different. Except for the most common units of weight, most of these terms seem to have been employed simply to denote the form of iron or a group of iron objects rather than a specific amount of weight. This is particularly true with the piece (*pecia* or *frustum*). The variation of the 'piece' can be seen in a list of goods seized from Spanish merchants in 1338, which included 1054 rods of long iron, 42 pieces of pointed iron, 60 pieces of plate iron, 786 iron bars, 62 cut pieces of iron, 52 iron plates, 220 welded iron gobbets, and 500 bars of long iron.[(97)] Similar vagaries in the piece's properties emerge when comparing records. In 1278 and again in 1323, seams were described as containing 72 pieces each, and in the latter document, 'bindings' contained 25 pieces. Based on this evidence, Salzman surmised that the 'piece' contained around 7 lbs.[(98)] However, in the early fourteenth century the *duodena* was reckoned to contain 6 pieces, and Schubert has provided us with several examples which lead us to believe that the piece weighed on average 2 lbs.[(99)] Yet at Berwick castle in 1297 the 'piece' is equated with a stone of iron, and we are also informed that 5160 heavy quarrels were made from 172 pieces of iron, in other words 30 quarrels per 'piece'.[(100)] For comparison, in the mid thirteenth century 1770 quarrels were made from 220 stones of iron, or roughly 8 quarrels per stone.[(101)] If we expand the investigation to other metals, it becomes clear that the 'piece' described any single mass of metal regardless of size. The undeniably large amount of lead purchased for £57 8s 2d for siege engines in 1277 was described as a 'piece.[(102)]

The 'garb' or 'sheaf' referred to steel more often than iron, but was employed almost as inconsistently. In 1278 Osmund steel was being purchased for 8 or 9d per sheaf, while a similar steel from Normandy was priced at 9s for half a hundredweight, or about 2d per pound.[(103)] Based on this evidence the sheaf appears to have contained 4-5 lbs. In 1294 'schaves' of steel were again purchased routinely for 8d and 9d each, and in the same account pieces of iron always cost 4d ob. each.[(104)] Likewise in 1302, 40 pieces of iron were purchased for making a springald at Lanercost for 13s 4d (4d each).[(105)] With steel normally costing two to three times as iron in our period, in these instances the piece appears to have contained either a similar or slightly more amount than the sheaf. All the same, an account from 1278 lists the sheaf (*glavettus*) as containing 30 pieces of iron.[(106)] In another instance five 'paners', or baskets used for horses to carry loads, were described as containing 20 sheaves.[(107)]

Evidence for prices of the band of iron is equally frustrating. In the last quarter of the thirteenth century, prices for bands of iron ranged from about 3d to nearly 4s. Three bands of iron cost 10d in 1278/9, while hundredweights were being bought at rates of 3 and 4s each.[(108)] However, 8 bands were purchased for 30s ob. for the same works.[(109)] Numerous purchases of *bendis* of iron were made at Carlisle between 1294 and 1296 at prices ranging between 18d and 2s 3d each.[(110)] In 1296 bands of iron were again purchased for Carlisle at rates of 17d, 2s 1d, and 3s each.[(111)] The same variance could be shown for almost all accounting terms mentioned above, forbidding calculations as detailed as figuring the percentage usage of Spanish and English iron in a particular project.[(112)]

Several references to the *summa*, or seam, indicate that its weight was likely to vary too much for accurate comparisons. In the accounts for Winchester castle, 1222-1223, the price of the *summa* ranged from 9s 6d to 12s. At the same time the *hes* was bought at rates of 3.9d and 5d each. Salzman took the seam as 500 lbs., and comparing prices of seams and *hes* bought from the same merchant suggested that in this instance the *hes* contained 20 lbs.[(113)] Pieces of steel defy reconciliation: *frusti* of steel at this time ranged from 4.9d to 12.5d each, with a sample average of 7.95d.[(114)] Willard has shown that for the purpose of tolls in the fourteenth the horseload was considered one-quarter of a cartload.[(115)] Langdon surmised that packhorse loads averaged about 200-240 lbs. with a maximum of 400 lbs. At the same time he readily acknowledges that the horseload was often equated with half of a cart load, and that carts regularly carried 1000 lbs.[(116)] In 1245, for example, the order for 10 wagons of iron and five wagons of steel were reissued as 20 horse loads of iron and 10 horse loads of steel.[(117)]

A better idea of iron's prices, and change in price, is obtained by limiting our evidence to relatively standard units of weight that can be reckoned through context. Even though the hundredweight ranged between 96 and 144 lbs. during this period, and the stone between 12 and 15 lbs., it is often possible to ascertain their values by scrutinizing the entire document for further indication of their meaning. The comparative lack of records before the mid thirteenth century impede on such limited methods. Occasionally we are afforded a glimpse, as in 1204 when twelve quarters of iron were purchased in Gloucestershire for 11s 9d, equating to £3 18s 4d per ton. More evidence survives from the second half of the thirteenth century, and it suggests that prices of high quality Spanish iron were reduced to the level of domestic products. Between 1253 and 1259 several purchases of tough iron (*ferri tenacis*), in other words iron similar to Spanish product, were made at rates which average at 16s 1d the hundredweight with only a shilling's variance.[(118)] These prices were similar to that of steel which fetched prices upwards of £15 per ton well into the fourteenth century, such as the 279 stones of steel purchased in 1324/5 for £27 15s 9s, or about £16 the ton.[(119)]

In comparison, the figures for Spanish iron later in the thirteenth century as presented by Salzman demonstrate that it must have fared very well in local markets, even inland. From their inception until the after the mid fourteenth century, customs valued the ton of iron coming into England at £2, except for Southampton's £4. In 1275 Spanish iron was sold for 3s 1d the hundredweight, for 2s 4d in 1280, and 3s 6d in 1292.(120) Salzman's wider ranging evidence provides numerous instances where Spanish iron and iron from the Forest of Dean was worth £3 or 4 per ton in the first half of the fourteenth century.(121) The relatively low customs valuation will have also served the purpose of encouraging more imports by suppressing tolls, allowing it to compete inland after transportation charges were added. Of course, if the Crown needed to purvey these materials, low evaluations also served to secure favourable prices. However, in the first half of the fourteenth century, iron occasionally sold for prices even lower than the customs valuation. Remarkably, 1032 lbs. of iron wire cost only 13s 6d in 1324, equating to £1 9s 3d ob per ton of a labour-intensive good.(122) In 1310/1, the 80 tons of iron brought by Spanish merchants was valued at £133 in 1310, equivalent to £1 13s 3d per ton.(123) While these prices constituted the low end of the spectrum for Spanish iron, they at least confirm that it was available at the rates referred to in customs. Even the prices for Spanish iron at the other end of the spectrum resembled prices for English domestic iron. In 1278, 5 thousand 9 hundredweight of iron was purchased for £20, or £6 15s 7d per ton.(124) Four thousand five hundredweight of Spanish iron cost £10 2s 6d in 1278 (£4 10s per ton), and three thousand eight hundredweight and a quarter of Spanish iron cost £7 14s 6d (£4 9d ob. per ton); thirteen thousand five hundredweight cost £27 (£4 per ton).(125) Furthermore, we can set these more reliable figures alongside the valuations set by customs for taxing imports which were often based on the ton and hundredweight. As early as 1265, for instance, imports into Winchelsea were assessed as quintals and taxed at rates of 1-2d per each.(126)

It is often taken for granted that England's iron industry slumped in the fourteenth century. Numerous reasons for this regression have been suggested by historians: the malaise of the economy in general, a wood shortage causing a rise in the costs of fuel and charcoal, increased competition from imports, and/or disruption caused by Scottish raids.(127) Contrasting it with the tin industry, Bolton believes that the English iron industry went into decline around the beginning of the fourteenth century.(128) Most of these opinions are based on evidence for the closure of mines and forges such as at Knaresborough.(129) However, we know that the first half of the fourteenth century was an active time for the ironworks in the Forest of Dean, the Forest of Pickering, and the Weald all of which continued to produce large amounts of iron and iron goods; indeed, by the second decade of the fourteenth century substantial ironworks remained in operation at Knaresborough. If not experiencing overall growth, England's own industry appears to have at least concentrated its output in these major centres. At the same time more substantial smithies became permanent features of villages. Ironmongers and ironworkers such as armourers also rose in prominence during the fourteenth century, becoming influential groups within the city of London for example as demonstrated by the blade smith cum sheriff.(130)

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Based on this fragmentary evidence it appears that up to the thirteenth century England's iron industry enjoyed an array of patrons but was essentially demand driven with sporadic production closely linked to specific orders. The diffusion of ironmills, small-scale iron works, and the rise of international trade moderately enhanced supply in the thirteenth century while the growth of local markets and commercial privileges provided ironworkers with the opportunity to profit from improving production. Together, by the mid thirteenth century these events had generated robust interregional trade in iron, engaging specialized centres for producing charcoal, working ore and fabrication with interlinked transport and commerce.

Geared for production, during the thirteenth century the commercialized iron industry surpassed Europe's faltering demand, as confirmed by the myriad of prices recorded then and evidence of a longer trend of declining prices until the sharp rise following the plague. The attempt to established a range of prices for iron and steel in England during this period is fraught with difficulties, but we have demonstrated that in all likelihood the price of domestically produced iron and steel declined by as much as 50%, while crucially, the prices of Spanish iron dropped dramatically to rival domestic products. Childs accepted the values in Roger's compilation: about 3s the hundredweight in the first half of the fourteenth century, rising to 6 or 7s for the remainder of the century, but the much superior Spanish product also became available at those prices. This decline in cost in the thirteenth century most probably resulted from improved production, transportation and market competition set against waning civil demand. Indeed, as outlined above imports of iron were probably a great influence on domestic consumption and prices. The greater availability of iron and steel had the effect of augmenting the quality, quantity and diversity of goods such as tools, instruments and armaments, gradually improving techniques in carpentry, masonry, and arms-making.

