MATERIALIZING THE MILITARY

Edited by

Bernard Finn
Barton C Hacker
Smithsonian Institution, Washington DC

Associate Editors

Robert Bud
Science Museum, London

Helmuth Trischler
Deutsches Museum, Munich

science museum

Published 2005 by NMSI Trading Ltd, Science Museum,
Exhibition Road, London SW7 2DD

Designed by Jerry Fowler
Printed in England by the Cromwell Press

ISBN 1 900747 60 X
ISSN 1029-3353

Website http://www.nmsi.ac.uk

Artefacts series: studies in the history of science and technology

In growing numbers, historians are using technological artefacts in the study and interpretation of the recent past. Their work is still largely pioneering, as they investigate approaches and modes of presentation. But the consequences are already richly rewarding. To encourage this enterprise, three of the world's greatest repositories of the material heritage of science and technology: the Deutsches Museum, the Science Museum and the Smithsonian Institution, are collaborating on this book series. Each volume treats a particular subject area, using objects to explore a wide range of issues related to science, technology and medicine and their place in society.

Edited by Robert Bud, Science Museum, London
Bernard Finn, Smithsonian Institution, Washington DC
Helmuth Trischler, Deutsches Museum, Munich

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Volume 2 Exposing Electronics
Principal Editor Bernard Finn

Volume 3 Tackling Transport
Principal Editors Helmuth Trischler and Stefan Zeilinger

Volume 4 Presenting Pictures
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Series preface

In prefaces to earlier volumes we have explained that we determined, in the mid-1990s, to develop a forum for the discussion of ways in which objects can be used for the serious study of the history of science and technology. Given our backgrounds as professional museum curators, it is hardly surprising that we were confident that we would come up with a number of compelling examples. We did; and we have been pleased to share them with you.

This is our fifth volume, and it seems an appropriate point to look back and consider how well we have met our expectations and how far we still have to go. We have published some 30 articles in five subject areas (medicine, electronics, transport, production and communication of images, and now military history), which provide a large enough sample to make it reasonable to seek a few generalisations.

In *Tackling Transport* Michael Bailey and John Glithero express feelings of fascination and excitement as they examine the *Rocket* locomotive, and in *Presenting Pictures* one can sense similar emotions in Oskar Blumtritt's approach to the 'telecinema' equipment associated with Manfred von Ardenne. All of which suggests that historians are not exempt from the kinds of reactions that ordinary people may have in the presence of old things. And, just like anyone else, historians may be stimulated to probe deeper. Frequently there is nothing more of interest to be found. But often enough, as in these cases, such investigations are rewarded with new information and fresh insights.

In Alan Morton's treatment of J J Thomson and the cathode ray tube he gave to the Science Museum (*Exposing Electronics*), and even more in the analysis that David Rhees and Kirk Jeffrey make of Earl Bakken's relationship to his pacemaker (also *Exposing Electronics*), we find that inventors themselves can be fascinated by the objects they have created. Both Thomson and Bakken used their objects as icons to promote recognition of their inventive genius.

In such disparate examples as microchips (Ross Bassett in *Exposing Electronics*), macrocircuits (Paul Ceruzzi, also in *Exposing Electronics*), and automobile interiors (Gijs Mom in *Tackling Transport*) we find that technical design can be idiosyncratic to the point of providing valuable historical insights. Furthermore, the insights can be quite different, ranging in these cases from corporate marketing strategies, to individual inventor proclivities, to the technology–consumption interface.

The physical distribution of objects can be significant. Larry Schaaf's description of the wide dispersion of Talbot material (*Presenting Pictures*) provides strong evidence of the popularity and influence of that photographic pioneer. At a different level – both in scale and stratigraphically – John Guilmartin (in the present volume)

examines English and Dutch cannons that were recovered from a Portuguese warship and is able to make judgments about how arms were recycled among the world's navies in the seventeenth century.

Survival of objects, and thus their availability to scholars, is often a matter of happenstance. This means that the reputations of individuals, the technical abilities of societies and a host of other large and small historical phenomena are subject to the arbitrariness of disasters (both natural and man-made) and to other accidents associated with the passage of time. Of course it also helps to be highly productive of physical objects and written records in the first place. Schaaf shows how the combination of good fortune and high productivity have served Talbot very well, as opposed to his contemporaries Daguerre and Wollaston and Wheatstone. Others touch on aspects of this argument, such as Paul Forman on 'Rabi's Relics' (*Exposing Electronics*) and Christine Finn (the present volume) in her analysis of the significance of the relics of German occupation left on the island of Jersey after the Second World War.

A closer examination of articles published in 'Artefacts' and elsewhere will no doubt reveal other ways that the study of material remains can enrich our studies of the history of science and technology. 'Enrich' seems an appropriate word, because unlike the traditional archaeologists we are for the most part studying periods where the availability of a written record is substantial, indeed even overwhelming. This means that we also need to consider how we express ourselves, and whether the objects complement or contradict the surviving words. The task can be especially challenging in the medium of the book, since the object that lies at the focus of our argument is reduced to being described in words and pictures. Are there special techniques that need to be developed? Should we be pressing the reader to treat our pictures as partners with the text, to be examined critically for special revelations and not seen simply as pretty adornments as is more commonly the case?

As museum curators we face a similar but more daunting challenge. In our exhibits we have the great advantage of being able to display the objects themselves. But the exhibition floor is not an ideal venue for serious reflection. As a consequence, there is a danger that we will avoid complex arguments, keep text to a minimum, and lose the opportunity not only to say something meaningful but also to educate our visitors to an understanding of how the things around us can convey messages.

In the pages of 'Artefacts' we have made occasional forays into a consideration of this dilemma without reaching any substantive conclusions. Jon Eklund and Bernard Finn (in *Exposing Electronics*) reveal how they anticipated that certain objects would support arguments made in the Smithsonian's 'Information Age' exhibition. In a response, Roger Bridgman pessimistically indicates his belief

that it is fruitless even to try to use objects in this way in modern exhibitions that tend to be organised around large social themes. In the present volume Robert Friedel has a different frustration because the exhibition (on American military history) lacks a clear thematic statement against which the presentation of objects can be measured. He also identifies another disturbing trend in the use of props as objects and objects as props. The value of the object as evidence is inevitably eroded by the confusion that this produces in the visitor's mind.

The growing interest that scholars have in questioning exhibitions – which can be seen in the number of journals that regularly publish exhibition reviews – causes us to believe that we are on the right track. The material relics of science and technology are no longer to be preserved and displayed simply as curiosities or as celebratory icons. They are evidence of historical processes. Academic historians are learning to incorporate them into what were previously object-free discourses, and museum curators are learning to display them in support of story lines based on intellectually serious themes.

We intend to encourage these trends as we continue the 'Artefacts' series. We invite, indeed challenge, our readers to be critical of our attempts and to join in the discussion.

Notes on contributors

Kelly DeVries is Professor of History at Loyola College in Maryland. His books include *Medieval Military Technology*, *Infantry Warfare in the Early Fourteenth Century*, *The Norwegian Invasion of England in 1066* and *Joan of Arc: A Military Leader*. He holds a PhD in medieval studies from the Centre for Medieval Studies at the University of Toronto.

Bernard Finn is curator emeritus at the Smithsonian's National Museum of American History and adjunct professor at the University of Maryland. His research interests are primarily in the history of museums and of electrical technology.

Christine Finn is an author, broadcaster, journalist and archaeologist. She has a DPhil in archaeology from Oxford University and is a Fellow of the Society of Antiquaries. Her books include *Artifacts: An Archaeologist's Year in Silicon Valley* and (as co-editor) *Outside Archaeology: Material Culture and the Poetic Imagination*. She is a former contributing editor of *Archaeology* magazine and has also written for the *Guardian*, *The Sunday Times*, the *V&A Magazine* and *New Scientist*.

Robert Friedel is Professor of History at the University of Maryland, where he has taught history of technology and science since 1984. Prior to his current appointment, he was director of the IEEE Center for the History of Electrical Engineering in New York City. His museum work includes exhibitions at the Smithsonian's National Museum of American History and the National Building Museum.

John F Guilmartin, Jr teaches military, maritime and early modern European history at Ohio State University. He served two combat tours as a rescue helicopter pilot in the Vietnam War, the second one after receiving his PhD in history from Princeton. His publications include *Gunpowder and Galleys: Changing Technology and Mediterranean Warfare at Sea in the Sixteenth Century* and *A Very Short War: The Mayaguez and the Battle of Koh Tang*.

Barton C Hacker has a PhD in history from the University of Chicago and is curator of military history at the Smithsonian's National Museum of American History in Washington DC. He has published extensively on the history of military technology, women's military history and the comparative history of military institutions.

Katherine Ott, curator at the Smithsonian's National Museum of American History, in the Division of Medicine and Society, works on the history of disability, medicine and the body. She is the author of *Fevered Lives; Tuberculosis in American Culture Since 1870* and co-editor of *Artificial Parts and Practical Lives, The Modern History of Prosthetics.*

Jan Piet Puype is senior consultant to the board of directors of the Legermuseum in Delft, the Netherlands. He was educated as a naval officer, but since 1970 he has made a career as a writer, lecturer and curator of exhibitions on arms, armour and tactics. He specialises in Western swords and historical naval ordnance, his chief publication being the three-volume catalogue *Arms of the Netherlands in the Collection of H.L. Visser.*

Nicholas J Saunders is Reader in Material Culture at the Department of Anthropology, University College London. Between 1998 and 2001 he was a British Academy Institutional Fellow, investigating the anthropology of the First World War. He is co-editor of the UCL Press series *Material Culture, Conflict and Modernity.*

Robert D Smith worked for the British Royal Armouries for almost 30 years and is now an independent scholar specialising in research in medieval and early modern artillery and gunpowder.

Margaret S Vining is a curatorial historian in the Division of Military and Diplomatic History at the Smithsonian's National Museum of American History, where she has served as a principal curator of numerous exhibitions and played a key role in acquiring the Colonial Dames uniform collection.

Deborah Warner is curator of the physical sciences collection in the National Museum of American History. She believes that museums should identify and explicate the objects in their care.

Barton C Hacker and Bernard Finn

Introduction

When one thinks of the history of military technology, the images that first come to mind are of arms and armour. And readers of this volume will not be disappointed. Three contributions (DeVries and Smith, Guilmartin, Puype) bring fresh insights to a well-travelled consideration of arms of the early modern period. This freshness is due in large part to the focus on the objects. But what may be surprising is the breadth of topics that can be creatively pursued if one examines carefully the material record. Looking at things, from uniforms and sextants to artificial legs and washing machines, can help us answer questions that we didn't even know could be asked. Strung together, these contributions provide us with a valuable body of research reaching back as far as the fifteenth century.

The book has its origins in a meeting at the Smithsonian's National Museum of American History in October 2001. The conference was sponsored, as are all 'Artefacts' activities, by the Smithsonian together with the Science Museum and the Deutsches Museum. Ironically, one might say, it occurred in the aftermath of the opening of a new kind of war, symbolised by the hijacking attacks of September 11. Participation by our European colleagues was understandably curtailed, but the event was otherwise highly successful. Half the articles included here emerged from that meeting; the rest were solicited from other scholars in the field, a primary consideration (as in other volumes) being to provide overall balance.

Kelly DeVries and Robert Smith offer us an account of their recently completed study of fifteenth-century Burgundian gunpowder weapons. The main product is a database of heroic proportions. The chapter presented here provides readers with an opportunity to sample the fruits of their labours and to appreciate the extent of the information that is now available. Of particular interest is the intricate mixture of artefactual and documentary evidence; they complement each other elegantly, making possible a special richness in the historical studies that will surely follow. In their brief summary of the complex ways that the introduction of gunpowder weapons affected the conduct of warfare, the authors suggest some of the value one may expect from such studies.

John Guilmartin has looked at a much narrower collection of guns (from a single ship) two centuries later. He examines them from, it would seem, every conceivable point of view, learning something at every step of the way. The pattern of guns on the ocean floor, their weight (both according to markings and experimentally determined),

their dimensions, the material out of which they are made, their ornamentation – all are consulted to make judgments about comparative levels of craftsmanship in various European countries, the state of the Portuguese economy and durability of guns over time. By implication the article makes a strong case for the protection of underwater sites, at a time when new technologies are making them ever more vulnerable to amateur probing.

The damage that these early cannon wreaked on human bodies could sometimes be repaired, but, as Katherine Ott argues, it took the large-scale production of amputees in the American Civil War to stimulate serious consideration of technological solutions to the design of replacement limbs. By the end of the nineteenth century an understanding of the origins of infection led to significantly higher survival rates for wounded soldiers, with the result that wars in the twentieth (and now twenty-first) century gave new incentives to the prosthetic industry, especially when governments, with politically understandable compassion, have been willing to pay for so much of the cost. Provoked by the Smithsonian's collections, Ott has opened up a new opportunity to study the impact of the military on technology.

For Margaret Vining and Bart Hacker the museum's holdings present an opportunity to pursue a quite different line of inquiry. After the First World War the National Society of the Colonial Dames, many of whose members had served during the conflict, began collecting women's uniforms, which they loaned to the Smithsonian for exhibition in the 1920s. These uniforms, augmented by others, eventually became part of the museum's collections. In no other war in American history has so broad a range of non-governmental organisations put so many women of such relatively high social status in uniform. Looking at these uniforms raises a host of fascinating questions about the roles that women were playing, and wanted to play, not only in the United States but also throughout Europe. Further research should shed new light on this much-studied era.

Nicholas Saunders makes a broader plea for preservation and interpretation of the artefacts of the Great War (and others). He is especially interested in memorabilia collected or constructed either by soldiers during the war as personal mementoes, or by civilians during and after the war (to 1939) for sale. He suggests that these relics comprise a material culture that was purposely created and which can therefore help us understand how people react to war, and how war shapes them for the peacetime that follows.

Deborah Warner returns us to a consideration of how the military can influence development of technology, even during peacetime. She studies celestial navigational instruments (sextants), the instruments of a technique with a very long history that gained new adherents in the 1920s and 1930s as international travel, especially by air, increased.

This was very much an international technology, both in terms of those who contributed to it and of the way it was disseminated – one consequence being, for instance, that American-made sextants were being actively promoted for sale in Japan.

Christine Finn looks at a very special application of material culture related to the Second World War. Invaded by German forces in June 1940, the Channel Islands (principally Jersey and Guernsey) remained under occupation during most of the conflict. Afterwards, the memories of residents mixed pride at having survived with shame over the means that some employed to make survival possible, including collaboration and black marketeering. It was something they avoided discussing. Yet material reminders of the occupation were literally built into the landscape, most particularly in the fortifications and tunnels along the coast. In recent years, on Jersey, these have been developed as visitor attractions, one consequence being that the islanders themselves have had to come to terms with their own past.

In the section of this book focusing on exhibits and museums, Bart Hacker describes an exhibition on nuclear submarines in the Cold War ('Fast Attacks and Boomers'). He explains how, as its curator, he used objects to juxtapose highly sophisticated weapons of destruction with mundane washing machines. There were also matters of scale, contrasting the relatively large size of the submarine (through a mock-up 'sail') with the cramped quarters for the crew (stacked bunks with shallow bins for storage). Overall there was an attempt to fit the technology of the ship and its weapons into a social context of geopolitics on the one hand and, on the other, of the lives of the crew and their families.

The submarine exhibition was a modest-sized temporary show. A much grander exhibition, occupying the same space and considerably more, is 'The Price of Freedom: Americans at War', which covers American military history by looking at conflicts from the French and Indian wars of the eighteenth century to the Iraq war of the twenty-first. Robert Friedel examines the exhibition, which features some 800 objects but lacks an explicit statement of purpose. He critically assesses the use of objects in relation to images and other display features in the light of what he deduces to be the exhibition's goals.

Finally, Jan Piet Puype makes an impassioned plea for not confusing museums of military history with war museums. In the former, the objects (especially arms) may be interpreted in contexts that are very narrow (technical, aesthetic) or very broad (cultural, social); but the interpretation should not include, as he feels it does in too many war museums, moral judgments that imply that the weapons themselves are somehow 'good' or 'bad'. Following Puype's essay is a list of military history museums compiled by Hacker and Vining, including no doubt several that step over the line, and also some with the word 'war' in the title that in fact make every effort to avoid such judgments.

Kelly DeVries and Robert D Smith

Perspectives on early gunpowder weapons, at the completion of a study of Valois Burgundian artillery

A historiography of early gunpowder weapons

The modern history of gunpowder weapons was born in the middle of the nineteenth century when the future Emperor Napoleon III, while imprisoned in Ham Castle, undertook an investigation of the origins of artillery. The result, the six-volume *Études sur le passé et l'avenir de l'artillerie*, was published in Paris between 1846 and 1871,[1] with the final volume ironically appearing in the year that the Franco-Prussian war ended Louis Napoleon-Bonaparte's reign. In fact, only the first volume was written by Napoleon; an artillery officer of some historical talent, Ildéfonse Favé, continued the work based on the emperor's outline and notes. This magisterial work, based largely on original research, not only introduced the subject to a scholarly world but also set a standard that was seldom matched over the next 150 years.

While Napoleon and Favé naturally concentrated on French sources and history, other scholars soon added works based on their own countries' archives and libraries. In England the works of Colonel Henry Brackenbury and R Coltman Clephan, in Belgium the works of Paul Henrard, and in Germany the works of Bernhard Rathgen, have all contributed significantly to our understanding of the history of gunpowder weapons in the last two centuries of the Middle Ages.[2] The value of these works, like those of Napoleon and Favé, was their strict adherence to contemporary documentary and narrative sources.

In the first half of the twentieth century, when politics began to infect all forms of scholarly inquiry, historical investigations into the history of gunpowder weapons were not immune and began to be strongly influenced by ideologies and nationalism. In addition, some of the operators of the artillery which played such a large role in the First and Second World Wars decided that they too should try their hand at explaining the historical background of the weapons of which they were so proud. The first set of historians manipulated the sources in an attempt to provide evidence of their nations' crucial role in the early developments of gunpowder and gunpowder technology in order to further cement the martial superiority of their armies then marching across Europe.[3] The second group, in their enthusiasm for the subject, but also in their inability to use difficult-to-access historical sources and methodology, substituted secondary sources and

their own experiences to provide historical interpretations. Their use of hindsight and assumption in the place of thorough research resulted in the development of many inaccuracies and myths concerning the effectiveness and success of early gunpowder weapon technology, and their work quickly replaced the more cautious and circumspect renderings of their earlier counterparts.[4]

A complicating factor was that the two world wars, as well as smaller military conflicts following them, most notably in Korea and Vietnam, produced an environment not conducive to the study of military history, and in particular to the study of military technologies. The resulting dearth of academic interest in the history of early gunpowder weapons during this period allowed those with lesser historical abilities to dominate the interest in this field.

All of this produced by the end of the twentieth century a mixture of bad and good scholarship about the origins and development of early gunpowder weapons. To be certain, some scholars did read the earlier historians on gunpowder weapons and were influenced by their scholarly methodology and caution. These, Howard L Blackmore, M G A Vale, Philippe Contamine, John S Guilmartin, and Bert S Hall, among others, produced investigations based on primary sources, although often with conclusions mixed with the romanticism of technological determinism.[5] Others, however, seem to have continued the errors of the less cautious writers of the past, often by repeating their conclusions and assumptions without critical focus on the original sources and their limitations.[6] Some, too, have been influenced by the conjectures of power contained within the early gunpowder weapons, so much so that they have determined that their ownership and use in conflicts created a 'military revolution' which led to the growth of modern states and the domination of Europe throughout the early modern world.[7]

Resulting problems

One result is that historians who enter the field of early gunpowder weapons as a detail in their syntheses of history in general, and military history and the history of technology in particular, are forced to use poor modern works which, all too frequently, they use uncritically. These writers then perpetuate the myths and errors about the manufacture, use and effectiveness of gunpowder weapons, unwittingly introducing and reintroducing them to an equally uncritical and unsuspecting new generation.[8]

However problematic this might be, there has been much good work over the last two decades on the history and development of early artillery, and this has brought into question many of the long-held ideas and suppositions. For example, it is now clear that wrought iron was used for the manufacture of guns from the fourteenth until well into the seventeenth century. Far from being the inferior

material, superseded as soon as was possible by bronze or cast iron, it was evidently seen at the time as a useful and appropriate material for some types of guns. Similarly, breech-loading cannon were not inefficient, dangerous pieces, as so often stated in modern works; breech loading was used well into the seventeenth century for large pieces and for smaller pieces until the eighteenth century, a length of time which surely argues against this supposition.[9] This recognition of the longevity of many types of gunpowder weapons and their effectiveness has also led to the redating of many existing guns, previously assumed to be fifteenth-century or earlier, to the sixteenth or even the seventeenth century.[10] In addition, patterns of gunpowder-weapon acquisition and use by late medieval states have been challenged: some powerful political entities, such as France and Burgundy, moved from local to central control of their realm's gunpowder weapons during the fourteenth and fifteenth centuries, while others, particularly England, followed an opposite pattern, one of central to local control during the same period.[11] Gunpowder weapons have also been recognised as more effective weapons at sea at an earlier time than previously believed,[12] and less effective as siege artillery.[13]

These examples alone show that a reassessment of the earlier history of gunpowder weapons is needed and must be made essentially from the ground up. Early works, such as Napoleon and Favé, established some foundations, especially in methodology, but even these failed to establish a framework from all contemporary sources: narrative, documentary and artefactual; nor has any subsequent scholarship managed to do so. It is very apparent that in the main these works do no more than scratch the surface of what is a complicated history. This is, in part, understandable, as the subject does not yield its secrets easily. Using narrative sources alone as a guide may be confusing because those witnesses, often not trained in the art of military technology, were themselves confused by what they saw. These chroniclers and other narrative writers were also obviously influenced by patronage, audience and personal allegiances, and were only able to use those sources available to them, with their attendant biases. Documentary sources rely on a sort of notarial code, the terminological technicality of which needs to be broken before it can be used. And extant weapons generally do not have accurate provenances, with the result that their type and date are often not known, while their use and effectiveness is misunderstood. At times, it seems that the more one investigates, the more confusing the subject becomes: the very complexity of the field often leading those who specialise in its study to conclude that it is not open to analysis and understanding, and that they may never see through the opaque veil.

On the whole, previous studies have also tended either to concentrate on one particular period or event or to have been part of

larger works where the history of artillery has been treated subsidiary to the wider picture. In addition, these works have tended to concentrate on the narrative or documentary sources and have made little or no attempt at relating these to existing guns or types of guns. Some work has been done, notably by François T'Sas on fifteenth-century bombards[14] and similar work on the same subject by one of the present authors,[15] but little has been published as a consequence of these works.[16] No studies have attempted to marry all three of the available source types – narrative, documentary and artefactual. In light of this, there is a real and pressing need to re-evaluate the whole history and development of artillery before the sixteenth century.

Some solutions

Our book on the artillery of the Valois Dukes of Burgundy[17] is an attempt to put together a coherent framework for the development of gunpowder weaponry throughout the fifteenth century from a synthesis of the available evidence: contemporary narrative, documentary sources and surviving examples. The fifteenth century is particularly rich in narrative sources covering the military events of the period, especially those occurring in France, Burgundy and the Low Countries, and these provide a background against which a better understanding can be achieved. They are, however, not without their problems, both of interpretation and perspective. The largest and most comprehensive of all the surviving documentary sources on fifteenth-century gunpowder artillery, and perhaps the most important, are the accounts of the Dukes of Burgundy: Philip the Bold, John the Fearless, Philip the Good and Charles the Bold. However, despite their obvious enormous value in the understanding of artillery in the fifteenth century, they too are not without their difficulties, the primary one being the terminology used and the apparent lack of notarial standardisation during this period. For example, while several different types of gun are listed, it is not always clear to the modern reader what exactly is being referred to. Finally, and equally important, are the surviving artefactual examples, and it is here that we are particularly fortunate. In the final wars of the reign of Duke Charles the Bold, the Swiss and Lorraine Confederate forces defeated the Duke's armies at the battles of Grandson, Murten and Nancy, and captured, among other things, their artillery. Although greatly reduced in number from those recorded to have been captured, some of these pieces are still preserved in museums in Switzerland, mainly in Murten, La Neuville and Basel.[18]

Of special importance for this chapter are the training and skills that both authors brought to this study. As reviewed above, most previous work on late medieval gunpowder weaponry has been approached through original documentary and narrative sources,

with little use of extant gunpowder weapons. In our opinion this weakened those studies – even the impressive Napoleon and Favé multivolume work took little notice of extant weapons. One can surely be sympathetic here, in view of the problems of dating and perceived use – almost always exaggerated – which plague even the display of these early guns.[19] However, in order to write a *complete* study of early gunpowder weapons, these artefacts must be included. This is where Smith's training benefited the book. Having spent more than a decade in researching early extant gunpowder weapons, Smith had traversed European and North American museums, armouries and city squares, studying, measuring, photographing and drawing any gunpowder weapons he found. In doing so, he acquired an extremely large amount of data on all sizes and sorts of extant early gunpowder weapons. These data formed the basis of his numerous writings on early gunpowder weapons, including his monograph 'Mons Meg and her sisters', written with Ruth Rhynas Brown, and a large number of articles.[20] DeVries' training is in drawing history from written sources, most notably from late medieval narratives, and this had directed his approach to the study of early gunpowder weapons.[21]

Interestingly, at the time that we met, both of us were seeking to supplement our separate approaches to gunpowder weapons with a study of Joseph Garnier's transcribed documents in *L'Artillerie des ducs de Bourgogne d'après les documents conservés aux archives de la Côte-d'Or*.[22] Garnier, a Dijonnais archivist, brought together and published transcriptions of the Ducal archives on artillery, most notably those contained in two account books, the first covering the period from 1411 to1445 and the second from 1446 to 1475. They include all the artillery and other munitions delivered into the *Chambre des Comptes* of the last three Valois dukes, John the Fearless, Philip the Good and Charles the Bold. Though these two registers form the nucleus of his work, Garnier includes a number of other transcriptions from the archives extending back to Philip the Bold and providing additional material from the entire period. Together, the transcriptions of these documents are an unparalleled source of information about artillery from the end of the fourteenth to the closing decades of the fifteenth century, providing not only details of the types and numbers of pieces of artillery but also about the changes with time that occur. A database compiled by us from these documents revealed the records of some 4000 Burgundian weapons, listed by various names – which we standardised as *bombard*, *canon*, *coulovrine*, *courtau*, *crapaudeau*, *hacquebus*, *mortar*, *pestereau*, *ribaudequin*, *serpentine* and *veuglaire* – together with details of their metallurgy and manufacture, surface treatment, marks, gunpowder, ammunition, carriage beds and mounts, loading and aiming, the personnel involved and, finally, ship's artillery.

By combining our respective skills with our work on Garnier's documents, we believe that we have written the most complete study

of early gunpowder weapons to date. One section is devoted to the narrative accounts of gunpowder weapon use between 1363 and 1477 by the four Valois Dukes of Burgundy; it also serves as a military history of the dukes, a framework essential for establishing the context in which these guns were made and used. A second section explores the various characteristics of the Burgundian gunpowder weapons as revealed by the documents transcribed by Garnier. The final section is a catalogue of all extant gunpowder weapons that can reasonably be attributed to the Burgundians during this period. Six appendices contain the database of gunpowder weapons and five documents, in the original language and English translations, showing particularly interesting examples of the types of records available for the historian researching late medieval gunpowder weapons: a Burgundian artillery train of 1475; a Burgundian ship's inventory of arms from 1445; the manufacture of iron guns in 1376; a Burgundian weapons dowry from 1449; and the transport of artillery in 1474. Examples from the catalogue and database are given in Tables 1 and 2 respectively; Figure 1 is a drawing of the weapon described in Table 1 and the object itself is shown in Colour plates 1 and 2. An example of the ducal archival artillery documents is given at the end of the chapter.

While we were writing these separate sections and beginning to arrive at our conclusions, it was suggested by Guy Wilson, past Master of the Royal Armouries, that we should place these conclusions before the narrative, documentary and artefactual sections, thus mimicking eighteenth- and nineteenth-century French historical works where evidence proving the purpose of the book was always placed at the end as *pièces justicatives*. This not only places the conclusions first, but also emphasises their importance to the reader.

Our conclusions

In short, these conclusions are that, as gunpowder weapons began to enter into military frameworks of the fourteenth and especially fifteenth centuries, there needed to be significant changes in military thinking, and not just in the sciences of strategy and tactics – which the entry of gunpowder weapons into conflict obviously affected – but also in the sciences of military administration, logistics, planning and technology. In their essence, the traditional branches of military service – cavalry and infantry – did not change, but added to them was an entirely new branch: gunpowder artillery. This was not just a question of new military personnel, nor even a question of a new weapon. Cavalry and infantry were largely self-contained. They could, and usually did, have assistants, varlets, squires, grooms, etc., but these personnel did not need a specialist's training, nor were they really required. If necessary, a cavalry soldier could take care of himself and his horse; and an infantry soldier generally took care of his own armour and weapons. They also could supply their own victuals,

Table 1 Sample entry in catalogue

Catalogue number	16		
Collection/museum	Musée de La Neuville, La Neuville, Switzerland	**Accession number**	
Category	Crapaudeau?	**Material**	Wrought iron
Description	The barrel is made from four staves bound with hoops and bands. Very unusually, the hoops are not set at regular intervals down the length of the barrel. The muzzle consists of a double hoop, that at the front being very large in diameter, over the front face of which the staves have been hammered. Set on top of this hoop is a horizontal plate in the form of a shield beneath which is a rectangular slot. The hoops are very narrow and set in groups of three. Behind the muzzle the outer surface is smooth though it is clear that it consists of six narrow bands of similar diameter. A second group of three hoops, with lifting ring, is followed by a barrel section made from four bands. There follows a series of three triple hoops and three band structures. Behind this the next triple hoop has a flat plate set horizontally on a rectangular projection pierced with a slot, as at the muzzle. This plate has three punched 'H' marks. Behind this the hoops are again in groups of three but the bands are double. The triple-hoop structure next to the breech has a similar lifting-ring loop and lifting ring as that near the muzzle. The breech consists of a triple-hoop structure, but the very end of the barrel is completely obscured by the carriage on which it is set. The touch hole is a small hole set within a shallow rectangular depression.		
Date	Florens Deuchler dates this piece to about 1460		
Dating evidence	Dated by Burgundian booty		
Provenance/booty status	Booty from Grandson		
Bore barrel	60 mm		
Length overall	2925 mm		
Literature	Florens Deuchler, *Die Burgundebeute: Inventar der Beutestucke aus den Schlachten von Grandson, Murten und Nancy 1476/77* (Bern: 1963), No. 237		
Notes	This gun is unique in the oeuvre of wrought-iron gunpowder weapons. Its non-regular structure and the use of very wide bands are not paralleled elsewhere. Uncommonly for a muzzle-loading piece there are no trunnions. The flat shield-shaped plates are also unusual. Interestingly, the lifting ring lugs are offset to either side of the centreline of the barrel and ensure that the slots in the hoops can be used as a sighting device. Trying to date it without any parallels is impossible, but there is no reason to doubt the attribution to the Burgundian wars and date it to the period of around 1470.		

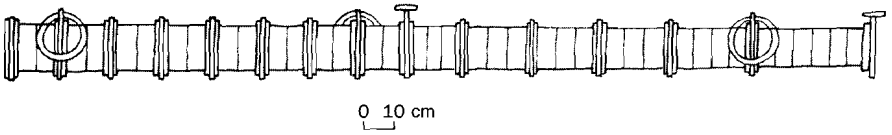

Figure 1 Drawing (side view) of a gun barrel dated to about 1470 (see Table 1). (Robert D Smith)

if necessary. On site, though, artillery personnel could do little for themselves and their weapons. While it is true that they did take care of their own personal protection and provided their own foodstuffs, their weapons – gunpowder weapons of all sizes – could not be so easily maintained. Except for the smallest of gunpowder weapons, late-medieval artillery personnel could not even carry their own artillery pieces.

Gunpowder weapons themselves were also an entirely different matter. Gunpowder artillery could rarely be constructed on site.

Table 1 Database example

Date	Artillery name		Quantity	Metal	Material	Weight	Length	Calibre	Ammunition type	Ammunition weight	No. of removable chambers	Chamber weight	Weight of gunpowder
	Standardised gunpowder weapon type	Spelling in transcribed document											
1433	Crapaudeau	Crappaudeaul	2	Copper alloy	...	...	...	...	...	...	1	...	...
1433	Crapaudeau	Crappaudeaul	1	Iron	...	...	...	...	...	...	7	...	...
1436	Crapaudeau	Crappaudeau	12	Iron	...	...	...	...	...	...	2	...	...
1436	Crapaudeau	Crappaudeau	3	...	...	...	...	...	...	...	...	...	...
1436	Crapaudeau	Crappaudeau	5	...	...	...	...	...	...	...	2	...	...
1436	Crapaudeau	Crappaudeau	2	Iron	...	...	...	...	...	...	2	...	...
1436	Crapaudeau	Petit Crappaudeau	2	...	...	...	...	...	Stone ball/ *plommée* or lead ball	...	...	...	...
1437	Crapaudeau	Crapaudeau	1	Iron	...	...	...	...	...	...	...	...	...
1437	Crapaudeau	Crappaudeau	5	Iron	...	...	...	...	...	...	4	...	...
1437	Crapaudeau	Crappaudeau	1	...	...	...	...	...	Stone ball	...	...	...	...
1437	Crapaudeau	Crappaudeau	2	...	...	...	...	...	*Plommée* or lead ball	...	2	...	...
1437	Crapaudeau	Crappaudeau	5	Iron	...	...	...	...	...	...	4	...	...
1437	Crapaudeau	Crappaudeaul	1	Iron	...	...	...	...	...	...	2	...	...
1437	Crapaudeau	Crappaudeaul	1	...	...	...	...	...	...	...	2	...	...
1440	Crapaudeau	Crappaudeau	1	Iron	...	...	...	...	...	...	...	...	...
1440	Crapaudeau	Gros Crappaudeau	36	...	...	...	...	...	...	...	2	...	...
1440	Crapaudeau	Gros Crappaudeau	4	...	...	...	...	...	...	...	2	...	...
1442	Crapaudeau	Crappaudeau	34	Iron	...	...	...	...	*Plommée* or lead ball	...	...	...	...
1442	Crapaudeau	Gros Crappaudeau	2	Copper alloy	...	...	...	...	...	...	...	...	...
1443	Crapaudeau	Crapaudeau	7	Iron	...	...	...	...	...	...	2	...	...
1443	Crapaudeau	Crappaudeau	2	...	...	...	...	...	...	...	2	...	...
1443	Crapaudeau	Crappaudeau	2	Copper alloy	...	...	...	...	...	...	2	...	...
1443	Crapaudeau	Crappaudeau	74	Iron	...	...	...	...	Stone ball	...	2	...	...
1443	Crapaudeau	Crappaudeau	29	Copper alloy	...	...	...	...	Stone ball	...	2	...	...
1443	Crapaudeau	Crapaudeau	4	...	...	...	...	...	Stone ball	...	...	...	...