Although England constituted around 5% of Europe's population, its consumption of iron and steel may have been as much as 10% of Europe's aggregate iron production, becoming in the process the primary consumer of the Basque region's iron exports. The Crown's military need for iron and steel, perhaps as much as 25% of England's gross consumption, led to its close involvement with the growth of the domestic industry and imports: an extension of administrative officials closely monitored the use and abuse of woodland resources as well as taxing ironworkers, charcoal makers and miners, while imports and purveyances were encouraged with low customs. The Crown's watchful eye of imports and domestic industries also aided in its purveyance. Forbidding exports of iron from the mid thirteenth century at latest, by the early fourteenth century the Crown became more controlling and began to set prices, control weights, measurements and trade. We must now turn to the costs of armaments to place these developments in the context of English military organization.

NOTES

1. John Trevisa translated Bartholomew as 'Vse of iren is more nedeful to men in many þ ings þ an vse of gold', *On the Properties of Things. John Trevisa's Translation of Bartholomaeus Anglicus* De Proprietatibus Rerum. *A Critical Text*, M.C. Seymour et al., eds., 2 vols. (Oxford, 1975), Book 16, Chapter 44, ll. 21-22.

2. Ibid, Book 16, chap. 45.

3. As quoted by J. Geddes, 'Iron',

English Medieval Industries. Craftsmen, Techniques, Products, J. Blair and N. Ramsay, eds. (London, 1991), p. 167.

4. Schubert, writing in the mid twentieth century, aptly remarked that we were still living in the Iron Age,

A History of the British Iron and Steel Industry, p. 4.

5. For Charlemagne: White,

Medieval Technology and Social Change, pp. 40-1; crusaders, R. Bartlett, *The Making of Europe. Conquest, Colonization, and Cultural Exchange, 950-1350* (London, 1993), p. 71; English armies, *Chronique de Jean le Bel*, J. Viard and E. Déprez, eds., i, (Paris, 1904), pp. 155-6.

6. W. McNeil,

The Pursuit of Power. Technology, Armed force, and Society since A.D. 1000 (Oxford, 1982), pp. 12-13 for ancient Assyria, and pp. 25-6 for his analysis of Chinese ironworking. J. Keegan, *A History of Warfare* (London, 1993), pp. 235-298, gives a recent and popular account of iron's impact on early warfare.

7. L. White, 'The Crusades and the Technological Thrust of the West',

Medieval Religion and Technology: Collected Essays, L. White, ed. (Berkeley, 1978), pp. 278-83, 291-2.

8. Rogers, 'The Military Revolutions of the Hundred Years War', pp. 241-78.

9. J. Scammel, 'The Formation of the English Social Structure: Freedom, Knights, and Gentry, 1066-1300' ,

Speculum 68 (1993), pp. 591-618; Strickland also posits that knighthood denoted the function of service in arms rather than a social class during that time, *War and Chivalry*, pp. 142-6; cf. Coss, 'Knights, Esquires and the Origins of Social Gradation, pp. 155-78.

10. H. Cleere and D. Crossley,

The Iron Industry of the Weald (Leicester, 1985), pp. 87-95, compares military and civil demands. G. Astill, 'Medieval Smithing in England: a Review'. *The Importance of Ironmaking. Technological Innovation and Social Change*, G. Magnusson, ed. (Stockholm, 1995), pp. 189-90, discusses the seigneurial perspective; W.R. Childs, *Anglo-Castilian Trade in the Fifteenth Century* (Manchester, 1978), p. 119, emphasizes the 'richest social groups' for sustaining an international trade in iron.

11. The most thorough treatment of medieval iron production remains R. Sprandel,

Das Eisengewerbe in Mittelalter (Stuttgart, 1968) summarized as R. Sprandel, 'La Production du Fer au Moyen Âge', *Annales* 24 (1969), pp. 305-21. R.H. Bautier, 'Notes sur le commerce du fer en Europe occidental du XIII au XVI siècle', *Revue d'Histoire de la Siderugie* 1 (1960), pp. 7-35, continued ibid, vol. 4 (1963), pp. 35-61, also treats medieval Europe's aggregate production of iron. More general coverage of ironworking in European history can be found in R.F. Tylecote, *The Early History of Metallurgy in Europe* (London, 1987), J. Finó, 'Notes sur la production de fer et la fabrication des armes en France au moyen âge', *Gladius* 3 (1964), pp. 47-66; and R.J. Forbes, 'Metallurgy', *History of Technology*, ii.

12. Childs,

Anglo-Castilian Trade, pp. 112-9.

13. Sprandel, 'La Production du Fer, pp. 305-21. Sprandel based this increase mainly on the advent and diffusion of the blast furnace.

14. At least 140 iron-working sites were discovered within approximately 1000 hectares (10,000 km2) in central France, P. Beck, P. Braunstein, M. Philippe, tr. M. Wolfe, 'Wood, Iron and Water in the Othe Forest in the Late Middle Ages: New Findings and Perspectives', in E.B. Smith and M. Wolfe, eds.,

Technology and Resource Use in Medieval Europe: Cathedrals, Mills, and Mines (Aldershot, 1997), p. 174.

15. Keene, 'Metalworking in Medieval London, p. 95. Core/periphery models are extremely helpful for analysing interregional supply and demand patterns, also known as exchange relations, Frank and Gills,

The World System: five hundred or five thousand?; Chase-Dunn and Hall, *Rise and Demise: comparing world systems*; C. Chase-Dunn, *Global Formation. Structures of the World Economy* (Oxford, 1989).

16. E. Miller and J. Hatcher,

Medieval England: Towns, Commerce and Craft, 1086-1348 (New York, 1995), p. 62.

17. Cleere and Crossley,

Iron Industry of the Weald, pp. 96-9.

18. Coal unearthed by tides and found on shores was given the name seacoal which was retained even when coal was mined inland, Gies,

Cathedral, Forge and Waterwheel, p. 187.

19. Tylecote, 'The Medieval Smith and His Methods', p. 43; Geddes, 'Iron', pp. 172-3.

20. White,

Medieval Technology and Social Change, p. 89.

21. The Cistercian monastery at Clairvaux employed a water race to supply running water in turn to the kitchens, grain mill, vats, fuller's mills, tannery and finally to carry away waste, J. Gimpel,

The Medieval Machine: The Industrial Revolution of the Middle Ages (New York, 1977), pp. 3-6.

22. Singer et al.,

A History of Technology, ii, p. 66.

23. T. Reynolds, 'Iron and Water: Technological Context and the Origins of the Water-powered Iron Mill',

Medieval Iron in Society, Inga Serning et al., eds. (Stockholm, 1985), p. 67.

24. Reynolds, 'Iron and Water', pp. 61-5; Schubert,

History of the British Iron and Steel Industry, p. 133; H. Clarke, *The Archaeology of Medieval England* (London, 1984), p. 162; Hill, *A History of Engineering*, pp. 169-72.

25. G. Magnusson, 'Lapphyttan-An Example of Medieval Iron Production',

Medieval Iron in Society (Stockholm, 1985), pp. 21-2.

26. Craddock, *Early Metal Mining and Production*, p. 235.

27. This figure is usually derived by comparing the size of bloom produced by conventional means, and those produced by the Byrkeknott ironworks, Crossley, *Iron in the Weald*, p. 106; Geddes, 'Iron', pp. 172-3; Tylecote, *Metallurgy in Archaeology*, p. 211.

28. Tylecote, *Metallurgy in Archaeology*, p. 273.

29. P. Craddock, *Early Metal Mining and Production* (Edinburgh, 1995), p. 248.

30. G. Magnusson, 'Ironmaking in a Long-time Perspective', *The Importance of Ironmaking. Technical Innovation and Social Change*, idem, ed. (Stockholm, 1995), p. 33.

31. Singer, *A History of Technology*, p. 75.

32. Tylecote, *Early History of Metallurgy in Europe*, p. 248. Some furnaces had ducts or taps to allow the slag to run off from the charge, but this technique did not always make a great difference in the quality of the bloom, see Clarke, *Archaeology in Medieval England*, p. 162.

33. See for instance the costs involved with more traditional mills, R. Holt, *The Mills of Medieval England* (London, 1988), pp. 86-9.

34. Relatively open because some protectionist measures were taken by the Crown regarding the import and export of iron and arms. See below.

35. The ores in the Basque region possessed several features which gave their workers an advantage over competitors. The ore was near to the surface, fairly rich at 48-58% iron, and low in phosphorous leaving the final product tough and malleable, Childs, *Anglo-Castilian Trade*, pp. 112-3.

36. Ibid, pp. 117-8; Childs, 'England's Iron Trade in the Fifteenth Century', pp. 26-7, 33.

37. M.M. Postan, *Medieval Trade and Finance* (Cambridge, 1973), pp. 355-6.

38. Childs, *Anglo-Castilian Trade*, p. 115-6.

39. Schubert,

History of British Iron and Steel Industry, pp. 110, 116.

40. Schubert,

History of the British Iron and Steel Industry, p. 116.

41. He arrived at that figure by cataloguing documented sites (150), making an allowance for others unknown (an additional 200), and then multiplied the total by what he presumed to be the average annual output of a forge (2.5-3 tons),

History of the British Iron and Steel Industry, pp. 93-109, esp. 108-9.

42. Beck, Braunstein, Philippe and Wolfe, 'Wood, Iron and Water', pp. 178-9.

43. Schubert,

History of British Iron Industry, p. 94.

44. Dyer,

Standards of Living in the Later Middle Ages, p. 101-2, quoting R. Morris, *Cathedrals and Abbeys of England and Wales* (London, 1979), p. 180.

45. P. Contamine, 'Peasant Hearth to Papal Palace: The Fourteenth and Fifteenth Centuries',

The History of Private Life, vol. ii: *Revelations of the Medieval World*, G. Duby, ed. (London, 1988), pp. 425-35.

46. Ibid, pp. 444-60.

47. One study noted the existence of smiths in 29 of 41 counties by 1066, Miller and Hatcher,

Medieval England, pp. 2-3.

48. J. Burrell, 'Peasant Craftsmen in the Medieval Forest'

Agricultural History Review 17 (1969), pp. 91-107. For women in the iron industry see, Geddes, 'Iron', pp. 186-8.

49. See above, Chapter Two.

50. Storey, 'The Tower of London', p. 176.

51. R.H. Hilton,

A Medieval Society. The West Midlands at the end of the Thirteenth Century (London, 1966), p. 207.

52. Schubert,

History of the British Iron and Steel Industry, pp. 85-7, 104.

53. Ibid, pp. 94, 118.

54. Geddes, 'Iron', p. 182.

55. J.G. Hurst, 'Rural Building in England and Wales',

The Agrarian History of England and Wales, 1042-1350, vol. ii (Cambridge, 1988), p. 855.

56. Astill, 'Iron Smithing in Medieval England', pp. 188-9.

57. Miller and Hatcher,

Medieval England, p. 62.

58. Geddes, 'Iron', pp. 174-81.

59. G. Astill, 'An Archaeological Approach to the Development of Agricultural Technologies',

Medieval Farming and Technology. The Impact of Agricultural Change in Northwest Europe, G. Astill and J. Langdon, eds. (New York, 1997), p. 212.

60. CCR, 1318-1323, pp. 43, 171, 270-1, 278.

61. For what follows see, Nicholls,

Iron Making in ...Forest of Dean, pp. 18-25.

62. H.G. Nicholls,

Iron Making in the Olden Times. As instanced in the ancient mines, forges and furnaces of the Forest of Dean (Gloucestershire, reprint, 1981).

63. M.L Bazeley, 'The Forest of Dean in its relations with the Crown during the twelfth and thirteenth centuries'

Transactions of the Bristol and Gloucester Archaeological Society 33 (1910), pp. 153-286.

64. J. Allen, 'A Possible Trade in Iron Ores in the Severn Estuary of South-west Britain',

Medieval Archaeologia 40 (1996), pp. 226-30.

65. Schubert,

History of the British Iron and Steel Industry, p. 103.

66. Cleere and Crossley,

Iron Industry of the Weald, p. 100; Gies, *Cathedral, Forge and Waterwheel*, p 63.

67. Schubert,

History of the British Iron and Steel Industry, pp. 112-4.

68. Miller and Hatcher,

Medieval England. Towns, Commerce and Crafts, p. 62; E. Straker, *Wealden Iron* (London, 1931), pp. 87-95.

69.

Victoria County History. Gloucestershire, ii: *Ecclesiastical history; religious houses; social and economic history; industries; agriculture; forestry; sport; schools*. W. Page, ed., (Oxford, 1972), p. 216.

70. J. Clark, 'Medieval Horseshoes',

Datasheet 4, Finds Research Group, pp. 2-3; idem, 'Horseshoes', *The Medieval Horse and its Equipment c. 1150-c.1450,* idem, ed. (London, 1995), pp. 75-124.

71. CLR 1251-1260, pp. 30, 109, 122, 141.

72. CLR 1251-1260, pp. 217, 231.

73. Cleere and Crossley,

Iron Industry of the Weald, p. 91.

74. CDS, iii, nos. 1283, 1307.

75. PRO, London E 101/12/3, Account of stores and arms for Flint and Rhuddlan, 32 Edward I.

76. Salzman,

Building in England, p. 287

77. PRO, London E 101/7/6, Account of John Burdon, constable of Berwick castle, 26 Edward I.

78. Altogether probably 30 or more tons or iron, PRO, London E 101/5/22, Account of stores and other expenses at Carlisle castle, 23 to 25 Edward I.

79. CDS, iv, p. 456.

80. CDS, iii, pp. 366-7.

81. PRO, London E 101/17/15, Account of William Chaillon, controller of Robert de Pippishull, for provision of stores for the Tower of London, 19 Edward II to 1 Edward III.

82. PRO, London, E 159/41, King's Remembrancer, Memoranda Rolls and Enrolment Books, 1266 Michaelmas to 1267 Trinity, 50/51 Henry III.

83. PRO, London E 101/20/28, Account of John de Wesenham for wages of crew on 'la Grace de Dieu' of Lynn. 11 and 12 Edward III.

84. *Foedera*, i, part 4, p. 94.

85. PRO, London E 101/5/20, Cost of the galley of Newcastle, 23 and 24 Edward I.

86. Bartlett, *The Making of Europe*, p. 61.

87. Finó, 'Notes sur la Production de Fer', p. 62.

88. Dyer, *Standards of Living*, pp. 102-3.

89. Tylecote, 'The Medieval Smith and his Methods', p. 46.

90. Childs, 'England's Iron Trade in the Fifteenth Century', p. 45.

91. Salzman, *Building in England*, pp. 303-17.

92. *Victoria County History*: Gloucestershire, ii, p. 216.

93. Schubert, *History of British Iron and Steel Industry*, p. 119-20, but for his concept of hundredweight p. 140, n. 1.

94. Childs, *Anglo-Castilian Trade*, p. 143, n. 58.

95. Attempts, however, are often made, Childs, 'England's Iron Trade in the Fifteenth Century', p. 29.

96. *Statutes of the Realm*, i (London, 1810), pp. 204-5.

97. Cal. Plea and Memoranda Rolls 1323-64, p. 149.

98. Salzman, *Building in England*, p. 287.

99. Schubert, *History of British Iron and Steel Industry,* p. 140.

100. PRO, London E 101/7/6, Account of John Burdon, constable of Berwick castle, 26 Edward I.

101. Schubert, *History of British Iron and Steel Industry,* p. 140, n. 3.

102. PRO, London E 101/467/7 (1), Counter-roll of the account of William de Kelleseye, clerk of the works at Westminster and the Tower of London, 2 and 3 Edward III.

103. Salzman, *Building in England*, p. 288.

104. PRO, London E 101/5/22, Account of stores and expenses at Carlisle castle, 23 to 25 Edward I.

105. PRO, London E 101/579/6, Expenses of springalds, 31 Edward I.

106. Salzman, *Building in England*, p. 288.

107. PRO, London E 101/7/6, Account of John Burdon, constable of Berwick castle, 26 Edward I.

108. PRO, London E 101 467/6 (2), Particulars of expenses of works at London and Westminster, 2 to 5 Edward I.

109. PRO, London E 101/467/7 (1), Counter-roll of the account of William de Kelleseye, clerk of the works at Westminster and the Tower of London, 2 and 3 Edward III.

110. PRO, London, E 101/5/22, Account of stores and expenses at Carlisle castle, 23 to 25 Edward I.

111. PRO, London E 101/6/7, Expenses of engines at Carlisle 25 Edward I.

112. See for instance Straker, *Wealden Iron*.

113. Salzman, *Building in England*, p. 287.

114. PRO, London E 101/491/13, Expenses of works at Winchester castle 6 Henry III; *Building Accounts of King Henry III*, H.M. Colvin, ed. (Oxford, 1971), pp. 130-46.

115. J.F. Willard, 'Inland Transportation in England during the Fourteenth Century', *Speculum* 1 (1926), p. 368.

116. J. Langdon, *Horses, Oxen and Technological Innovation : The Use of Draught Animals in English Farming from 1066-1500* (Cambridge, 1986), pp. 116, 225-6.

117. CLR 1240-1245, pp. 322, 324.

118. PRO, London E 101/467/1, 2, 3, Rolls of expenses of works at Westminster, 38, 43 and 44 Henry III.

119. PRO, London E 101/17/6, Account of Robert de Pippushall for fortifications and garrisons in Aquitaine and the Tower of London, 18 to 20 Edward II.

120. Salzman, *Building in England*, p. 286.

121. Salzman, *Building in England*, pp. 286-17.

122. PRO, London E 101/17/6, Account of Robert de Pippushall for fortifications and garrisons in Aquitaine and the Tower of London, 18 to 20 Edward II.

123. Childs, *Anglo-Castilian Trade*, p. 116.

124. PRO, London E 101/466/30, Account of works at Westminster 37 Henry III.

125. PRO, London E 101/467/7 (1), Counter-roll of the account of William de Kelleseye, clerk of the works at Westminster and the Tower of London, 2 and 3 Edward III.

126. PRO, London SC 6/1031/19, Ministers and Receivers' accounts, Bailiff of Winchelsea, 51 Henry III.

127. Schubert, pp. 111-15.

128. Bolton, *Medieval English Economy*, pp. 192-3.

129. Schubert, *History of British Iron Industry*, pp. 102, 104, 112.

130. Keene, 'Metalworking in Medieval London', p. 96; Lloyd, *Cutlery Trades*, p. 81.

CHAPTER SIX

The Costs of Armaments

'And over that a fyn hawberk,
Was al ywrought of Jewes werk,
Ful strong it was of plate;
And over that his cote-armour
As whit as is a lilye flour,
In which he wol debate
His sheeld was al of gold so reed,
And therinne was a bores heed,
A charbocle bisyde

Chaucer, 'The Knights Tale', c. 1385[(1)]

Many have come to read 'The Knight's Tale' as a satire on chivalry, wherein the noble classes cared about appearance and money more than prowess, while ignoble mercenaries and commoners filled the ranks of armies. Chaucer may have been alluding to these circumstances, but his description of the knight's armours was not altogether unrealistic for noble society. Armaments indeed provided a unique visage for chivalry possessing an unsurpassed ability to present authority and power with one's person. That opportunity was especially prized and seized upon by a society grounded in personal loyalty and conspicuous consumption, resulting in some luxuriously embellished arms. Consequently, the study of the costs of munition arms and their availability must take into consideration armaments' significance and the growing trend towards conspicuous consumption which produced many artificially expensive arms. Besides the need to delineate the two for identifying the true costs of munition grade arms, sumptuous arms warrant special attention as prominent financial, technological and ideological investments.

Although several estimates have been made for the prices of an entire harness of arms and armour as discussed in Chapter Two, virtually no attempt has been made to ascertain changes in the prices of individual arms nor changes in their prices over a period of time. We are not lacking evidence for prices of specific arms in England from the thirteenth century onwards, but like most industrial goods of the period their study has been shunned except for very cursory efforts. Postan berated industrial products as economic indicators because of the staggering variations in quality which are not always apparent to the historian but greatly affected prices.[(2)] Based on such fragmentary investigations drawn mostly from noble wills and inventories, most historians assume that prices of arms experienced the same inflation as many other goods which quadrupled in price during the twelfth and thirteenth centuries.[(3)] Whereas the misapprehension regarding arms prices reinforces J. Campbell's opinion that a hauberk might be worth as much as the annual income 'from a rather big village', as we shall see Campbell's estimate has more in common with Tolkien's Middle Earth than medieval England.[(4)] The overwhelming evidence suggests that conspicuous consumption aside, prices and to a greater extent the costs of almost all types of munition-grade arms fell over the course of the thirteenth and fourteenth centuries.