Date	Artillery name		Quantity	Metal	Material	Weight	Length	Calibre	Ammunition type	Ammunition weight	No. of removable chambers	Chamber weight	Weight of gunpowder
	Standardised gunpowder weapon type	Spelling in transcribed document											
1443	Crapaudeau	Crappaudeaul	1	Copper alloy	...	...	...	...	*Plommée* or lead ball	...	2	...	...
1443	Crapaudeau	Crappaudeaul	1	Copper alloy	...	...	...	...	...	...	2	...	...
1443	Crapaudeau	Gran Crappaudeau	9	...	...	...	...	...	...	...	2	...	...
1443	Crapaudeau	Gros Crappaudeau	9	Copper alloy	...	...	...	...	...	...	2	...	...
1443	Crapaudeau	Pesan Crappaudau	4	...	...	...	...	...	...	...	2	...	...
1444	Crapaudeau	Crapaudine	1	Iron	...	...	...	...	...	...	...	...	...
1445	Crapaudeau	Crapaudeau	120	Iron	...	...	...	2.0	Stone ball	...	3	...	...
1445	Crapaudeau	Crapaudeau	50	...	...	...	...	...	...	...	3	...	...
1445	Crapaudeau	Crapaudeau	12	Iron	...	...	...	4.0	Stone ball	...	3	...	...
1445	Crapaudeau	Crapaudeau	115	Iron	...	...	...	...	...	...	0	...	...
1445	Crapaudeau	Crapaudeau	5	Copper alloy	...	...	...	...	...	...	0	...	...
1445	Crapaudeau	Crappaudeau	3	Iron	...	175.0	...	...	...	...	...	...	...
1445	Crapaudeau	Crapaudeau	2	Iron	...	132.0	...	...	...	...	2	...	...
1445	Crapaudeau	Crappaudeau	6	...	...	...	...	...	...	...	2	...	...
1445	Crapaudeau	Crappaudeau	120	Iron	...	191.7	...	2.0	Stone ball	...	3	...	...
1445	Crapaudeau	Crappaudeau	50	Copper alloy	...	140.0	...	...	...	...	...	...	...
1445	Crapaudeau	Crappaudeau	2	Copper alloy	...	...	...	...	...	...	2	...	...
1445	Crapaudeau	Crappaudeau	5	Iron	...	...	...	...	*Plommée* or lead ball	...	2	...	...
1445	Crapaudeau	Crappaudeau	2	Copper alloy	...	...	...	...	...	...	2	...	...
1445	Crapaudeau	Gros Crappaudeau	3	...	...	...	...	...	...	...	...	...	...
1445	Crapaudeau	Gros Crappaudeau	3	Copper alloy	...	...	...	...	...	...	2	...	...
1446	Crapaudeau	Crappaudeau	87	...	...	...	5.0	2.0	Stone ball	...	2	...	...
1446	Crapaudeau	Crappaudeau	15	...	...	106.7	...	2.0	Stone ball	...	2	...	...
1446	Crapaudeau	Long Crapaudeau	24	...	...	...	...	2.0	Stone ball	...	2	...	...
1449	Crapaudeau	Crappauldeau	1	Iron	...	...	4.5	1.0	Stone ball	...	2	...	...
1451	Crapaudeau	Crappaudeau	12	Iron	...	...	4.0	2.0	Stone ball	...	2	...	...

The general thus had to plan to take gunpowder weapons to a siege or battle in advance; he also had to plan what types and sizes, and how many, were needed to be gathered and transported. All of the ancillary equipment to operate these guns also had to be planned for, gathered and transported. At the least, this meant gunpowder, ammunition, loading and firing accessories, mounts and beds, but could also include defensive shields – mantlets and pavises – smiths' forges, masons' tools, replacement parts and fire, not to mention the extraordinarily large number of horses and carts needed to transport all of the guns and their equipment. (In 1475, for example, the whole artillery train needed over 5000 horses and in excess of 1000 carts.) Of course, these too needed their personnel: carpenters, masons, smiths, farriers, grooms, pioneers, carters, joiners, tent builders and maintainers, ammunition founders and their servants.

And this was only what was needed on site. Behind all of this were gunfounders and gunsmiths, gunpowder-makers and carpenters who constructed mounts, carriages and shields. Moreover, to bring this together there needed to be a substantial increase in the administrative mechanisms to ensure that the gunpowder weapons required on the battlefield or at siege were available. Gunpowder weapons, their powder and carriages needed to be purchased, made and stored.

Naturally, there was also the effect of gunpowder weaponry on strategy and tactics: the speed and terrain of travel, deployment of forces, order of fighting, position, timing, etc. What was the general trying to achieve and how was he trying to achieve it? What he was trying to achieve was, of course, victory at the lowest possible cost. To do this he had to make the crucial decisions about how and how quickly to arrive at a battlefield or siege and, once there, where to deploy what forces he had – cavalry, infantry and artillery – in places which he hoped would provide him with a quick and convincing victory. At Nicopolis this was done poorly with cavalry and infantry forces alone. In contrast were Crécy and Agincourt, where the English developed tactics, with only the addition of limited gunpowder weapons, against the French that led to overwhelming victories. Sometimes a general using gunpowder weapons could also fail in his tactics, such as at Beauvais in 1472, when Charles the Bold dragged a huge bombard to the town but failed to bring sufficient ammunition to achieve the conquest, or at the battle of Gavere in 1453, when a stray spark flying into an open gunpowder sack was so misunderstood that it caused the artillery operators to flee and take others with them, despite the fact that there was no real danger; the battle was lost. While elsewhere, at Odruik in 1379 and Melun in 1420, to name just two, tactics using gunpowder weaponry seem to have been decisive in determining victory. What this all means is that gunpowder weapons alone were not the sole determining factors in victory or defeat. Victory still relied largely on the acumen and sometimes

the inventiveness of the general, in addition often to generous doses of luck. The general who could use gunpowder weapons well undoubtedly benefited from them, though not always.

We do not wish to suggest that *The Artillery of the Valois Dukes of Burgundy, 1363–1477* will serve as a history of *all* late-medieval gunpowder weapons. Indeed, it is but one of the chapters in this history. Similar chapters could, and should, be written on the history of English, French, Spanish, Italian, German, Scandinavian, Scottish, Ottoman Turkish, Hungarian, Russian and even Teutonic and Hospitaller gunpowder weapons. It is, however, the wealth and range of original sources that make the Valois Burgundian example so capable of presenting a vivid picture of what early gunpowder weapons were like, how they were made, how they were transported and mounted, what the ammunition and gunpowder used in them were, who the personnel were who operated these weapons, and, finally, how they were used in warfare.

Example of documentary evidence: the transport of artillery in 1474[23]

When weights are given for most of the artillery pieces listed in the Burgundian archival records, they are given in *livres*. In this rather intriguing order for arms to be transported to Dijon from Luxembourg at a time when Charles the Bold was preparing his artillery train for the unsuccessful siege of Neuss, the gunpowder weapons, their equipment and the arms accompanying them are listed with the number of horses needed to transport them.

> *Estat de ce qui semble ester necessaire pour la fait et conduit de l'artillerie que mon très redoubté seigneur M. le duc de Bourgoingne a ordonné estre menée en Bourgoingne, de celle qui se doit prendre en son dit pays de Bourgoingne à la conduit de Estienne Ferroux par lui commis au gouvernement et exercité de d'icelle.*
>
> State of that which seems to be necessary for the making and conducting of the artillery that our most redoubtable lord, M. the Duke of Burgundy has ordered to be taken into Burgundy, the which ought to be taken into his said land of Burgundy under the direction of Estienne Ferroux by his commission to his government and army.
>
> *Primo*
>
> First
>
> *A mondit seigneur ordonné ester méné deux courtaulx de metal estans presentement à Luxembourg et convient pour iceulx mener, 16 chevaux.*
>
> To my said lord it is ordered to be taken two copper alloy *courtaux* presently at Luxembourg and for which it is suitable to take, 16 horses.
>
> *Item pour mener cinq moiennes serpentines et quatre petites, fault avoir assavoir aux moiennes serpentines, trois chevaulx et aux petites deux; font 23 chevaulx.*
>
> Item to take five medium and four small *serpentines*, that is to say that for the medium *serpentines*, three horses and for the small [ones] two, making 23 horses.

Item pour mener trente cacques de pouldre à compter sur chacun chariot cinq cacques feront six chariots qui font 24 chevaulx

Item to take thirty casks of powder at the rate of five casks on each cart making six carts which makes 24 horses

Pour mener deux cent pierres de courtaulx à compter 40 pierres sur chacun (charriot) à quatre chevaulx font 20 chevaulx

To take two hundred stones [shot] for *courtaux* at the rate of 40 stones on each (cart) of four horses making 20 horses.

Pour mener les plomets servans ausdites 9 serpentines ung chariot et demi, 6 chevaulx.

To take the *plommées* for the said 9 serpentines one and a half carts, 6 horses.

Item pour mener 2,500 arcs, 2,700 douzaines de flesches, 6,000 cordes, 11 charriots qui feroient 44 chevaulx.

Item to take 2,500 bows, 2,700 dozen arrows, 6,000 strings, 11 carts which make 44 horses.

Pour mener picqs, horeaulx, lochets, ung chariot à 4 chevaulx.

To take picks, *horeaulx*, spades, a cart with 4 horses.

Pour mener oingt de garnison, les baghes du carrelleur et du cuvelier, ung chariot, 4 chevaulx

To take grease, the bags of the saddler and of the cooper, a cart, 4 horses.

Pour mener les baghes de Estienne Ferroux et ses aides par un commis du receveur de l'artillerie, 6 chevaulx.

To take the bags of Estienne Ferroux and his aides by a commission of the receiver of the artillery, 6 horses.

Prendre en Bourgogne une bombarde à Dijon et pour mener celle convient du moins avoir 24 chevaulx.

To take into Burgundy a bombard to Dijon and to take which is needed no less than 24 horses

Pour mener ung manteau servant icelle, convient dix chariots qui font 40 chevaulx.

To take a mantlet for this [bombard], ten cart are needed which makes 40 horses.

Pour mener ung affusts, 4 chevaulx

To take one carriage, 4 horses.

Pour mener du moins cent pierres servans à ladite bombarde à dix pierres, ung chariot à quatre chevaulx, font 40 chevaulx.

To take no fewer than one hundred stones [shot] for the said bombard at ten stones per cart with four horses making 40 horses.

Convient mener les baghes des charpentiers leurs hostiz et harnaix, 4 chevaulx.

It is necessary to take the bags of the carpenters, their baskets and equipment, 4 horses.

Pour mener les baghes des harnesqueurs et autres menues gens de ladite artillerie, 4 chevaulx.

To take the bags of the carters and other men of the said artillery, 4 horses.

Pour mener les baghes des cannoniers deux chariots, 4 chevaulx.

To take the bags of the *cannoniers* two carts, 4 horses.

Notes and references

1 Louis Napoleon had trained at the Swiss military academy at Thun and in 1834 was promoted to the rank of Captain of Artillery in the Berne militia. Intriguingly, his uncle, the Emperor Napoleon I, also trained as an artillery officer. Napoleon-Bonaparte, L and Favé, I, *Études sur le passé et l'avenir de l'artillerie*, 6 vols (Paris: 1846–71).

2 Brackenbury, H, 'Ancient cannon in Europe. Part I: From their first employment to A.D. 1350', *Proceedings of the Royal Artillery Institution*, 4 (1865), pp287–308; Brackenbury, H, 'Ancient cannon in Europe. Part II: From A.D. 1351 to A.D. 1400', *Proceedings of the Royal Artillery Institution*, 5 (1867), pp1–37; Clephan, R C, *An Outline of the History and Development of Hand Firearms, from the Earliest Period to about the End of the Fifteenth Century* (London: 1906); Clephan, R C, 'The military handgun of the sixteenth century', *Archaeological Journal*, 67 (1910), pp109–50; Clephan, R C, 'The ordnance of the fourteenth and fifteenth centuries', *Archaeological Journal*, 68 (1911), pp49–138; Henrard, P, *Histoire de l'artillerie en Belgique* (Brussels: 1865); Henrard, P, 'Documents pour servir à l'histoire de l'artillerie en Belgique. 1er partie: Les fondeurs d'artillerie', *Annales de l'académie d'archéologique de Belgique*, 45 (1889), pp237–90; Rathgen, B, 'Feuer- und Fernwaffen des 14. Jahrhunderts in Flandern', *Zeitschrift für historisches Waffenkunde*, 7 (1915–17), pp275–306; Rathgen, B and Schäfer, K H, 'Feuer- und Fernwaffen beim päpstlichen Heere im 14. Jahrhundert', *Zeitschrift für historisches Waffenkunde*, 7 (1915–17), pp1–15; Rathgen, B and Schäfer, K H, *Die feuer- und Fernwaffen in Naumburg von 1348–1449* (Naumburg: 1921); Rathgen, B and Schäfer, K H, *Das Aufkommen der Pulverwaffe* (Munich: 1925); Rathgen, B and Schäfer, K H, *Das Geschütz im Mittelalter* (Berlin: 1928; reprinted Dusseldorf: 1987)

3 A prime example of this sort of scholarship is the translation of *Das Feuerwerkbuch von 1420*, which was edited by W Hassenstein and was published in Munich in 1941, while several of the articles appearing before the First World War and Second World War in the *Zeitschrift für historisches Waffenkunde* (which was later renamed *Zeitschrift für historisches Waffen- und Kostümkunde*) also fall into this category.

4 As examples of these historical works see Hogg, O F G, *English Artillery, 1326–1716* (London: 1963) and *Artillery: Its Origin, Heyday and Decline* (London: 1971); and Rogers, H C B, *Artillery through the Ages* (London: 1971).

5 Blackmore, H L, *The Armouries of the Tower of London, I: Ordnance* (London: 1976); 'The Boxted bombard', *Antiquaries Journal*, 67 (1987), pp86–96; 'The oldest dated gun', *Canadian Journal of Arms Collecting*, 34/2 (May 1996), pp39–47; and 'Master Jacobo's culverin, 1517', *Journal of the Arms and Armour Society*, 12/5 (1988), pp312–44. Vale, M G A, 'New techniques and old ideals: the impact of artillery on war and chivalry at the end of the Hundred Years War', in Allmand, C T (ed.), *War, Literature and Politics in the Late Middle Ages: Essays in Honour of G.W. Coopland* (Liverpool: 1975), pp57–72; and *War and Chivalry: Warfare and Aristocratic Culture in England, France and Burgundy at the End of the Middle Ages* (London: 1981). Contamine, P, 'L'Artillerie royale Française à la veille des guerres d'Italie', *Annales de Bretagne*, 71 (1964), pp221–61; *Guerre, état et société à la fin du moyen âge: Études sur les armées des rois de France, 1337–1494* (Paris: 1972); *La Guerre de Cent Ans*, 3rd edn (Paris: 1977), translated as Jones, M (trans.), *War in the Middle Ages* (London: 1984); 'La Guerre de siège au temps de Jeanne d'Arc', *Dossiers de archéologie*, 34 (May 1979); and 'Les Industries de guerre dans la France de la Renaissance: l'exemple de l'artillerie', *Revue historique*, 271 (1984), pp249–80. Guilmartin, J F, 'The early provision of artillery armament on Mediterranean war galleys', *Mariner's Mirror*, 59 (1973), pp257–80; *Gunpowder and Galleys. Changing Technology and Mediterranean Warfare at Sea in the Sixteenth Century* (Cambridge: 1974); and 'Ballistics in the black powder era', in Smith, R D (ed.), *British Naval Armaments* (London: 1989), pp73–98. Hall, B S, 'The corning of gunpowder and the development of firearms in the Renaissance', in Buchanan, B (ed.), *Gunpowder: The History of an International Technology* (Bath: 1996), pp87–120; and *Weapons and Warfare in Renaissance Europe: Gunpowder, Technology and Tactics* (Baltimore, MD: 1997).

6 Of particular note here is the work of Adrian B Caruana, *The History of English Sea Ordnance, I: The Age of Evolution, 1523–1715* (Rotherfield, 1994), which the present authors consider is littered with many errors of fact, transcription and translation.

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'The military revolutions of the Hundred Years War', *Journal of Military History*, 57 (1993), pp241–78; Eltis, D, *The Military Revolution in Sixteenth-Century Europe* (London: 1995); and Arnold, T, *The Renaissance at War* (London: 2001).

8 See, for example, Keen, M H (ed.), 'The changing scene: guns, gunpowder, and permanent armies', in *Medieval Warfare: A History* (Oxford: 1999), pp273–91.

9 Smith, R D, 'Port pieces: the use of wrought-iron guns in the sixteenth century', *Journal of the Ordnance Society*, 5 (1993), pp1–10

10 Smith, R D, 'Wrought-iron swivel guns', in Bound, M (ed.), *The Archaeology of Ships of War* (Oxford: 1995), pp104–13

11 DeVries, K, 'Gunpowder weaponry and the rise of the early modern state', *War in History*, 5 (1998), pp127–45

12 DeVries, K, 'A 1445 reference to shipboard artillery', *Technology and Culture*, 31 (1990), pp818–29; and 'The effectiveness of fifteenth-century shipboard artillery', *The Mariner's Mirror*, 84 (1998), pp389–99

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14 T'Sas, F, 'Dulle Griet. La grosse bombarde de Gand, et ses souers', *Armi Antiche* (1969), pp13–57

15 In particular, Smith, R D and Rhynas Brown, R, 'Mons Meg and her sisters', Royal Armouries Monograph No. 1, London, 1989.

16 Although recently Beyaert, M, 'Nieuwe historisch onderzoek van de Dulle Griet bombarde in Gent', *Handelingen der Maatschappij voor geschiedenis en oudheidkunde te Gent*, 53 (1999), pp3–59, and Gillet, C and Lefebvre, M, 'Quelle etait la puissance de feu de la "Mons Meg", bombard bourguignonne conservée à Edimbourg?', *Le Musée d'armes*, 28/98–99 (December 2000), pp2–22, have appeared, so perhaps the trend is beginning to change ever so slightly.

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18 And yet, even these have been little studied, with the only catalogue being that in Florens Deuchler's seminal *Die Burgundebeute: Inventar der Beutestucke aus den Schlachten von Grandson, Murten und Nancy 1476/77* (Bern: 1963).

19 See, for example, the misdating of early gunpowder weapons in the Swedish Armémuseum in Stockholm and the Naval Historical Center Museum in Washington DC, and the mislabelling of removable chambers as bombards in the town squares of Diest and Thuin, Belgium, and the French Musée de l'Armée, to name but a few of the many examples.

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John F Guilmartin, Jr

Exploiting the guns of the Santíssimo Sacramento*: an analysis of early modern naval ordnance, gunnery and gunfounding*

The following is a study of ordnance recovered from the wreck of the Portuguese ship *Santíssimo Sacramento*, sunk off Salvador, Brazil, in May of 1668. Its purpose is to exploit a unique collection of ordnance in order to improve our understanding of the theory and practice of naval gunnery and the casting of bronze ordnance during the early modern era, and to demonstrate in the process the utility of nautical archaeology as a window to the past.

A *galeão* and thus by definition a warship, *Santíssimo Sacramento* was at the time of her sinking the flagship of the annual convoy of the Companhia Geral do Comerçio do Brasil, the Portuguese Brazil Company, outbound from Lisbon. A famous tragedy in Portuguese history, the loss of *Santíssimo Sacramento* finds an English parallel in the loss of Henry VIII's flagship, the carrack *Mary Rose*, off Portsmouth in 1545 and a Swedish parallel in the loss of the galleon *Vasa*, sunk in Stockholm harbour in 1622. Although the Portuguese vessel is the least well known of the three, the parallels extend beyond legend and popular culture to the considerable historical value of physical artefacts recovered from the wrecks. Relevant to our concerns, the Portuguese vessel went down in much deeper water than the other two and in a more hostile environment. Whereas *Vasa*'s hull and much of its contents were preserved almost *in toto* by the cold, brackish, barnacle-free waters of the Baltic, and some three-quarters of *Mary Rose*'s hull and much of that which lay within were protected by an anaerobic blanket of silt, *Santíssimo Sacramento* was fully exposed to scouring currents and marine life, leaving little behind but the ballast pile – within which, to be sure, important artefacts were preserved – and the ship's ordnance, the subject of the following analysis.

For nearly three centuries the location of *Santíssimo Sacramento*'s wreck was lost to all but local fishermen to whom the site, notorious for snagging nets, was an underwater reef known as *o galeão*. The connection was not made until the mid-1970s, when sport divers discovered the wreck and began looting it. The first looted objects to

attract public attention were bronze cannon sold to salvage yards as scrap. Providentially, the wreck lay within the jurisdiction of Brazil's 2nd Naval District, under the command of Vice Almirante Fernando Ernesto Carneiro Ribeiro, a serious student of naval history. Hearing reports of 'old cannon' in salvage yards, Carneiro investigated. Instead of the pieces of Napoleonic vintage he had expected, he found seven substantially older bronze pieces including several beautifully preserved English guns cast in the 1590s.[1] He immediately slapped a prohibited zone around the site and, with the endorsement of Capitão-de-Mar-e-Guerra (RRm) Max Justo Guedes, director of the Serviço de Documentação Geral da Marinha, the Historical Service of the Brazilian Navy, sought support for a recovery effort.

The recovery of *Sacramento*'s guns and their value

In response to their entreaties, the Navy assigned its sole submarine rescue vessel, *Gastão Moutinho*, commanded by Capitão-da-Fragata Oscar Moreira da Silva, and its complement of divers to *Santíssimo Sacramento* in a salvage archaeology operation. During 1976–78 *Gastão Moutinho*'s divers, working under the guidance of archaeologist Ulysses Pernambucano de Mello e Neto, recovered a host of artefacts including two bronze astrolabes and the signet ring of a senior Portuguese official that removed any doubt as to the identity of the wreck.[2] Of importance to the present study, they recovered 19 bronze cannon to which we can add the seven looted pieces impounded on Admiral Carneiro's authority under the provisions of Brazilian admiralty law. *Gastão Moutinho*'s divers also recovered eight cast-iron cannon before those in charge realised that they deteriorated catastrophically on exposure to atmospheric oxygen. These guns provided the data for the study that follows. The value of these guns stems in large measure from the fact that they form a coherent and largely complete collection of early modern naval ordnance of unimpeachable provenance: the actual gundeck of a known warship at an established date.

In dealing with early modern ordnance on public display and in museum collections we rarely know why a given piece survived. Was it preserved because it was unusually beautiful? Because it was too unwieldy to be taken into the field? Because of association with some long-forgotten event? In most cases we simply do not know. These questions are particularly vexing when dealing with bronze ordnance, since worn, damaged or obsolete bronze pieces were habitually melted down and recycled into newer guns, not only reducing the number of surviving pieces, but rendering the reasons for their preservation obscure in all but a handful of cases, mostly involving archaeological recovery from an underwater wreck, as is the case here.

The author's involvement with *Santíssimo Sacramento*'s guns began with an invitation from Capitão-de-Mar-e-Guerra Guedes to travel

to Brazil in October of 1978 to study them. The initial findings of my investigation were published in *Navigator*, the journal of the Brazilian Navy's Historical Service, in 1981[3] and in *Technology and Culture* in 1983.[4] The present article originated in an October 2001 presentation at a conference on material culture hosted by the Smithsonian's National Museum of American History. It revisits the original data set with the benefit of knowledge gained during the intervening 20 years in materials science, internal ballistics and cannon founding, and in the history of the 1624–54 Luso-Dutch struggle for control of Brazil, for which *Santíssimo Sacramento* and her guns were designed and constructed.

Santíssimo Sacramento as a warship

Before addressing the guns in detail a few words on *Santíssimo Sacramento* and the environment for which she was designed are in order. One source states that she carried 60 guns,[5] a figure that is compatible with our expectations of a vessel intended to serve as flagship for convoys of the Companhia Geral do Comerçio do Brasil, laid down about 1649 and launched no earlier than 1650, probably in 1653. The absence of any guns bearing dates later than 1653 and the fact that the best of her heavy bronze ordnance was cast in that year (Table 1) militates against a later launch date. Inasmuch as the struggle for Brazil did not end until 1654, and unexpectedly at that – the Dutch simply abandoned their Brazilian interests under the pressure of the First Anglo-Dutch War of 1652–54[6] – it is clear that she was built for war. That the war in question was fought far from home in an age in which the most powerful warships were insufficiently seaworthy for transoceanic operations suggests that she was relatively large for her weight of ordnance by English standards. Those standards are relevant, since we know a great deal more about contemporary English warships than about their Portuguese equivalents. In brief, English third-rate warships, as distinct from the huge first- and second-rates built to dominate waters close to home, *could* engage in transoceanic operations, albeit with a reduced ordnance load.[7] It is thus reasonable to view *Sacramento* as a third-rate equivalent.

In this light it is useful to review the armament of contemporary English third-rates. The Royal Navy's Ordnance Establishment of 1666, a list of the armament of all English warships as of April of that year, yields four third-rate warships of 60 guns.[8] Their main batteries consisted of 22 or 24 32-pounders, that is guns firing a cast-iron ball of 32 pounds, mounted on the lower gundeck. Of the four vessels, one mounted 26 9-pound demi-culverins on the middle gundeck; the other three mounted 24 and 26 12-pounders respectively, plus two and four 18-pound culverins. The vessel with the lightest second-tier ordnance also carried ten sakers, nominally 5-pounders, almost certainly mounted on the upper deck.[9] The culverins, demi-culverins and sakers

Table 1 Bronze guns recovered from the *Santíssimo Sacramento*. The weight marks give the weight of the barrel in *quintaes* (hundredweights), *arrobeis* (fourths of a hundredweight), and *arrateis* (Portuguese pounds)

Ball weight in pounds	Date cast	Founder's marks	Author's identification number	Weight marks	Weight in pounds	Weight of barrel per pound of ball	Maximum barrel thickness as function of bore diameter
26	1649	Matias Escartim[a,b]	10	+36-2-10+	3758	144.6	0.97
26	1649	Matias Escartim[a]	11	+36-1-16+	3739	143.8	0.96
26	1649	Matias Escartim[a]	12	+36-3-08+	3782	145.5	0.96
26	1649	Matias Escartim[a]	14	+36-1-00+	3723	143.2	0.96
26	1649	Matias Escartim[a]	15	+35-1-00+	3620	139.2	0.95
26	1649	Matias Escartim[a]	16	+36-2-04/+	3752	144.3	0.96
28	Mid-1600s	A.G.F.[a,c]	9	39-1-16	4047	144.5	0.95
24	Mid-1600s	[a]	17	-37-0-8-	3808	158.7	0.96
11	Reign of João III	[a]	18	+25-1-08+	2601	236.5	1.06
11	Reign of João III	[a]	19	+25-3-08+	2657	241.6	1.07
11	Early 1600s	A.G.F.[a,c]	3	23-2-16	2430	220.9	1.06
11	Mid-1600s	[a]	4	25-2-0	2619	238.1	1.20
11	Mid-1600s	[a]	5	+26~0~1+	2671	242.5	1.04
11	Mid-1600s	[a]	23	+25~3~1+	2645	240.5	1.11
14	Mid-1600s	PDB[a,d]	6	31-2-12	3247	231.9	1.11
20	1590	John and Richard Philips	13	3640Ã[e] 3600-1-6	3728	186.4	1.11
20	1590	John and Richard Philips	8	3610Ã[e] 3500-1-1	3620	181.0	1.14
20	1590	George Elkine	20	2700Ã[e] 2600-1-5	2702	245.6	1.14
20	1590	George Elkine	2	2650Ã[e] 2500-3-9	2654	241.2	1.16
11	Mid-1500s?	[a]	1	2630Ã[e] 2500-1-25	2619	238.1	0.95
8	Mid-1500s?	[a]	21	2640Ã[e] 2500-2-18	2637	329.6	1.12
20	1649	Conrad Wagwaert	7	37-1-19	3844	191.7	1.07
14	1622	Henricus Meus	22		3548[f]	247	1.09
20	1634	Assuerus Koster	24	38-0	3902	195.1	0.96
4½	Mid-1600s	Assuerus Koster	34	...	...	...	0.79
4½	1646	Henricus Vesterinck	35	...	...	...	0.62

a Indicates Portuguese royal crest on barrel.

b In my previous work, I conflated Matias Escartim's name with that of Lieutenant General of Ordnance Rui Corea Lucas, whose name was cast on the barrels along with Escartim's, making the latter Lucas Matias Escartim. I am indebted to Dr Luis Filipe Marques de Sousa, formerly of the Museu Militar, Lisbon, for correcting me on this point and for identifying the founder PDB.

c A.G.F. for Antonio Gômes Feio, a Lisbon-based founder.

d For Pedro Dias Bocarro, a Goa-based founder.

e Indicates weight in pounds avoirdupois.

f Based on the gun's calculated volume, as explained in Figure 8.

were mostly if not entirely cast-bronze pieces of obsolescent design, the rest cast-iron ordnance of recent manufacture. As we will see, the weight, amount and pattern of armament provide both revealing contrasts and useful clues in evaluating *Santíssimo Sacramento*'s armament.

The capabilities, limitations and manufacture of early modern ship-borne ordnance

Our next step is to address the capabilities, limitations and manufacture of ship-borne ordnance in *Sacramento*'s day, an area in which there is a great deal of misinformation in general histories, much of it stemming from the implicit assumption that early modern ordnance can be judged by the standards of present-day artillery. In fact, modern rifled artillery firing high-explosive shells with smokeless, nitrocellulose-based propellants differs fundamentally in ballistic properties and tactical characteristics from early modern smoothbore ordnance using black powder to fire an inert spherical projectile. With modern artillery, long-range accuracy is both attainable and, because of the destructive power of high-explosive shells, tactically relevant. Long barrels are necessary to obtain long ranges. In contrast, early modern smoothbores were inherently inaccurate. This was due in the first instance to the space, or windage, left between the ball and bore to prevent the ball from jamming as powder residue built up with repeated firings. In consequence, the ball would rebound back and forth, or ballot, on firing, departing the muzzle in an unpredictable direction. It was due in the second instance to the inherent inaccuracy of a slowly spinning spherical projectile. Whatever spin the ball acquired from contact with the barrel was around an axis at right angles to the line of flight, causing the ball to hook or slice like a golf ball. More fundamentally, air flows in an erratic fashion around a slowly spinning sphere, causing it to deviate unpredictably from its line of flight in the manner of a baseball pitcher's knuckle ball. The resultant inaccuracy was multiplied by the fact that the barrels were mounted rigidly in wooden carriages that moved rearward with recoil on firing, transferring their lateral and vertical movement to the projectile. The net result was that gunners could not reliably hit small targets at long ranges and the maximum effective range of naval guns was of the order of 200–300 yards, a figure further reduced by the difficulties of aiming from a rolling deck. Finally, the destructive capabilities of inert projectiles fell off sharply as range increased. On occasion, a long shot would cripple the rigging of a pursuing enemy or disable a fleeing foe, but the expression 'long shot' says it all.

The next misconception involves the relationship between barrel length and maximum range. For the reasons indicated, maximum range was of peripheral tactical relevance in early modern warfare at sea. That notwithstanding, the notion that maximum range was important and that it was proportional to barrel length has enjoyed

remarkable longevity. With modern artillery, maximum range *is* proportional to barrel length. This is for two reasons. First, the burning rates of nitrocellulose-based propellants increase as a function of temperature and pressure: the hotter the chamber and the greater the pressure the faster they burn. Second, the decomposition products are light, being entirely gaseous except for traces of water vapour. With proper powder grain geometry, the burning rate of the charge will increase progressively as the projectile moves down the bore, imparting increased velocity more or less indefinitely.[10]

The ballistic properties of black powder and their implications

None of the above characteristics applies to black powder, the traditional mixture of saltpetre, charcoal and sulphur in the approximate proportions of 75:15:10 by weight. Because of the thermochemical properties of black powder, the burning rate does not vary as a function of pressure or temperature. In addition, the decomposition products are relatively massive, consisting of 57 per cent solid particles by weight. These characteristics placed a strict upper limit on the velocity that a black-powder charge could impart and an equally strict limit on useful barrel length.[11] In practical terms, once a cannon ball had travelled 8–10 feet from the face of the powder charge it was moving as fast as ordinary grained black powder could move it. From the ballistic point of view, any additional barrel length was a waste of metal.[12]

But while barrel length had no appreciable effect on maximum range, it did have important structural consequences. That was because cannon were cast muzzle-up, and the greater pressure of molten metal at the breech resulted in denser and stronger metal where it was most needed.[13] We know that early modern gunfounders were empirically aware of the relationship because we can observe gradual but systematic reductions in barrel length and wall thickness over time. Gun metal, ideally an alloy of 9 parts copper and 1 part tin by weight, was expensive and the founder used no more than he had to. Moreover, shorter, thinner guns were lighter and easier to handle. With this in mind, the gradual reduction in length and barrel thickness in guns cast within the same national tradition – a phenomenon clearly observable in *Santíssimo Sacramento*'s bronze guns – reflects both gradual improvements in founding technique and a clear appreciation of just how short and thin guns could be cast at a given time.[14] Quality was ensured by proof firing with a heavier than normal projectile, a larger than normal powder charge, or both. Enough guns 'failed proof', that is, burst on firing, to give founders an accurate sense of how close to the limits of safety they were. Our best evidence is from the eighteenth century, but the technology of bronze cannon founding remained essentially unchanged from late medieval times through the early modern era, and proof firing was central to the process.[15]

Bronze cannon founders' methods and the importance of cast-iron ordnance

To appreciate fully what *Santíssimo Sacramento*'s guns have to tell us, it is necessary to go into the founding process in some detail. It started with the creation of a positive image of the gun, begun by wrapping rope around a wooden mandrel and finishing with wax. The positive was suspended above a long box, using the mandrel as an axle, and the final form was imparted by a strickle-board, a wooden template cut to the outline of the barrel that was pressed against the wax-covered positive which was slowly turned to impart the desired shape. As we shall see, this seemingly crude process could be remarkably precise. The trunnions in which the finished gun would be suspended in its carriage, lifting lugs or dolphins, royal crests, founder's marks and other external decorations were then sculpted in wax and attached to the positive.

The positive was then coated with successive thin coats of fine pottery clay to which an admixture of finely chopped wool and horse manure had been added. The first layers were dried in the open air, then, after an appreciable thickness had built up, a slow charcoal fire was lit in the box to harden successive layers of coarser clay. Once the mould had reached the desired thickness, it was reinforced with wrought-iron staves around which white-hot, wrought-iron hoops were shrunk. The mandrel and rope were then removed and the inside of the mould fired to melt out the wax, vitrify the clay and burn out the fragments of wool and horse manure, leaving a sintered surface to provide an escape route for the moisture released from silicates in the clay upon contact with molten bronze. The mould for the cascabel, the breech cap, was constructed by the same basic process.

Once the mould was dry, it was suspended breech down over a pit at the bottom of which the breech cap was firmly embedded in rammed earth. The core that would form the gun's bore was carefully lowered into the mould and centred at the base by means of a wrought-iron chaplet or *cruzeta* (Figure 1). This was critical, since a gun with an off-centre bore was inherently dangerous. The work in the pit was done by candlelight and, considering the fragility of the mould and the close tolerances involved, the standards of craftsmanship were remarkable. After the core was centred, the mould was lowered onto the breech cap and a feeding head or casting bell attached atop the mould. The whole assembly was embedded in rammed earth and channels cut to convey the molten metal from the melting furnace to the mould.

After the metal had been poured, the gun was left to cool – a critical part of the process that determined the crystalline structure upon which the metal's strength depended – then dug from the pit, broken out of the mould, and the metal from the feeding head sawed off. Finally, in most casting traditions the gun was weighed and the weight incised into the metal.

A final technical note is necessary before we turn to *Sacramento* and her guns. It involves the relationship between bronze cannon and cannon of cast iron. The ability to cast reasonably safe cannon of iron, first mastered by the English in the 1540s and then by the Dutch, Germans and Swedes, was an achievement of immense importance, but primarily for economic reasons. Iron guns were substantially larger and heavier than guns of bronze cast to fire a ball of the same weight. Worse, they were subject to internal corrosion and, partly as a result, were less safe. When they burst, they did not remain essentially intact as bronze guns did, parting like a torn sponge along a longitudinal line near the breech; rather, they blew apart in jagged fragments like a bomb. The primary drawback of bronze ordnance was its high cost. While we do not know what *Sacramento*'s guns cost, commodity prices give an idea of the difference between bronze and iron: in 1570, bronze cost £40–60 per ton in England, 3⅓ to 6 times more than iron; by 1670, bronze cost £150 per ton and the ratio had increased to 8⅓ to 1.[16] By *Sacramento*'s day, the British Royal Navy was armed mostly with cast-iron guns, and those that passed proof were acceptably safe, but British third-rates were armed primarily to fight close to home, and for a warship intended for operations in distant waters the weight advantages of bronze would have been compelling.

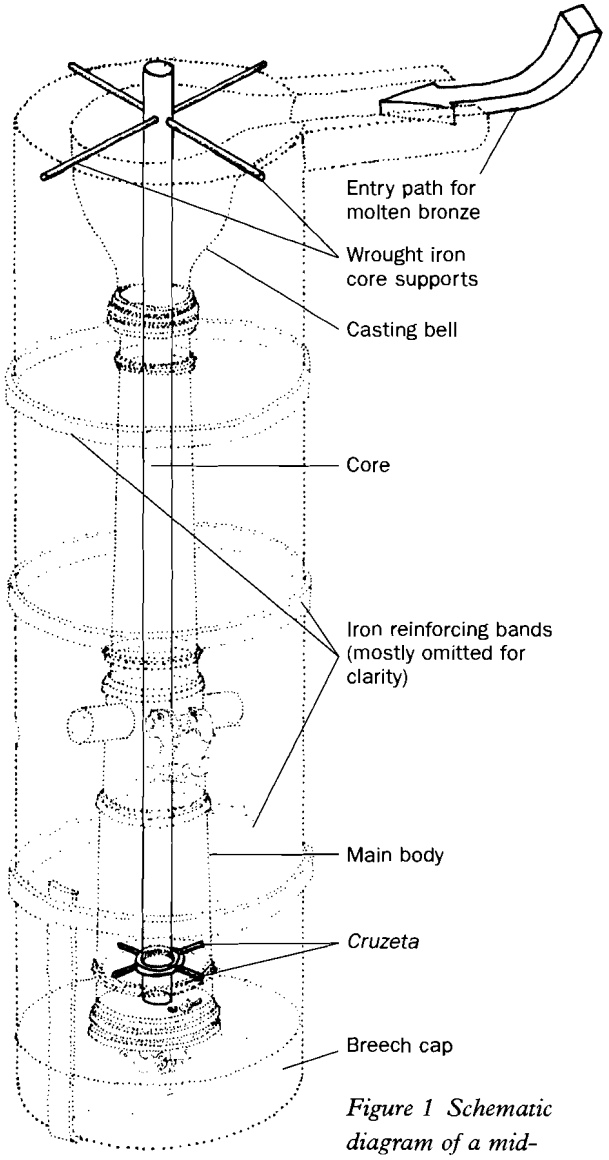


Figure 1 Schematic diagram of a mid-seventeenth-century Portuguese cannon mould. The cannon depicted is a Matias Escartim 26-pounder, number 12 in Table 1. The mould reconstruction is the author's, based on literary evidence extrapolating backward from later practice presented in de Beer, C (ed.), note 15. (John F Guilmartin, Jr)

Sacramento's guns: distribution and description

Thirty-four cannon, 26 of bronze and 8 of cast iron, were raised from the wreck; Table 1 lists the bronze guns and their salient features. In addition, we must take into account the 8 iron guns left on the bottom, adding to a total of 42 guns. For reasons addressed below, all but two of these were probably mounted on *Sacramento*'s enclosed gundecks. The archaeologist's site plan (Figure 2) shows the distribution on the bottom of most of the major items recovered, including 35 of the cannon. Though incomplete – the locations of the 7 cannon recovered before archaeological controls were imposed

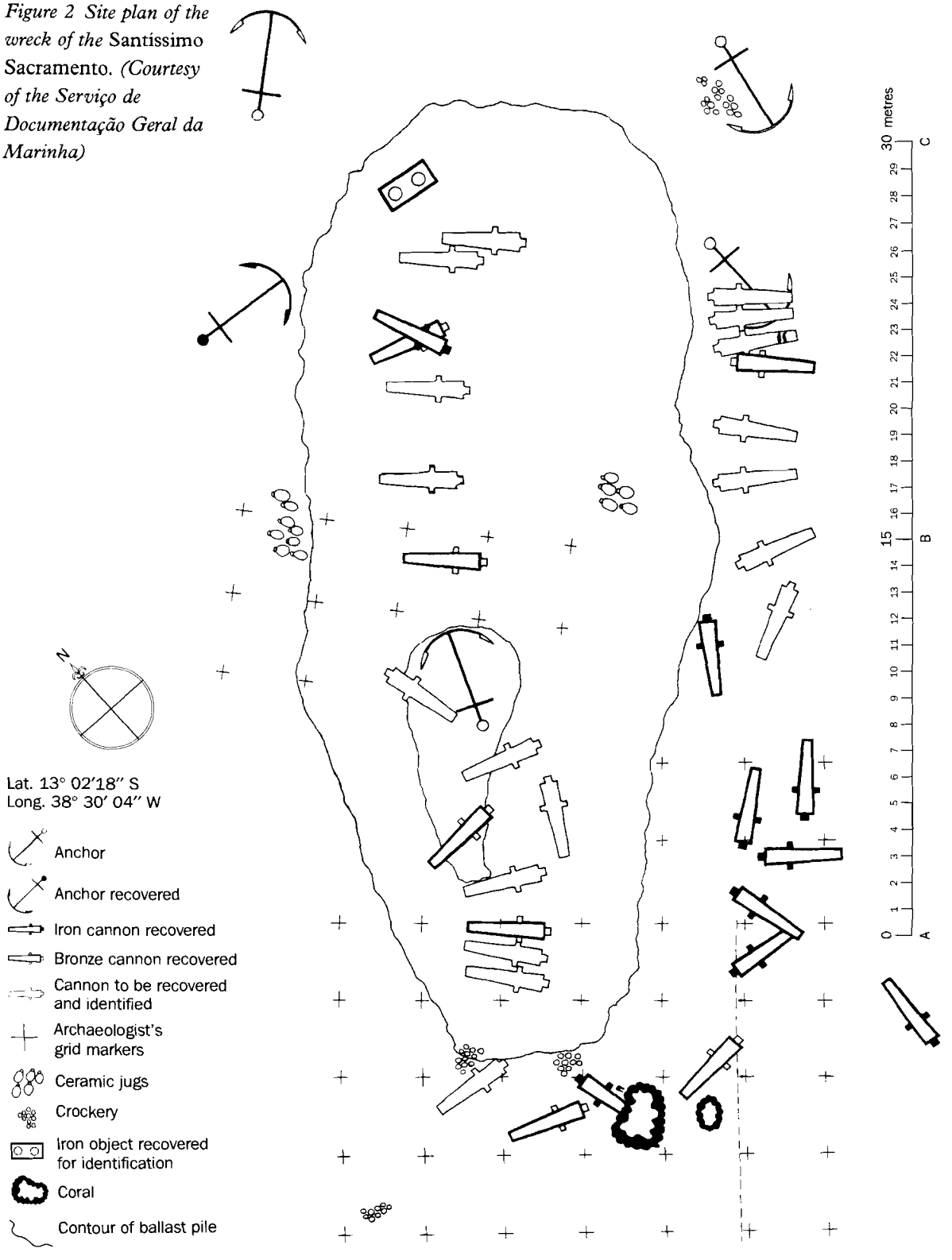


Figure 2 Site plan of the wreck of the Santíssimo Sacramento. *(Courtesy of the Serviço de Documentação Geral da Marinha)*

are unknown – the evidence provided by the plan is critical to reconstructing *Sacramento*'s gundecks.

The distribution of wreckage suggests that the ship came to rest on the bottom, right side up on a relatively even keel. This disposition is plain from the arrangement of anchors and guns. The cannon were found in two ragged parallel lines flanked by four of the five anchors at what we can safely assume was the forward end of the ship, since a ship's main anchors were carried outboard in the bows. Deviations from this overall scheme are minor and reinforce the conclusion that the locations from which the cannon were recovered correspond closely to their locations on a horizontal plan of the ship before she went down.

The lines of cannon curve inward at the extreme stern just enough to suggest that the two cannon in the opposing lines closest to one another were stern chasers, mounted side by side to fire rearward on either side of the rudder. The lines of cannon are least regular at the stern, where the hull and superstructure would have been deeper, leaving a greater mass of rotting timber to disorder the rows of cannon in their slow trip to the bottom. The length of the lines of cannon suggests a gundeck about 158 feet (49 m) long and an overall hull length of about 200 feet (61 m) from stem to stern. *Sacramento* was thus, as we would expect, somewhat larger than contemporary British third-rates, whose gundecks ranged from 130 to 151 feet.[17]

Of the 26 bronze cannon recovered, two are very small pieces, 4½ pounders (Figure 6) that would have been mounted on the upper decks. In light of their beauty and small size they are surely representative of a number of similar pieces looted from the site, conceivably the 18 needed to fill out *Sacramento*'s complement of 60 guns. The rest of the bronze pieces are split almost evenly between 20-pounders or larger (12) and 12-pounders or smaller (10). This and the close spacing of the guns in their two rows erase whatever doubt we may have that the ship's main battery was mounted on two decks.

The eight iron guns recovered fell into two distinct categories. Judging by their gross external dimensions, four were 20-pounders or larger and four were 12-pounders or smaller, an observation that supports the two-gundeck hypothesis, since the plan indicates that at least seven of the eight were found adjacent to one another in an area corresponding to the starboard quarter; in other words, it would appear that the smaller guns of the middle gundeck fell through the rotting hull onto a like number of larger guns below them. *Gastão Moutinho*'s captain, Capitão-da-Fragata Moreira da Silva, formed the opinion, based on his divers' reports, that most if not all of the eight cannon left on the bottom fell into the 20-pounder or larger category. Logic suggests that *Sacramento* carried 22 guns on her lower deck, all 24-pounders or larger, and 18 guns on her middle deck, eight of them 20-pounders and ten 11-pounders (including the archaic English

8-pounder on the basis of size). The heavy concentration of guns at the stern of the wreck (Figure 2) suggests that two guns were carried there in chase, and the logical candidates are the two bronze 14-pounders. *Sacramento* would have looked very much like the Spanish galleon of 60–64 guns drawn by the Dutch master William Van de Velde the Younger in 1666 (Figure 3).

Turning to the ordnance, I have given the weights of the guns in the original Portuguese units. My purpose is comparative and, so long as I am consistent, Portuguese *arrateis* will serve as well as any other unit. In contrast, I have given the 'ratings' of the cannon, that is the weight of ball they were intended to fire, in pounds avoirdupois to facilitate comparison with the armament of contemporary ships of other nations. Since the weights of the guns and their projectiles are central to my analysis, my reliance on the weight markings incised on the guns' breeches requires explanation. Doubt as to the meaning of the markings was eliminated by calculating the volumes of selected cannon and determining their expected weights based on the density of bronze. While the results were imprecise in light of the complexity of the guns' shapes and variations in the density of bronze, they yielded a range of weights that encompassed those marked on the guns.

Figure 3 Drawing of a Spanish two-decker by William Van de Velde the Younger, 1666. It was pierced for 60–64 guns and must have been similar to Santissimo Sacramento *in appearance, although somewhat larger. A contemporary English warship of the same dimensions would have carried 70–80 guns.*[18] *(© National Maritime Museum, London)*

My confidence in the markings' accuracy is based on analysis of the double sets of markings on *Sacramento*'s six English guns, giving the weights of the pieces in question in English pounds avoirdupois and Portuguese *arrateis*. A least-squares regression analysis of the two sets of markings showed that they are parallel expressions of the same quantities in different, but consistent, units of measure with a correlation of 0.9989.[19] This analysis also yielded a value

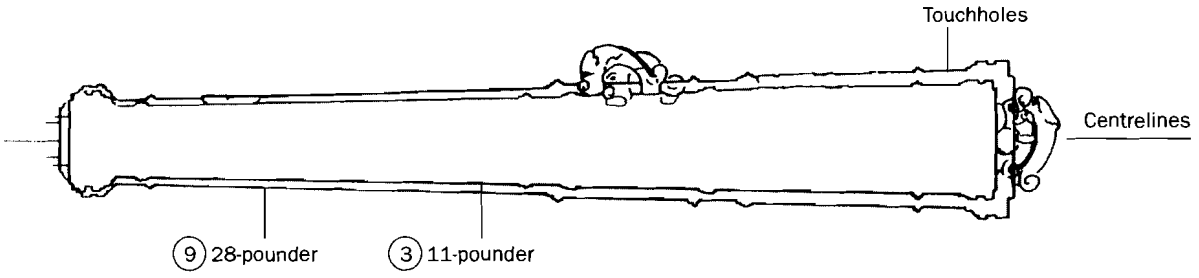


Figure 4 Comparison of a 28-pounder and an 11-pounder made by Antonio Gômes Feio. The outlines are drawn with superimposed centrelines and touchholes so as to depict the bases of the bores in the same transverse plane. (John F Guilmartin, Jr)

Comparative data

Gun	Weight of barrel per pound of ball	Relative length of barrel	Thickness of barrel wall at base of bore
28-pounder	137 pounds	18.4 calibres	0.95 bore diameter
11-pounder	209 pounds	24.8 calibres	1.06 bore diameter

for the *arratel* of 1.027 pounds avoirdupois, heavier than the value of 1.012 pounds usually given.[20] Small discrepancies between the English and Portuguese weights of individual cannon make it clear that the Portuguese did not simply multiply the English weights by a conversion factor: they actually weighed the guns. They did so, moreover, with impressive accuracy: within 0.07 per cent on average and within 0.02 per cent if we throw out cannon number 13 as an outlier.[21] These findings indicate that English gunfounders and Portuguese arsenal workers observed similarly high standards of precision, suggesting a shared technical tradition.

Analysis of the guns recovered suggests that the *Sacramento*'s preferred main gundeck battery would have been of bronze 26-pounders, but that a shortage of first-class ordnance led to the inclusion of older bronze pieces of disparate calibres and numbers of cast-iron cannon. This hypothesis is supported by examination of the bronze Portuguese guns that we can unequivocally assign to the lower gundeck based on size. There are eight of these: a 28-pounder by the founder A.G.F. (Antonio Gômes Feio), the largest cannon recovered (Figure 4); a 24-pounder by an unknown founder (though unsigned, the piece is plainly Portuguese); and six 26-pounders by the founder Matias Escartim (Figure 5). The uniformity of these six guns suggests that their founder and his customers believed them to be of a superior design, an impression reinforced by analysis of their weight and their similarity to the earlier A.G.F. piece. Comparison with *Sacramento*'s captured Dutch guns (Figure 6) indicates that they were right. Though the three larger Dutch guns all fired a smaller ball – 20, 20 and 15 pounds respectively – they are heavier, longer, or both, than the Portuguese 26-pounders.

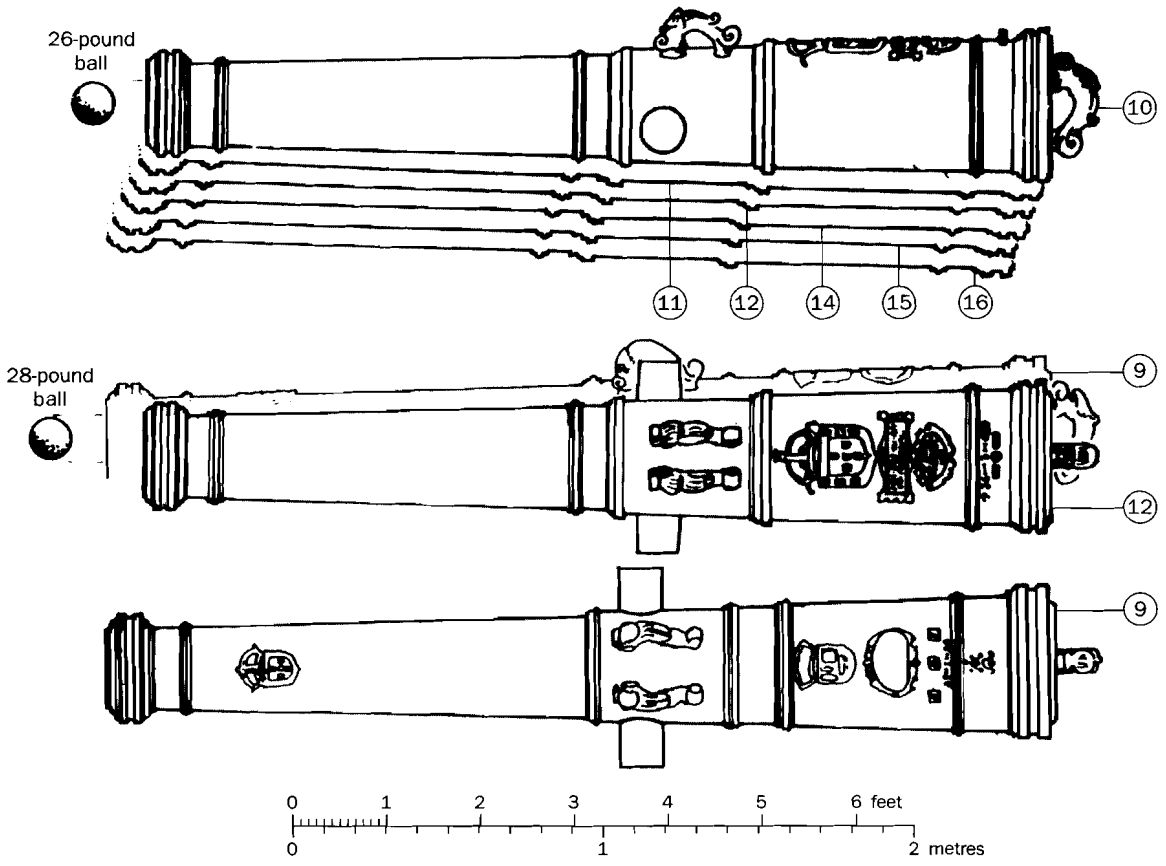


Figure 5 Six 26-pound cannon made by Matias Escartim and an Antonio Gômes Feio 28-pounder. Both Matias Escartim and Antonio Gômes Feio worked in Lisbon. (John F Guilmartin, Jr)

Sacramento's guns: the logic of size and efficiency

At this point we need to address the logic that dictated the size of the guns on *Sacramento*'s gundecks, bearing in mind that 11-pounders seem to have been preferred for her middle deck. In this we are assisted by the serendipitous fact that *Sacramento*'s largest recovered gun and one of her 11-pounders were cast by the same founder, Antonio Gômes Feio, permitting a closer comparison between the two categories of gun than would otherwise be the case.

The similarity in the lengths of 24- to 28-pounders on the one hand and 11-pounders on the other, graphically demonstrated here, was driven by the ballistic properties of black powder. If we assume a powder charge with a density of 58 lb/in^3 weighing three-quarters the weight of the ball, then the 28-pounder's charge would have occupied about 1.7 times the internal diameter of the bore, that is 1.7 calibres, and the ball would have travelled just over 8½ feet before exiting the muzzle, very close to our posited optimum length.[22] The 11-pounder's ball would have travelled a bit further, perhaps indicative of the founder's implicit awareness of the lesser ballistic efficiency of smaller bores. The principal difference between the two categories of gun is

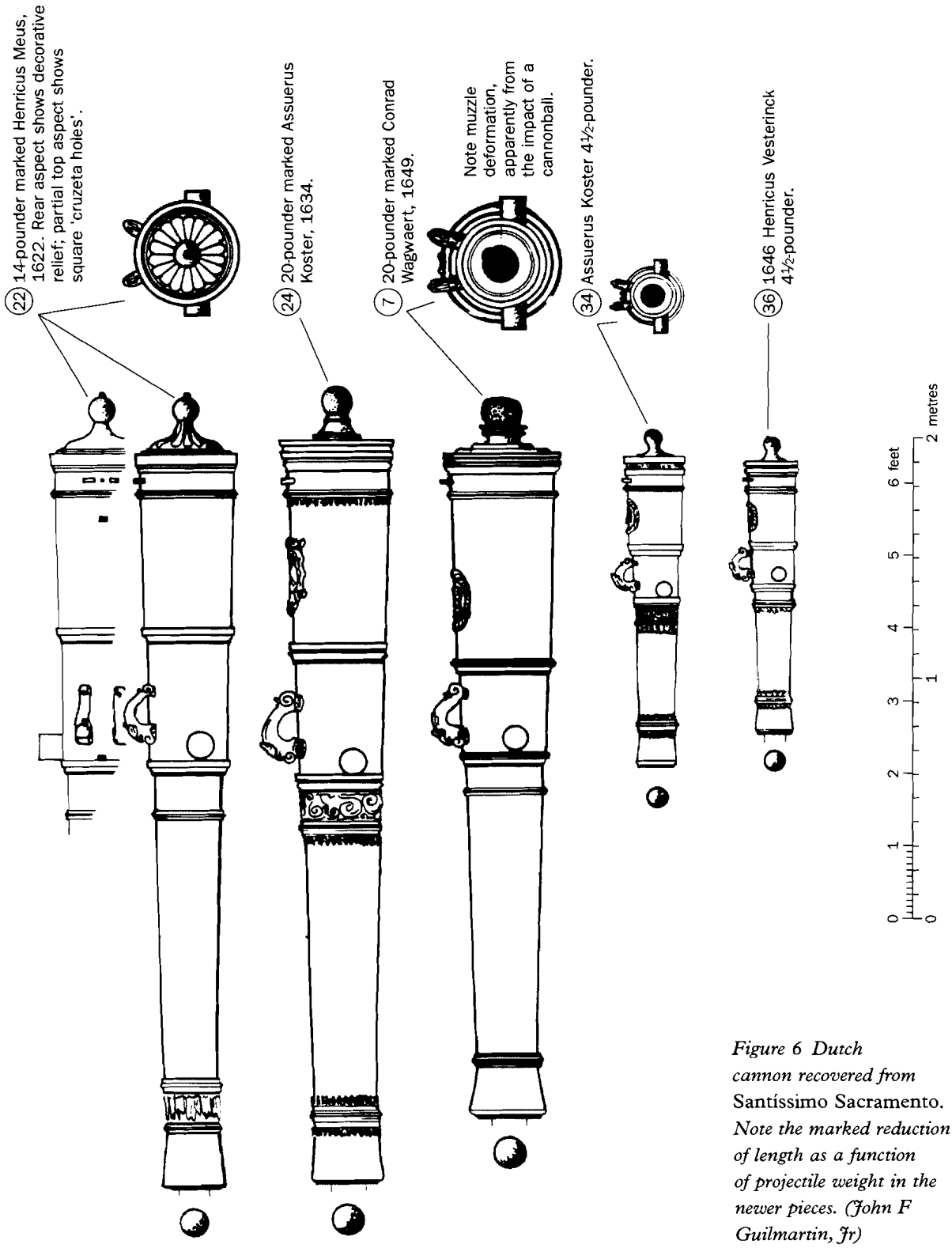


Figure 6 Dutch cannon recovered from Santíssimo Sacramento. *Note the marked reduction of length as a function of projectile weight in the newer pieces. (John F Guilmartin, Jr)*

their relative efficiency. Significantly, the smaller cannon were heavier in terms of projectile weight than larger ones across the board, and the difference was not trivial. *Sacramento*'s six 11-pounders range from some 221 pounds of barrel per pound of ball (the A.G.F. piece) to over 242 pounds, all containing nearly 100 more pounds of metal per pound of ball than her 28- and 26-pounders.

It is legitimate to ask why these inefficient smaller guns were cast at all. In land service, the rationale for greater numbers of smaller guns, as opposed to a few larger ones, however ballistically efficient, is clear. The fixed restrictions of horse traction placed inflexible limits on the mobility of large guns, and several small projectiles were tactically more effective than a single large one when engaging dispersed human and animal targets. But at sea, where the criterion for success was the ability to inflict damage on an enemy ship, the advantages of larger guns in terms of ballistic efficiency and relative cheapness would seem to have been compelling.

In reality the issues were more complex, revolving around such questions as the strength and weight of decks, frames and bulwarks, centres of gravity and moments of inertia – though these were not explicitly understood for many decades. The naval architects who designed and built *Santíssimo Sacramento* undoubtedly had clear ideas concerning the preferred size, composition and arrangement of her lower and middle batteries. It is likely, therefore, that 26-pounders below and 11-pounders above represented a ballistic and structural ideal, the optimum combination of usable firepower that could be built into a large transoceanic warship in Lisbon – or anywhere else – in the 1640s and 1650s. Does *Sacramento*'s varied assortment of 15- and 20-pounders (of which there were no fewer than six, all of them, except for a single long, heavy and probably old Portuguese 15-pounder, either Dutch or English) therefore represent convergence toward the ideal or the acceptance of limited supply? The absence of first-class Portuguese cannon in the 15–20-pound category strongly suggests the latter, but we simply do not know.

Turning to what we can presume to have been the best pieces of *Sacramento*'s main battery, the barrels of the six Matias Escartim pieces were identical within the limits of my ability to measure them with a steel tape. Other less critical dimensions were not so closely controlled: the trunnions of two of the six are noticeably skewed in the horizontal plane. Comparison with Antonio Gômes Feio's 28-pounder suggests that the two founders were of comparable ability: the larger A.G.F. piece contains just over 140 pounds of bronze for each pound of ball thrown, while the Matias Escartim pieces contain from 140 pounds to just under 142 pounds. The Matias Escartim pieces' uniformity in weight is both remarkable and significant. The heaviest of the six weighed only 1.42 per cent more than their mean weight of 3740 *arrateis,* and the lightest only 2.93 per cent less, this despite

the documented difficulty in controlling the density of cast bronze, a problem that was never solved as long as bronze cannon were cast.[23]

Sacramento's Dutch ordnance and the Luso-English founding tradition

Examination of *Sacramento*'s Dutch guns indicates that Dutch founding technology differed significantly from Portuguese and English practice. The considerable variation in colour among the Dutch pieces – when I examined them in 1978 the Conrad Wagwaert 20-pounder had a blackish, almost ebony-like sheen, and the Henricus Meus 15-pounder had oxidised to a light pastel green – suggests that Dutch founders had not established the same degree of control over their alloy as their English and Portuguese contemporaries. Examination of the Dutch guns also supports the proposition that over time founders within a given national tradition systematically reduced the length and weight of their guns as a function of projectile weight. The Dutch cannon were cast without weight markings, yet the two largest have Portuguese markings roughly incised on their barrels, suggesting that they were weighed in the field rather than in a fully equipped arsenal (Table 1). These Dutch guns were considerably less efficient than their Portuguese equivalents: the Assuerus Koster 20-pounder contains 195 pounds for each pound of ball and the Conrad Wagwaert 20-pounder 192 pounds.

Dutch foundry technique differed sharply from contemporary Luso-English practice in at least one demonstrable particular. Following a tradition that can be traced back to Biringuccio's *Pirotechnia* of the 1530s, the bores of *Sacramento*'s Portuguese cannon and newer English cannon were centred with a chaplet or *cruzeta* of wrought iron affixed to the base of the mould's core, as depicted in Figure 1.[24] The *cruzeta*, commonly a ring around the core supported by four arms, remained embedded in the gun. Where it had corroded away – surprisingly few had, particularly on Portuguese and English guns – I could surmise *cruzeta* design from the holes left behind. Where the *cruzeta* remained intact, I could locate the tips with a magnet.

The newer Portuguese and English guns showed holes or indications of ferromagnetic metal in the locations suggested by Figure 1, although several older Portuguese pieces may have had *cruzetas* with only three arms, and it is possible that the Philips brothers used a design with two horizontally-opposed supporting arms.

Nevertheless, it is clear that the founders who produced *Sacramento*'s Portuguese cannon and her four newest English guns worked within the same tradition of *cruzeta* design and placement. The Dutch cannon are another story. The 4½-pounders seem to have had four-armed *cruzetas*. That may also be true of the Conrad Wagwaert 20-pounder, though there were no holes and I found magnetic indications in only one spot. The two remaining Dutch guns

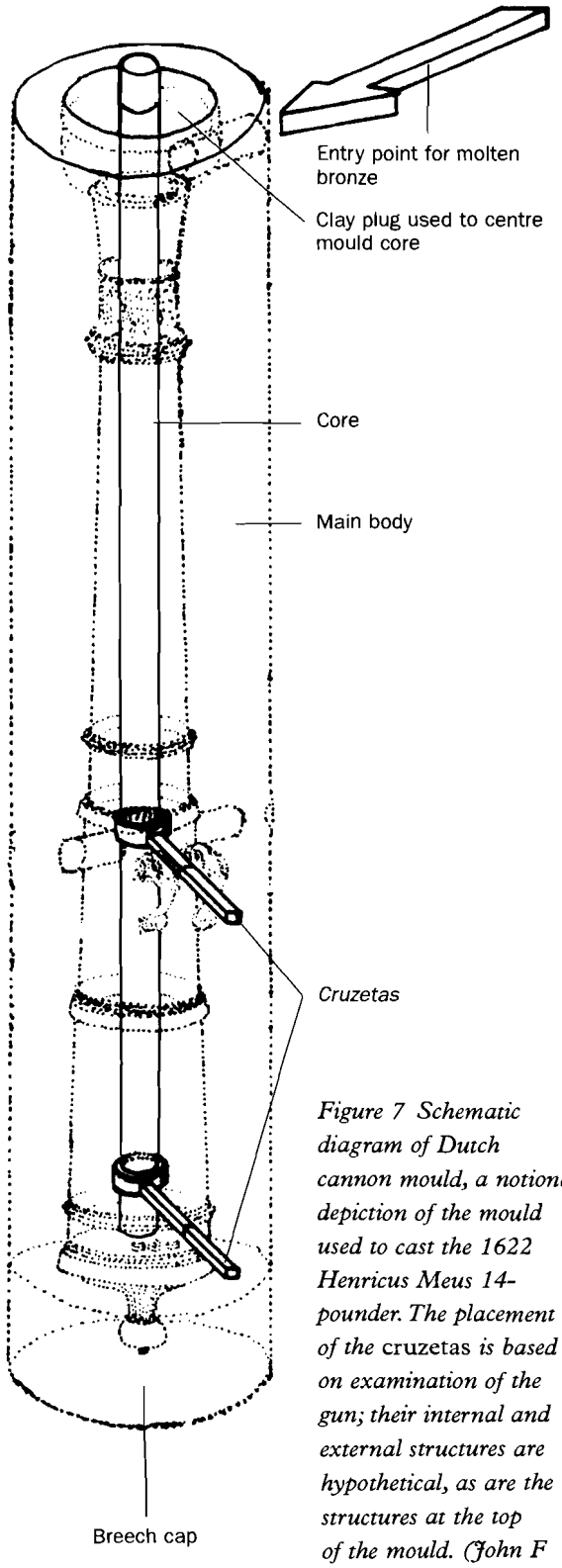


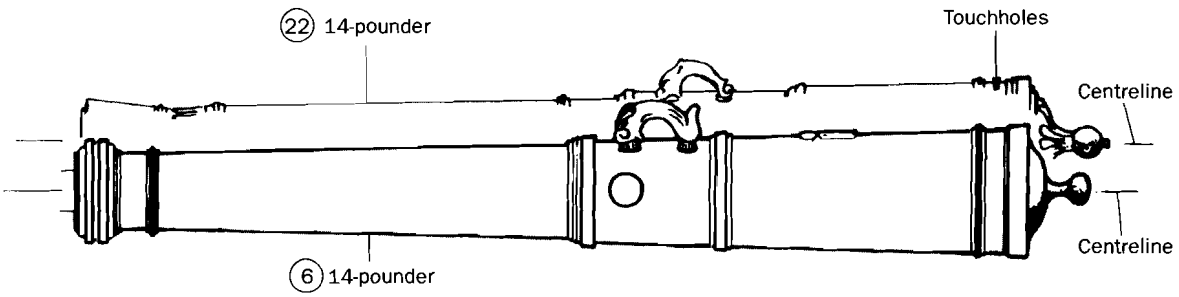
Figure 7 Schematic diagram of Dutch cannon mould, a notional depiction of the mould used to cast the 1622 Henricus Meus 14-pounder. The placement of the cruzetas *is based on examination of the gun; their internal and external structures are hypothetical, as are the structures at the top of the mould. (John F Guilmartin, Jr)*

were cast with an embedded internal iron structure in the middle of the barrel. The 1622 piece by Henricus Meus has two square holes measuring about 1 × ¾ inches (2.5 × 2.0 cm) on top of the barrel, one forward of the touchhole and the other between the dolphins. The 1634 Assuerus Koster 20-pounder shows evidence of a conventional *cruzeta*, but there are also magnetic indications of a mass of ferrous material beneath the surface between the dolphins: based on the detection range of my magnet, it lies within three-quarters of an inch of the surface; the implications are unclear. Figure 7 is my best guess at the manner in which the Henricus Meus piece was cast.