Sumptuous Arms

Although the range of records generated by the propertied classes provide an abundance of specific prices for arms, the extraordinarily high prices of sumptuous armaments have been trimmed from the sample presented in Appendix I. In most cases even the slightest decoration on an armament raised its price or evaluation for well above the cluster of prices presented in the sample, and in many more cases the decoration is so elaborate the item's cost is staggering. A few examples easily demonstrate this point. Although Richard II's court is considered to have become more extravagant in its dress, previous kings managed to dress with style. Henry III owned at least four helms graced with gems.[(5)] Shipments of arms and horses to Edward I were likely to contain gold cloth, silk and velvet as well.[(6)] We have already seen the amounts spent by Edward II's armourers who provided helms to him for £8 and £10 each. Edward III's indulgences extended to a sword with a an alleged
[(7)]

splinter of the Cross, and the more detailed accounts of his reign provide fuller descriptions of his arms. Edward's blue-taffeta and white- silk jupon adorned with a pound of gold plate and dozens of silver buckles was typical for him.[(8)] For the Dunstable tournament in 1342, he spent over £7 on a surcoat (tunica ad arma) embroidered with silver and gold figures.[(9)] In an account from 1350-1352, we learn that a crest for Edward III's helm was made from red velvet and silk with a design of branches and wild men outlined in pearls; this crest sat upon a golden leopard itself wearing a crown of silver set with sapphires.[(10)] Richard II's dress may have been even more lavish as indicated by the descriptions of'jewels' he pawned. In the indentures we read of coronets designed to fit over his basinets, a Spanish saddle bedecked with pearls and other precious stones, a sword with gold settings and diamonds, rubies, sapphires and pearls, and most startling, an apparently famous 'Spanish palet' itself valued at £1708.[(11)]

Less extravagant but equally fashionable arms were also worn by nobility and gentry. Whether or not popular fashions grew more extreme in taste and lavishness during the fourteenth century as suggested by the introduction of sumptuary laws in England and elsewhere, the evidence is undeniable that lavish dress prevailed among the class-conscious.[(12)] Most inventories and evaluations by escheators specify extravagant decoration or unusual qualities of arms. An inventory of the goods of Thomas Arundel listed a Milanese basinet with a silver collar and two covered pairs of plates garnished with silver, among other comparable small arms.[(13)] John fitz Marmaduke, governor of Perth during Edward II's reign, possessed in addition to numerous ordinary arms five aketons each worth between 40s and 53s (ten times the ordinary), and two swords worth 8s and 10s (four to five times the ordinary).[(14)] Edmund Appleby, a Leicestershire knight, owned £16 6s 8d worth of armour in 1374, or more than 12% of his total possessions.[(15)] The jupon and gambeson of a 'doctor' taken by the Scots during Edward II's reign were claimed to have been worth £10.[(16)] In fact, trade in these upscale arms was buoyant enough that Francesco Datini, a merchant operating in Avignon in the fourteenth century, became wealthy in his trade with an affluent group of nobles and gentry.[(17)]

The improvidence of such elaborate decorations may be questioned, but were finely woven into the period's social dynamics and were legitimated on a personal, local and national level. On a national or state level, Quentin Skinner maintains that early states organized around personal authority virtually equated sovereignty with the dsisplay of majesty in a ruler.[(18)] Other sociological theories also support this notion. In a sense a ruler's appearance represented the aggregate wealth of his subjects and the solvency of his realm.[(19)] A princely appearance was especially important in ceremonies, which were becoming much more elaborate affairs in the thirteenth and fourteenth centuries, demonstrating the scale of resources available in society not just in terms of wealth, but also in cultural, intellectual and material sophistication. Legitimacy and the ability to rule was often equated with grand spectacle, especially as the king's iterations were beginning to be abandoned.[(20)] Furthermore, when concepts of the crown and the king's two bodies became a prominent issue in political theory, more care was taken to present the king's person as an ideal image.[(21)]

While such iconography and regalia were employed as prime expressions of the state and public office, they are also thought to have performed similar roles in private and civic affairs in confirming social relationships and station.[(22)] For Gurevich, ceremony and ritual offered regular opportunities to compete for social prestige and gauge each other's economic and social power. Great expenditure and elaborate display were meant to 'awe spectators and overwhelm their senses of proportion, worth and norm'.[(23)] Likewise, Geertz believed that an individual's place in the social order depended on his or her ability to 'engage passion and dominate minds'; obviously enhancing one's appearance helped to achieve this.[(24)] In these societies ceremony and spectacle often provide opportunities to express social roles and aspirations, and ultimately provided opportunities to resolve underlying tension by making elusive relationships publically visible. In this way changing conditions are continually reassessed so that the various actors gain legitimacy, establishing rank and identity.[(25)] Lords demonstrated their ability to provide for their retainers through their opulence. For Keen, franchise rendered the nobility into a hierarchy of benefactors chasing or choosing vassals depending on economic conditions and the availability of vassals.[(26)] Largesse and noblesse also encouraged loyalty and reinforced deference.[(27)] Appearance and conspicuous consumption helped to identify the appropriate or expected value of gifts and payments for marriages, alliances and political affiliations. Ingenuity in such matters were a mark of refinement: even hunting arrows might be bound with gold.[(28)] While such conspicuous display has been ascribed a normative function in class-oriented societies predicated on clientage and vassalage, the choice of arms as a primary medium must surely be viewed alongside the proliferation of munition-grade arms during the twelfth and thirteenth centuries.

Munition arms

At the other extreme, a well-rounded sample prevents us from assuming that abnormally low prices were typical. In the Royal Exchequer and Wardrobe accounts, a multitude of purchases provides prices for every kind of armament. The agents making these purchases or arranging manufacture would normally have had several advantages working in their favour which insured lower prices. In cases of widespread provision to supply the army or navy at large, low-cost munitions whether outdated, secondhand or less than pristine would not have been ignored; indeed they probably sought for such bargains when hundreds of basinets and pairs of plate were immediately required. These officials would have been familiar with grades of quality and the going rates, and in dealing with the same armourers or merchants time and time again they probably would have begun to receive better treatment and prices. After all, royal demands and the equipping of large forces created work for many craftsmen and artisans, and would have been highly sought after by craftsmen and merchants alike.(29)

There is much evidence which points to a constant if not steady decline in the costs of arms since the early the middle ages. Several methods exist for determining the costs of armaments, or their value in relation to other goods and wages, and when placed in the context of standards of living we can assess their costliness across many sectors of society. To avoid undue discrepancies from fluctuations in the value of the currency, historians often convert prices and wages to a more standard unit such as pure silver. Although a combination of monetary factors from Edward I's reign onwards created the potential for sharp turns in prices, sound policies in recoinage and the fairly stable silver content of the English penny smoothed over such disturbances when viewed from a long-term perspective, allowing a fairly straightforward comparisons of prices and wages.(30) At present the consensus holds that the prices of most products virtually doubled when averaged over the course of the thirteenth century.(31) On average, wages rose only slightly less during this period but at a far more even pace, meaning that by the beginning of the fourteenth century a slight deficiency had accrued in the purchasing power of wages. D.L. Farmer's work in this area has become the standard point of reference, and demonstrates that for craftsmen and labourers, more work was required to achieve the same standard of living as the thirteenth century progressed. More relevant for our purpose is his data of prices for a range of goods such as cereals, cheese, salt, wool, and various livestock, all of which rose during the thirteenth and early fourteenth centuries albeit at different rates.(Table 6.1).(32)

Table 6.1: Prices of Common items (in shillings)

YEAR	Wool (stone)	Cheese (wey)	Salt (qtr.)	Livestock (head)	Grain(qtr.)
1210-1240	2.31	7.84	1.75	5.45	2.97
1240-1270	3.12	8.82	2.18	6.29	3.34
1270-1300	4.34	9.49	3.16	7.63	4.40
1300-1330	4.97	11.47	3.85	9.42	4.92
1330-1356	3.36	10.58	4.31	7.83	4.16

Source: Farmer, 'Prices and Wages', p. 757.

Estimates for average 'prices' of arms prior to the twelfth century make for dangerous comparisons because of Europe's relatively low commercialization then, but the scant evidence provides some indication of the longer trend of declining prices. In the fourth century, based on the values stated in the arms requirements of the Ripuarian Law, Delbrueck estimated that a helmet, hauberk, sword with scabbard, greaves, lance and shield in Europe would have cost 33 solidi, incidentally the same amount needed to purchase 33 cows.(33) During that time the majority of people survived on a minimum of 3 solidi per year.(34) For quick comparison, by the fourteenth century arms comparable to that contained in the Ripuarian law cost on average 23s 5d in England, when the minimum level of subsistence hovered around 1d per day, or 30s 5d per year.(35) Even if the cost of arms equalled the cost of living in 1300, the real cost of these arms in the fourteenth centuries had been reduced to an eleventh of their cost in the fourth century. In the eighth century armaments were still highly-treasured objects. Bloch has provided us with an example from 761, when a man relinquished his ancestral lands and a slave for a horse and a sword.(36) In the eleventh century armaments were still being exchanged for land. In 1080 a *mansus* was given to Cluny Abbey in return for a lorica worth 100 sous, or roughly 20s sterling.[(37)] We are in a much better position to assess changes in the costs of armaments from the late twelfth century onwards, though prices during those decades must be viewed cautiously due to that period's widespread inflation.[(38)] M. Strickland has already proposed that the lengthening of the hauberk to include the arms and legs at this time probably reflects cheaper costs of mail.[(39)] Scammel has also proposed that arms became more widely available during the twelfth century whereas beforehand, he argues, 'knighthood was in the arms not the man.[(40)] Based on individual and group prices, the hauberk, usually termed 'lorica', often sold for 40s or more, as did the mail trapper. In 1182/3, some 52s 2d was granted for a hauberk (lorica), as was 62s in 1186/7.[(41)] A lorica, a pair of iron boots and robes for two people purportedly cost £23 13s in 1183/4, while a lorica, iron boots and helmet for the king of Sweden were purchased for £7 10s in 1185/6.[(42)] Bulk purchases reveal similar prices: two hauberks, four haubergeons and six iron headpieces were purchased in 1207 for £7 8s.[(43)] Lower prices such as the £4 paid for 11 haubergeons and a hauberk (lorica) in 1184/5 occur much more rarely.[(44)] In 1211 a purchase of 23 mail trappers, 6 pair of iron boots, 35 loricae, 11 haubergeons and 45 hundred quarrels cost £89 21d.[(45)] In 1244 a mail trapper and a pair of iron boots were purchased for £5.[(46)]