What function did the iron structure within the Assuerus Koster piece serve and how was it positioned during casting? Could it have been part of a structure intended to reinforce the bronze in the manner of steel reinforcement bars in concrete? We can only speculate. All we can say with certainty is that some Dutch founders used a second *cruzeta*-like structure embedded in the cannon halfway down the barrel.

A final difference between Dutch and Luso-English practice lies in ornamentation. To a gun, the Dutch pieces are encrusted with elaborate raised floral ornamentation, inscriptions and nautical motifs. The presence of elaborately decorated guns as functional booty on the gundecks of an enemy ship shows that such ornamentation was not confined to a handful of select presentation pieces. Precisely what to make of this is unclear, except to say that the Dutch gunfounder's methods and ethos and those of his customers plainly differed from those of their English and Portuguese contemporaries.

Comparison of the only two 14-pounders recovered (Figure 8), one Portuguese and the other Dutch, suggests that the Portuguese advantage in foundry practice was of fairly recent origins, though we



Comparative data

Gun	Barrel weight	Relative length of barrel	Weight of barrel per pound of ball	Thickness of barrel wall at base of bore
1622 Henricus Meus	3548 pounds[a]	23.3 calibres	247 pounds	1.09 bore diameter
Undated Dias Bocarro	3247 pounds	23.9 calibres	232 pounds	1.11 bore diameter

a Based on the calculated volume of the barrel and a metal density of 516 lb/ft^3, about the same as that of piece number 24, the Assuerus Koster 20-pounder.

should not overgeneralise from a small sample. The two guns are remarkably similar in shape and, although the Portuguese piece has a slight advantage in efficiency, the difference is surely within the margin of error in my calculation of the Dutch gun's volume. As we have already indicated, the internal structures of the two guns were dramatically different. The lesson is that founders could arrive at the same destination by very different routes. Seventeenth-century cannon founding, in short, was anything but standardised.

Sacramento's smaller Portuguese pieces (Figure 9) are clearly products of the same tradition as its Portuguese 28- and 26-pounders and were probably cast in the same foundry, but there are intriguing differences. Of the six Portuguese 11-pounders, only three appear to be of a quality comparable to that of the larger pieces by Matias Escartim and Antonio Gômes Feio. One of these was cast by Gômes Feio himself. Though they bear no founder's mark, the other two are clearly closely related to the larger guns. Their external shape and details are virtually identical, as are the royal crest and monogram of Dom João III. That the smaller pieces bear no founder's mark probably reflects the greater importance attached to the larger pieces and the greater difficulty and danger in casting them. The larger pieces were no doubt cast under the eye of the master founder, while the smaller pieces were entrusted to understudies or apprentices. This hypothesis is reinforced by the fact that the only 11-pounder to bear a founder's mark, A.G.F., is the lightest of the six by some 150 pounds, despite probably having been cast at least a decade earlier when smaller cannon presumably commanded a master founder's attention.

Figure 8 Comparison of Santíssimo Sacramento*'s two 14-pounders: the Henricus Meus piece 22, cast in 1622, the oldest of* Sacramento*'s five Dutch guns; and the undated Pedro Dias Bocarro piece 6, which appears to be the oldest of* Sacramento*'s Portuguese guns, based on its proportions. In addition, the simple and relatively small royal crest atop the breech is unlike those on* Sacramento*'s other Portuguese guns, but is very similar to those on the two oldest English pieces (Figure 11) which I believe to have been cast prior to 1580. (John F Guilmartin, Jr)*

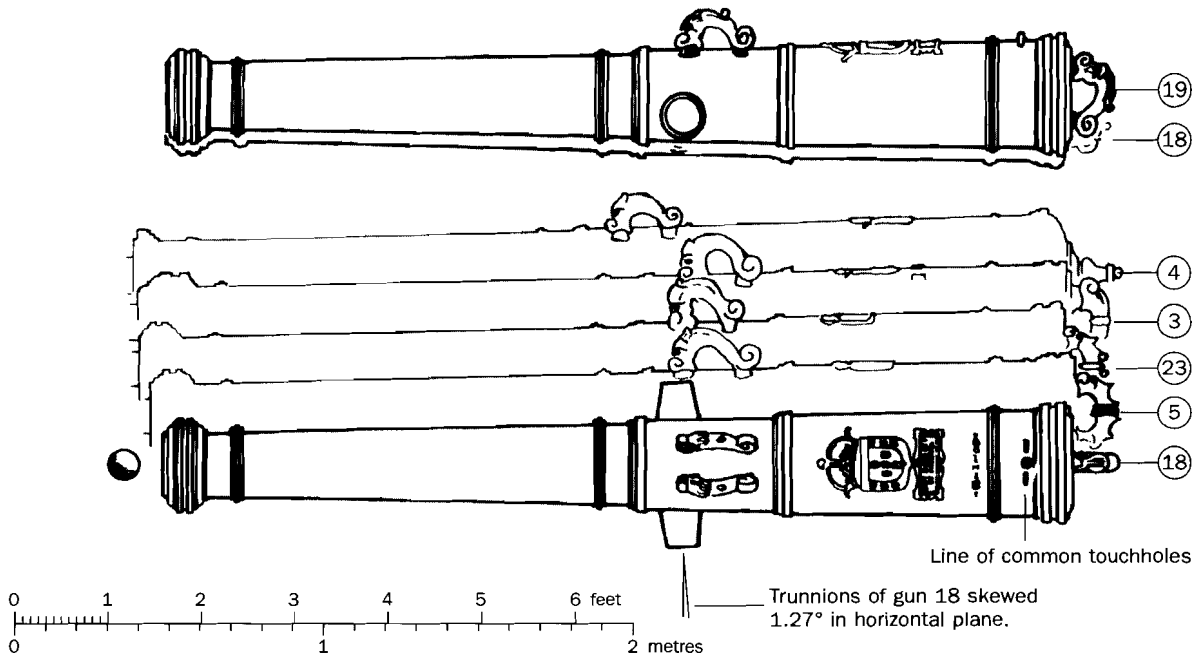


Figure 9 Santíssimo Sacramento*'s Portuguese 11-pounders. Guns 18 and 19, cast with the royal monogram of Dom João III (reigned 1640–56) are virtually identical. The other four are undated, but bear the Portuguese royal arms. (John F Guilmartin, Jr)*

The remaining three 11-pounders are a mixed bag. They all appear to be older than the other three, but do not differ dramatically in proportions or weight.

The Portuguese had apparently found guns of this size and ball weight to be useful well before the mid-1600s and had standardised on them to the degree possible. If our *galeão*'s gundecks are an accurate indication, the English may have standardised earlier along similar lines, for three of *Sacramento*'s nine bronze 11-pounders are English.

Sacramento's English ordnance

Beyond informing us of the shared English and Portuguese penchant for precisely weighing naval ordnance, *Sacramento*'s English guns (Figures 10 and 11) have much to tell us. They show unequivocally that good bronze ordnance could have a remarkably long service life, even in a harsh salt-water environment; the youngest of the four dated pieces (Figure 10) was over 70 years old when *Sacramento* went down. That was unexpected. They also provide evidence that English foundry practice in the 1590s was world class. The two pieces by John and Richard Philips have less bronze per pound of projectile than Dutch 20-pounders cast four to five decades later. The two later pieces by George Elkine are less efficient, but are still impressive. The four were *Sacramento*'s shortest gundeck pieces, with barrels at the low end of the ballistic optimum; if we calculate the volume of the powder charge as before, their projectiles would have travelled between just over 7 feet (the 11-pounders) and 7½ feet before exiting the muzzle. In line with our hypothesis, the Philips brothers' newer 20-pounder was slightly

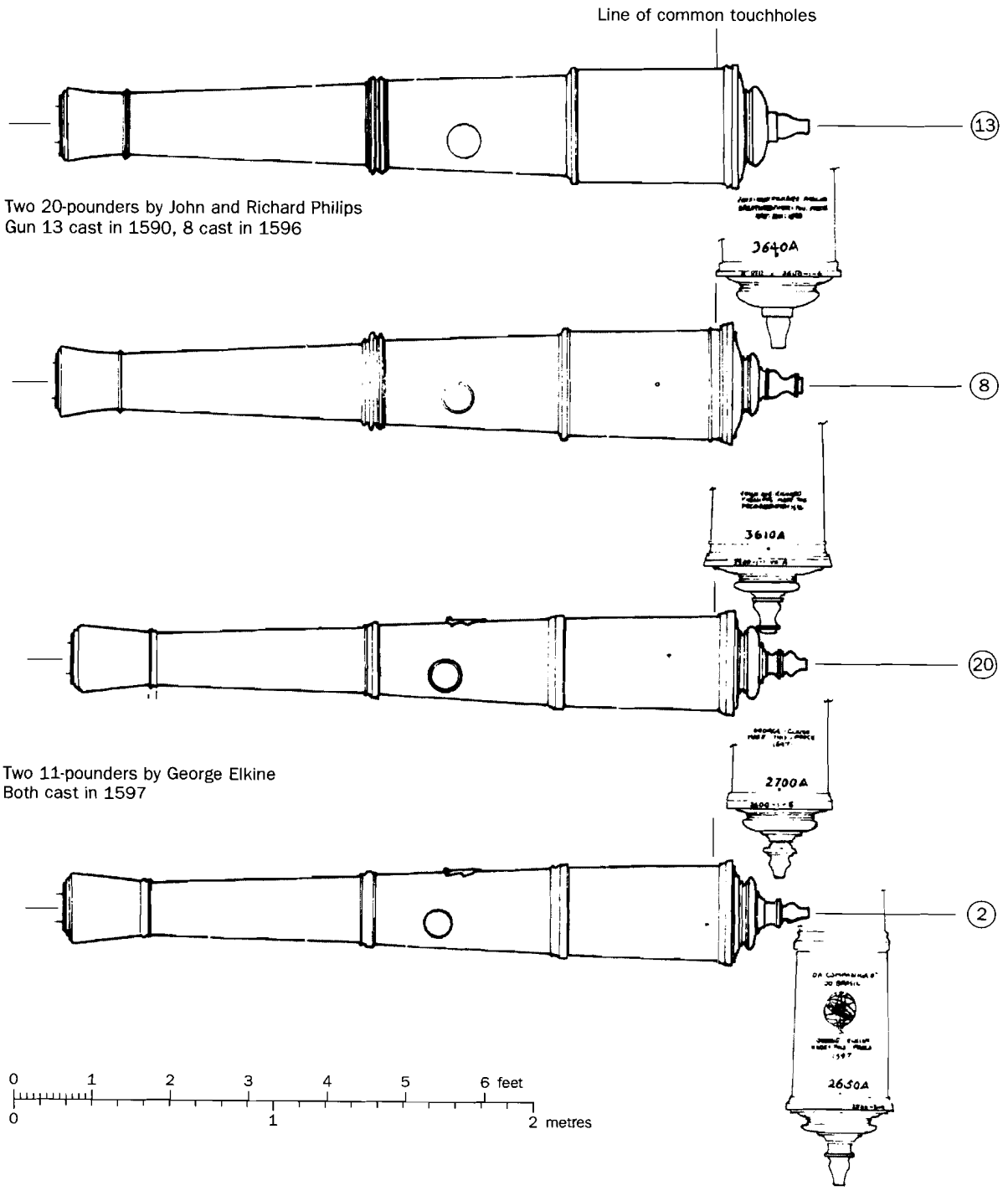


Figure 10 Dated English guns by John and Richard Philips and George Elkine.[25] *Note the double weight markings atop the breeches. The Portuguese weight markings are in a slightly different style from those on later pieces. (John F Guilmartin, Jr)*

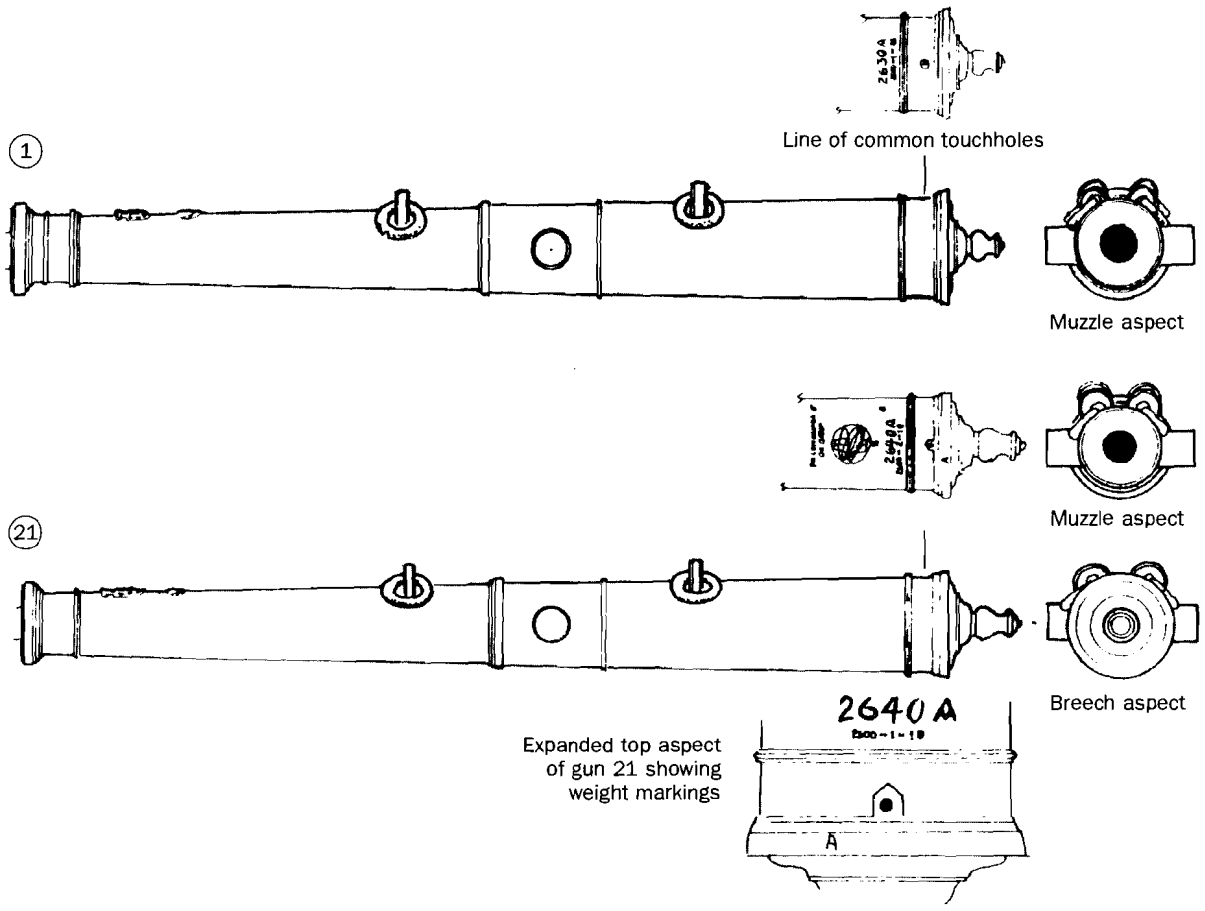


Figure 11 Santíssimo Sacramento*'s two undated English guns. These two pieces, an 11-pounder (top) and an 8-pounder (bottom) are similar in external form, though they differ in detail. Both have the Portuguese royal crest cast atop the barrel near the muzzle; both have the inscription 'DA COMPANHIA G^{L} DO BRASIL' and an armillary sphere with the logo 'SPERO IN DEO' incised atop the breech. (John F Guilmartin, Jr)*

more efficient in pounds of bronze per pound of projectile than the older one even after, as we suspect, the older piece was rebored to a larger calibre.

Sacramento's oldest English pieces (Figure 11), identified as such by their weight markings, great length and archaic features, particularly the lifting lugs and rings atop the barrels, are intriguing. They bear no founders' marks and are not dated, but are plainly much older than the others, corresponding in size and shape to demi-culverins from the wreck of the *Mary Rose*, sunk in 1545.[26] The Portuguese royal crest is cast atop their muzzles, suggesting that they were founded before Portugal's absorption by Habsburg Spain in 1580. Their form is older still, bearing distinct similarities to early-sixteenth-century Portuguese and Ottoman pieces. Showed them out of context and asked to date them, I would estimate that they were cast between 1500 and 1530.

They were apparently cast with conventional four-armed *cruzetas* set a bit further forward than later practice, but there were strong magnetic indications of ferrous material beneath the bronze surface all around the breech caps, within the trunnions and in the lifting lugs. Curiously, the lifting rings appear to be entirely of bronze. What

purpose the internal iron structure served and how it was held in place during casting is a mystery. Was the internal iron meant to strengthen the pieces, or was it there to displace more expensive bronze? We can only speculate. Particularly vexing is the question of how the cast bronze rings were mounted on the lifting lugs. Surely they were not cast in place after the guns were broken out of their moulds. But the alternate hypothesis, that they were embedded in the moulds and the guns cast around them, seems even more improbable. All we can say with certainty is that, however it was done, it was done well, for the guns survived for an uncommonly long time. It is equally clear that the process had inherent drawbacks, for it was abandoned. The obvious hypothesis is that the process was both skill- and labour-intensive and gave way to cheaper methods.

Conclusions: the importance of nautical archaeology and the economics of gunfounding

In conclusion, our exercise strongly underlines the value of nautical archaeology. Had the bulk of *Sacramento*'s guns not been recovered under controlled circumstances, we would know substantially less about early modern naval ordnance and bronze gunfounding. Next, the heterogeneity of *Sacramento*'s gundeck provides clear evidence of a shortage of good ordnance, particularly heavy ordnance, on the part of the Companhia Geral do Comerçio do Brasil, and it is hard to imagine that any other part of Portugal's naval establishment was any better off. We know that Portugal initiated large-scale importation of Swedish cast-iron ordnance after throwing off Spanish rule in 1640, and it is likely that the bulk of *Sacramento*'s iron pieces were Swedish.[27] Swedish or not, the cast-iron pieces on *Sacramento*'s gundecks were there not because of superior technical qualities: they were there because of their low price. Conversely, *Sacramento*'s gundeck provides unimpeachable evidence of the high quality of mid-seventeenth-century Portuguese bronze ordnance and, indirectly, of its high cost. It also provides solid evidence of the excellence of sixteenth-century English bronze ordnance and at the same time of the remarkable longevity of well-cast bronze guns. Without the hard evidence raised by *Gastão Moutinho*'s divers, the notion that guns could remain in naval service from 70 to 90 years or more would have seemed improbable at best. Even if the pieces in question had not been in continuous service, their simple survival as operational pieces is both unexpected and informative.

Sacramento's four newest English pieces also provide hard evidence that the very best bronze guns of the sixteenth century were equal in quality to all but the finest of the seventeenth, contradicting the commonly held notion that technology advances in a steady, linear fashion. The wide variation in design and quality of *Sacramento*'s Dutch guns makes the same point. Indeed, one of the most powerful

facts to emerge from the study of *Sacramento*'s guns is an awareness of the enormous variations in foundry practice as a function of time and place. These differences have implications at which we can only guess and merit additional study.

In addition to raising fundamental questions about early casting methods, *Sacramento*'s two oldest English pieces provide evidence that earlier foundry practice may have produced technically superior ordnance by labour-intensive methods that could not be retained in the face of the wage and price spiral of the late sixteenth and seventeenth centuries.

Finally, the degree of control that the best Portuguese and English founders exercised over the physical characteristics of their products represented on *Sacramento*'s gundecks suggests that historians have underestimated the early modern cannon founder. Moreover, the precision with which the English and Portuguese weighed their naval ordnance suggests that the early modern sailor, shipwright and gunner have been similarly underestimated. Their work was not based on elegant theories of internal ballistics, metallurgy or the relationship between stress and strain; nevertheless, their application of incremental development based on trial and error supported by close quality control was highly successful. We still have no satisfactory theoretical explanation for their success.

Notes and references

1 Information to the author from Admiral Carneiro, autumn 1978

2 Pernambucano de Mello e Neto, U, 'O galeão *Sacramento*', *Navigator* (Journal of the Serviço de Documentação Geral da Marinha, Rio de Janeiro), 13 (June 1976 – December 1977), pp3–40

3 'Os canhoes do *Santíssimo Sacramento*', *Navigator*, 17 (January–December 1981), pp3–43, 44–82, in English translation

4 'The guns of the *Santissimo Sacramento*', *Technology and Culture*, 24/4 (October 1983), pp559–601

5 Pernambucano de Mello e Neto, U, 'The shipwreck of the galleon *Sacramento*', *International Journal of Nautical Archaeology*, 8 (August 1979), p215

6 Guilmartin, J F, Jr, *Galleons and Galleys* (London: Cassell, 2002), pp13, 210–11

7 Fox, F, *Great Ships: The Battlefleet of King Charles II* (Greenwich: Conway Maritime Press, 1980), contains a full treatment of the tactical dominance and lack of endurance and seaworthiness of the giant English three-deckers of the first- and second-rates of the 1652–77 Anglo-Dutch Wars and their Dutch and French equivalents. See p95 for the tactically decisive role of the largest English ships in the Second Anglo-Dutch War (1664–67) and p21 for their unwieldiness. The smaller 'rates' that were on occasion employed far from home had two ordnance allowances: an augmented establishment 'to be carried only during wartime [...] in home waters' (p187), which in practical terms meant during the relatively calm months of late spring and summer, and a reduced allowance for peacetime cruising and for extended operations on overseas stations in wartime.

8 English first-rates carried a main battery of cannon-of-seven, cast-iron guns designed to fire a 42-pound cast-iron ball, as did the largest second-rates. Both first- and second-rates had three full, enclosed gundecks; third-rates had two enclosed gundecks. English

third-rates carried main batteries of 32-pounders. In general, first-rates carried more than 80 guns, second-rates at least 70, and third-rates between 56 and 64.

9 Fox, F, note 7, Appendix III, 'Ordnance establishment of 1666', pp184–5

10 The limiting factor for very large high-velocity guns is the ability of the chamber to withstand the extremely high temperatures involved.

11 Guilmartin, J F, Jr, 'Ballistics in the black powder era: a cursory examination of technical factors influencing the design of ordnance and of the emergence of ballistics as an applied science', in Smith, R D (ed.), *British Naval Armaments*, Royal Armouries Conference Proceedings 1 (London: Trustees of the Royal Armouries, 1989), pp73–98. See also Guilmartin, J F, Jr, *Gunpowder and Galleys: Changing Technology and Mediterranean Warfare at Sea in the Sixteenth Century*, 2nd revised edn (London: Conway Maritime Press, 2003), Appendix 2, 'The external and internal ballistics of sixteenth-century cannon', pp295–303.

12 Guilmartin, J F, Jr, 'Ballistics...', note 11, p78. This view, supported by nineteenth-century tests as well as the empirical evidence provided by the guns themselves, replaces the generally accepted notion that the relevant metric was the length of the bore in calibres, that is in multiples of the bore diameter, with a maximum useful length of 18 to 20 calibres obtaining for guns of the sizes with which we are concerned here. Maximum useful barrel length was less for smaller cannon, since smaller barrels transfer the heat of the propellant charge to the atmosphere more efficiently, but the difference is relatively small for guns firing a ten-pound ball or larger.

13 Guilmartin, J F, Jr, *Gunpowder and Galleys...*, note 11, Appendix 3, 'The design and construction of bronze cannon in the sixteenth century', pp305–13. For experimental confirmation of the relationship between density and strength, see Rodman, T J, *Reports of Experiments on the Strength and Other Properties of Metal for Cannon...* (Philadelphia, PA: 1856), pp152–3, quoted in Guilmartin, J F, Jr, *Gunpowder and Galleys...*, note 11, Appendix 3, p307, n. 8: a 5.4-per-cent increase in density yielded a 52-per-cent increase in tenacity, a measure of resistance to shearing stress.

14 The incremental but steady trend in sixteenth-century cannon founding toward shorter, lighter guns has been exhaustively documented for the English case in Lewis, M, *Armada Guns: A Comparative Study of English and Spanish Armaments* (London: 1961).

15 The definitive study is de Beer, C (ed.), *The Art of Gunfounding: The Casting of Bronze Cannon in the Late 18th Century* (Rotherfield: Jean Boudriot Publications, 1991).

16 Lavery, B, *The Arming and Fitting of English Ships of War, 1600–1815* (London: Conway Maritime Press, 1987), pp84–5

17 Fox, F, note 7, Appendix I, 'List of ships in service, 1660–1685'

18 Fox, F, note 7, p134

19 Guilmartin, J F, Jr, 'The guns of the *Santíssimo Sacramento*', note 4, Appendix A, 'Linear regression analysis of double weight markings on *Santíssimo Sacramento*'s six english cannon', pp598–601

20 See, for example, Lewis, M, *Armada Guns: A Comparative Study of English and Spanish Armaments* (London: 1961), p219. The pound avoirdupois contains 453.6 g, the value usually given for the *arratel* is 459 g and that experimentally determined here is 465.2 g.

21 Number 13 is off by –88 pounds; the differences between the Portuguese and English weights of the other five are –11 pounds, –3 pounds, +11 pounds, +4 pounds and +1 pound, leading to the suspicion that number 13 was rebored to a larger calibre before it fell into Portuguese hands.

22 Douglas, H, *A Treatise on Naval Gunnery, 1855* (London: Conway Maritime Press, 1982), reprint, p475, gives the density of black powder. Powder in Douglas's day would not have varied in any significant way from seventeenth-century Portuguese corned powder. The weight of the charge is an estimate based on earlier practice given in Collado, L, *Platica Manual de Artilleria* (Milan: 1592). Collado specified a charge equal to the weight of the ball and powder charges became progressively smaller with time.

23 Rodman, T J, note 13, pp152–3, describes a test conducted on two 12-pound howitzers

cast eight to ten minutes apart from the same vat of molten metal that varied in the density of their bronze by 3½ per cent.

24 Biringuccio, V, *Pirotechnia*, trans. Smith, C S and Gnudi, M T (New York: 1942), based on the 1540 Venice edition, pp246–8

25 John and Richard Philips are mentioned in the Calendar of State Papers of 16 August 1588, as purveyors of cannon to the British Crown; George Elkine, who apparently died in 1604, is first mentioned in 1595 (Admiral Sir Terence Lewin, GCB, MVO, DSC, ADC, to Capitão-de-Mar-e-Guerra (RRm) Guedes, 14 June 1977, courtesy of Captain Guedes).

26 Examined by me in the Museum of the Royal Artillery Institution in the Rotunda at Woolwich, England, in 1975; the earliest date on these cannon is 1529, *Catalog of the Museum of Artillery, Part I, Ordnance* (London: 1963), p7. This impression is sustained by the appearance of dated cannon in the collections of the Museu Militar, Lisbon; the Museo del Ejercito, Madrid; and the Askeri Musesi and Deniz Musesi, Istanbul.

27 Portugal imported 127 metric tonnes of iron ordnance from Sweden in 1661, and by 1694 was Sweden's biggest customer; see Cipolla, C M, *Guns, Sails and Empires: Technological Innovation and the Early Phases of European Expansion, 1400-1700* (New York: 1965), p56.

Katherine Ott

Carnage remembered: prosthetics in the US military since the 1860s

The Iraq War is so far removed from the experiences of American Civil War soldiers that it brings to mind the Polish cavalry riding out to meet German tanks early in the Second World War. Changes in ordnance and materiel over the last 150 years have been dramatic. Of equal importance to the weaponry are dramatic changes in the level of medical knowledge and practice, especially in the field of trauma care. One measure of the enormous change in battlefield experience is illustrated by the survival rate from combat injuries. During the American Civil War, mortality from combat injury was 33 per cent, compared with 30 per cent in the Second World War and 10 per cent in Iraq.[1] With each war, as the destructive power increased, mortality was reduced. Combat mortality rates only represent a piece of the history of war's mischief with the marrow of human existence.

The elusiveness of past wars has attracted novelists, historians and curators who speculate on everything from the provocation behind the first Palaeolithic stone aimed at the head of an enemy to the interior life of blogging infantrymen in Iraq.[2] For those tasked with trying to explain the cultural and material impact of wars and armed conflicts in the nineteenth and twentieth centuries, the record is deep and abundant with tactics and weaponry but also overflowing with the shadowy memories of scarred veterans, bomber pilots with reminisces best left buried, and relationships interrupted by military service and forever haunted by 'what if?'. Scholars of modern wars have a wealth of documents, graphic images, ephemera and souvenirs, and letters from the front. War's materiality is collected, traded and re-enacted. But these are incomplete measures of the impact of slaughter and havoc on human lives. The physicality of war is not so easy to capture and analyse.

The intangible and tragic aspects of past wars often lay hidden in technology. Yet a study of the weaponry alone masks the spoliation of the combatants' bodies. Bodies cut to pieces by rapidly moving projectiles need never be considered when interpreting the technology of a breech-loaded rifle or the numerous systems that support an F-16. The corporeal experiences of war are hard to retrieve and infelicitous to discuss. Medical intervention and subsequent rehabilitation illustrate the immediacy of war's carnage. Examination of the medical record can temper the tactical and strategic record of what happened in a skirmish or hostile encounter. But the corporeal evidence is

most real in the scars on an injured soldier's body. And no matter how unreliable memory may be, a prosthetic device is a cold, hard, irrefutable fact.

Prosthetic devices illustrate both the human cost of war and the uneasy intimacy of technology and flesh.[3] The history of military prosthetics can be approached from several angles – material culture, history of technology, history of disability and the body, history of medicine, gender and masculinity. Prosthetics are difficult to separate from the wounded soldier and society's complicated cultural relationships with nationalism, manhood and power, and concepts of health and physical wholeness. It is nearly impossible to avoid linking prosthetics with national recuperation, modernity and masculine redemption because prosthetics are such compelling icons for empire and rehabilitated masculinity – the most popular tactics of scholars studying prosthetics.[4]

This essay is intended as an admittedly eccentric and incomplete survey of the history of the relationship of the military to the development of prostheses, beginning with the American Civil War. It is incomplete because the field is sadly underdeveloped, with so much yet to learn, and eccentric because of the heavy weight given to the collections at the Smithsonian's National Museum of American History and the interests of the misfit curator authoring this piece.

The American Civil War: a market emerges

The history of prostheses in the military proceeds in parallel with changes in both the destructiveness of military technology and in the treatment of the wounds it inflicts. A comparison of the Civil War (1861–65) and the Spanish–American War (1898) dramatically illustrates the changes in treatment and survival of casualties, which in turn affected use of prostheses. Three-quarters of all Civil War operations were amputations, compared with about two-fifths in 1898, and surgical mortality rates were 26.3 per cent versus 0.4 per cent.[5] There were several reasons for the improved rates experienced by soldiers between the 1860s and 1898. By the end of the century, surgeons had a basic understanding of asepsis and antiseptic surgery, and germ theory was widely accepted. Battlefield kits made triage more effective. Although X-ray technology was still being perfected, surgeons who used X-ray equipment instead of their fingers to probe for bullets no doubt prevented countless fatal infections.

Most of the casualties in the Spanish–American War (91 per cent) were in Cuba and from disease, largely typhoid fever (80 per cent).[6] Consequently, this war put little pressure upon prosthesis makers. The American Civil War, on the other hand, was a watershed moment for limb prosthetics. It was significant not so much in terms of initiating design innovations – limbs and eyes looked pretty much the same before and after the war[7] – but in terms of the immense

Figure 1 This 1863 prototype leg was submitted by D D Parmelee along with his patent application. The innovation points in nineteenth-century artificial legs were flexion (ankle and knee joints) and attachment. This leg has an ingenious knee design and a complicated toe attachment. (Collections of the Division of Medicine and Science, National Museum of American History, Smithsonian Institution)

increase in availability of commercially produced legs. Artificial limbs made the transition from custom or home-made one-offs to marketed commodity (Figures 1–4).

There were multitudinous war injured. Surgeons' preferred method of managing battlefield casualties was amputation. They performed amputations on about 60,000 soldiers during the war, of whom about 35,000 survived.[8] To care for these men, state and federal governments supplied prostheses for them.[9] Congress passed a law in 1862 that granted one artificial limb to each honourably discharged soldier or sailor who needed one. Another federal law passed in 1871 gave a new limb every five years to veterans, followed by an 1891 law providing a

Figure 2 The maker of this 1863 wooden patent model attempted to solve the problem of ankle movement and provide for toe flexion, essential for maintaining balance on uneven terrain. Catgut was often used for the joint tendons but was affected by humidity and degraded over time. Silk was a better alternative. Sockets made the stump more comfortable and provided a better interface between body and device, but were not well developed in the nineteenth century. (Collections of the Division of Medicine and Science, National Museum of American History, Smithsonian Institution)

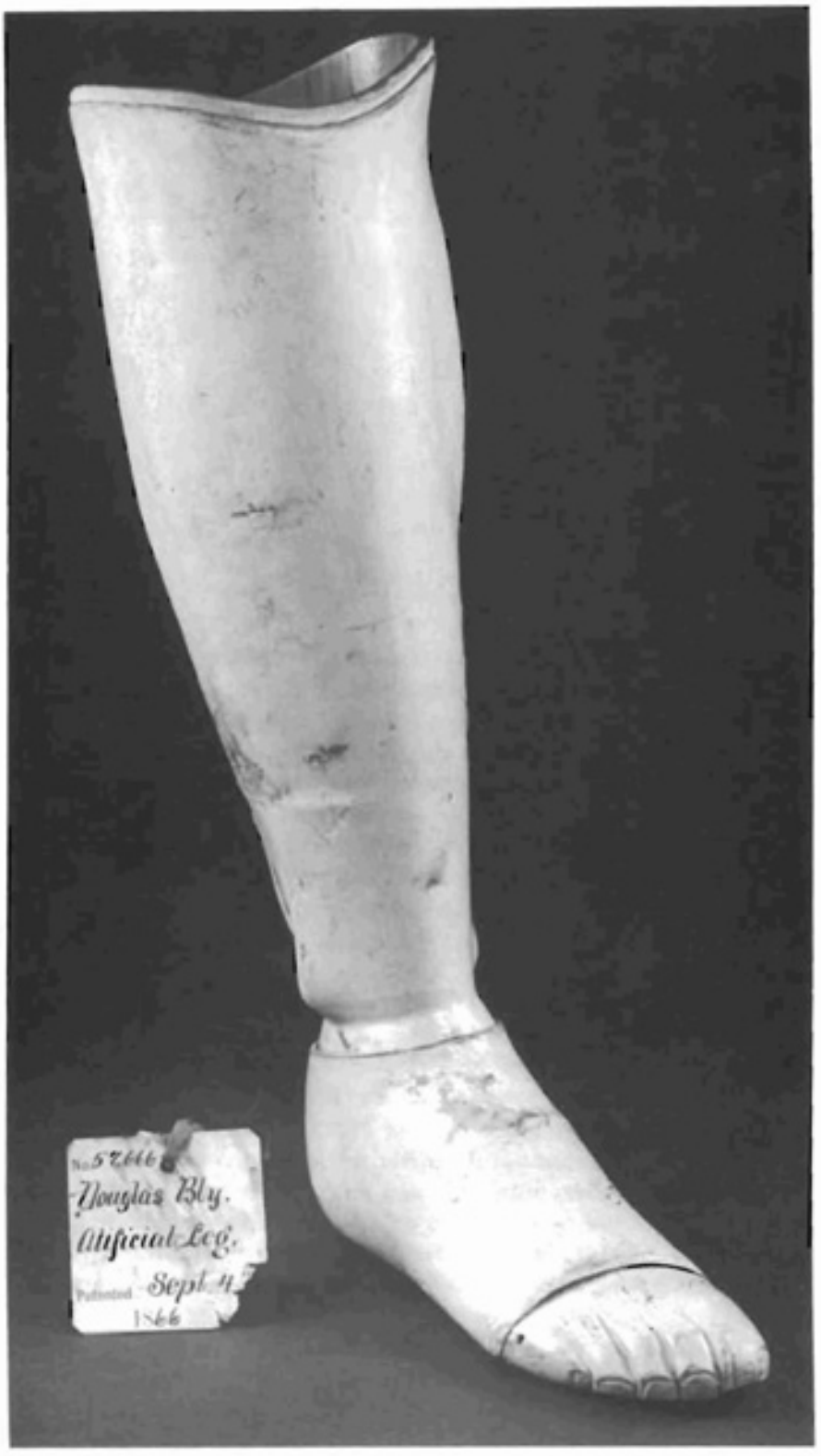


Figure 3 Most battlefield limb injuries are to the lower extremities, which explains why the majority of existing artificial limbs and prosthesis literature and ephemera relates to legs and feet. This is Douglas Bly's 1866 patent model for a below-the-knee appliance. Bly was among the many manufacturers competing for the government contracts for veterans. Note how Bly sculpted the toes and slope of the ankle. The rigid joints would have made for a noticeably stiff gait. (Collections of the Division of Medicine and Science, National Museum of American History, Smithsonian Institution)

Figure 4 Nineteenth-century peg-leg patent model, made of leather, wood and metal. Until the twentieth century, available materials were limited to wood, metal, rubber and leather. Willow and cork were commonly used for lower-extremity prostheses. This design attached over the shoulder and fastened over the stump with a lace. (Collections of the Division of Medicine and Science, National Museum of American History, Smithsonian Institution)

limb every three years. Limb manufacturer A A Marks was awarded federal contracts for limbs and expanded his business, selling them through his catalogue, then fitting them in person if there was a problem. Otherwise, the wearer did the measuring and fitting.[10] Rival James E Hanger of Staunton, Virginia, started making artificial legs after he lost his own while serving in the Confederate Army. Until the flood of manufactured limbs for Civil War veterans, limbs were usually simple home-made pegs attached with a leather harness. A wearer ensured that a limb would last for many years by padding the socket with cloth as the stump changed shape with the seasons and as the wearer aged.

Benjamin Palmer had given commercially produced limbs a boost with his widely lauded designs (Figure 5). Palmer's several patents (1846, 1849, 1851) marked steady changes – not necessarily improvements. Palmer's second patented leg, in 1849, won first prize in London in 1851, making him a minor celebrity. It had a steel knee joint, catgut cord tendons at the ankle and a painted wood shank. The Bly leg and others also competed for amputee business through attempts to improve upon the peg design, as well as to simulate the look of a real leg. J E Hanger added his rival design after the Civil War by introducing a cordless ankle and a wooden socket (Figures 6 and 7).[11]

But in some communities, notably in the South, not wearing a prosthesis valorised one's identity in a positive manner. An ex-soldier's stump was viewed as a mark of courage in glorious service to community. War wounds without a compensatory prosthesis were

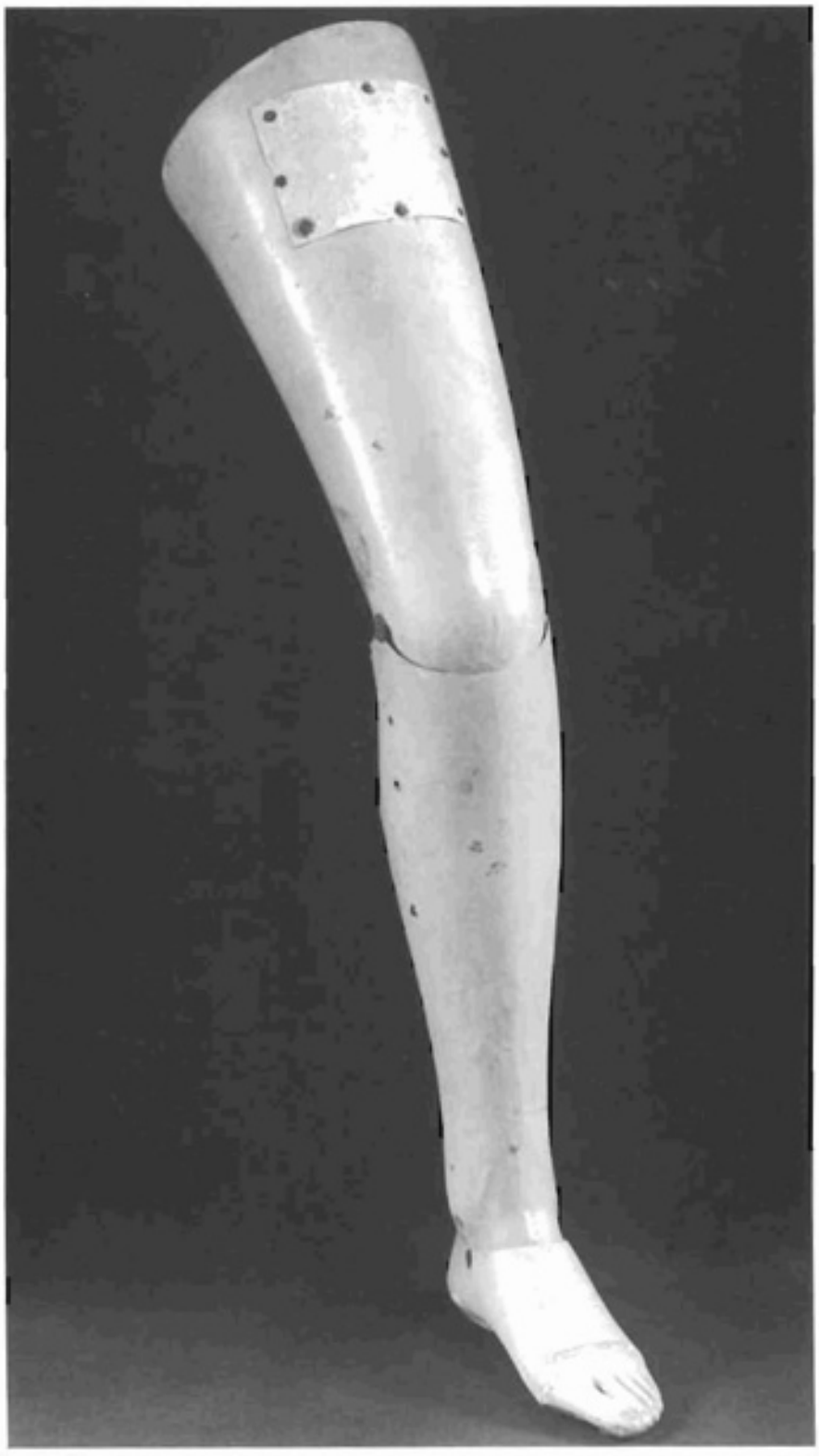


Figure 5 Benjamin Palmer's 1849 design was the gold standard for many years. The US Civil War created a robust prosthetics marketplace once the US government passed legislation to provide amputee veterans with artificial legs. (Collections of the Division of Medicine and Science, National Museum of American History, Smithsonian Institution)


The Salem Leg,
Patented June 21 and July 22, 1862, and October 4, 1864.
Leg Amputation.
Thigh Amputation.
Leg Amputation.
MANUFACTURED BY THE
SALEM LEG COMPANY, SALEM, MASS.

Figure 6 This advertisement from the 1860s for the Salem leg does not show much technical detail but illustrates the growing emphasis on realism in limb design. The Salem leg was supplied to soldiers by the US government. (Collections of the Division of Medicine and Science, National Museum of American History, Smithsonian Institution)

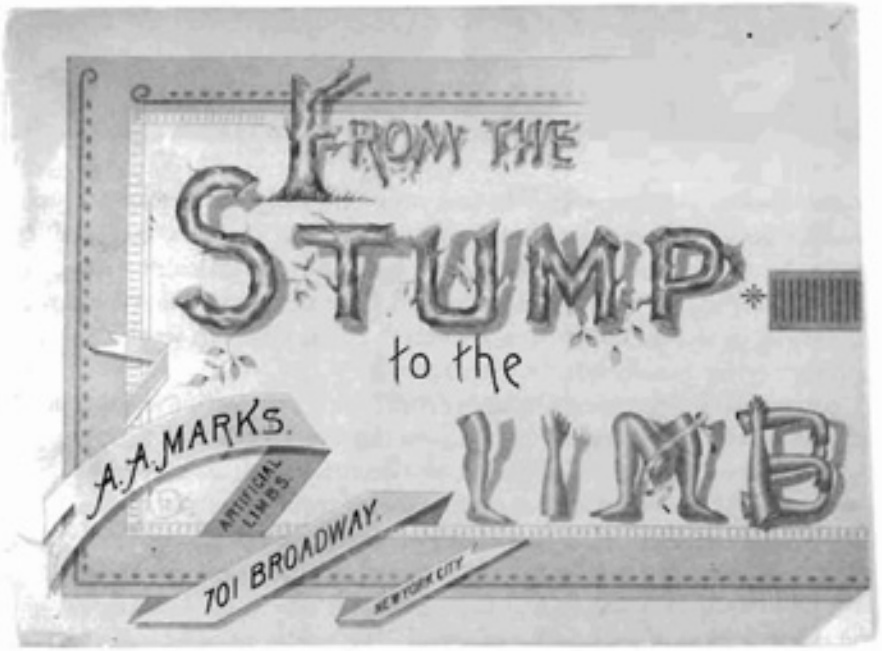
memorialised in soldiers' poems and songs.[12] For veterans who chose to wear an appliance, by the end of the century, limb design had gone about as far as it could go, given the limitations of wood, metal and leather.

The First World War: some international comparisons

The First World War affected US prosthetics most notably through the services created to aid wounded soldiers. The Army created the Division of Physical Reconstruction for injured soldiers. There was also a civilian Federal Board for Vocational Education active in prosthetics work. In 1918, the Vocational Training Law for Disabled Soldiers was passed (Figure 8).

The US government paid veterans based on the part of the body disabled. Germany, on the other hand, paid military disability according to rank. In Germany, until around the time of the First World War, there were two basic designs for upper-extremity prostheses: a Sunday arm that was a cosmesis, not functional but resembling a real arm, and the work claw. Only the wealthy could afford more complicated arms and other terminal devices. The Carnes arm was a popular import from the United States until national pride motivated German orthopaedists to create an alternative. During the First World War, German hospitals and clinics were overwhelmed by the number of injured. Eventually, German officials came to believe that restoration of function was necessary for the rehabilitation of the worker. Consequently, only work-specific arms were created and the

Figure 7 The cover of an A A Marks pamphlet on artificial limbs. Established in 1853, by the end of the nineteenth century, Marks was the largest limb-maker in the country. (Collections of the Division of Medicine and Science, National Museum of American History, Smithsonian Institution)



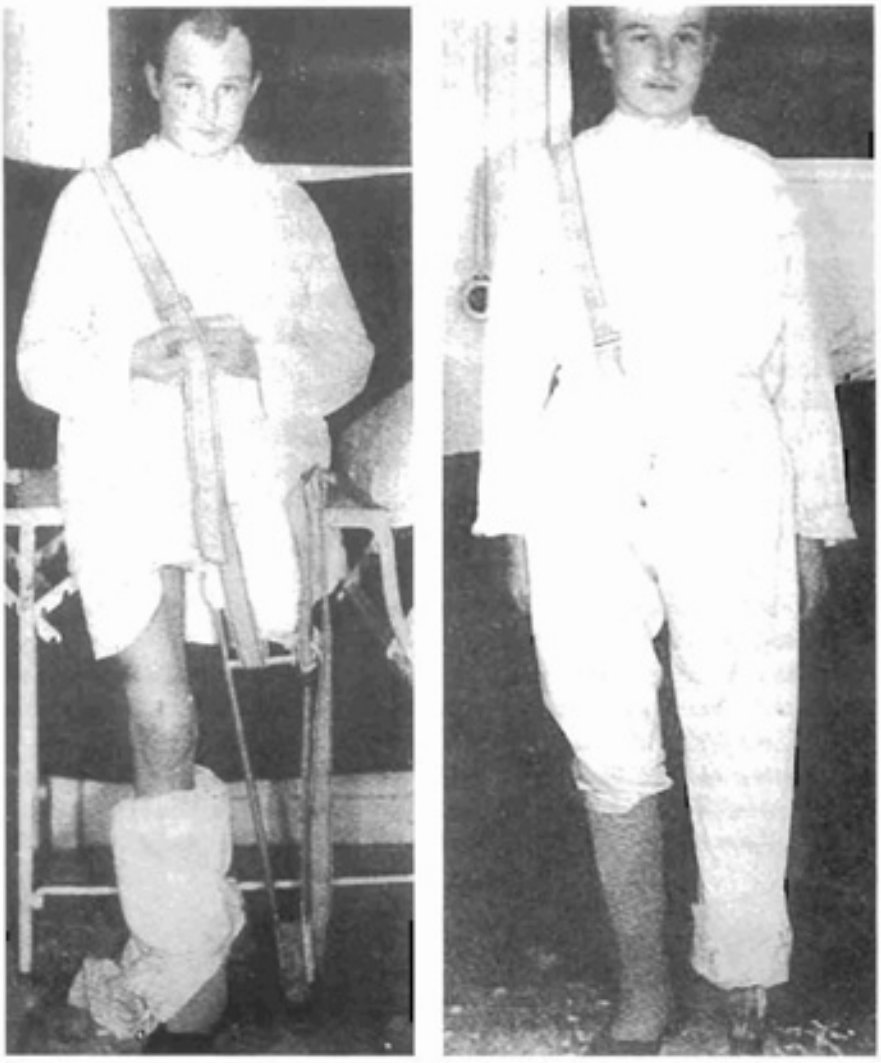


Figure 8 This First World War soldier demonstrates the temporary appliance given to him. Soldiers wore temporary and crudely fabricated appliances while their more durable limb was being made and their stump was healing. A stump changes shape and size while healing, especially if it is shedding shrapnel, as is often the case with blast injuries.[13]

cosmesis, or cosmetic arm, was discontinued. Of course, workers still wanted cosmetic arms and hands, but only 'head workers' received them. Note also that the influence of the American efficiency expert Frederick Winslow Taylor was strong in German prosthesis-making, as well as in German industry. By about 1917, German workers were producing Taylorised standard arms.[14]

Although designs for prosthetics had barely changed, the speciality of orthopaedics was largely created during the First World War by American, British and German physicians. Roger Cooter has explained the development of orthopaedics from the1880s to the 1940s as an expression of the emerging ideologies of power embedded in corporatism, rationalisation and statism. Cooter focused on crippled children, soldiers and industrial workers in his analysis of the organisation of care and treatment. The economic and political

systems taking shape at the turn of the twentieth century heavily influenced how disabled veterans became integrated into civilian society.[15] For whatever reason, the rehabilitation of soldiers to occupations suited to their changed physical condition grew into a thriving, although small, sector.

The most significant changes in actual prostheses that resulted from the First World War were advances in facial restorations. The First World War was the impetus behind serious attention being given to the techniques for repairing and, lacking that, restoring lost tissue through artificial parts. Medical war work produced the first generation of plastic surgeons, such as Varaztad Kazanjian and Vilray Blair, who went on to train hundreds of younger surgeons in the techniques they had developed in military trauma units. The success of the war's innovative plastic surgeries fuelled the rise of cosmetic and aesthetic facial surgery in the 1920s, as peacetime surgeons learned of the techniques.[16] Surgeons established the American Association of Plastic Surgery in 1921 and began to build a consumer market for cosmetic surgery. Successful surgical repair of maxillofacial injuries, sometimes leading to the need for facial prostheses, was made possible by general medical advances during the war, such as the development of anticoagulants for blood products and understanding of blood types. Facial restorations and surgical repair for soldiers focused on the need to foster economic independence for men. Medical specialists emphasised normality of appearance, both of the face and in mobility, to enable men to be successful in earning a living.

The Second World War: creating a speciality

Despite the maturation of orthopaedics and the evolution of facial prostheses and slowly improving amputation techniques, on the eve of the Second World War the design of limb prostheses still remained much like that of 100 years earlier. An artificial leg was the common plug-fit wooden socket with a conical exterior. One bright spot in the 1930s that would later prove influential in the area of prosthetics was the establishment of the field of rehabilitation medicine as a result of the emergence of physiotherapy (or physiatry in the US). Physiotherapists had begun to refine their ideas several decades earlier, when most physicians who practiced physical medicine were either in electrotherapy or radiology. Over time, physical medicine drew physicians from other specialisms who were interested in rehabilitation and disability. The American Medical Association recognised physiotherapy as a speciality in 1947. Physiotherapists sought to habilitate injured soldiers to their new body and changed circumstances rather than train them back into their former bodies and lives.

Howard Rusk, a Missouri physician and one of those early activists, created a plan for Army Air Corps Convalescent Centers. Then in

1946 he went to New York University Medical Center, where he was instrumental in creating the modern discipline of rehabilitation. His revolutionary approach, refined during his service in the Army Air Force Medical Corps, was to focus on the whole patient by integrating injured or disabled people into the spectrum of life's activities. In 1948 he founded the Institute of Physical Medicine and Rehabilitation at NYU, with $1 million donated from Bernard Baruch. Physiotherapy was on the map.

The work of Rusk, Mary Switzer, Henry Kessler and others resulted in standardised prosthetic devices and treatment protocols, which in turn fostered the creation of post-war veterans' hospitals with large rehabilitation units. Mary Switzer furthered this work as the first administrator of the Social and Rehabilitative Services Administration of the United States Department of Health. Henry Kessler was a surgeon who served in the Pacific theatre. He had extensive experience in performing guillotine amputations. This was a straight-off cut and the common technique for limb amputation after shrapnel wounds, effective in preventing gangrene. Unfortunately, the stump left after a guillotine amputation was not good for fitting a prosthesis. Kessler's dissatisfaction with available options led him into extensive work with kineplasty – the use of muscle contraction to power the prosthesis that had been introduced in 1939.

Kessler worked at Mare Island Naval Hospital in California for a few years. The Smithsonian has several prototype limbs from Mare Island and other veteran hospitals of this era. They document the work of the US Artificial Limb Program, which contributed to understanding of biomechanics and functional anatomy.[17]

In 1945, the National Academy of Sciences (NAS) convened a conference of surgeons, scientists and prosthetists to improve the amputation–prosthesis interface. The NAS oversaw an intensive two-year research programme, called the US Artificial Limb Program, with subcontracts from universities and industrial research laboratories.[18] Northwestern University, the University of California at Los Angeles and at Berkeley, and Oakland Naval Hospital received study grants under the programme. For the first time, physicians, surgeons and engineers coordinated their efforts to work with a large amputee patient population. The labs made notable contributions to knowledge of the biomechanics of gait and both upper- and lower-extremity locomotion. The results fuelled the creation of a new field of study and also helped to invigorate ergonomics as a valid approach to human engineering.

Northrup Aviation also received a government contract under the US Artificial Limb Program. It initiated Project 17 with the funding received (Figure 9). Northrup engineers adapted Bowden steel-wire cable, used for aeroplanes, to replace the leather thongs that manipulated limbs. They also invented a device to mechanically lock

Figure 9 This prosthetist and soldier were part of Project 17, funded by the US government at the end of the Second World War, to study the biomechanics of locomotion and improve the design of prostheses. Here the technician is aligning a pylon and socket during fitting for a prosthesis. (Collections of the Division of Medicine and Science, National Museum of American History, Smithsonian Institution)

the elbow joint by using a shoulder motion. Project engineers visited the Limb Fitting Centre at Queen Mary's Hospital in Roehampton, UK, where the suction socket was popular. They also travelled to Sunnybrook Hospital in Canada and a few other sites in search of ideas to adapt. Overall, the US Limb Project resulted in several advances in limb design, such as the introduction of thermosetting resins to replace wood and leather, and plastic laminating. These innovations led to the biomechanical (total-fit) socket designs used today.

As in the First World War, survival rates of battle injury in the Second World War had improved over the previous war, which created another large pool of soldiers in need of prostheses.[19] General medical

advances, such as the ability to batch penicillin in huge tanks and its widespread use with infections, chemical methods to increase the shelf life of bottled blood, and the overcoming of long-standing reluctance to retract the heart to perform cardiac surgery for bullet wounds, contributed to improved outcomes.

An interesting, although minor, advance in prosthetics brought about by the Second World War was the advent of plastic artificial eyes. Previously, there had been few plastic artificial eyes to be found. Techniques for working plastic were not perfected and the demand was not there. The transition to acrylic eyes was a direct result of wartime pressure.[20]

The dependence of American eye-makers, also known as ocularists, upon German glass (the preferred glass for artificial eyes) became increasingly uncomfortable after 1933. During the mobilisation of German industry for war, the Nazis forbade exportation of many products and raw materials, including glass. Among the Allies, glass shortages became acute and supplies of artificial eyes and glass tubing disappeared. Although the need of eye tubing was critical, consumers comprised a small niche market. As had happened during the First World War, when supplies dwindled, American glass manufacturers did not find it cost effective to put their scarce resources into research for perfecting glass-eye tubing. It was left to Army medical officers to search for alternatives.

Where and by whom the first successful acrylic eye was made is a subject surrounded in dispute and confusion. Plastic eyes first began to appear in the late 1930s in Britain, and word of mouth slowly spread news of their existence. Three Army dentists, Milton Wirtz, Stanley Erpf and Victor Dietz, have been credited with producing the first acrylic eye in 1943. What they actually did was adapt existing materials and techniques to create a system for mass production of acrylic eyes. The three men had been experimenting with acrylic eyes in their own labs and were dispatched together to Valley Forge, Pennsylvania. Since they were dentists, they turned to common denture-making processes, instruments and substances. They achieved success with acralain, also known as methyl methacrylate, the thermoplastic from which dentures were made. Acralain was easy to mould and harden, although the process took a few days. Plastic dentures had evolved from the rubber ones popularly used in the late 1800s. An international trust controlled the rubber market of the time and set prices exorbitantly high, so dentists searched for alternative materials. They first used celluloid with good results and then switched to methyl methacrylate in the 1930s, after it became commercially available. Acrylic plastic came into its own during the Second World War, when war researchers studied its potential use in aerodynamics, automobiles and elsewhere. By then, methyl methacrylate was readily available, its chemistry was well known and a cadre of dentists existed

who were experienced in working with it. Since the Second World War, most of the artificial eyes made and worn in the United States have been of acrylic.

Iraq: the impact of body armour

The Iraq War has once again brought social and political pressure upon military prosthetics labs to rehabilitate injured soldiers. National wars reawaken politicians and citizens to the desideratum to care for those wounded in service to their country. The black-powder, low-velocity, large-calibre bullets of the 1860s are only found in museum gift shops now. High-velocity bullets actually cause more damage to tissue than the old, large lead bullets. The speed of impact means the bullets penetrate further and the force is displaced into surrounding tissue, producing a large area of destruction.[21]

In Iraq, blast injuries are most common. Soldiers' bodies are well protected, largely thanks to Kevlar and other body-armour materials, but head and extremities remain vulnerable. Consequently, those areas take the brunt of damage. During the twentieth century, most battlefield deaths occurred before the injured soldier received medical assistance. The medical response chain for injured soldiers has been streamlined so that field medics are immediately on the scene and administering clotting agents. They evaluate, stabilise and transport the injured to the proper facility.[22] The result is the lowest mortality rate of any war.[23]

Reduction in time elapsed between injury and treatment has improved survival rates, which in turn results in more mangled soldiers in need of prostheses.[24] The soldiers who require prostheses are sent to Walter Reed Medical Center in Washington DC, where they begin rehabilitation with their hi-tech devices. The Department of Defense first supplied amputee soldiers with microprocessor-controlled legs in 2003, after land-mine casualties began to occur during the Afghanistan campaign, called 'Operation Enduring Freedom'.[25]

Before microprocessing computers, radical improvement in function of lower-extremity prostheses was at a dead end (Figure 10). In the 1970s, the Blatchford or endolite knee was the first significant innovation. Its drawback was that it had to be locked in place. Blatchford was followed by the microprocessor-controlled C-leg. Otto Bock developed the C-leg in the mid-1980s and introduced it in the United States in 1999. The C-leg is the state-of-the-art prosthesis currently given to Iraq War soldiers. The plastic socket is designed with computer assistance (CAD/CAM) technology so that it exactly fits the patient's stump. The microprocessors monitor the terrain, speed and pressure placed upon the appliance through a force-sensing pylon as the wearer moves. The signals make minute adjustments to the user's gait. Gait is smoother because the wearer does not swing the leg forward, as with more conventional legs.[26]

Figure 10 This shoulder-harness, cable-activated, upper-extremity prosthesis with a split-hook terminal device dates from the Vietnam War era. It is made of canvas webbing and leather, metal, moulded plywood and thermosetting resins. (Collections of the Division of Medicine and Science, National Museum of American History, Smithsonian Institution)

The upper-extremity prostheses used at Walter Reed are a new generation of myoelectric arms, such as the Utah arm. These appliances operate in response to amplified electrical signals initiated by muscle movement. Myoelectric prostheses have been in use since the 1940s, but have only become popular through microprocessing engineering and lighter plastics. Upper-extremity prostheses do not take the pounding and battering of lower limbs and so have lent themselves to more delicate mechanics. It remains to be seen how long the Iraq War and its aftermath will continue to influence the development of prostheses.

In 1839, Edgar Allen Poe created the character of a Brevet Brigadier General grievously injured in sharp and savage Indian battles. Without

the enhancement of his prosthetic appliances, General Smith was 'a large and exceedingly odd looking bundle of something' on the floor of his dressing chamber. After the general's valet helped him into all four of his limbs, bosom and shoulders, scalp, teeth, palate and one of his eyes, he became 'a truly fine-looking fellow' who could pass for absolutely normal.[27] Poe's imagination was well ahead of technical realties. His dubious achievement is that readers today can still easily understand General Smith. The many wars since Poe's time have created thousands of disabled soldiers who continue to look to physicians, technicians and engineers for repair. Let us hope that readers will one day find Poe's General Smith to be inscrutable.

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1 Gawande, A, 'Casualties of war – military care for the wounded from Iraq and Afghanistan', *New England Journal of Medicine*, 351 (9 December 2004), p2472

2 I wish to acknowledge my debt to Audrey Davis, for many years a curator in the history of medicine and my predecessor at the National Museum of American History. Davis's path-breaking curatorial work in collecting artefacts related to disability laid the groundwork for much of this essay.

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6 Cirillo, V J, note 5, pp31–3

7 It is useful to distinguish between prostheses and orthotics. For the purposes of this essay, a prosthesis is an external appliance used to restore function and/or for cosmetic effect. It is different from an orthosis, which is a device that does not replace, but supports a part of the body having limited function. The distinction between prosthesis and orthosis is not always clear, however. These are general definitions and there is overlap between them – such as where cochlear implants, artificial hips and artificial larynges fit within this typology.

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11 Stephen Mihm discusses Palmer's leg and Victorian designs in general in Mihm, S,

'A limb which shall be presentable in polite society: prosthetic technologies in the nineteenth century', in Ott, K, Serlin, D and Mihm, S (eds), note 3, pp282–99.

12 For more on this, see Ott, K, 'Introduction', in Ott, K, Serlin, D and Mihm, S (eds), note 3, pp27–8.

13 From Bainbridge, W S, *U.S. Naval Medical Bulletin Report on Medical and Surgical Developments of the War* (Washington DC: US Government Publications, 1919).

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Margaret Vining and Barton C Hacker

Uniforms make the woman

Shortly after the Great War ended, the National Society of the Colonial Dames of America assembled an extraordinary collection of the uniforms American women had worn during the war. The Smithsonian Institution in Washington DC accepted the society's proposal to exhibit the collection, which remained on display throughout the 1920s. This chapter explores the background of the Colonial Dames collection, discusses the characters of the exhibition, describes some of the uniforms exhibited, and assesses the larger significance of women wearing uniforms.

Women negotiating recognition

When the First World War ended, Dr Marcus Mitchell Benjamin was in his 22nd year as a distinguished and widely admired scientific editor at the United States National Museum, the public face of the Smithsonian Institution. He and Carolyn Gilbert Benjamin, his wife of 16 years, were listed in Washington's Social Register and active in a variety of causes. In 1902 they appeared among the incorporators of the National Trust for Places of Historic Interest and Natural Beauty. Mrs Benjamin was also an active member of the National Society of the Colonial Dames of America, one of a number of hereditary and patriotic societies formed in late-nineteenth-century America.[1]

Like tens of thousands of other middle- and upper-class women, members of the Colonial Dames eagerly volunteered to support the American preparedness movement before 1917, and even more the American war effort afterwards.[2] Founded in 1891, the society had already established a commitment to wartime relief in the 1898 war with Spain. On war's eve, one of the founders declared to a reporter that:

> the dames will do their share when the time for action comes; they have not inherited the blood and spirit of the country's first founders and preservers – the old heroes of colonial and revolutionary days – not to be ready if the bugle calls again today.[3]

Among its varied activities during the war, the society raised funds to aid the sick and wounded, contributing thousands of dollars to the Navy for the hospital ship *Solace*.[4]

After the war, to honour 'the soldiers and sailors [...] who gave up their lives for their country in the war of 1898–99 with Spain', the society sponsored 'in sorrow, gratitude, and pride [...] in the name of all the women of the nation' an impressive monument in Arlington National Cemetery.[5] Erected in 1902 near the enshrined

mast from the battleship *Maine*, whose sinking in Havana harbour had triggered the war, the 54-foot shaft towered over the grounds. President Roosevelt and other distinguished speakers joined Colonial Dames President Mrs Howard (Anna Kopp) Townsend in dedicating the monument. Women had always participated in American wars, but only rarely demanded public recognition. This last nineteenth-century war marked the beginning of a new era. In a pattern that would become the rule in the First World War, the Colonial Dames proudly announced their contribution, both to the war and its memorialisation.[6]

Only a few Colonial Dames actually joined the armed forces during the First World War, chiefly because they had so few options: the Army Nurse Corps peaked at over 21,000 (Figure 1), but the Navy Nurse Corps barely topped 1700, and both required special qualifications; the US Navy enlisted over 11,000 Yeomen (F) (for female), but its Marine Corps equivalent, the Marine Reservists (F), accepted only a few hundred women, and both Navy and marines offered only enlisted grades.[7] Most of the Dames, by far, wore the uniforms of civilian relief agencies. They joined tens of thousands of other civilian women (and men) who donned military-style garb for the duration to express their patriotism and symbolically claim full citizenship.[8]

The manifest significance of women's uniformed participation in the war, culminating in the passage of the Nineteenth Amendment (Woman Suffrage) to the US Constitution, struck many observers. One of them suggested to Mrs Joseph R (Clarinda Pendleton) Lamar, President of the National Society of the Colonial Dames of America, 'that it would be a good thing if [the society] would undertake to

Figure 1 Case no. 16, uniforms, left to right: US Army Contract Surgeon's uniform; US Army Nurse Corps; US Army Nurse Corps; US Army Nurse Corps. (National Museum of American History, Division of Military and Diplomatic History)

preserve, in suitable place, the uniforms that were worn during this war'.[9] Herself a veteran of the wartime Woman's Committee of the Council of National Defense, Mrs Lamar responded warmly to the idea, despite her opposition to woman suffrage.[10] Judging no place more suitable than the National Museum, she turned to Mrs Benjamin, who promptly proposed adding an exhibit of American women's wartime uniforms to the extensive and growing collection of American, Allied and captured German war material being prepared for display in the National Museum. That collection already included women's uniforms from several of America's allies.[11]

Creating the exhibit

On behalf of the Colonial Dames, Mrs Benjamin contacted William de Chastignier Ravenel, the recently-appointed head of the National Museum's Arts and Industries branch. Officially, his new title was administrative assistant to Smithsonian Secretary Charles D Walcott. Having come to the Smithsonian from a distinguished 35-year career with the US Fisheries Commission, Ravenel proceeded cautiously in so unfamiliar an area. He sought the advice of Theodore T Belote, who had been the museum's curator of history since 1908. After conferring with Belote, early in January 1919 Ravenel recommended to Secretary Walcott accepting the Colonial Dames' offer to

> collect at once and offer to the Institution as an exhibit in connection with the war museum the uniforms and equipment of the women connected with the various activities during the war including the Army, Navy, Red Cross, Y. M. C. A., Y. W. C. A. and Salvation Army.[12]

The proposal, Ravenel informed Mrs Benjamin, 'met with the hearty approval of the Secretary'.[13]

As chair of the society's Committee on Relics, Mrs Benjamin took charge of assembling the collection, which, the *Washington Post* reported, 'will be permanently installed in [...] the National Museum and remain an object lesson to future generations of the part American Women played in the world war'.[14] Curator Belote acknowledged receipt of the first uniform in October 1919; most of the rest had arrived by the following spring. They included many more organisations than Mrs Benjamin had cited in her proposal. In June 1920 Ravenel formally thanked the Colonial Dames for loaning to the National Museum 'the collection of uniforms of the type worn by American women members of war organizations during the World War, 1914–1918'.[15] The uniforms went on display in the museum's Arts and Industries Building, along with captured German ordnance, the small arms of all combatants, and war toys. Other war-related exhibits occupied space in the Natural History Building across the mall to the north.[16]

All did not go smoothly. Enthusiastic uniform donors ignorant of museum policies threatened decorum and strained resources.