Despite continued inflation for other goods, the prices of arms fell during the early to mid thirteenth century. Evidence from the middle third of the thirteenth century indicates that the hauberk cost 20s or more, while haubergeons or partial hauberks were frequently priced at one mark.[(47)] In a slight twist on the tradition of bestowing arms with knighthood, Henry III frequently granted £5 for a knight to equip himself.[(48)] One may wonder whether this amount may have been intended as a gift as well as bestowing arms, but in royal accounts that much was often spent on an individual's harness. In one instance 16 marks were spent on 2 surcoats, 2 (mail?) corselets and 2 pair of iron boots.[(49)] In 1267 Henry III's marshal was granted 5 marks for one hauberk (though it must be remembered that steel hauberks continued to command this much even during the fourteenth century).[(50)] Prices for arms associated with Genoa's advanced requirements of the mid thirteenth century are comparable. The hauberk alone was estimated to cost between 120 and 152s Genoese (30s to 38s sterling), and altogether a headpiece (*barberia*), hauberk, leg protection and various arms is said to have cost £10 Genoese, roughly £2 10s sterling,[(51)]

During the second half of the thirteenth century, arms in England began to exhibit much more variation in price especially in decreasing from earlier levels as demonstrated when compared with the prices in Appendix I. Even though arms prices declined over the course of the thirteenth century, the vagaries of economic influences prevented consistent decline everywhere. Due to these variables almost every kind of armament from arrows to hauberks exhibited a wide range of prices. Bulk purchasing did not always obtain lower prices. Comparisons of the circumstances of a few prices from the index compiled from the years 1285-1349 easily demonstrate the extent of variation occurring in arms prices by then. The lowest (2d) and highest (10s) sword prices in the index occurred in the same will.[(52)] The lowest (2s 2d) and highest (10s) prices for basinets both occurred in 1324.[(53)] The index's most expensive price for a coat of plates (26s 8d) occurred in 1335, the least expensive (6s 8d) in 1312.[(54)] Three hauberks in the same inventory as the latter pair of plates were valued at 22s, 13s 9d and 6s. The index's lowest price for a hauberk (5s) was recorded in 1322, yet £10 for ten hauberks was requested by the constable of Portchester in 1335.[(55)]

Of all armaments, bows and their ammunition experienced the least deviation from an average price and the least decline in price over this period. Still this condition did not prevent surprising variations in prices. In the Crown's national orders of 1341, prices were set at 12d per garb of arrows, or 14d if steeled, but these prices may have been set high deliberately.[(56)] Arrows purchased in Robert Pippushall's account for the War of St Sardos (1324-5) ranged in price from ninety-two hundred for £11 9d (7d per sheaf of 24) to
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thirteen hundred for 13s 6d (3d per sheaf). Quarrel prices fluctuated slightly more than arrows, especially with the larger versions. Quarrels for one-foot crossbows ranged in price from 111 per shilling to 29 per shilling, while quarrels for springalds ranged from 25 per shilling to a shilling each. Yet the difference in quarrels sizes cannot have been great: often they are described as quarrels for crossbows of one or two-feet, two-feet or *a tour*, and *a tour* or springald.(58)

Arms such as wood or horn crossbows exhibited greater variations in quality and price. Some very low prices were probably attempts to gain royal favour, such as Bristol's contribution of 100 crossbows of two-feet for £6 (1s 2.4d each) when Edward II's army was embarking for Gascony.(59) In another account also during 1324-5, crossbows *a tour* were purchased at rates of 2 at12s 6d each and 26 at 6s 8d each; crossbows of two-feet were purchased at rates of 16 at 5s each and 4 at 4s each. Crossbows of one-foot were purchased in rates of 20 at 2s 10d each and 10 at 2s 7d. In the same account John de Weston, obtained much better prices in Flanders, where crossbows *a tour* were purchased for 5s each, and crossbows of two-feet were purchased at 18d each. John's purchasing prowess did not always triumph, for he too was forced to pay the more traditional price of 3s 4d per crossbow of two-feet on occasion.(60)

In some cases the prices of arms can reveal for us something about their construction and nature. We saw how the meaning of the terms aketon and coat of plates were merging in the arms requirements in the first quarter of the fourteenth century and before being replaced by the pair of plates or solid breast and back plates. The aketon originally signified a predominantly textile armour, only somewhat stiffer than the padded gambeson. Great similarity with the gambeson is suggested for London in 1322, when a regulation stipulated that both aketons and gambesons must be stuffed with paper, cotton and/or linen.(61) As late as 1297 men on watch in London were required to wear a gambeson *and* an aketon, and the aketon was assigned in addition to a hauberk in the national assessments of 1276-7, 1316, and 1322-3.(62) With the advent of heavier armours the term aketon also came to imply a coat reinforced with stiff materials giving rise to the coat of plates. In 1335 the hauberk was dropped from arms requirements and replaced with either an aketon or pair of plates.(63) Such a shift in meaning can therefore cause some problems in identifying price changes. The aketon valued at 12d in 1337 must have been something much more akin to a gambeson rather than a doublet reinforced with mail, *cuir boulli,* or some other stiff material.(64) An account for expenses at Scarborough castle for the year 1322-1323 included *aketons de coro.* In 1322 the inventory of Robert of Flanders included aketons of plate and pairs of plate.(65) In an effort to equip a levy in 1323/4, the terms aketon and pairs of plate seemed to have been used interchangeably based on the prices paid for each item.(66) Clearly, the constable of Portchester castle had in mind something similar to the plate-armoured aketons when his request in 1335 included among other things, 12 aketons worth £16; the figure seems incredibly expensive for a lesser armour. He also requested £10 for ten haubergeons (i.e. cheaper than the aketons), but it should be noted that the costs of his repairs also seem high compared to others.(67)

Likewise basinets exhibited a wide price range for seemingly normal pieces. An ornate basinet with visor and aventail might fetch as much as £8 or £10, but these definitely remained the preserve of the wealthy.(68) An array in Lincoln in 1315/6 included 18 purchases of basinets which ranged from 12d to 3s 6d, and one other lot at 6s 8d.(69) An appraisal made in 1324 valued three unremarkable basinets at 30s, an average of 10s each.(70) In the same year, however, 44 basinets were purchased by royal clerks for 16d each and covered in white leather for another 10d each.(71) Compared with other basinet prices from around that time it may be said that the latter price was much more typical of the period. Purchases for arming a galley in 1294/5 included 60 basinets at a shilling each.(72) When equipping *la Phillipe* at Lynn in 1337/8, 60 basinets with aventails were purchased for 3s each.(73) Some purchases reveal the scale of England's industrial capacity. To raise a requested 500 troops from Surrey and Sussex in 1322 multiple purchases were made on very short notice: 100 sets of aketons, basinets and iron gauntlets were purchased for a total of £80, another 100 basinets were purchased for £17 10s (3s 6d each), and 300 pairs of gauntlets were purchased for £15 (12d per pair). Two more purchases were made, each time comprising 100 basinets and 100 aketons, at costs of £60 and £75.(74) Within this short time, several purchases of reasonably large quantities of armours were made in the same region with considerable variations in price.

These prices demonstrate that an acute drop occurred in the second half of the thirteenth century. Another indication that armaments had become more prolific is indicated by blurred terminology as we have seen with the 'aketon'. Whereas hauberk (lorica) and haubergeon (haubergellus) had been consistently distinguished by name and price in the early thirteenth century, by the fourteenth century the proliferation of armours and styles had surpassed neat classifications. Two of the highest priced mail coats in the sample were in each case described as haubergeon instead of hauberk or lorica.(75) Although we occasionally find low values for equipment in early thirteenth-century records like the 6s 8d pledged for a hauberk and pair of greaves, even lower prices occurred in the fourteenth century.(76) In 1290 a gambeson, haubergeon, basinet with collar, cuisses, crossbow, baldric and quarrels was valued at only 8s 10d.(77) In 1356 a pair of gauntlets and bracers, pair of plates, basinet, dagger and buckler were valued at only 5s 6d.(78) Recall that in 1211 a purchase of 23 mail bardings, 6 pair of iron boots, 35 loricae, 11 haubergeons and 45 hundred quarrels cost £89 21d.(79) Compare that purchase with the 24 pairs of plate, 9 basinets with aventails, 12 plate gauntlets, and 13 aketons valued at £17 8s in 1342.(80) Likewise the mail trapper appears to have dropped in cost over the course of the thirteenth century. Whereas early in the thirteenth century purchases of mail trappers racked up costs equating to £2 or more each, later we see much lower evaluations. In 1274 a mail trapper in an Exeter inventory was described as worn and scarcely worth £1.(81) Two sets of mail barding were valued at 40s in Edward II's reign.(82)

Arms which contained little iron and which remained relatively unaltered in design and composition exhibited very little change in price between the thirteenth and fourteenth centuries. In the early thirteenth century quarrel prices typically ranged from 1,091 per £1 to 1,550 per £1, almost identical to the early fourteenth century.(83) Baldrics, targes and crossbows displayed similarly consistent price tendencies.(84)