Shipment after shipment, some through Mrs Benjamin, but others direct to the museum, began piling up. Too often they arrived without prior notice or itemised lists of their contents. That sometimes led to misunderstandings, if not worse.[17] Concerned about space, Curator Belote refused to accept what he considered to be duplicate uniforms.[18] Shipments might also arrive with more than uniforms. In January 1920 Emergency Aid of Pennsylvania sent the museum two uniforms, two wax figures and a representative of Wanamaker's Department Store to dress the figures in the uniforms, a practice which the museum had some years earlier tried and rejected, as Arts and Industries Director Ravenel explained to Mrs Benjamin.[19]

Consternation ensued. Curator Belote objected to the incompatibility of such a display not only with the other women's uniforms, but also with all the building's serious historical exhibits. He readily acknowledged women's contribution to winning the war, but he also alluded to 'a decided feeling in many quarters that the uniforms now being assembled by Mrs. Benjamin represent more the personal ideas of the prominent individuals who wore them, rather than essential service to the Government during this trying period.'[20] More fundamentally, Belote appears to have questioned any place for women's uniforms in a modern history museum. Such a museum should no longer be seen as, he would assert at the 1924 annual meeting of the American Association of Museums in Washington, 'merely a sort of junk shop for the care of miscellaneous relics', a category that for him likely included women's uniforms.[21]

Ravenel's attempted diplomacy in the wax-figure controversy only added to the confusion.[22] Finally, he resorted to a straightforward statement that such figures violated museum policy, even if limited space had not precluded their general use.[23] Despite the friction, a certain degree of which may have been unavoidable, the project achieved its major goal. By 1921 Mrs Benjamin could report at the biennial council of the National Society of the Colonial Dames of America that the Committee on Relics had accomplished its task. She had personally written 820 letters to prospective donors. Many Colonial Dames had responded, as had members of other organisations; Colonial Dames, in fact, provided only about one-quarter of the collection. Mrs Benjamin believed the 80 more-or-less complete uniforms collected represented 'essentially all authorized war organizations' and all were on display in the United States National Museum.[24] So they would remain until the end of the decade.

The exhibition, in part

A set of record photographs from the early 1920s shows 60 uniforms displayed three or four to the case in 18 cases. Uniforms hung suspended at the back of each case, with headgear above and footwear and other accessories below. Photographs or drawings of the uniform

Figure 2 From case no. 1 (Figure 3), drawing of Red Cross canteen worker's cape.

as worn (Figure 2), if available, hung on the back wall at eye level, while related material or memorabilia, if any, rested on the case floor. This is how they were exhibited in the Arts and Industries Building on the Mall in the early 1920s.[25]

Uniforms in the display represented 14 Red Cross bureaus. The American Red Cross, by 1914 a large corporation affiliated with both the government and the armed forces, actively organised medical and other relief workers for several years before the United States entered the war. It oversaw a vast network of Red Cross units all over the nation and, under official alignment with the War Department, it also served as an umbrella organisation for most other relief agencies, bestowing on them a measure of government sanction. Uniformed women drivers served in the Red Cross and several other civilian wartime volunteer agencies (Figure 3). Women especially took to motorcars and trucks, both as drivers and mechanics, transporting soldiers and supplies in both the United States and Europe where they sometimes worked close to the front lines.[26]

A few organisations, such as Emergency Aid of Pennsylvania, had junior auxiliaries (Emergency Aid Aides of Pennsylvania), the younger members wearing a version of the official uniform. Headquartered in Philadelphia, Emergency Aid of Pennsylvania numbered more than 4000 members divided among 26 committees, each responsible for a distinct area in 'virtually all the Allied countries, meeting many and diverse needs and covering practically the entire gamut of war relief enterprise.'[27]

The National League for Woman's Service tapped into the outpouring of women's patriotic volunteerism leading up to the United States' entry into the war in Europe. Although it never became,

Figure 3 Case no. 1, Red Cross uniforms, left to right: Red Cross Motor Corps driver's skirt and tunic; Motor Corps driver's uniform; Motor Corps driver's overcoat; Foreign Service uniform. (National Museum of American History, Division of Military and Diplomatic History)

as many of its members hoped, the government's official arm for women's war-related work, the League registered and trained millions of women for a variety of activities. Its Bureau of Registration and Information compiled systematic data on women's employment, housing and general welfare that proved invaluable to the government Bureau of Labor Statistics and the Federal Employment Service. Until mid-1918 its motor corps served as the official motor service of the Red Cross.[28]

In 1916 the Woman's Section of the Navy League organised the First National Service School in Chevy Chase, Maryland, and three similar schools in California, Wisconsin and Rhode Island later that year. Inspired by the preparedness movement and modelled on the male Plattsburg movement, the national service camps usually lasted a month. The women wore uniforms (Figure 4), lived in tents, did callisthenics, drilled and marched. Despite the military atmosphere, thought to facilitate the training process, classes and lectures prepared them for national service in the form of 'their traditional and sacred duties of feeding the hungry, nursing the sick and caring for the sorrowing'. Their noncombatant status would in no way be jeopardised.[29]

The US Army sanctioned the work of both the Young Women's Christian Association (YWCA) and the Young Men's Christian Association (YMCA) overseas and in military camps at home. Three types of uniforms for women – home, overseas and regular service – represent the service of women wartime volunteers in the YMCA and YWCA.[30] Like the YMCA and YWCA, and many other organisations, the American Library Association (ALA) provided uniforms for its

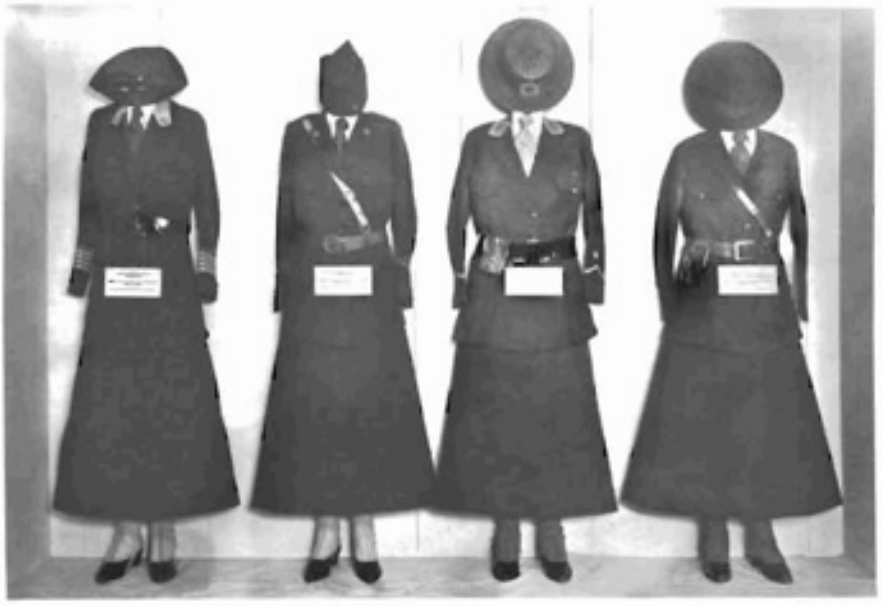

Figure 4 Case no. 7, uniforms, left to right: Emergency Aid of Pennsylvania; Emergency Aid Aides of Pennsylvania; National League for Woman's Service; First National Service School. (National Museum of American History, Division of Military and Diplomatic History)

workers or specified appropriate uniforms for purchase. Exactly what kind of uniforms did the ALA's Library War Service authorise?

Of the 329 women engaged as war service librarians in the United States and overseas, 170 served in hospital libraries, the others in camp libraries, dispatch offices and field supervision.[31] Caroline Webster, who oversaw hospital libraries in Library War Service Headquarters at the Library of Congress, spelled out the need for uniforms: 'Our representatives are equipped with a uniform so that they may have standing with the military authorities and be given the respect and attention which an official connection with the military gives.' An incomplete uniform was no uniform at all. She warned that 'unless you are willing to conform to the uniform in every detail, do not equip yourself with an outfit either at your own or the Association's expense'.[32]

The ALA specified the uniforms and reimbursed a portion of their cost. Hospital librarians wore pongee dresses cut much like nurses' uniforms.[33] Of these we have no example. Figure 5 shows the uniform worn by the other librarians, those not working in hospitals. Librarians purchased their uniforms by sending their measurements (taken by a tailor) and payment to Weltman, Pollack and Company in New York, which guaranteed to ship the uniform within ten days. The signed bills then went to ALA headquarters for reimbursement. Similar arrangements applied for hats from the Ferry Hat Company and overcoats from Best & Company, both of New York. The ALA directly supplied two ties and three pins: a large one for the hat, two smaller ones for the collars. An official ALA circular specified the required white high-necked blouse of madras and tan or black low-heeled,

Figure 5 Case no. 10, uniforms, left to right: YWCA;YMCA;YMCA; American Library Association worker. (National Museum of American History, Division of Military and Diplomatic History)

broad-toed boots. These items workers provided for themselves, but material was available on request without cost for spats.[34]

During the First World War, the US Army Medical Department refused to accept female physicians into its organisation, but did allow them to serve as civilians under contract. The category 'contract surgeon' included not only physicians, but also such medical support personnel as anaesthetists, laboratory technicians and dietitians. Although the army denied military pay, rank, and benefits to contract surgeons, it nonetheless imposed military discipline and uniforms upon them. They readily accepted the discipline and wore the uniforms proudly as the price of serving their country in wartime, but many still resented the army's refusal to grant them full military status.[35]

Like the contract surgeons, the women hired under contract as telephone operators for the American Expeditionary Force in France served eagerly, accepting military discipline and proudly wearing the uniform. Unlike the contract surgeons, however, the hundreds of volunteers who answered the army's call thought they had enlisted in the service, rather than been hired as civilian contractors. The army's denial of military rank, pay and benefits remained a source of friction for the next 60 years.[36]

The Colonial Dames collection and the Smithsonian exhibition included uniforms worn by the members of many other organisations. Each had its own story, but the examples here presented will serve to suggest the range and significance of the collection.[37]

Why the exhibition mattered

Toward the end of the 1920s, the women's uniforms were still displayed in the Arts and Industries Building, but now filled two large, very crowded cases that occupied about 150 feet of wall space.[38] The exhibition remained in place until 1929, when a decision to shift the war exhibits in the Natural History Museum to Arts and Industries crowded out the women's uniforms. In Curator Belote's opinion,

> Women's costumes of the period of the World War now shown on the south side of the west gallery of this building [Arts and Industries] [...] are not of primary historical or scientific interest and the space which they now occupy is urgently needed for the accommodation of material of very much greater value which is to be removed from the Natural History building and installed in this building.[39]

Ravenel sought and received from the Colonial Dames permission to remove the exhibition of women's uniforms, either returning them to the Society or holding them in storage against the possibility that they might return to public display at some later date.[40] The Colonial Dames accepted the offer of storage and the museum packed the uniforms into four identical mothproof boxes, each 25 × 25 × 43 inches (roughly 64 × 64 × 109 cm), and placed them in storage.[41]

The exhibition had not remained static during its lifetime. Additional material had trickled in through most of the decade, while donors withdrew other material during the course of the exhibition. With the uniforms no longer on display, requests from individual donors for the return of their uniforms increased. The museum took the position that it was merely custodian of the collection that belonged to the Colonial Dames, to which it referred all requests. During the 1930s, especially after the 1932 opening of the Dames' Dumbarton House to the public, the museum repeatedly sought to return the collection to the Dames.[42] The Colonial Dames canvassed the country to find a venue suited to exhibiting the uniform collection. More than one promising lead failed to pan out, and by 1941, as Mrs Benjamin reported to the Colonial Dames biennial meeting, the National Museum looked like the safest bet for the collection. 'It is beautifully packed in cases; each article marked and numbered, and under present condition is safe and we have nothing to lose and much to gain in keeping it intact for the Society.'[43]

The museum benefited as well, in the long term. The uniforms provide solid documentation of the extraordinary range of organisations – secular, religious and military – in which women enthusiastically volunteered for war work. The Colonial Dames collection of women's uniforms from the First World War now housed in the Smithsonian Institution's National Museum of American History includes many more uniforms than those we have specifically discussed – over a hundred in all, some fully accessorised, others less complete.[44]

Despite its size, it is by no means as complete as Mrs Benjamin thought it was. It does not include examples of all the uniforms of organisations that sent women volunteers to Europe, nor any of the uniforms worn by working-class women such as munitions workers or other factory operatives. It includes no uniforms of female streetcar (tram) conductors, mail carriers or police. Neither are there examples of uniforms worn by members of the National American Woman Suffrage Association, nor those authorised by the War Department for European women employed by the US government.[45] It is nonetheless a thought-provoking collection of uniforms of early twentieth-century volunteer workers who represented a wide range of women's organisations largely supportive of and active in the women's suffrage movement.

In particular, this collection has stimulated us to think about the reasons why such large numbers of women seemed to feel that volunteering (as they had done in past wars) was not enough. This phenomenon was not limited to the United States. Uniformed women appeared throughout Europe before and during the First World War. Why did so many women conclude that wearing a uniform must visibly validate their public service? We have essayed a substantial answer to this question in another article.[46] Here we briefly summarise

the conclusions to which our research has led. Lacking full access to the political system, women resorted to claiming full citizenship symbolically by donning uniforms. Uniforms also served them as visible statements of their patriotism and national pride. By wearing uniforms in voluntary organisations, women identified themselves with the same principles of military order and discipline as men. At the same time, they reminded government officials and male voters of the gap between women's legal rights and the responsibilities as citizens they had willingly accepted and effectively fulfilled during the war.

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45 For examples of other uniforms, though by no means comprehensive, see Brown, C, *Rosie's Mom: Forgotten Women Workers of the First World War* (Boston, MA: Northeastern University Press, 2002); Smith, J H, *Dressed for Duty: America's Women in Uniform, 1898–1973* (San Jose, CA: R James Bender, 2001).

46 Vining, M and Hacker, B C, note 44

Nicholas J Saunders

Culture, conflict and materiality: the social lives of Great War objects

War is the transformation of matter through the agency of destruction, and industrialised war creates and destroys on a larger scale than any other human activity. Modern war has an unprecedented capacity to remake individuals, cities and nations, and thus to shape conceptions of individual and collective identity. The unparalleled production of material culture during industrialised conflict embodies and provokes the extremes of human behaviours, and nowhere is this more evident than in the world's first globalised industrial war of 1914–18 and its many diverse consequences – of which, in different ways, the Second World War and the early twenty-first century's global 'war on terror' are two examples.

A new approach

Until recently, twentieth-century conflict (and especially here the First World War) has been the domain of military history[1] and of analyses concerned with the economic, social and political consequences of individual wars.[2] Apart from art history's interest in war painting[3] and a broader concern with post-conflict commemorative monuments,[4] the audits of war have ignored or avoided an anthropological–archaeological focus on the materialities of conflict and its aftermath.

Nevertheless, much first-hand memory of the twentieth century's many conflicts is fading, and perforce our views of and reactions to these events are increasingly determined by interpretations of material culture with which we have no personal connection, in design, production or original use. As those who took part in, or were directly affected by, these conflicts pass away, it is the postwar generations who become the custodians not only of their memories, but also of the 'afterlife' of the many and varied materialities of war. As generations change, along with technology, academic disciplines and the philosophy of knowledge develop, so new ways of engaging with the remains and consequences of conflict emerge.

Today, there is a clear and urgent need for an explicitly anthropological–archaeological approach to the materialities of modern conflicts, large and small – a process which, while it has only just begun,[5] is rapidly gaining momentum. In particular, we need to re-evaluate the role of material culture as multivocal representational embodiments of war and its aftermath. The fact that modern conflicts are defined by their technologies as wars of materiel is an unequivocal

invitation for such an approach – an invitation unspoken but inherent in several recent publications by cultural historians.[6]

Anthropology and archaeology, by their focus on material culture, are singularly well equipped to deal with these aspects of conflict. The objects of war are not anonymous weapons, scrap or ephemera, but rather different kinds of matter that can be seen as embodying an individual's experiences and attitudes, as well as cultural choices in the varied technologies of production. Such objects occupy a dynamic point of interplay between animate and inanimate worlds, inviting us to look beyond physical form and consider the hybrid and constantly renegotiated relationships between material culture and people.[7]

Conflict-related objects are endlessly ambiguous and varied, despite their often apparently straightforward nature in military terms. They can be small, e.g. a bullet or piece of shrapnel, intermediate, e.g. an artillery piece or a tank, or large, e.g. an aircraft or a whole battlefield landscape. They also include what are perhaps the most poignant, often tragic, 'artefacts' which are not usually conceived in such terms, i.e. the war-maimed and, in a different way, the war-bereaved – both of whom possess distinctive relationships with various kinds of material culture (see below).

All are united by virtue of being artefacts rather than naturally-occurring objects, though natural processes may alter their nature and appearance and our engagements with them over time. For the First World War, the 500-mile-long Western Front can be considered as much an artefact as a bomb-shattered town, the wreckage of a Zeppelin airship or a small talismanic bullet inscribed with its maker's name in the trenches. For other conflicts artefacts may include a V2 rocket, underground tunnel systems used by North Vietnamese soldiers, the symbolic terrain of war memorials or the temporarily empty space once occupied by the World Trade Center in New York. By identifying and engaging with artefacts of all sizes we can construct a 'biography of the object'[8] and explore its 'social life'[9] by assessing the changing values and attitudes attached to it by different people over time.

Like all artefacts, the material culture of war embodies a diversity – though perhaps a unique intensity – of individual, social and cultural ideas and experiences. The analysis of such objects reveals the social origin of artefact variability[10] and the fact that simultaneously they are part of, and constitute, the physical world.[11] Battlefield landscapes, memorials, cemeteries, reconstructed buildings and towns, museums and memorabilia are all material representations of memory, spirituality, ethnicity, politics and emotion that link the living with the dead in a complex interplay of past and present.

If we accept that an individual's social being is determined by his or her relationship to objects that represent the individual, that objects are a way of knowing oneself through things,[12] then we must also acknowledge that objects make people just as much as people make

objects.[13] Nowhere is this more true than in modern war. The sheer quantity of artefacts produced for and created by modern conflict represents a material medium within which we are immersed and with whose constituent parts we constantly interact, both consciously and subconsciously.[14]

The transformational power of industrialised conflict is evident at every scale of human activity, and the study of its material consequences is a slippery endeavour as it migrates across disciplinary boundaries. How, for example, are we to assess the 'social life' of First World War memorabilia, identical items which were, variously, displayed as 'memory objects' in the home for 80 years, are stored or exhibited in museums and are being excavated (legally and illegally) from Great War archaeological sites – some of which subsequently excite and feed the international trade in military collectables? In this instance, attention is focused on a set of issues that have hardly been recognised, let alone problematised or investigated by the range of disciplines whose territories they traverse.

Here, we are faced with another unique aspect of modern war: the ubiquity and similarity of its industrially produced material culture, which can appear in a range of locations from a munitions factory to the home, museum to battlefield, antiques showroom to car-boot sale and Internet auction site. In our attempts to understand such objects it seems that such traditionally-important indices for investigation as material, shape and function will be less important than the relationship between the individual, time, place and conditions – in other words, context.

Any attempt to explore the meanings of such objects has to adopt an approach that moves back and forth between anthropology and archaeology. This is far easier today than even ten years ago, but is still problematic. Nevertheless, by maintaining a focus on the material nature of objects – on their physical presence in the world, and thus their altering of our perceptions and emotions (agreeable or not) – we are able to initiate a new kind of debate on the nature of war which will also have consequences for archaeology and anthropology. In his posthumous book *Art and Agency*, Alfred Gell makes a statement concerning art objects that serves equally well for the material culture of conflict, that objects represent 'the visible knot which ties together an invisible skein of relations, fanning out into social space and social time'.[15]

Case studies in materiality

Small scale: making memorabilia

While the material culture of conflict is deliberately broadly conceived, as noted above, only a few examples of small-scale objects will be given here. I will focus mainly on personal items, the majority of which can be called memorabilia. I include shrapnel fragments,

bullets, artillery shells, military paraphernalia (badges and uniforms), wood, stone, minerals and pieces of buildings. Each of these is a potential memory object, connected in the mind of its owner with the circumstances surrounding its acquisition – a process which I shall also explore. It is important to note in this respect that soldiers and civilians (during and after the war) did not regard these items in the same way, even when they embodied life-threatening events.

The example of shrapnel and bullets illustrates this point. In the In Flanders Fields Museum in Ypres, Belgium, is a wartime identity card and bullet belonging to Henri Janssens, a volunteer wounded in 1918. Janssens survived, and when the bullet was removed from his chest he decided to keep it as a talisman for the rest of his life.[16] An even more remarkable story is that of Vincent Sabini of the 18th London, 47th Division, who was wounded in the leg at Messines, Belgium, in 1917. Sabini, a devout Catholic, also survived, but when the bullet was removed he carved it into a crucifix, had it gold-plated and wore it around his neck until he died in 1981 (Colour plate 3).[17]

Counterpointing these two examples is the case of Harry Patch, who fought as an 18-year-old in a machine-gun platoon of the Duke of Cornwall's 7th Battalion at the Battle of Third Ypres (Passchendaele) in 1917. Still alive in 2004 aged 106, Patch recalled how he had been wounded by a piece of shrapnel, hospitalised and the metal shard removed from his groin. The doctor then asked 'if I wanted the shrapnel as a souvenir and – officer or not – I swore at him: "I've had that bloody stuff long enough. Throw it away."'[18]

These examples illustrate the diametrically opposed reactions of soldiers towards one kind of war-related object. Such diverse attitudes were also held by civilians, at the time, and still today. No meaningful analysis of such objects can afford to homogenise their meanings for the individuals associated with them in the beginning – either as always 'sacred relics' or as nothing other than scrap or 'dreadful kitsch'. To do so would be to conflate their original meanings, elide their role as (hitherto ignored) three-dimensional narratives of the Great War, and to deny or at least make more difficult the possibility of an afterlife in personal associations between these items and those who would engage with them today, not least the legions of schoolchildren who visit the Western Front in ever-increasing numbers.

One corpus of war-related objects illustrates well the potential of an anthropological approach to investigating the material culture of war. First World War 'trench art' is a seemingly amorphous group of three-dimensional objects made from various materials including war scrap, materiel, stone, textiles and wood. Millions of items were made between 1914 and 1939, and each one was unique. What permits a meaningful classificatory framework to be constructed is not a straightforward description of material, shape, function or production

process – though this can be done – but rather who made what, when, where and why.

Trench art was made variously by soldiers, prisoners of war, civilians (often refugees) and internees at different times during the war and interwar years. The objects, the materials from which they were made and the techniques employed to produce them are often similar if not identical throughout this period. However, while all such objects are a consequence of war and its aftermath, either directly or as a legacy, they all objectify and memorialise the very different experiences of their makers and those who purchased and used them.

What appears at first as a confusing mass of war-related kitsch is revealed instead as a uniquely informative body of materials, narratives of the war experience inscribed in three dimensions. There are many categories and subcategories of Great War trench art,[19] but two main kinds suffice to illustrate my main point here: (1) objects made by soldiers between 1914 and 1919, and (2) items manufactured by civilians between 1914 and 1939. What follows is a brief exegesis of how complex these objects are and an outline of the issues which they embody and represent.

Trench art made by soldiers was produced in the front line, behind the lines, by the active soldier, the wounded, and by prisoners of war (Figure 1). Each of these is in fact a subcategory, as each possesses different contexts of production and meanings.[20] Soldiers carved in chalk, wood or bone, and made objects from bullets and artillery-shell cases. Objects were made by a variety of nationalities, with French, British and Belgian objects differing not only from German examples, but also from items made by Senegalese and Indian soldiers and Chinese labour-corps battalions – the latter three examples

Figure 1 French soldiers making trench-art vases from artillery-shell cases. (Nicholas J Saunders)

Figure 2 Detail of an unusual chromed artillery-shell vase showing a Chinese dragon, probably made between 1919 and 1922 by a member of the non-combatant Chinese Labour Corps who helped clear the battlefields. (Nicholas J Saunders)

encapsulating culturally distinctive ideas and imagery, albeit mediated by the experience of industrialised conflict (Figure 2).

While some examples, such as aluminium finger rings, were made in the trenches, others, such as sophisticated shell-case vases, were made in safer rear areas (Colour plate 4). Some were made by experienced craftsmen with professional tools (such as blacksmiths and the Royal Engineers), and others by men with little or no artistic ability. However, all are equally valuable in an anthropological assessment of such objects.

Some items were made to order and for sale, others for barter and exchange, and some as personal mementos or souvenirs sent home to families. Still others were made as mental and physical therapy in hospitals. The terrible conditions of combat made a lasting impression on soldiers who lived in landscapes whose unprecedentedly awful sights included an inexhaustible supply of raw materials for trench art. Acquiring the raw materials, itself often a potentially lethal process, and sometimes technically illegal, all but guaranteed that the objects themselves would be deeply ambiguous even before they were made. This aspect of the nature of the raw material was meaningful only or mainly to the maker of the trench-art object, and was elided in the appearance of the finished piece. Trench-art objects made by soldiers embodied experiences and emotions impossible for civilians to understand, in the same way, as we shall see, that civilian 'attraction' to such objects was mainly not shared by soldiers who survived the war.

Trench art made by civilians is far more numerous, if less varied, than that fashioned by soldiers. While soldiers made objects between 1914 and 1919, civilians made these items for 24 years, between

1914 and 1939. Wartime refugees made trench art to sell for money, as did civilian internees, and during the postwar years such activities continued due to harsh economic conditions. However, between 1919 and 1939, such objects were sold not to soldiers but to battlefield pilgrims and tourists eager to draw close to the places and experiences of their loved ones through the purchase of souvenirs. What differentiates wartime and postwar trench-art objects made by civilians is not raw material, or finished forms, but rather the temporal shift from war to peace. This is a pivotal issue for understanding how the meanings of objects for members of the same generation can shift dramatically while shape, form and technology remain the same.

Objects made by civilians between 1919 and 1939 were sold to war widows on battlefield pilgrimages as poignant memory objects. These items helped authenticate the pilgrimage experience, and enabled pilgrims to take home a tangible link with the dead. When these objects entered domestic space they became an integral part of the house-worlds of their owners, reordering the symbolic terrain of memory. They ornamentalised the home, mediating between the past and present lives of families who had lost a brother, father or husband. They objectified and stimulated memories for widows, and for a wider informal community of the bereaved. Such objects were a constant reminder of missing loved ones – a presence of absence. Decorated shells on a mantelpiece, a bullet letter-opener on a desk or a shell dinner gong sounded at meal times, were examples of where the memory of the body had been replaced by the memory of the object (Colour plate 5).[21]

Those objects that arrived ultimately in the realm of domestic space played an important but uninvestigated role in the ways in which the war was regarded during the interwar years. Yet, despite anthropology's concern with the home as a centre of emotion and as an articulatory focus between individuals and family and between household and community, it has never concerned itself with this category of memory objects. What is required is an interdisciplinary analysis of the multiple trajectories through social space that these objects can take, and their effect on the lives of those with whom they come into contact.

Large scale: encounters with landscape

In modern war, perhaps to a greater extent than in any other kind of cultural activity, every kind of object is embedded in a larger scale of human activity and physical location. First World War memorabilia illustrate this point particularly well, and investigators find themselves moving back and forth between different scales of objects and their analysis, rather than attempting to compartmentalise an item into one rigid category – the approach taken by militaria collectors and sometimes also museum curators.

The physical forces unleashed by industrialised war may distort or breach the boundaries of classificatory schema, one consequence of which is that investigations need to be reoriented towards the varied acts by which individuals acquire objects that they regard as meaningful.

The process of acquisition is a focal point for analysis, as it forges a link between objects, individuals and landscape. In part, this is due to the visceral relationship between memory object and memory landscape, which associates people with places in the minds of the living, and also, for those inclined to think this way, in the imaginary realms of the dead.

The study of landscape has been revitalised in recent years, and has drawn together anthropology and archaeology.[22] The study of battlefield landscapes – as some of the largest and most complex artefacts known – has benefited from this development, regardless of whether such places have been reconstructed, memorialised or left undisturbed.

Battlefields and war zones are no longer thought of as inert and empty backgrounds for the conduct of war, but as prime examples of socially-constructed landscapes – that is, landscape as ongoing process where individuals are redefined, or redefine themselves, by their experiences of place. Battlefield landscapes, like any landscapes, are palimpsests and cultural icons. A battlefield landscape is neither a single concept nor a solely-historical entity, but rather something political and dynamic, and always open to renegotiation.[23]

First World War battlefield landscapes, indicating this multi-layered complexity are, as I have noted elsewhere, composed variously of industrialised slaughter houses, vast tombs for 'the missing', places for returning refugees and contested reconstruction, popular tourist destinations, locations of memorials and pilgrimage, sites for archaeological research and cultural heritage development, and as still deadly places full of unexploded shells and bombs.[24]

Here we see that an anthropological assessment of battlefield landscapes is a hybrid undertaking which acknowledges the many associations between different scales of artefacts. Small artefact and landscape, meaning and memory, came into play via large and small cruciform objects, in the shape of wayside calvaries and talismanic crucifixes worn by soldiers, such as that already mentioned for Vincent Sabini. Great War soldiers observed how calvaries – while stationary, and larger and more visible than a human being – seemed to survive battle intact. It occurred to many men that these monuments were protected by the sacred image of a crucified Christ (Figure 3). Such observations appear to have forged a connection between landscape and human body mediated by large and small cruciform objects. By analogy, it was believed that the protection afforded the calvaries could be transferred to those who carried or wore small amuletic crosses and crucifixes. [25]

Figure 3 A postwar battlefield calvary on the site of Maltz Horn Farm near Guillemont on the Somme. (Nicholas J Saunders)

A different kind of relationship between landscape and smaller objects was that which saw landscape images captured on the surface of decorated artillery-shell cases. The ironies here are clear. Shells were definitive icons of the war and modernism,[26] and the agency bestowed on them by women (in munitions factories) and by men (in firing them) destroyed old landscapes and created new ones, and killed,

maimed and remade countless men against whom they were fired. Images of these landscapes and such lethal activities were engraved, hammered and painted onto the surface of empty shell cases. This appears to be a visceral example of Gell's point that 'Decorative patterns attached to artefacts attach people to things, and to the social projects those things entail.'[27]

A pair of these decorated shells from the Eastern Front depict a common theme: the before and after of war. One shell shows a peaceful and bucolic farmhouse scene while the other depicts a destroyed building with a biplane flying above. Both have the identical painted inscription '1917. Osmihowicze. Russl.'.[28] Another example from the Western Front is a blue-on-white painting depicting a snowy winter landscape and a bomb-shattered house, with a black painted inscription, 'Yser. 1914–1918', and signed 'H.J.' (Colour plate 6).[29] Other examples show bomb damage to the Medieval Cloth Hall at Ypres and to the Basilica at Albert on the Somme. In the latter case, the scene represents the famous leaning Golden Madonna and Child atop the Basilica of Notre Dame de Brebrières. The leaning Madonna was a common sight to soldiers between 1915 and 1917, and was finally destroyed by British artillery fire between March and August 1918.

Identity and landscape were also manifested in another kind of object: windmills made from empty artillery shell cases. Windmills were common in France and Belgium before the war, where they had often embodied a town's economic and political identity since the Middle Ages. In Belgium they were highly visible monuments on the flat plains of Flanders, and acted as a secular counterpart to churches – the two kinds of buildings matching each other in prominence and visibility, and representing secular and sacred power respectively. A town's windmill was often regarded as the symbol of the community.

The body of such items was usually a single artillery-shell case which had part of its surface engraved into a design imitating brickwork, sometimes with a door added. The sails tended to be of brass and copper, though sometimes of thick copper wire inset with pieces of shrapnel and copper drive-band, and often incorporated a clock.[30] One well-documented example was made in Belgium by Jules and Camiel Versavel between 1916 and 1917 – not for sale but as a commemorative object, keeping alive the memory of their historic town of Passchendaele's own windmill, destroyed during the war, and inspiring the building of a new one after 1918.[31]

Acquisition and memory-making

At the heart of the relationship between small- and large-scale artefacts, that is, memorabilia and landscape, and, in a sense overlapping archaeological and anthropological concerns, is the process of acquisition.

In war-zone locations there exists a nested hierarchy of artefacts, small-scale objects embedded within larger ones such as trenches, dugouts or shell craters, which themselves are framed by the larger artefact of the battlefield landscape. It is through, rather than over the surface of, this thick multi-layered palimpsest of artefacts that soldiers move and are wounded, killed or survive. Each of these potential outcomes creates a distinctive relationship between the individual and the various scales of object that are encountered.

For those who survive, their experiences may be embodied in a piece of shrapnel, a talismanic item of trench art, a souvenir taken from a dead comrade or enemy, a smell, a sound or a fragment of the earth itself. No kind of object is privileged, as it is the experiential process of acquisition that defines significance – a process whose unpredictability and randomness is a unique consequence of modern warfare, and which was widely commented upon by soldiers of the Great War.