Knowing whether or not arms prices continued to drop in the later fourteenth century will require further research, but preliminary findings suggest as much. Prices in the late fourteenth and early fifteenth centuries still exhibited wide price ranges but at a markedly reduced level especially for those arms being supplanted by newer ones. A hauberk was in one instance valued as low as 40d; the Earl of Kent's guns were worth only 3s 4d each in 1400 although the smallest ribalds cost £1 in the 1340s.(85) Breastplates in the earl of Arundel's inventory (1397) were valued at 5s and also at 6s 8d; 17 pairs of gauntlets were valued at 4d per pair.(86) Even if the escheator(s) had assigned low values to the earl's used armaments, the comparison leads us to believe that the price of armaments had certainly not risen in England during the second half of the fourteenth century. In France the inflated prices of Datini's less August armaments were at least comparable to prices of munition arms in early fourteenth-century England. Other examples from France hint that prices there may have dropped further. In 1384 basinets with visors and aventails all in the latest fashion were valued at 2-3 l.t., whereas Datini's fashionable basinets were selling from upwards of 5 l.t. in the 1360s. Datini's less fashionable helmets had sold for 1 l. 4 s.t., but in 1389 ordinary basinets with plain camails were worth from 8 to 32 s.p.(87)

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Rather than seeing differences in arms prices as incomprehensible, the wide range of prices should be taken as an indication of a developing and possibly vibrant industry. The evidence presented here suggests that in England prices for arms with high iron and/or steel contents experienced the most drop over the course of the thirteenth and fourteenth centuries. In most cases the prices of substantial arms such as hauberks or iron helms fell to a quarter or even an eighth of their price in 1200. A hauberk for instance which commonly cost 40s in 1200 was often valued for 20s during the early thirteenth century and could be found for 5s in the fourteenth century. In relation to the costs of living, arms which experienced such large price drops may have cost one-sixteenth as much in 1300 as they had in 1200. The reduction in the prices of hauberks may have been heavily influenced by the introduction of new technologies such as wire draw-plates, but the overall trend is corroborated by prices of other substantial arms.[(88)] When the coat of plates first appeared in English records during the late thirteenth century, its price was similar to the hauberk even though it is usually presented as a superior armour, and eventually the pair of plates or breastplate superseded both and at a lower price presumably because in addition to the wider conditions which reduced arms prices the breastplate and other plate armours required less labour and materials to construct. Thus the lower price of arms actually represents three improvements in that better arms became more widely available for much less cost.

A combination of general factors seem to have been at work in increasing the accessibility of armaments over the thirteenth and fourteenth centuries, both in terms of cost and availability. The alterations or developments which reduced prices, such as improved manufacturing techniques, cheaper materials, and the extension and specialization of the industry, overcame steady or increased demands for arms. Even though England does not seem to have imported large amounts of arms, the possibility of imports may have worked to keep domestic prices down. We know that the rise in the production and import of iron during the thirteenth century increased its availability and reduced its cost. However, a change in the price of iron can only account for a fraction of the reduction of some arms prices. Take the price of a hauberk as an example. If two to three times as much iron as the final weight (around 30 lbs.) was needed (ie max. 100 lbs), even if Spanish iron was used its drop from at most 10s to 4s per hundredweight would only account for a saving of 6s in the hauberk's price, and in most cases only 2 to 4s would have been saved by cheaper iron. Moreover, the drop in the price of iron seems to have occurred mostly during the second half of the thirteenth century, whereas the price of hauberks were declining since the late twelfth century.

The number of craftsmen engaged in arms manufacturing must also be considered. Before the mid thirteenth century the price of a major armour such as a hauberk remained at levels reminiscent of the late twelfth century, leading one to believe that the industry was still confined to few craftsmen who had fixed prices or rates. Such circumstances would explain the extraordinarily high status afforded to smiths during the early middle ages.[(89)] If Europe's population doubled during the thirteenth century, the number of craftsmen available to produce arms would have doubled if remaining proportionate to society's growth, but the number of smiths may actually have increased above the population curve due to new opportunities and increased demands for iron goods and iron-working. The growth in cottage crafts sectors of the iron industry and professional smiths/armourers probably increased competition and reduced the opportunity for higher profits.[(90)] Furthermore, with the appearance of distinct crafts such as wire-drawers, heaumer, etc., specialization would have increased productivity, possibly aided by the extension of the guild system. The durability of armaments may also have meant that the number of armaments per capita was constantly increasing as production continued. Inspections into royal armouries usually returned disheartening reports on the conditions of armouries, but better treatment may have been given to private possessions which represented a much greater investment.

NOTES

1. *The Riverside Chaucer*, L. Benson, gen. ed. (Oxford, 1988, third edn.), ll. 863-71.

2. M.M. Postan,

The Medieval Economy and Society. An Economic History of Britain in the Middle Ages (Middlesex, 1972), pp. 260-1.

3. Dyer,

Standards of Living, pp. 102-4; M. Prestwich, 'Edward I's Monetary Policies and their Consequences', *Economic History Review* 22 (1969), p. 416.

4. J. Campbell, 'England, Scotland, and the Hundred Years War in the Fourteenth Century',

Europe in the Late Middle Ages, J. Hale, R. Highfield, B. Smalley, eds. (1965), pp. 184-216. J.R.R. Tolkien, *The Fellowship of the Ring*, p. 417, has a character exclaim that a magical hauberk of 'mithril' has greater worth 'than the Shire and everything in it'.

5. CLR 1245-1250, p. 66.

6. CPR 1301-1307, p. 245.

7. Oakeshotte, *Records of the Medieval Sword*, pp. 268-93.

8. Nicholas, 'Observations on ...Order of the Garter', pp. 34-5.

9. Barker, J., *The Tournament in England, 1100-1400*, (Woodbridge, 1986), p. 182.

10. K. Staniland, 'Court Style, Painters and the Great Wardrobe', *England in the Fourteenth Century*, pp. 236-46.

11. Riley, *Memorials of London*, pp. 429-30, 443.

12. Edward III began to issue sumptuary laws which dictated materials and garments appropriate for each class, but such legislation was either very difficult to enforce, aimed primarily at court society, and/or was intended as a general inhibition because we have no evidence for prosecution until the fifteenth century. N. Harte, 'State Control of Dress and Social Change in Pre-Industrial England', in D.C. Coleman and A.H. John, eds., *Trade, Government, and Economy in Pre Industrial England. Essays presented to F.J. Fisher* (London, 1976), pp. 132-65. Cf. S. Newton, *Fashion in the Age of the Black Prince. A Study of the Years 1340-1365* (Woodbridge, 1980), pp. 30-40.

13. Salzman, L.F., 'The Property of the Earl of Arundel, 1397', *Sussex Archaeological Collection* 91 (1953), pp. 32-52.

14. *Wills and Inventories Illustrative of the History, Manners, Language, Statistics, etc. of the Northern Counties of England from the 11th century Downwards*, Surtees Society 2, part 1 (1835), pp. 16-18.

15. Dyer, *Standards of Living*, p. 76.

16. CPR 1338-1340, p. 416.

17. M.M. Postan and E. Miller, eds., *The Cambridge Economic History of Europe*, ii: *Trade and Industry in the Middle Ages* (Cambridge, second edn., 1987), pp. 378-9, 393.

18. Skinner, 'The State', pp. 90-131.

19. J. Huizinga *The Waning of the Middle Ages*, F. Hopman, tr. (London, 1924), pp. 16, 26.

20. B. Guenée, *States and Rulers in Later Medieval Europe*, J. Vale, tr. (Oxford, 1985), pp. 67-78.

21. E. Kantorwiz, *The King's Two Bodies*, especially pp. 336-42; A.J. Duggan, ed., *Kings and Kingship in Medieval Europe*, (London, 1993), p 162.

22. D.A. Bullough, 'Games People Played: Drama and Ritual as Propaganda in Medieval Europe', TRHS, fifth edn., 24 (1974), pp. 97-122.

23. A.J. Gurevich, *Categories of Medieval Culture*, G.L. Campbell, tr. (London, 1985), pp. 248-51.

24. C. Geertz, *Local Knowledge. Further Essays in Interpretive Anthropology* (New York, 1983), pp. 121-3. Anthropologically, this idea presupposes that an individual's persona can be equated with a symbolic value of vitality and relation to the centre of the social order.

25. M. James, 'Ritual Drama and the Social Body in the Late Medieval English Town', *Past and Present* 98 (1983), pp. 3-29.

26. Keen, *Chivalry*, pp. 2, 16-7.

27. N. Elias, *The Court Society* (Oxford, 1983), pp. 89-90.

28. K.B. McFarlane, *The Nobility of Later Medieval England* (Oxford, 1973), p. 100.

29. In the early fourteenth century, a relatively small order for harness 'provided a year's income for a few mercers and weeks of work for 40 sempstresses and painters', Williams, *Medieval London*, p. 108.

30. Prestwich, 'Edward I's Monetary Policies, pp. 406-416, see also the discussion in J.L. Bolton, *The Medieval English Economy 1150-1500* (London, 1980), pp. 73-81.

31. See for instance the prices on a range of items taken from the Pipe Rolls in N. Barratt, 'English Royal Revenue in the Early Thirteenth Century and its Wider Context, 1130-1330' in *Crises, Revolution and Self Sustained Growth*, pp. 87-90.

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39. Strickland, *War and Chivalry*, p. 170.

40. Scammel, 'The Formation of the English Social Structure', pp. 591-618; Strickland also posits that knighthood denoted the function of service in arms rather than a social class during that time, *War and Chivalry*, pp. 142-6; cf. Coss, 'Knights, Esquires and the Origins of Social Gradation in England', pp. 155-78.

41. Pipe Roll 29 Henry II, p. 121; Pipe Roll 33 Henry III, p. 101.

42. Pipe Roll 30 Henry II, p. 135; Pipe Roll 32 Henry III, p. 199.

43. Pipe Roll 9 John, p. 31.

44. Pipe Roll 31 Henry II, p. 155.

45. Pipe Roll 13 John, p. 108.

46. CCR 1244, p. 227.

47. E.g. 4 haubergell' for 4 marks, Pipe Roll 1 John, p. 33; 10 lorica for £10 and 2 haubergell for 2 marks, Pipe Roll 2 John, p. 209; 2 haubergeons for 2 marks, Pipe Roll 7 John, p. 10.