Of the many processes of acquisition that occurred between 1914 and 1918, it was the one called 'souveneering' – a common euphemism for stealing[32] – which best illustrates how objects become attached to people in memory-making events. So common was this activity that it was noted at the time that 'This war will undoubtedly go down to posterity as a "War of Souvenirs".'[33]

Souveneering could take a variety of forms, from picking up a piece of stained glass from the ruins of Ypres Cathedral en route to the front line[34] to risking one's life to acquire a fragment of battlefield debris. There are many wartime accounts of soldiers taking life-threatening risks to acquire an unusual souvenir or trophy.[35] In fact, so commonplace was it for a soldier to be killed or wounded in such activities that it was reported almost nonchalantly. One officer who was sniped and killed while looking for souvenirs was described simply as 'a lovely young fellow'[36] and in another incident 'Napper was found dead, bayoneted in several places; he was a great souvenir hunter.'[37]

Apart from such risks, the process of souveneering could be nauseating. Soldiers rifled through putrid decaying bodies, covered with flies, contorted in their death throes. Yet there was also 'a fascination in going from dead to dead, seeking and looking with great intensity'.[38] On 8 March 1916, Captain P H Rawson wrote a letter home in which he asked:

> Has that Bosche button arrived? Mind you don't lose it as I cut it off with my own hands, the only real hun I have been close to and an awful brute he looked to [sic].[39]

Even wounded soldiers could not escape the consequences of this obsession with acquiring such objects. On one occasion, splinters from anti-aircraft shellfire rained down on soldiers in the trenches and broke the wrist of one man. 'He had barely exclaimed when half a dozen men scrimmaged for the nose-cap that hit him, and two grovelled

between his feet to get it.'[40] Similar events also occurred behind the lines, such as that at the Locre Hospice, a wartime orphanage run by nuns near Ypres. On 17 July 1916, shell shrapnel crashed through the roof of a building onto a bed vacated just minutes before. In gratitude to God, Mother Claudia permitted soldiers to collect the shell fragments, not as personal souvenirs, but to work them into a flower container for the chapel.[41]

Sometimes, an artefact could be representative not of one but several acquisition events and its significance for the maker perhaps magnified as a result. An insight into this process is given by the unusual repertoire of items made by Sapper Stanley K Pearl of the Australian 5th Field Company Engineers. Pearl kept detailed notes of where, when and under what circumstances he acquired the raw materials for making his trench-art souvenir objects.

In his account of the making of an inkstand, we see his experiences materialised in a variety of items belonging to different technologies from three armies (British, French and German) and also, via toponymy, a miniaturised embodiment of the local military geography (above and below ground) of the Somme battlefield.

> [The item was] completed on the Somme in February 1917. The base and pen handles are of oak and were cut from a table in a German dugout in Contalmaison and polished with boot polish. The bowl is from a propeller of a Vickers biplane wrecked at Le Sars. The ends are German anti-aircraft shell fuzes, one from Martinpuich, the other from Bazentin-le-Grand. The brass bands, standards and lid were souvenired from an 18-pounder battery near 'Needle Dump', and the French buttons on the base were exchanged for cigarettes in Albert. The ink container is a flare cartridge from Eaucourt-l'Abbaye.[42]

For civilians also, souvenir hunting often verged on obsession, though the context-driven associations were different. As early as 1914, *The War Illustrated* published photographs of civilians searching for German bullets in the grass, with the prescient comment that:

> Souvenir hunting has become quite an industry where the fire of battle has raged, and it is certain that the traffic in war souvenirs will flourish in the years to come when battlefields are the haunt of summer tourists.[43]

The associations of civilian-acquired objects, however, mainly derived from postwar battlefield visits and pilgrimages, and in this sense direct wartime meanings were absent. Yet, in seeking to authenticate their own experiences, civilians also forged distinctive relationships with artefacts of different scales. They may have repeatedly walked a particular route across a battlefield, annually laid a wreath at a battlefield memorial or Commonwealth War Graves Commission cemetery, purchased a souvenir from a local shop, or drunk and eaten in the same battlefield café–museum (Colour plate 7).

For those ex-servicemen who revisited the battlefields, as part of civilian tour groups or on their own, purchasing memory objects was not common practice. These individuals had no need to authenticate second-hand experiences. German battlefield visitors during the interwar years were especially harsh in their condemnation of the civilian process of acquiring objects (and memories). In 1927, Gerhard Schinke returned to Ypres, where he was shocked by the profusion of war souvenirs for sale in shops and peddled by children on the streets.[44] Gerhard Weixler was equally disgusted and regarded the whole business as sacrilegious.[45]

These opinions reveal that such objects were highly contested kinds of material culture – objectifications and miniaturisations of a contested terrain where attitudes and reactions continued to confront each other in peacetime just as the armies had a few years before. Soldiers and postwar pilgrims had (sometimes identical) battlefield souvenirs in their homes, and it was thus not the shape, size or kind of the object which was contested, but rather the circumstances surrounding the acquisition of the item (and that generated meaning) which were considered important.

Towards an archaeology of conflict

The study of Great War objects has recently benefited from the beginnings of a professional archaeological engagement with the First World War,[46] itself part of a wider multidisciplinary concern with twentieth-century conflict (Figure 4).[47] The relationships between objects and landscapes have taken on added significance as a result. Not only can the embedding of an object in a landscape be an explicitly archaeological event, but also this relationship is at the nexus of the creation of meanings between war and memory from 1914 to the present (and for the public as well as for professionals). This nascent archaeology of twentieth-century conflict can be considered and theorised, at least in part, as but one of the many and appositely termed 'archaeologies of the contemporary past'.[48]

Significantly in this regard, Great War battlefields are some of the most comprehensively documented, personalised and spiritualised areas ever to be subject to archaeological investigation by virtue of descriptions in letters, memoirs and regimental war diaries which describe events on a day-by-day, sometimes hour-by-hour, basis.[49] Probably no other kind of archaeology has the quantity and quality of detail with which to contextualise its investigations, which suggests that First World War archaeology will, as its methodologies mature, have a significant impact on its parent discipline.

The political, ethical, ethnic and technical challenges of creating an archaeology of the Great War are significant, as they cut across issues such as the excavation of still lethal battlefields, and the recovery, identification and reburial of the multifaith and multiethnic dead. There is also the need to build methodologies for this new kind of

Figure 4 Belgian archaeologists inspect an excavated duckboard at the Crossroads site, part of the A19 excavations outside Ypres in 2004. (Nicholas J Saunders)

archaeology as well as for coping with the management of battle-zone landscapes as national and transnational cultural-heritage locations and tourist destinations. The increasing memorialisation – including the establishment of new museums – of the old Ypres Salient battlefield illustrates these issues particularly well (Figure 5). In Europe these concerns extend from 1914–18 to the Bosnian conflict of 1992–95, Kosovo and beyond.

Figure 5 On the site of the infamous Battle of Third Ypres (Passchendaele) in 1917, a billboard advertises a new war museum at nearby Zonnebeke. The words 'dugout experience' appear bottom right, highlighting the display's sensorial dimension. (Nicholas J Saunders)

The anthropological nature of this kind of archaeology is evident in many aspects of the study of the material culture of war. For example, small and portable items such as soldiers' souvenirs, personal effects and equipment move back and forth between anthropology and modern archaeological practice and discourse. These kinds of objects are often attached – literally and figuratively – to bodies and body parts, and are sometimes the only way to identify the remains. It is ironic that despite uniforms, badges and a vast literature on the actions and whereabouts of particular regiments and battalions, identification may depend on a name, initials or service number scratched onto a miscellaneous object. Such items are not necessarily conclusive proof, but they may help in the process of permitting official and private closure during the subsequent reburial in a Commonwealth War Graves Commission cemetery.

Yet, it is these same items which are coveted by militaria collectors who, particularly since the 1960s, have sought to acquire them through a shadowy network of contacts or directly from illegal covert digging. Here is a direct association between the archaeology of the First World War and such anthropological issues as personal and social identity, the study of consumption, art in its broadest sense, economics, memory, trauma and loss. If professional excavators cannot find any identifying objects on human remains, then they are unable to reclaim the individuals from the list of 'the missing'. In other words, identification is rendered impossible through subordination to local and transnational commercial imperatives. These imperatives seal an individual's identity within the object, alienating it for ever from its rightful owner.

At the same time that archaeology is engaging with the First World War and such issues are being recognised, so the commercial pressure is increasing through the advent of the Internet, which is stimulating the market in such objects to the extent that potential purchasers of these items can now provide a wish-list of items to unscrupulous battlefield looters.[50] What is more heartening is that, since about 1999, the activities of battlefield scavengers and of illegal diggers have increasingly attracted public and official opprobrium. In this sense, it seems, what was an amateur's free-for-all even in 1999 has today become more sensitised and more scientific, a consequence in part of the move towards an anthropological and archaeological engagement with the many landscapes of war and the objects within them.

This development is most marked in and around the old Ypres Salient in Belgian Flanders. The In Flanders Fields Museum in Ypres was once home to a traditional (albeit magnificent) collection of objects. Since 1998 it has transformed itself into a popular multimedia experience with special and temporary exhibitions and artists in residence. Even more significant are its plans for a dramatic expansion in the coming years and a concept-driven philosophy which envisages an essentially anthropological approach to large-, medium- and small-scale artefacts – a dynamic relationship between the surrounding landscape, the museum and its objects.

Conclusion

Excavating the social lives of Great War objects provides opportunities for exploring the ways in which the dead and the living find proximity via materialities and places.[51] In part this is because such objects play with ideas of moral intent, acquiring meanings that often go to the furthest limits of the human imagination and endurance.

Hidden within the cultural life of such objects are stories of how human beings are defined by their own technologies and the technologies of others, of how their bodies and minds are shaped and reshaped by their experiences of conflict and its aftermath, and how they dealt with these experiences by materialising them in material culture.

In keeping with empirical and theoretical developments in anthropology and archaeology more generally, the objects of modern conflicts are being conceptualised and investigated in new ways – ways that conceive artefacts as self-reflexive embodiments of human experiences rather than the trash or ephemera of war. Such an approach is one way in which generations that have no (or very limited) experiences of war can come to understand, preserve, conserve and represent conflict to themselves and subsequent generations.

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Deborah Warner

Celestial navigation aloft: aeronautical sextants in the US

'Failure in navigation is often as serious as failure in the power plant or plane itself.' So wrote Philip Van Horn Weems, a 1912 graduate of the US Naval Academy who devoted his remarkable talents and energies to the promotion of celestial navigation aloft. This chapter focuses on American efforts to develop one of these instruments: the sextant that navigators used to determine their locations. It is based, in large part, on the Weems papers and the aeronautical instrument collections in the Smithsonian Institution.[1] Many of these instruments were technically octants rather than sextants, but since the two terms were often used interchangeably, I will refer to them all as sextants.[2]

Interest in aeronavigational instruments arose with the demonstration of the military potential of aviation during the First World War, and built slowly in the 1920s. The introduction of commercial transoceanic flights in the mid-1930s, together with growing international unrest, led to increased attention to this technology. The military services purchased large numbers of air sextants in the early years of the Second World War, and again during the Cold War, as did commercial airlines in the postwar period. Some air sextants were used aboard ships at sea.

With a standard sextant, the observer looked through the eyepiece and brought the image of a celestial body into coincidence with the actual horizon; with the air sextant, the observer brought the celestial image into coincidence with an artificial horizon. Early celestial navigation aloft took place in open cockpits. The pressurised aeroplanes of the early 1940s had observation domes for navigational use. To eliminate the problems caused by these domes, periscopic instruments were introduced.

Russell's experiments

American experiments with celestial navigation aloft began in 1918 when the Princeton astronomer Henry Norris Russell spent several months at Langley Field, Virginia, testing aeronavigational instruments under the auspices of the Army Bureau of Aircraft Production.[3] Russell's best results came with a marine sextant, equipped with a bubble level mounted above the telescope tube, that belonged to Robert W Willson, a professor of astronomy at Harvard University. Willson had designed a bubble sextant of this sort for nautical use in the 1890s, and an improved version for aeronautical use in

1910.[4] These instruments were probably made by Brandis & Sons of Brooklyn, New York. In 1925, three years after Willson's death, his estate applied for a patent on his bubble sextant design. The patent was issued in 1929 and assigned to Brandis & Sons Inc.[5]

Russell also used an air sextant with a pendulum-type artificial horizon, probably of the sort that Ernst G Fischer, the long-time chief of the instrument division of the US Coast & Geodetic Survey, would patent in the early 1920s. Russell reported good results with this instrument, but others found the form too large, heavy and complicated for actual use.[6] Fischer also designed a rapid-release lever for a sextant's micrometer that remained in use for many years.[7]

Richard Evelyn Byrd

A third American design, promoted by Richard Evelyn Byrd, has the bubble level mounted on the sextant frame near the filters for the horizon glass, on the opposite side from the telescope. Byrd was a 1912 graduate of the Naval Academy who commanded two naval air stations in Nova Scotia in 1918 and who supported the Navy's plan to fly large aircraft across the Atlantic. In 1919, when assigned the task of procuring navigational instruments for the Navy-Curtiss flying boats that would travel from Long Island to England, Byrd chose sextants made according to his design (Figure 1).[8] Since Weems was Byrd's colleague and classmate, it is not surprising that he had an instrument made for this historic occasion.[9] Later examples of the Byrd sextant were equipped with a Fischer rapid-release lever, a tangent screw with a micrometer drum reading to half minutes, and electric light bulbs to illuminate the level and the scale.[10]

Byrd filed a patent application in June 1919 and approached Brandis about producing his instrument for sale.[11] Negotiations broke

*Figure 1 Three Navy-Curtiss flying boats took off from Rockaway, Long Island, in early May 1919. Three weeks later, after stops in Nova Scotia, Newfoundland, the Azores and Lisbon, the NC-4 landed in Plymouth, England, thereby becoming the first plane to fly across the Atlantic. Richard Evelyn Byrd designed the sextants for this important adventure, and this is one of those instruments. It is marked 'BRANDIS & SONS, BROOKLYN, N.Y.'. PV H Weems, Byrd's colleague and classmate, donated this sextant to the Smithsonian in 1963. It is housed in the Armed Forces Collection of the National Museum of American History (AF*59054-N). (Smithsonian Institution)*

off when the courts decided that Byrd had been scooped by Luis de Florez, a mechanical engineer who had graduated from MIT in 1912 and had organised the Navy's Division of Aircraft Instruments and Accessories during the war.[12] Undeterred by this legal setback, Byrd continued to claim credit for the design. In an article describing the preparations for the flight that Byrd and Floyd Bennett made over the North Pole in the spring of 1926, the *New York Times* reported that Byrd had 'invented the so-called "bubble sextant," an air navigation instrument based on the principle of the carpenter's level'. This instrument, the piece continued, 'enables the flyer to obtain an artificial horizon and to calculate his position while in flight, even if the actual horizon is not visible', and it 'has added greatly to the safety and success of flights over long-distances without the aid of landmarks'.[13]

The Brandis Model 206

The Pioneer Instrument Company acquired control of Brandis in 1922 and hired Victor Carbonara, a clever engineer from Italy. Carbonara realised that air navigators never measured angles greater than 90°, and so could use an octant rather than a sextant. And if the octant had a micrometer rather than a vernier, it could be reduced in size. Brandis introduced their first air octant (the Model 206) in 1925. This had a radius of 5¼ inches, and was equipped with a Willson bubble telescope, a Fischer rapid-release lever, a drum micrometer and electrical illumination for the bubble and the divided arc. Carbonara was understandably proud of his achievement. But, aware that air instruments were 'far from being perfect', he asked navigators to 'relate their experiences and offer constructive criticism'.[14]

The Army tested a Model 206 at McCook Field in 1926 and designated it their Model A.[15] The Navy tested another at the Naval Observatory and designated it their Mark I, Model 2. The Navy Bureau of Supplies and Accounts then published specifications for this instrument that were based on the prototype and asked for bids to produce 15 examples. Brandis were the only bidders.[16]

Captain G H Wilkins, leader of the Detroit Arctic Expedition in 1926, had two examples of the Model 206.[17] Press reports noted that this 'Pioneer Octant' enabled the location of an aeroplane to be 'ascertained within ten miles under practically all conditions' and that Wilkins and his aviator, C B Eielson, set a new record by flying 140 miles north of Point Barrow, Alaska.[18] Piero Bonelli carried a Model 206 in his attempted flight from New York to Rome in 1928, as did the Byrd Antarctic expedition in September 1929.[19]

Brandis's slightly revised Model 206B was known to the Navy as the Mark I, Model 3. Charles Colvin, the founder of the Pioneer Instrument Co., opined: 'We do not think for a minute that our present sextant is the best that can be made, but we do think it

is the best now being made and the Bureau of Navigation, Navy Department, evidently agrees with us as they have standardized on it.'[20] There were actually two versions of this instrument. One was designed to be held in the right hand; the other was to be held in the left hand 'so as to leave the right hand free to write down the time and the observed altitude'.[21] A 1930 advertisement noted that: 'It is indeed amazing that nobody ever thought before of making a sextant for the left hand so as to avoid the necessity of putting down the instrument or changing hands every time an observation had to be noted. The change of design from right to left was first proposed four years ago by the Bureau of Aeronautics of the United States Navy, and it has now met with general approval.'[22]

The Model 206C, introduced in 1930, had the legs on the front of the frame so that the instrument could be set down with the handle uppermost, two coloured objective caps to reduce glare in daylight observations, and a radium illuminator for star observations. The Navy designated this the Mark I, Model 4 and arranged to purchase 100 examples.[23]

The DARAD sextant

Another bubble sextant – this one designed by Noel Davis and Lawrence Radford, and developed by Keuffel & Esser – had enclosed optics and an external divided scale, and was so constructed that the observer looked down into the eyepiece at an angle of about 45°. Noel Davis was a graduate of the Naval Academy who, after having received further degrees from the Navy's aeronautical school at Pensacola and from Harvard Law School, was put in charge of all naval reserve flying in 1922. He and Radford filed a patent application for their sextant in February 1927. Davis died two months later, having crashed the plane in which he hoped to make the first non-stop flight across the Atlantic, from New York to Paris, and which he hoped to navigate 'using a new sextant of his own invention'.[24] Keuffel & Esser received a Navy contract to produce a number of these instruments but asked for 'flight tests and service comments' before producing them all. By the end of 1927 Keuffel & Esser were advertising the 'DARAD SEXTANT for use with or without natural horizon, Patents Pending' that they made 'for the U.S. Army and Navy, for use in Aerial and Marine Navigation'. This instrument had a retail price of $550. The Navy Bureau of Aeronautics published a technical note on the DARAD (which it knew as the Mark II, Mod 1) in early 1928.[25]

Keuffel & Esser introduced a new version of the DARAD (Navy designation Mark II, Mod 2, and Army designation A-3) in 1929.[26] This was lighter and more compact than the original, and of improved optical quality. It was, however, tricky to build. 'As you know,' Keuffel & Esser informed the Navy, 'this is an entirely new design and it is not always possible to keep exact delivery dates when making a new

instrument of this kind.' In March 1930 there were problems with the final adjustments of these instruments. In August the delivery of these instruments was 'delayed indefinitely'.[27] By 1932 Keuffel & Esser had introduced a new model (Navy designation Mark IV, Mod 1) that was more compact still, with the divided scale moved inside along with the optical train.[28]

The AIS improved sextant

The Aeronautical Instruments Section (AIS) of the National Bureau of Standards was established in 1918 and charged with collecting, evaluating and developing instruments for American use. By 1921 the AIS was said to be working on an 'improved aircraft sextant' that 'differs radically in form from the marine sextant'. This new instrument had a rotating mirror turned by a worm and wheel suitably graduated instead of the large divided scale used in marine sextants, a method of varying the size of the bubble to compensate for temperature changes, and electrical illumination of the bubble and scales for use in dark conditions.[29] Keuffel & Esser made the prototype.[30]

This AIS aircraft sextant was designed for the Navy's Bureau of Aeronautics and based, in large part, on the instruments that had been designed at the Royal Air Establishment (RAE) at Farnborough and used by the Royal Air Force.[31] Lionel Burton Booth and William Sidney Smith, both of the RAE, obtained a British patent for the British instrument in 1919, and Booth obtained an American patent in 1921.[32] Franklin L Hunt and Karl H Beij, both of the AIS, applied for a US patent for a similar instrument in 1921.[33] Hunt was a PhD physicist from MIT who had been sent to Europe in 1918 to examine and collect European instruments for the Bureau. Beij was a surveyor with a BS from Trinity College who would soon write a report on 'Astronomical methods in aerial navigation' for the National Advisory Committee on Aeronautics.[34]

The AIS began discussing their 'improved bubble sextant' in September 1923. Work was rushed in January 1924 as the Navy hoped to use this instrument for the polar flight of the *Shenandoah*, the first rigid helium airship built in the US. The sextant was delivered in July, but the *Shenandoah* was lost in a storm before the Arctic flight could occur.[35] The Smithsonian has two instruments of this sort, both marked 'BUBBLE SEXTANT / U.S. Navy / BUREAU OF STANDARDS / MODEL NO. 2 / 1924'. One (s/n 2) came from the Naval Observatory. The other (s/n 4) is shown in Figure 2 and came from Weems, who noted that he drew it 'from the storeroom in North Island, at the Naval Air Station, San Diego, and made numerous tests with it, along with Byrd, Lindbergh, Ellsworth, etc. etc.' Weems went on to say that this was one of six instruments made by the Bausch & Lomb Optical Co. in Rochester, New York, at a cost of $250 each,

*Figure 2 This bubble sextant was developed for the Navy by the Aeronautical Instrument Section of the National Bureau of Standards in 1924, and produced by the Bausch & Lomb Optical Co. (AF*59069-N). (Smithsonian Institution)*

and although Bausch & Lomb 'lost money on the deal', they 'naturally recuperated on later orders and on later models'. When Bausch & Lomb checked their figures several years later, they found that they had actually spent $650 apiece on these six sextants.[36]

Since the bubble was filled with a liquid hydrocarbon that tended to expand and contract with changes in temperature, Hunt and Beij patented a 'means for compensating for temperature changes affecting the leveling bubble'. Beij also patented an ergonomic version of the Bureau of Standards original that had filters to reduce the glare of sunlight and an electric light to provide illumination at night. These patents were issued to Hunt and Beij as individuals, but it was widely understood that they had been developed on government time, and thus government agencies could use them without paying royalties.[37]

Bausch & Lomb

In the late 1920s, having recently compiled his first star altitude curves that would simplify celestial navigation aloft, Weems was eager to assemble a package of related instruments and documents.[38] He favoured the Bureau of Standards bubble sextant, encouraged Bausch & Lomb to manufacture an improved model for commercial use, and convinced Charles Lindbergh and B F Mahoney (President of the firm that manufactured the *Spirit of St. Louis*) to join in the crusade.[39] In the mid-1930s, as the air sextant business began to look profitable, Bausch & Lomb signed a licence agreement with Hunt and Beij:

Bausch & Lomb would have exclusive rights to the three key patents, and the inventors would receive a royalty of 5 per cent of the net sales price.[40]

Bausch & Lomb brought out their Model B bubble sextant in 1929 and their Model C in 1930.[41] Weems helped design the Model C and described it as 'a good example of a modern instrument'. Lincoln Ellsworth thought it 'looks mighty crude to give such accurate results'. Lindbergh made good observations on his first attempt, noting that he could hold the sextant in one hand while piloting the plane with the other. Others were less enthusiastic. The Assistant Superintendent of the Naval Observatory reported that the Model B was 'being made with a view of getting it on the market, for commercial use', but was not being used by the Navy, and had been discarded by the Bureau of Aeronautics. The Observatory tested ten examples of the Model C and found them still wanting.[42]

The Model D of 1933 had a more stable bubble and a lower cost of manufacture. An improved method of bubble illumination and a built-in marking pad were introduced in 1937.[43] An improved bubble cell followed in 1938, and Bausch & Lomb deemed it 'the one outstanding virtue' of their sextants. Since this feature had caused them 'so much grief', they thought that 'it would be a hindrance rather than a help to deliberately offer the bubble element for use on any other make instrument'.[44] Edward F Flint, a Bausch & Lomb employee, patented bubble cells that were adjustable and temperature compensated in the early 1940s.[45]

The US Army began testing Bausch & Lomb bubble sextants around 1935, approved them for service use, and gave them the designation A-6.[46] Japan ordered 60 of these instruments in 1937 – a fact that Bausch & Lomb proudly advertised – and may have used some of them at Pearl Harbor.[47]

The Pioneer Instrument Co.

The Pioneer Instrument Co. joined the competition in 1931 with a compact and lightweight sextant designed in large part by Victor Carbonara (mentioned above in connection with Brandis).[48] This instrument had prisms rather than mirrors in its optical train. The bubble chamber was placed in the optical path and easily illuminated with ambient light. The dial was illuminated with radium paint, thus obviating the need for battery and electric light (the examples in Smithsonian storage are still 'hot'). The eyepiece was rotatable around the vertical axis, so that the navigator could easily take sights backwards as well as forwards. An astigmatiser elongated the image of the Sun, Moon or star, thus rendering observations more accurate. The unit cost was $350.[49]

Charles and Anne Lindbergh used a Pioneer sextant in 1933 when they flew the *Tingmissartoq* across and around the Atlantic, surveying air

routes for Pan American Airways, and appreciated its 'compactness and mechanical construction'.[50] Fred Noonan used a similar instrument to navigate Pan American's *China Clipper* in 1935 and, although heavy cloud cover interfered with dead reckoning and drift observations, he was able to bring the airship from California to Honolulu 'within a short time of its scheduled arrival'.[51] He probably used it again when he navigated Amelia Earhart's ill-fated flight in 1937.

The Lindberghs reported that their instrument 'proved entirely satisfactory', except that 'the bubble element gave trouble'. Weems went on to say that 'the construction of a bubble element which will not leak has proved to be a problem for all bubble sextant manufacturers'.[52] Pioneer solved this problem by adopting a bubble similar to the one used in the Bureau of Standards instrument. As business increased, Bausch & Lomb argued that the design of Pioneer's bubble was covered by the Hunt and Beij patent, and forced Pioneer to pay royalties on all instruments sold for civilian use.[53] Pioneer also had access to the bubble patented by Richard Weniger of Brooklyn and assigned to the Bendix Aviation Corp., Pioneer's parent company.[54]

While civilian aviators captured media attention, military sales kept Pioneer in business. The Pioneer sextant received 'very favorable service comments' at an early date and Navy designation as the Mark III, Mod 1. This was soon followed by the Mark III, Mod 2 (Army designation A-5), the Mark III, Mod 3, the Mark III, Mod 4 and the Mark III, Mod 5 (Army designation A-7) in 1937 – these several iterations indicating a continuous effort to improve the instrument.[55] The civilian counterparts were advertised as small, rugged and highly accurate instruments that had been 'developed in collaboration with the United States Navy'.[56] As war approached and military demand increased, Pioneer reported that 'unexpected orders for unusually large quantities' meant that it could not quote delivery of instruments for civilian use 'of under six months'. The unit price at that time was $670.[57]

Developing the averager

The Pioneer Mark III, Mod 5 was not available to civilians 'without special permission from the Navy Department, inasmuch as it contains developments not common to sextants to be bought abroad or elsewhere'.[58] The development in question was undoubtedly an averager. By the mid-1930s, having discovered that the turbulence of the air and the unsteadiness of aircraft caused individual observations to be unreliable, aviators were routinely averaging several observations made in quick succession.[59] The next obvious step was to mechanise the process. Captain Julius Hellweg, Superintendent of the Naval Observatory, designed a mechanical averager for marine sextants, and Thomas L (Tommy) Thurlow, a creative, tenacious and fearless Army aviator, designed another for air sextants.[60] Weems was excited about the averager, deeming it 'extremely important' and seeing it as 'the

next big advance in celestial navigation'. Thurlow's design, he said, 'saves the time, trouble, and possible errors in writing down each of several observations and then taking the average'.[61]

In May 1936, while arranging for a British edition of his *Air Navigation*, Weems mentioned Thurlow's work to Arthur J Hughes, the managing director of Henry Hughes & Son, the leading British firm manufacturing nautical and aeronautical instruments.[62] Hughes put his staff to work on the task and soon had a working model in hand. Years later, when Weems reminded Hughes that it was he who had suggested the averager to him, Hughes replied that this device 'cannot be traced to any particular individual'. Weems may have provided the spark, he said, but the heavy lifting was done 'in the Drawing Office and the factory'.[63] P F Everitt of Hughes filed an application for a British patent for the averager in August 1936, and another for an American patent on 2 August 1937.[64] Thurlow filed his American application on 3 August 1937.[65] After months of litigation, Thurlow conceded Everitt's priority and, with war on the horizon, Hughes agreed to give American manufacturers a free licence for instruments made for government use. S Smith & Sons, the British corporation that acquired Hughes' sextant patents in the postwar period, sued Bendix for patent infringement and received a judgment of $1,379,211 in 1956.[66]

Bausch & Lomb received an Army contract for an averaging sextant in early 1937: the model A-6-A was an A-6 equipped with a Thurlow averager that could handle eight consecutive readings.[67] Subsequent modifications led to the A-8 and A-8A, instruments that Bausch & Lomb produced in large numbers during the war.[68] In 1940, Bausch & Lomb obtained a licence from Fairchild (see below) to sell Thurlow averagers to civilian customers.[69]

The Army also provided funds so that Pioneer could equip their air sextant with a Thurlow averager. Thurlow received the first two examples in July 1938, just a few hours before he and Howard Hughes took off on their record-breaking flight around the world, and was able to 'obtain extremely accurate position fixes despite turbulent air'.[70]

Bausch & Lomb also produced an experimental model of the 'continuous integrating' averaging sextant designed by Captain Paul Gray of Pan American Airways. Charles L Bausch thought Gray's device 'may do a good job', but was 'too complicated' for actual use.[71] The same was true of the 'time and arc average recorder' that Weems proposed in 1938. Bausch opined that this 'complicated and delicate' mechanism would work 'if perfectly made' by 'a good custom mechanic with good clock-making experience', but it could not be manufactured at a reasonable cost.[72] There is no evidence that anything further became of either of these projects.

Bausch & Lomb's last air sextant was their model #61-90-04 (Army designation AN 5854-1 and Navy designation F.S.S.C. 88-S-375).

The firm donated an example to the Smithsonian in 1948, noting proudly that it had been 'patented and manufactured by them'.[73] Representatives from several aviation training commands conducted extensive tests with an instrument of this sort in September 1943 and recommended that it be 'considered for adoption as the standard sextant for the Army Air Forces'. It was rugged and compact, and easy to balance, and gave less trouble than any other sextant. It had an electric light for standard illumination and radium for low-intensity illumination. It also had a 15-shot median device that was simple and self-explanatory, and that offered 'a fool-proof visual average, which is easily understandable to the navigator'.[74]

The median device was a mechanism that determined the median rather than the arithmetical average of several observations. While the device itself was relatively simple, its origin is so complex that it is difficult to know who deserves credit for what. Weems and Thurlow were apparently inspired by an account of a French version published in 1938, and each man, working independently, worked out the details.[75] Bausch & Lomb made an example according to Weems' design and offered to apply for a patent in his name until a patent search revealed that Weems had been scooped by one Bart Diggins. Edwin Link thought that Weems' design resembled a device that had been suggested by an RAF officer named David Waghorn.[76]

As the US military was preparing for America's entry into the war, the Pioneer Instrument Division of Bendix Aviation (as the firm had become) made bubble sextants for the Navy and the Army. Both were modifications of the sextant that Pioneer had introduced in 1931. The Navy's Mark III, Mod 7 had a mechanism that averaged observations and the times at which they were made, and that had been designed by Lt Comdr Ira Hobbs of the Naval Aircraft Factory. The observations were recorded on a rotating cylinder covered with a pressure-sensitive paper.[77] The Mark III, Mod 7 also had a novel method of illuminating the bubble designed by Gregory Rylsky, an engineer employed by Pioneer.[78] The Mark IV, which followed in 1941, was similar in most respects.[79]

The Army's A-7 had a simple finger-activated pencil that made vertical marks on a piece of roughened grey paper. After a series of shots, these marks would be visually averaged and the average time of the series determined from a stopwatch.[80] Pioneer/Bendix received a contract worth $1,068,000 to make 2400 A-7s in January 1942.[81] By September the Army was boasting that an experienced navigator using an instrument of this sort could 'set his plane down at the end of a transoceanic flight within an error radius of only 15 miles, less than four minutes' flying time'.[82]

The AN 5851 (Army designation A-14, Navy designation Mark V), which followed in 1942, had a successful mechanical device that averaged 60 discrete altitude readings taken over a period of two

minutes. The AN 5851-1 (Army designation A-15) was essentially similar, but could obtain average readings for any period of time up to two minutes. These instruments were heavy, and so were designed to be suspended from an arm installed in the centre of the astrodome. Many were still in use in the 1960s. Production was begun by Pioneer/ Bendix and continued by the Eclipse-Pioneer Division of the Bendix Aviation Corporation (as the firm then was).[83]

The Fairchild Aerial Camera Corporation

The same day in 1937 that Thurlow filed a patent application for his averager, he and his colleague Samuel M Burka filed another describing an optical system for an indirect-sighting bubble sextant that was 'more compact' than 'those heretofore employed'.[84] The Fairchild Aerial Camera Corporation acquired the rights to this instrument, 'lock, stock and barrel', and went after it 'in a big way'. Thurlow noted that 'Simplicity and ruggedness, small size, optical characteristics, and the averaging device (vernier type)' were the key features of the new design. Moreover, with the elimination of the precision worm, 'factory run machine work and optics may be used'.[85]

Weems visited the Fairchild factory in January 1938, had 'a good look' at the new sextant, and 'placed an order for the first commercial instrument they build for sale'.[86] Although Fairchild was a well-established firm that manufactured various technical devices, this instrument presented numerous unforeseen challenges. Thurlow reported in February 1940 that 'Fairchild had let him down and are starting all over again to design another sextant,' and later that 'Fairchild has made a perfectly atrocious mess of the sextant.'[87] By July 1941, however, he was sufficiently pleased with the new instrument to recommend Army designation.[88] The A-10, as this instrument was known, was actually a median sextant. The navigator pushed a plunger whenever he made a shot, making a series of marks on a white plastic disc. At the end of a series of shots, the disc would be removed and the median determined by eye.[89] The A-10-A (Figure 3) had an electrically operated timer such that observation marks were made once a second as long as the navigator held down the trigger. The Air Force was still using this instrument in the late 1950s.[90]

In March 1942, the Army signed a contract worth $2,682,618 under which Fairchild would produce some 8984 sextants, with a like number of adjustable bubble-chamber assemblies. The number represented the largest number of instruments that Fairchild could produce by the end of 1943. Since more air sextants were needed, the Army signed a similar contract with the Agfa-Ansco Division of General Aniline & Film Corp. in Binghamton, New York; this contract was worth $2,259,625 and included a $7500 payment to Fairchild for 'flow charts, material, specifications, bills of material, engineering aid, etc.'[91]

*Figure 3 The A-10-A bubble sextant was made for the US Army Air Forces in 1944 by the Fairchild Camera and Instrument Corporation. The navigator would push the plunger while making a shot, thus making a mark on the white plastic disc (AF*59062-N). (Smithsonian Institution)*

A third Army contract, this one with the Polarizing Instrument Co. in New York City, came to $2,289,890; the unit cost of these A-10 sextants was $201.03 (plus $23.96 apiece for jigs, dies, fixtures, etc.). Since no instruments bearing the name of this firm seem to have survived, they may never have been produced, or they may have been produced and sold under Fairchild's name.[92]

Although the A-10 was a fairly simple instrument, and although the Army established fine training facilities for pilots and navigators, personal attention was required. The Army informed Fairchild in June 1943 that navigators who met directly with Fairchild representatives 'were "sold" on the A-10 and therefore had the necessary confidence in it for successful operation'. But where the representatives did not visit, the navigators 'were not sure' they could rely on the instrument. That same summer, Fairchild conducted, at its own expense, a series of week-long courses covering the maintenance and repair of the A-10.[93]

Link Aviation Devices

Another army contract, this one with Link Aviation Devices in Binghamton, New York, covered the purchase of 6130 'Sextants, Spare Parts and Data' for a total cost of $1,115,387. The instruments in question were the A-11 and A-12 bubble sextants. The two were essentially identical, but the former was a single-shot instrument designed for training purposes, while the latter was a multi-shot instrument with a median device.[94] Theodore 'Dutch' Van Kirk, the navigator of the *Enola Gay*, used an A-12 on the long flight across the Pacific Ocean and back in August 1945.[95]

The story of these instruments began in April 1938, when Weems asked Edwin A Link to develop an inexpensive bubble sextant suitable for student use. Since the Army had recently issued an order for more than $26,000-worth of his Star Altitude Curves, Weems expected 'a big spurt in the celestial navigation business'.[96] In a letter to Thurlow, Weems said that if Link 'starts out to make an instrument at a low price, he might actually have an instrument that would be not only low-priced but good. It would probably not be quite as complete so far as averaging devices are concerned; on the other hand, I believe it would be a wonderful thing for fast training of navigators.' Moreover, Link 'is not only ethical but financially responsible, as well as being of mechanical genius'.[97]

Link was soon doing 'a large amount of playing around with a sextant under various conditions'. After finding that 'the main factor in getting good results is to take a large amount of observations very quickly', he made sketches of an averager and asked his attorney to search for patents describing instruments of this sort. On his next trip to London, Link 'met Mr. Henry Hughes on several occasions [...] and had some very interesting conversations with him'.[98] Since Hughes was the chief executive of Henry Hughes & Son, the subject of averagers must have come up. In the end, however, the Army asked Link to produce 'median sextants'.[99]

The basic form of the Link sextants was suggested by Edgar J Lesher, an assistant professor of aeronautical engineering at Texas A&M University. Lesher had sent an example of his 'new low-priced' instrument to Weems in early 1939, noting that he did not have a patent on the form, but he was sure that Weems and Link would treat him fairly.[100] Link planned to have these instruments manufactured by W & L E Gurley, an old line mathematical-instrument firm, and sell for under $100. When Gurley proved unable to do the job, Link began production in house. By November 1940, Thurlow had run the Link sextant through a number of tests and was considering putting through specifications for 500 examples.[101]

When production took longer than expected, Link and his colleagues redesigned the instrument so that it could be 'comfortably held without unnecessary strain' and easily serviced, even by the

user.[102] The frame was made of aluminium and the recording drum was formed of a white plastic made by Plaskon.[103] The first examples of this new model were made in April 1941. In June these sextants were 'nearly in production'. In late August Link had 'hundreds of sextants about ready to go out, but as can be expected, there have been some manufacturing difficulties encountered when they are first put in production'. Over 600 sextants were 'nearly completed' in early October, but 'held up for one thing or another'. By the end of the month, production was under way. In mid-December, shortly after America's entry into the war, Link reported that 'the Air Corps has urgently requested that we send them every available sextant, as they have a shortage of sextants right now and need them for use on bombers'. By June 1942 Link was building sextants 'at the rate of 25 a day'. By October they were building 'several hundred units per week'. Five months later, however, Link were considering cutting their sextant production in half, as 'the government has brought in three or four other manufacturers, also building sextants, and does not have the demand for all the sextants they now have on order'. At this point, Link requested permission to obtain the necessary materials to produce air sextants for customers who were not affiliated with either the Army or the Navy but who, nonetheless, intended to use these instruments 'in connection with the war effort'. A new A-12 cost $262 in December 1941. By the fall of 1945, it was considered war-surplus, and available at deeply discounted prices.[104]

Not content to let well enough alone, Link patented and produced a horizon attachment for use with a bubble sextant that enabled the navigator to view the real horizon.[105] This design seems to have been technically successful, but it could not staunch the rapid decrease in military demand for air sextants.