48. E.g., CLR 1251-1260, pp. 230, 253, 263, 266, 357, 395, 398.

49. Ibid,, p. 380.

50. CLR 1260-1267, p. 282.

51. Contamine, *War in the Middle Ages,* p. 95.

52. *Wills and Inventories Illustrative of ...the Northern Counties of England*, pp. 16-18.

53. PRO, London E 101/165/1, Roll of Adam Lymbergh in superintending Robert de Pippushall in providing springalds and arms, 18 Edward II; Cal. Inquisitions Miscellaneous 1307-1349, no. 797.

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61. Ffoulkes, *The Armourer and his Craft*, pp. 169-70.

62. Riley, *Memorials of London*, p. 35.

63. Powicke, *Military Obligations*, p. 192, citing Rot. Scot., i, pp. 328-9.

64. See the inventory of Hugh le Bevere in Riley, *Memorials of London*, p. 200.

65. Gaier, *L'industrie et le Commerce des Armes*, pp. 79-80.

66. PRO, London E 101/16/30, Inquisitions as to levies for war in Scotland, 17 Edward II.

67. Cal. Inquisitions Miscellaneous, 1307-1349, pp. 358-359.

68. PRO, London E 101/383/19, Expenses of Thomas de Usefleet, clerk of Great Wardrobe, 2 Edward III.

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71. PRO, London, E 101/165/1, Expenses of Adam de Lymbergh in providing springalds and arms in Aquitaine.

72. PRO, London, E 101/5/12, Account of John Flemming for wages and expenses of the galley of Southampton, 23 Edward I.

73. PRO, London E 101/20/37, Account of Thomas de Melcheburn of victuals and arms for the galley 'la Philippe' at Lynn, 11 and 13 Edward III.

74. Calendar of Letter Books, *'E'*, pp. 170-171.

75. Cal. Inquisitions Miscellaneous, 1307-1349, no. 1472.

76. Prestwich, *Armies and Warfare in the Middle Ages*, p. 21.

77. Calendar Inquisitions Miscellaneous 1219-1307, no. 1530.

78. Riley, *Memorials of London*, p. 283.

79. Pipe Roll 13 John, p. 108.

80. CCR 1341-1343, p. 435.

81. Calendar Inquisitions Miscellaneous 1219-1307, no. 1005.

82. *Wills and Inventories Illustrative of ...the Northern Counties*, i, p. 16.

83. Pipe Roll 13 John, p. 43; Pipe Roll 14 John, p. 61.

84. E.g., Pipe Roll 5 Henry III, pp. 9, 99; CLR 1226-1240, p. 148.

85. Calendar Inquisitions Miscellaneous 1399-1422, nos. 109, 136

86. Salzman, 'The Property of the Earl of Arundel', pp. 32-52.

87. P. Contamine, *Guerre, état et société à la fin du moyen âge. Etudes sur les armées des rois de France 1337-1494* (Paris, 1972), p. 656.

88. For the wire drawplate, Singer, *A History of Technology*, ii, p. 74.

89. Tylecote, The Medieval Smith and His Methods', p. 42.

90. Brown has found similar trends in other industries as a result of population growth, *A Perspective on Wages and Prices*, p. xv.

Conclusion

'Quod necesse est homines simul viventes ab aliquo diligenter regi'
Thomas Aquinas, De regno, c.1267

Not surprisingly, Thomas Aquinas struck an optimistic balance between what can be called the influences of agency and structure in a society's development, manifest in the metaphors he chose for describing society's struggle in terms of man against nature. This struggle, according to Aquinas, can be won through man's propensity to live together obediently and diligently in support of the commonweal, guided by faith, reason, and leaders such as kings and bishops. We saw at the opening of this work that a less optimistic Petrarch attributed fourteenth-century Europe's deplorable condition to men's actions and particularly their avarice mediated through technology, but he still cast his work as a remedy against Fortune that allows man to take control of his destiny. Regardless of technology's role in provoking war in the thirteenth and fourteenth centuries, how far did such optimism in man's ability to transform nature extend to the English Crown's military technology? Although Edward III's armies were much better equipped than previous ones, how much of the Crown's military technology was promoted deliberately rather than acquired incidentally with Europe's maturing system and polities, or as phrased at the outset of this work, how much real technological growth occurred in English warfare?

England certainly drew on the steady development of the twelfth and thirteenth centuries to meet the increased demands of war from Edward I's reign onwards. By the fourteenth century, however, Europe possessed a trove of resources- material, intellectual, and infrastructural- that imparted Europe with a rich diversity ripe with comparative advantages and disadvantages. These conditions fostered competition and creativity, and we have seen several ways in which technological concerns gained importance in England's organization and perception of warfare abruptly from Edward I's reign onwards rather than proportionally during the preceding centuries. As we saw in the first two chapters, the synergy of Europe's political economy and the nature of the perpetual, expanded warfare were uniquely important for technological and industrial growth. In this endemic warfare, preparations became an ongoing and constant affair requiring closer scrutiny. This constant attention provided almost unlimited opportunities for improving the organization of production and production itself, but realizing this growth was seldom simple or straightforward. Governments were faced with a barrage of problematic tasks: what devices or techniques warranted investment and experimentation, how to adapt existing defences, what kind and how many devices to mobilize and drawn from what source, how to obtain and transport goods, what craftsmen were needed, etc.

Although society's technical congruence had improved steadily over the twelfth and thirteenth centuries, coordinating the often enormous and complex tasks proved essential for effecting the new warfare. The scale of efforts early in our period outstripped England's capabilities; the siege of Kenilworth in 1266 placed a great strain on the industrial, logistical and financial resources of nearby counties. Even though England's productive capabilities increased during the following decades, that factor alone cannot account entirely for society's ability to meet Edward I's much greater and more frequent demands. The political and administrative processes for handling these tasks were improved by the firm adoption of a corporate organization, or a 'mixed constitution', which the Crown's ambitions required financially and logistically as its war efforts came to rely on more of society. Replacing idiosyncratic service and organization, a system of defence offered a more direct logistical process which could benefit from economies of scale in production and mobilization. Reliance on private capital such as fortifications, shipping and personal arms, while still requiring administrative efforts to incorporate into a system of defence, nonetheless minimized the Crown's financial and logistical duties, as did its myriad means of acquiring arms, materials and labour.

As we saw in Chapter Two, attempts were also made to distribute orders for goods and conscripted labour more evenly across its territories, and by the second quarter of the fourteenth century, large orders for the manufacture of arms as large as springalds could be issued as a kind of national purveyance. By Edward III's reign such requests were absorbed with less need for specially appointed manufacturing or administrative corps, allowing the Crown to give more attention and indeed develop the careers of ordinary craftsmen, merchants, artisans and officials- those middling gentry accused of subverting the politico-social order and the norms of warfare. These changes, while perceived as subverting the private basis of military service and political authority, worked to bring about a much more capable system of defence which could meet the demands of the new warfare more systematically and autonomously.

In Chapters Three and Four we saw several direct and deliberate means whereby technological concerns came to the forefront of the Crown's conduct of war. Since the twelfth century stoneworks and siege warfare had been a conspicuous feature of England's strategies and landscape, and the Crown's continued investment in fortifications to secure its territories virtually committed it to that type of defence in the fourteenth century. Edward I sought to establish a dense infrastructure of fortifications and bastides, but continuing this policy of fortifying newly acquired territories was abandoned for a policy of maintenance in the more difficult years of Edward II's reign and great care was only given to the most important sites in Edward III's reign. The Crown itself had witnessed exponential growth in its offensive siege capabilities, and the uncertainty of holding contested areas reduced the viability of large scale investments when financial and administrative energies were needed elsewhere. Military architecture improved, but the slow process and high cost of altering stone defences worked against their upkeep, and as early as Edward I's reign potent innovations arose in heavy counterweight trebuchets, springalds, and pre-gunpowder explosives. Combined with the ability to maintain armies in the field for longer periods of time, these advances made the Crown's sieges more likely to succeed or at least much more harrowing to endure. With this command of men and materials, by Edward III's reign the Crown became adept at employing the threat of siege for political effect, to bring armies to battle or to spare strategically important sites.

The Crown's employment of large artilleries beginning under Edward I and continuing through Edward III's reign suggests that these devices offered a perceivable payoff, either physical or psychological. Military planners did not have our hindsight of knowing which devices would be most decisive, and so an ongoing experiment in techniques, devices and their deployment occurred in a rational and non-rational manner. The continued usefulness of most devices allowed for experimentation with more novel designs. Springalds, torsion engines, trebuchets, bows and crossbows all continued in the Crown's employ into the fifteenth century despite gunpowder's invention. Early guns and cannon, for example, lacked the potency to replace conventional siege engines, yet their prestige and psychological effects encouraged experimentation, as did their cost, ease of use and prestige. The days of paying a caretaker 2d per day to watch over a patch of maturing saltpetre were disappearing; pestles, mortars, spoons for pouring lead, balances for weighing powder: these and other precise instruments were becoming as common in armouries as the hammer and anvil.

Perhaps the most conspicuous evidence for the material intensification of war, though, can be found in the ways the Crown integrated its forces and engineering works in more scenarios, blurring distinctions between siege and battle. The Crown undertook larger engineering works in the field such as Rhuddlan's canal or fortified pontoon bridges, and relied on peels and bretaches as a quick method of imposing some defences. The combined deployment of these works, naval forces and field units became more common in sieges and elsewhere. Twice Edward I based his campaigns in Scotland on portable and well-defended bridgeworks aided by large navies. In 1324-1325, Edward II set up defensive works in the city of Bordeaux, its port and exterior, trailing batteries of springalds and more defences along the Garrone. In the 1330s, batteries of springalds were again chosen to aid in protecting England's southern coast, and by the 1340s this technique was greatly aided by the adoption of firearms into an ever-widening array of scenarios on land and at sea. Within this industrializing warfare, more military service was devoted to guard and transport duties or engaging in works which, while less glorious than combat, came to occupy more of the army's time and energies further altering the character of war and drawing more attention to its organization.

Arms and armour developed within this industrializing landscape and warfare, diversifying in form and becoming more specialized in function in response to both rational and seemingly irrational influences. A society's arms were a direct reflection of its economic and cultural development: interaction across societies and cultures induced emulation, trends in tactics and fashion influenced armament design, knowledge of manufacturing techniques was prerequisite as was the accessibility of materials, and finances constrained soldiers and governments alike in procuring equipment. The fluid transmission of tactics and design of personal armaments as compared to the technology of siege warfare meant that emulation of battle tactics could occur much more easily and quickly, leading to rapid-paced innovations in armament design. Although crude plate armours were available at higher costs in the early thirteenth century, their widespread adoption in English armies occurred in the fourteenth century when the Crown began to emphasize infantry formations. The gradual discovery of better manufacturing techniques produced plate armours which weighed less than mail, provided similar or better protection, and at less cost. The reduction in price, the proliferation and the diversification of personal armaments were all due to some extent to the increased availability of iron and steel, and a greater productivity in the arms industry in terms of an expanding industrial base and increased specialization, and the rise of international trade. Combined with societies increasing diversification, the gap in the quantity and quality of equipment carried by different armies was potentially widened. The expansion of government made it more possible than ever for societies to implement such advantages, but several conditions were necessary for a society to produce up-to-date armaments and at competitive prices. A persistent effort to improve English armies' equipment is revealed in the crown's arms requirements which complicated sensitive debates over military service, its regulation of their trade and guilds, and treatment of specialists. English arms probably lagged behind the best armed continental armies until the second quarter of the fourteenth century, prompting an obvious desire for better equipment, but the Crown's decision not to provide them outright appears to have been based on England's disperse and fledgling arms industry as much as cost. Arms requirements and the provision of arms, the most politically charged aspect of the Crown's management of arms, began to require extensive involvement in the localities during Edward II and Edward III's drastic attempts to draw more military service from the counties, but those schemes were relinquished to defensive duties and much smaller, paid retinues who could afford substantial investments in arms and horses prevailed for expeditionary forces.

Thus despite decline in agriculture and population during the first half of the fourteenth century, gross industrial production in England and its ability to mobilize goods appears to have continued to improve, reducing the length of cycles imprinted by extensive preparations and the exhaustion of industries, finances and/or society's cooperation. Although England's industrial and financial abilities made such ambitious efforts possible, governments were still faced with the enormous task of transforming wealth into military power and coordinating the new warfare. Whether or not we view England's dramatic material intensification of war from the late thirteenth century as rapid growth or the culmination of a prolonged cycle may ultimately depend on the importance historians assign to the task of coordinating these efforts- in successfully navigating the various social and material obstacles to realizing such growth in relatively few years. The Crown began to give military technology more attention over the course of the thirteenth century, but struggled with implementing and executing its plans even during the fourteenth century.

In addition to more strenuous efforts, more attention and ingenuity were necessary to support the new warfare. The English Crown improved on an already impressive administration and established a much more efficient process of providing defence, but still encountered major setbacks. In many instances society's capabilities or willingness fell short of the Crown's requests for arms; at other times communications, transport and incompetency hindered its logistics. Poor planning or unforeseeable problems naturally took their tolls. Military campaigns came unravelled from poor planning, internal division and disrupted logistics. Financing and accounting fell arrear of needs. Strategies for the deployment of material were often out of touch with society's capabilities and occasionally out of step with campaigns.

Thus, although a great amount of momentum was generated by the previous centuries' growth, the Crown's ambitions were directly linked to its ability to induce society's cooperation. Edward I coerced the construction of monumental defences and deployed some of the period's largest armies. Although Edward II failed to mobilize England's full potential, the progressiveness and thoroughness of his policies are rarely acknowledged as a crucial step in the militarization of English society. Edward II not only had to overcome the convention of poorly armed levies, he was also faced with the task of refining English tactics and improving the quality of arms above that which the nobility had been expected to own. Success in recruitment would have to wait until Edward III's reign, but it was the consistent progress in the militarization of English society over the previous fifty years that enabled a more specialized and articulated military system.

It may not be an over simplification to say that with the sudden increase in military activity from the late thirteenth century, the crown began to concentrate on the material tasks of war, leaving the organization of manpower in private hands. Most historians would agree that the reversion to recruitment based on social ties which combined private and public power was the greatest liability of the crown's military organization and the most enduring obstacle in the creation of a national army. The nobility could not rival the crown's finances or administration, but the delegation of recruitment opened the door for socio-political rivalries capable of disrupting or even dividing the Crown's efforts. It is probably no coincidence, then, that England reaped such huge rewards during Edward III's reign when sound leadership was combined with a prosperous realm's diligence, skill and purpose.

APPENDIX I

Average Prices of English Arms from the years 1294-1339 (in pence)(1)

Item	Average	Lowest	Highest	Sample Size
Aketon	67	12 (2)	160 (3)	60
Arrows	5 per 1d			13
Aventail	32			04
Basinet	43	12 (4)	120 (5)	47
Baldric	8			08
Bow	9			14
Braces, pair	35			02
Coat/pair of plates	167	27 (6)	320 (7)	12
Crossbow:				
one-foot	25			19
two-foot	50			11
a tour	79			12
winch for crossbow	14			05
Cuisses, pair	56			04
Gambeson	28			06
Gauntlets, pair	44	12 (8)	120 (9)	10
Gorget	40			06
Hauberk	138	60 (10)	264 (11)	14
Helm, iron	28			03
Jambs, pair	39			04
Knife	1			02
Lance	8			09
Polearm	6			04
Poleyns, pair	57			02
Quarrels				
for crossbow:				
one-foot	56 per 12d			14
two-foot	25 per 12d			05
a tour	14 per 12d			03
for springald	9.7 per 12d			12
Quiver	3			01
Sabatons, pair	53			01
Shield/target				
small	6			04
great	16			03
Springald	657 (54s9d)			08
Sword	41	2 (12)	120 (13)	15

NOTES

1. Price averages have been rounded to nearest pence. 'Price' denotes either value of purchase or cost of manufacture. 'Sample size' denotes number of price entries per item. Price averages have *not* been weighted to reflect volumes of purchases, ie 20 basinets @5s each = one entry of a basinet price @ 5s. The lowest and highest prices have been provided when considerable range occurs in price data and an arbitrary ceiling (highest) has been set to exclude sumptuous arms (see above, Chapter Six).

2. Riley, *Memorials of London*, p. 200.

3. Rogers, *History of Agriculture and Prices in England*,ii, p. 559.

4. PRO, London E 101/15/10, Inquisitions for supplies for war in Scotland, 9 & 11 Edward II.

5. Calendar of Miscellaneous Inquisitions,1307-1349, no. 797.

6. Riley, *Memorials of London*, p. 109.

7. Calendar of Miscellaneous Inquisitions, 1307-1349, no. 1472.

8. PRO, London E 101/20/37, Account of Thomas Melcheburn for the galley 'La Phillipe' 11 & 13 Edward III.

9. CDS, ii, no. 1413.

10. Calendar of Miscellaneous Inquisitions, 1307-1349, no. 527.

11. Rogers, *History of Agriculture and Prices in England*,ii, p. 559.

12. *Wills and Inventories Illustrative of the ....Northern Counties*, pp. 16-7.

13. *Wills and Inventories Illustrative of the ....Northern Counties*, pp. 16-7.

APPENDIX II

Arms Requirements and their Costs

The evolution of arms requirements and their costs are summarized with the following table beginning with the Assize of Arms of 1181 and culminating with some particularly ambitious orders under Edward II and Edward III. Estimates of costs for requirements prior to 1285 are derived from evidence presented in Chapter 6, for 1285 onwards from the index of prices in Appendix I.

Assize of 1181

Class	Required Arms	Cost per person
£20	Hauberk, iron helm, sword, knife	60s
16 marks	Haubergeon, small arms	40s
10 marks	Pourpoint, small arms	10s

Assize of 1242

Class	Required Arms	Cost per person
£20	Hauberk, iron helm, sword, knife; two covered mounts	40s +£4 for barding
£15	Same personal arms; one covered horse	40s +£2 for barding
£5-10	Sword and knife	5s
3-10 marks	Polearm	3s
£2	Bow	2s

Arrays of 1276 and 1277

Class	Required Arms	Cost per person
c.£20	Aketon, hauberk, basinet, lance, sword, knife; two covered mounts	23s 1d +£2 for barding
c.£15	Same personal arms; one covered mount	23s 1d +£1 for barding
c.£10	Gambeson, iron helm, lance or polearm	6s
c.£5	Crossbow	4s
under £5	Bow	2s

Statute of Winchester (1285)

Class	Required Arms	Cost per person
£100	Hauberk, iron helm, sword, knife; two covered mounts	15s 9d +£2 for barding
£15 or 40marks	Same personal arms; one coveredmount	15s 9d +£1 for barding
£10 or 20 marks	Same personal arms	15s 9d
£2	Sword, bow, arrows and knife	3s 9d
Less than £2	Polearm, knife	8d
Less than £1	Sword, knife	3s
ex forest	Bow and arrows	1s 2d
in forest	Crossbow and quarrels	4s 6d

London Array of 1316

Class	Required Arms	Cost per person
Crossbowmen	Aketon, hauberk, basinet, gorget, crossbow, quarrels	25s 9d

Array of 1322

Class	Required Arms	Cost per person
c.£20	Aketon, haubergeon, basinet w/aventail, steel gauntlets, lance, sword, knife	29s 10d
c.£10	Same personal arms	29s 10d
c.£5	Same personal arms	29s 10d
c.£2	Aketon, palet, plate gauntlets, lance, sword, knife	15s 4d

Array of 1324

Class	Required Arms	Cost per person
Footmen	Aketon, coat of plates, basinet, steel guantlets	26s 2d

Array of 1335

Class	Required Arms	Cost per person
£10 'Hobelars'	Coat of plates, basinet, gorget, iron guantlets	27s 1d

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