Scattered evidence suggests that several other designs were developed on military contracts in the early years of the war. Link made a bubble sextant 'of the student type of design' that had 'three identical sealed tubes, the differing periods being obtained by the use of different liquids,' and could be 'read to the nearest minute of arc'.[106] Pioneer received a contract worth $6250 to develop an averaging sextant with 'a horizontal line of sight and incorporating a liquid-wedge type of horizontal reference'.[107]

With a pressurised cabin and an astrodome, navigators could take observations in safety and comfort. The downside was the necessity for a dome refraction correction to the calculations, and the fact that the astrodome interfered with the streamlining of the plane and was always in danger of blowing out.[108] Recognising that a periscope would eliminate these problems, Thurlow, Burka and another colleague patented a periscopic sextant in 1941.[109] Soon thereafter, the Army signed a $5940 research and development contract with Fairchild for a periscopic bubble sextant 'for experimental tests in comparison

with similar instruments manufactured by Bendix'.[110] None of these instruments saw much service, if any, during the war. Similar work was done in Britain, and these sextants went into production in the late 1940s.[111]

The Kollsman Instrument Company

The Kollsman Instrument Company dominated the air sextant field from the late 1940s until the introduction of GPS in the 1980s made sextants all but obsolete. They made hand-held and periscopic instruments, some with pendulous-mirror artificial horizons and others with bubbles. Paul Kollsman was an immigrant engineer from Germany who worked briefly for the Pioneer Instrument Co., established his own firm in Brooklyn in 1928, and enticed Victor Carbonara and Charles Colvin of Pioneer to join this endeavour.[112] The firm became the Kollsman Instrument Division of Square D Co. in 1940, and the Kollsman Instrument Corporation a decade later.

Carbonara informed Weems in October 1935 that Kollsman had developed an averaging device for air sextants that 'is well on the way of being "a fait accompli"', and Bausch & Lomb understood that Kollsman was preparing to market an instrument that would 'embody a bubble cell similar to ours'.[113] As it happened, however, Kollsman did not produce any such instruments at that time. The historian Monte Wright believed that Kollsman found the engineering problems 'more perplexing than anticipated'.[114]

Kollsman introduced their first aircraft sextant in 1948, noting proudly that both Pan American Airways and KLM had installed these instruments in their transoceanic planes.[115] This instrument used a pendulous mirror and a periscopic mount designed by Carbonara.[116] It also had an integrator that produced a continuous moving average over any observation period up to two minutes.[117] This was based on the 'ball integrator' that had been patented by Richard Deimel and William A Black, and assigned to the General Time Instrument Corp. Deimal was a professor of mechanical engineering at the Stevens Institute of Technology who, during the war, was a consultant to Sperry Gyroscope and to Fairchild Aviation, and director of research at the General Time Instrument Corp. His co-inventor has not been further identified.[118]

Air sextants with gyroscopes

To round out this story, mention should be made of the air sextants that used a gyroscope as an artificial horizon. The French had been experimenting with instruments of this sort since the 1880s. The US Army adopted a gyroscopic instrument in 1922, designating it the A-1. The Sperry Gyroscope Company introduced another version in 1933.[119] The Navy joined the hunt in 1935, informing several instrument companies that they were interested in 'the possibility of

developing a gyroscopic sextant for aircraft use'.[120] Navy Captain Harry Connor, the second navigator on the Hughes round-the-world flight in 1938, opined that the 'greatest single needed improvement is a gyroscopically stabilized octant'. An instrument of this sort, he said, 'will enable navigators to take accurate sights in rough air. And it won't be a simple job, either, to develop such a device. But it will be done soon, mark my words.'[121] Connor clearly understood the difficulty of developing such an instrument, but he was overly optimistic. The Pioneer Instrument Company had an Army contract to produce a 'Panoramic Sextant, gyro bubble type' in 1942.[122]

Summary and conclusions

Celestial navigation aloft was never a high military priority, but military demand was a key factor driving development and production of these instruments. This demand began in the First World War, and rose steadily in the interwar years. During this period, when the technology was not yet of critical importance, the military provided the steady employment and other resources with which talented innovators could develop new ideas, test the instruments as they became available, and provide feedback that contributed to their redesign.

The air sextants business in the 1930s might be seen as a vicious circle: small demand inhibiting the easy availability that might build a greater demand. When Weems told Bausch & Lomb about orders trickling in, the firm mentioned the 'prohibitive cost' of batch production. And when Weems asked Bausch & Lomb to make these instruments in batches of 50 to 100, the firm was reluctant to tie up the resources needed to maintain such a large inventory. In early 1940, despite orders in hand for 39 air sextants, Bausch & Lomb would not start production until they received a large order from the War Department.[123]

As the American military began gearing up for the Second World War, it faced the challenge of obtaining suitable instruments in sufficient quantities. In March 1941, nine months before Pearl Harbor, the military established specifications for, and began encouraging the manufacture of, small and lightweight air sextants equipped with an averager or a median device.[124] When Bausch & Lomb and Pioneer could not meet the demand, other firms were encouraged to enter the field. And when production was still behind schedule, the Air Inspector of the Army conducted an investigation 'with the idea of improving conditions in any way possible to expedite the delivery of these items of equipment very badly needed'.[125] To further improve the situation, a military navigation conference held at Fort Worth in May 1943 recommended the standardisation of sextants and listed the features desired.[126] The firms that manufactured air sextants for the military probably made money on these deals, but found themselves

with unwanted equipment and excess inventory as the war drew to a close.

Major technological breakthroughs might make good stories, but the false leads and incremental developments of the air sextant better represent the norm. Moreover, while design changes in a mature technology often reflect attempts to hasten the obsolescence of otherwise still useful items, design changes in an evolving technology often reflect honest efforts to improve the product. Improvement is clearly a slippery concept, unless suitably circumscribed. The users of air sextants were especially concerned with accuracy and ease of handling. In this regard, the reliable and ergonomically satisfactory Bausch & Lomb and Pioneer instruments of the mid-1930s were clearly better than the clunky and error-prone instruments of the 1920s. The Army recognised that the quality of an air sextant was best judged by its actual performance. To this end, navigators were given sextants at the start of their training and expected to 'become familiar with their personal instruments through extensive use'.[127] Cost may have been a factor for student navigators, but for the military and for commercial airlines with transoceanic routes, the cost was trivial compared with the value of the aircraft, crew, armaments, cargo and passengers that the instrument was designed to protect. Finally, since ease of manufacture affected the bottom line, manufacturers struggled to design sextants that did not demand the special skills of a precision instrument maker.

Developmental challenges occurred in the process of manufacture as well as in the basic design. Edwin Link clearly understood the long hard slog that often separated clever ideas from reliable products: 'In my experience with inventions, which has covered a considerable number of years,' he said, 'I have found that there is a lot to be done between making something which just about works and possibly not too successfully, and getting something to work in a successful manner, and have found many inventions that have had to be abandoned due to this intermediate stage.'[128]

The air sextant story raises questions about the national identity of a rapidly evolving technology. How can this be defined when innovators from different countries are in frequent contact with one another, when inventors secure patents in several countries, and when the rights to these patents are cross-licensed? Another question concerns consequences that might have been anticipated. Why, for instance, were Bausch & Lomb eager to sell sextants to Japan in the late 1930s, and why did Weems extol the 'obvious efficiency of the Japanese night bombers, the Italian military flyers, etc.'?[129] Yet another concerns technological obsolescence. Aircraft sextants were always used in conjunction with compasses, ground-speed and drift meters, altimeters, calculators, radio and, eventually, other electronic aids, and the development of these several navigational technologies progressed

at about the same pace. Thus, as the aircraft sextant improved, it became increasingly irrelevant.

One final issue concerns memory, and the efforts that some people make to ensure a favourable remembrance of some achievements. Weems, who organised his papers and donated his instruments to the Smithsonian so that historians would have the materials needed to tell the story of celestial navigation aloft, must clearly be seen in this light. So too must the American Institute of Navigation, which offers a Thurlow Award for contributions to the science of navigation. Weems received the Thurlow Award in 1955. Samuel Burka, who received it in 1957, was honoured as a PhD physicist who 'devoted a long and distinguished career' in the Air Corps to the 'research and development of air navigation equipment'.[130] The Institute of Navigation also gives a Burka Award for contributions to the advancement of navigation and space guidance, and a Weems award for individuals making continuing contributions to the advancement of navigation over a period of years.

Notes and references

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5 The Smithsonian has two instruments of this sort. NASM cat. 1957-637 (from the National Bureau of Standards) is marked 'BRANDIS & SONS M'F'G CO. BROOKLYN, N.Y. 3193' and so was made in the period 1914–16. NMAH cat. 59055-N (from Weems) is marked 'BRANDIS & SONS, INC. BROOKLYN, N.Y. 5675' and so was made after the firm was incorporated in 1916. Willson, R W, 'Instrument including means for determining the horizontal direction', US Patent No. 1,705,146.

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11 Brandis–Byrd private correspondence, 1920–21, Ohio State University Archives, RG 56.1, Papers of Admiral Richard E Byrd

12 'Rear Adm. Luis de Florez dies; invented air training devices', *New York Times* (6 December 1962), p43; de Florez, L, 'Attachment for sextants', US Patent No. 1,536,286. For records of the lengthy patent litigation between Byrd and de Florez see Ohio State University Archives, note 11.

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14 Carbonara, V E, 'Aircraft instruments for oversea navigation', *Journal of the Society of Automotive Engineers*, 21 (November 1927) pp528–31

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19 Bonelli's instrument is now NASM cat. 1977-1 (from Mrs Bonelli). Wallace, W O, to Brandis & Sons, 3 January 1929, NARA, RG 78, USNO outgoing correspondence, Box 13, Folder F49-7/L5-1.

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30 'Aeronautical Instruments Section progress report' for March, August, November, December 1921, NARA, RG 167, NN3-167-80-7, Box 1. Keuffel & Esser was a firm in Hoboken, NJ, that built sextants and octants to Navy specifications. They also made NASM cat. 1957-632 (from the National Bureau of Standards), a marine sextant of 6 in radius with a Fischer rapid-release lever on the vernier, an electric light over the scale and a bracket on the frame that might have held a Fischer pendulum (now missing).

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Christine Finn

Artefacts of occupation: the enduring archaeology of Jersey, Channel Islands

'We are told that Jersey is the last place the Nazis would attack. It is of neither economic or strategic importance [but] so far from this being the case, I think – nay, I am sure – that the exact opposite is true, and that at the present juncture no part of the Empire is in greater peril.'

Letter from Jersey islander Frank Johnson, published in the *Jersey Evening Post*, May 1940.

'We were ditched by the UK government. We felt stripped naked. After demilitarisation, we had no means of defending ourselves.'

Jersey schoolteacher Harry Aubin[1]

Introduction

The small, bay-rich islands of Jersey, Guernsey, Alderney, Sark, Herm and Jethou lie in the English Channel off the northwest coast of France, considerably closer to that country's regions of Normandy and Brittany than to the south of England (Figure 1). The islands' geographical position has proved to be a crucial factor in their cultural identity since prehistory: their proximity to the European mainland, their endowments of rich flora and fauna, semitropical climate and

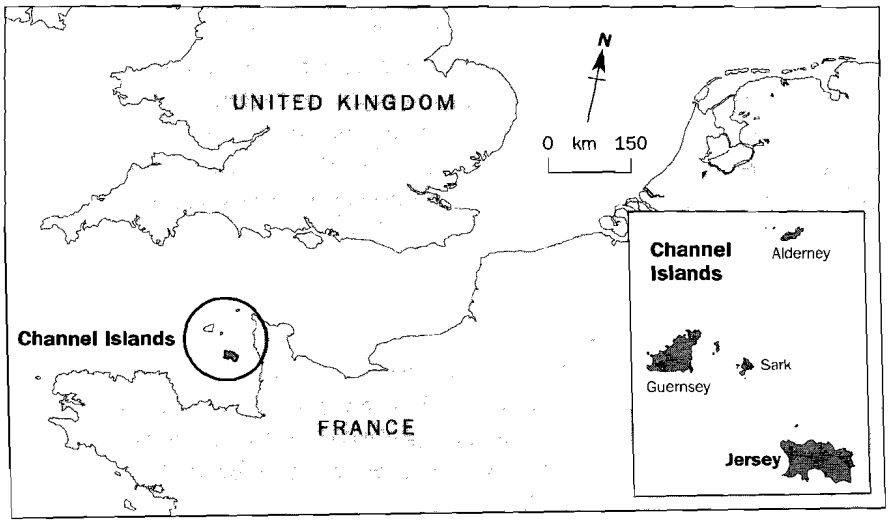

Figure 1 The location of Jersey.

the variety of their landscapes have given the islands a unique value, resulting in a complex history of possession over millennia. Jersey is the largest island, with an area of 44 square miles (114 km^2), while the next largest, Guernsey, measures 24½ square miles (63½ km^2); both have international airports and frequent sea crossings to the UK and France.

Artefacts found on the islands suggest habitation over several millennia, and the islands' history encapsulates not only the fortunes of waves of invaders, but also the fate of those forced to flee their homes on mainland Europe. For years, the islands have provided a refuge; in the twentieth century they welcomed new waves of émigrés, northern Europeans lured by the sun and the prospect of new lives, banking professionals seeking to make their fortunes from the islands' offshore tax status, and Madeira islanders in search of seasonal work in the hotel trade, who brought with them an enduring Portuguese population. The islands also hoped, but failed, to repel those who arrived by force, and it is the marks left by this activity with which this chapter is most concerned. Visitors to the islands today will still find 50-year-old remains of metalwork and concrete, many of them perched incongruously next to ancient sites, and at locations of extraordinary natural beauty (Colour plate 8).

From AD 933, the Channel Islands belonged to the Duchy of Normandy and, as a result of William the Conqueror's claim to the English throne after the Battle of Hastings in 1066, the islands became the property of the British monarchy, a situation which prevails to this day. However, the islands are also independent: they have their own jurisdiction, coinage and stamps, and boast other cultural anomalies, including the prevailing use of Norman French. They are not controlled by the British government from Westminster, and they also lie outside the dictates of the European Union. They have resisted the pressure of change, although, at the time of writing, there are measures planned which would bring the islands in line with Europe in those areas of finance and taxation which have benefited Jersey and Guernsey in particular, and which, together with tourism, have created the islands' healthy economy. Despite the prospect of any possible reforms, the islands have entered the twenty-first century maintaining the unique quality of being both distinctively Continental while projecting an aspect of quintessential Englishness.

However, this dual culture, exemplified in the easy confluence of French street names and surnames and British customs, acquired a different aspect with the onset of war and the question of loyalty to a British government which, many islanders felt, had simply chosen to leave them vulnerable to the German forces. The islanders' ambivalence towards the United Kingdom needs to be closely borne in mind when considering the events of the Second World War and the artefacts that were left behind.

The narratives of Jersey

The historical and archaeological literature of the Channel Islands reflects the enduring challenge of understanding the nature of 'invasion' and 'occupation'. The sought-after, or now lost, antiquarian works, which describe dolmens, druid sites, castles, pleasant cliff-top walks, and bestow on Jersey the earlier name of 'Caesarea', find their balance in other rare works – the unpublished diaries and memories kept by those who lived out the Occupation on the islands. Many of these works will have been kept at times of indescribable conditions, and many will have gone for ever, being either too painful to be kept, and hence destroyed, or simply lost. Nevertheless, some accounts have made their way into print, such as Audrey Anquetil's privately-published and undated *Wartime Memories*, John Dalmau's *Slave Worker*, privately published in 1946, and Frank Stroobant's *One Man's War*, published only in 1992. The printing presses of the Channel Islands' newspapers have also produced invaluable source material, notably Leslie Sinel's *The German Occupation of Jersey: A Complete Diary of Events, June 1940 – June 1945*, published in 1945 by the *Jersey Evening Post*, and V V Cortvriend's *Isolated Island: A History and Personal Reminiscences of the German Occupation of Guernsey June 1940 – May 1945*, published in 1946 by the *Guernsey Star and Gazette*. The titles of other volumes, such as *Islanders Deported*, reflect the utter transformation undergone by the once-blessed Channel Islands during the war.[2]

Before the Second World War, the numerous cultures which made up the distinctive character of the Channel Islands could be identified traditionally, through the vestiges of material culture displayed in the islands' museums, much of it coming from excavations carried out by antiquarians and archaeologists: coins from the Continent, ceramics and potsherds, and other familiar archaeological artefacts which helped to build a picture of the earliest inhabitants. Other less tangible remains were left to be discerned through the roots of the language and personality of the people, who continued to speak and write a patois of old Norman French and to harbour a historic grudge toward the other islanders.

For this chapter, however, I am largely drawing on the works of two women writers, researching 60 years apart: Jacquetta Hawkes, the archaeologist, whose monograph on Jersey prehistory was researched and written just as Europe was descending into the Second World War, and Madeleine Bunting, whose book *The Model Occupation* exposed the many layers of island life during the traumatic Occupation years for a postwar generation and was published to mark the 50th anniversary of the Liberation. I will also concentrate on the island of Jersey.

From 28 June 1940, when the Channel Islands were invaded by German forces, through an Occupation lasting the duration of the Second World War, to the aftermath, modern archaeological evidence

is shaped by the context of those engaged with these artefacts. This chapter is inspired by the idea of 'modern archaeology', which I have explored elsewhere, but not to such a personal degree.[3] It is also important to note that I am a Channel Islander who grew up in Jersey surrounded by the material culture of this and other occupations, not least via my mother and grandmother, who lived on Jersey throughout the war and for many years afterwards. This has necessarily produced a different sensitivity to the subject matter, about which – crucially – no oral testimony from family members is available.

The British historian Madeleine Bunting, author of *The Model Occupation*, who conducted hundreds of interviews for her critically-acclaimed, and controversially-received, book on the Channel Islands under the Occupation, introduces the process of gathering such memories from those still coming to terms with their own history: 'memories they had celebrated and memories they had denied'.[4] She writes: 'Interviewing them was like an archaeological investigation into collective memory; digging down into the recesses of individual recollections, piecing fragments together with diaries and documents to build a history which had never been recorded before, and was in danger of going to the grave with the person who had lived it.'[5]

Fifty years after the Occupation of the islands began, the events of that time remain a controversial issue. Often, those making gentle enquiries on the islands, or pursuing deeper investigation, receive short shrift from those islanders who have lived there all their lives, and many resent repeated questioning, particularly on the issues of collaboration and black-marketeering, not least for the manner in which they are judged for actions carried out during what they regard as a state of siege. However, the questions continue to be asked, and this chapter will also describe the delicate balance of presenting this difficult history on an island where some of those who lived through it are still alive.

Adolf Hitler's grand design for the islands was to create fortresses which would be both an example of Anglo-German cooperation and a devastating blow to British morale, being the only part of the British Isles under Nazi rule.

On 20 June 1940 the last of the British troops were evacuated from the Channel Islands. The demilitarisation was kept secret by the British government, with the consequence that the Germans treated the islands as a legitimate target for the bloody air raids that followed. From this event came the feeling of 'being abandoned' by Britain, particularly given the sense of chaos surrounding the evacuation of some 30,000 islanders between 19 and 22 June. Documents revealing this were only made public in 1992.[6] The histories and anecdotes from this period need to be seen through various filters, depending on whether the narrator was one of those who remained on the islands during the war, or who was forced to leave, or who suffered losses as a

result of the Occupation, or, particularly controversially, could be said to have gained in some way, notably financially, from the war.

Retelling the events which led to the Occupation of Jersey in June 1940 presents a challenge to those engaged with informing the public, particularly those from the younger generation of Jersey islanders, or from abroad, who are often new to the idea that any part of the British Isles was occupied during the Second World War. The way in which this challenge is being met, and the innovative presentation of this recent past to the public, forms the central theme of this chapter. While the more traditional archaeology collections on the island, such as that gathered and displayed by the Société Jersiaise at its museum in St Helier, and the artefacts shown at the prehistoric site of La Hougue Bie, are indeed significant, this chapter concentrates on a more recent museum, a prime example of a less orthodox collection of artefacts, housed at the visitor attraction called the Jersey War Tunnels.

Jersey 'things'

To bring the German Occupation into context, as being the latest of several incursions of the islands since prehistory, this chapter also considers how these earlier occupations, and the artefacts they left behind, have been discussed and perceived. These artefacts in some respects may not be regarded as 'artefacts' at all, being seen as items of historical interest, but not evidence of past social process. However, echoing the sentiment of Arjun Appadurai's *The Social Life of Things*, objects of any age might be used to construct biographies, and indeed they are given life, socialised, by that conjunction of 'thing' and 'human activity'.[7] For many years after it ended, the Channel Island Occupation was a piece of lost history. Its reconstruction is a unique aspect of the growing interest in the recent military past, but, unlike the records of the British Isles, which have spawned a largely open disclosure, the traumatic events in the Channel Islands have led to a more fragmented and difficult approach to the recent past. Many of the thousands who died in prison camps, or constructing the concrete edifices of Hitler's 'fortress island' ideal which still stand today, have been nameless for decades. It is only now, through the process of reconstituting the history of the Occupation, in which every scrap of material from that period is significant, that the Channel Islands are memorialising their past.

Elsewhere, I have discussed the movement of things over time, and how changes in the practice of archaeology itself have resulted in a re-viewing of the same object.[8] However, given that it is only in recent years that there has been genuine information available about the Occupation, and the problem of obtaining information from the many people who still experience prevailing discomfort when asked to remember the details, such artefacts as there are – documents, photographs, radios, foodstuffs – take on an added poignancy.

Not only have they survived the long war years, but also they have not been destroyed by those who have found their presence too difficult to bear. Liberation Day must surely have created many such reminders. Likewise, in the days before and at the beginning of the Occupation, fleeing islanders left a desperate trail of artefacts such as furniture and suitcases, and sometimes even pets, in their abandoned homes and at the quaysides.

The first work I will consider is one of traditional archaeology. In 1937, the archaeologist and writer Jacquetta Hawkes (Figure 2) visited Jersey to write a major volume on the island's ancient remains. The book was published in the summer of 1939 as *The Prehistory of the Channel Islands, Volume II: The Bailiwick of Jersey*.[9] The publication helped to make Hawkes's name as a leading archaeologist and earned her the Fellowship of the Society of Antiquaries of London. What is interesting to consider in the context of this chapter is the timing of the publication, and how Hawkes's use of the terms 'occupation' and 'invasion' was prescient for the events which were to come: the volume's map of the island's prehistoric and historic sites would soon be augmented by the military artefacts of German Occupation. Hawkes also includes in the volume a rather portentous illustration

Figure 2 The author and archaeologist Jacquetta Hawkes, with Christopher Hawkes (left) and an unnamed man. (Jacquetta Hawkes Archive, Special Collections, J B Priestley Library, University of Bradford, ref. HAW/18/1/3/2/9)

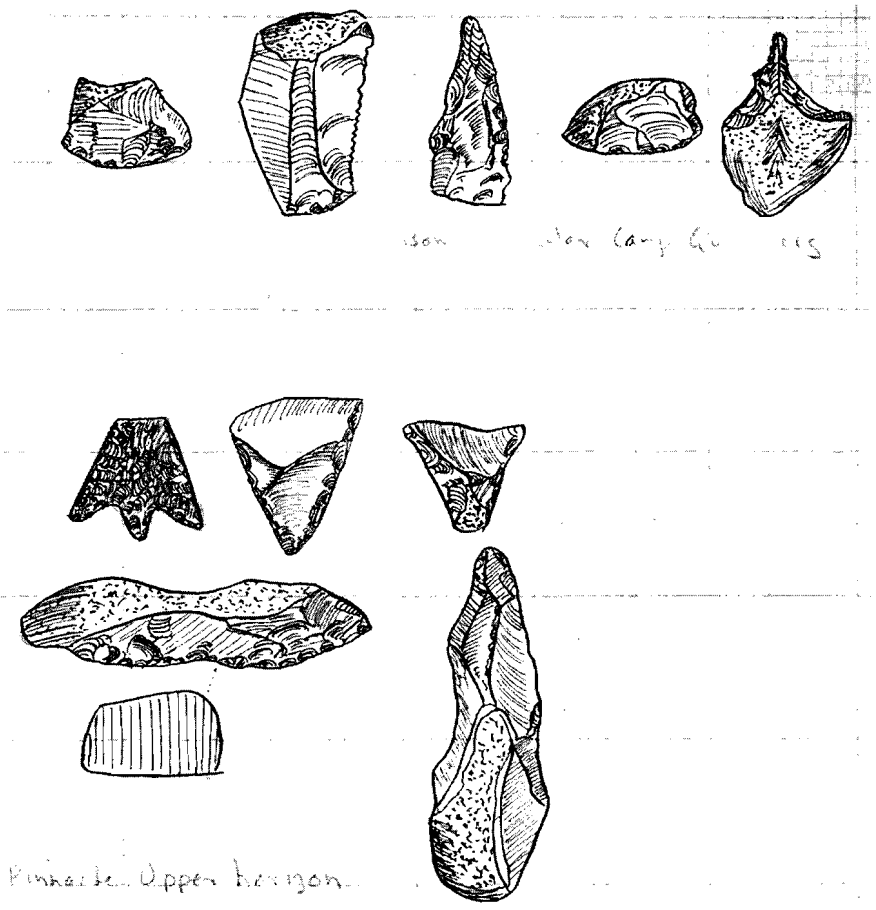

Figure 3 Drawings of stone tools found at the site of a First World War 'Prisoner of War camp', attributed to the archaeologist Jacquetta Hawkes. (Jacquetta Hawkes Archive, Special Collections, J B Priestley Library, University of Bradford, ref. HAW/1/14)

from one of her own drawings: 'Flints from "chipping areas": prisoners of war camp sites' (Figure 3). This, it transpires, was a First World War prisoner-of-war camp, active from 1915 to 1919 at Les Blanches Banques.[10] Hawkes writes: 'A considerable piece of ground in the sandy terrain of the Lower Quennevais is still scarred by the last traces of the Prisoners-of-War Camp which was established there during the Great War. The disturbance of the occupation and dismantling of this camp, followed by a severe storm, revealed a very extensive area of prehistoric occupation marked by pottery, flint and stone implements, and shell middens. [...] To judge from the pottery, the occupation was at least roughly contemporary with the period when the Ossuary was in use, that is to say probably towards the very end of the megalithic period.'[11] Aside from the contextual significance, this military usage had performed a type of 'excavation'.[12]

Hawkes, then the wife of the leading prehistorian and Roman archaeologist Christopher Hawkes (Figure 2), had taken over the project from Tom Kendrick, one of her husband's colleagues at the British Museum, who had written *Volume I* on the neighbouring

Bailiwick of Guernsey. The islands had intrigued archaeologists for years, given their unique culture. Despite the close proximity of Jersey and Guernsey, there is a geological difference which is crucial for consideration of any 'invasion' hypothesis in prehistoric times. Jersey is formed from a landmass that includes the coast of what is now Brittany, while Guernsey has a different geological origin. Hence, the two islands can be discussed distinctly in terms of their earliest colonisations and relationship with the mainland. It is these remains of occupation – in both prehistoric and modern times – with which this chapter is concerned.

The complex prehistory of Jersey presents a series of particularly rewarding sites. Jacquetta Hawkes was working from notes made by Kendrick, and these in turn were compiled from archaeology carried out by the earliest archaeologists and antiquarians on Jersey. Occupation and invasion was also a concern in the nineteenth century. *The 'Complete' Guide to Jersey* by 'A Jerseyman', published in 1896, includes a section called 'Druidical Remains' which concludes that the dolmens and cromlechs 'scattered all over the island especially in the undisturbed moorland districts of Grosnez and La Yoye, are evidence of still much earlier races. These consist of innumerable flint chippings and wrought flint tools and weapons, with axes, mullers etc, in syenite and greenstone.'[13] The writer continues with descriptions of thousands of chippings and cores found at an archaeological exploration in 1881, an event in which he apparently took part. There is comment also on the ancient name of Jersey, 'Caesarea', commonly interpreted as 'Caesar's Isle' and related to the conviction that there had been a Roman occupation of Jersey nearly 2000 years before.[14] Furthermore, a ruin known as 'Caesar's fort' formed a part of the later Mont Orgueil (or Gorey) Castle on the west of the island; he also notes the remains of another, 'la petite Caesarée', found near Rozel, a 'Caesar's Wall', and the arms and coins dating from the Roman period in the collection of the Société Jersiaise.

The unknown author of a volume entitled *Caesarea, the Island of Jersey* published in 1840 appears to have been convinced of Caesar's presence on the island.[15] In the section on 'Antiquities, druid temples, Roman works, Early Christian edifices, ancient privileges of Sanctuary (perquages)' he notes of Jersey's origins: 'It has been contended that it was known by the name of Augia previously to its occupation by the Romans, and that this was changed to Caesarea by that people.'[16] He goes on: 'Although there can be no doubt that the Romans had possession of Jersey, history does not furnish any account of the time that they first invaded the island, or the period at which they quitted it.'[17] Citing again the evidence of Roman coins and the 'Caesar's Wall', the nineteenth-century author writes: 'there was a tradition, which has been preserved, that Julius Caesar crossed over from Gaul to some islands, and took possession of them.'[18]

A century later, Jacquetta Hawkes overturns this idea: 'The Roman name of Jersey is doubtful,' she writes, 'but it certainly was not Caesarea.' She suggests instead that this name was 'wantonly selected for it from the Antonine Itinerary by early antiquarians'.[19] She further updates the antiquarian hypothesis of a Roman invasion of Jersey using the benefit of new finds and a broader archaeological perspective, suggesting it was not Romans per se who had lived on the island of Jersey, but refugees fleeing from Rome. The evidence for this, Hawkes argues, included the building of a strong promontory fort not *by* the Romans but *against* the Romans. Not least, 'the burial of a huge numbers of coins' on Jersey was significant, and to support this Hawkes lists the artefactual evidence of Roman coins from Gaulish hoards and the finds of Roman Imperial coins.[20] Further, she notes this evidence and 'the apparent absence of settled burial places', all of which points to the conclusion that the invaders were fugitives whose effective occupation of the island may have been brief and unstable. The exact date of their arrival is not perfectly clear; as the hoards include late and degenerate looking Armorican pieces and Roman coins of Octavius and Marcus Antonius, one of which is as late as 32 BC, they cannot be invariably connected with Caesar's defeat of the Armorican insurrection of 56 BC.[21]

Developing the idea of a north–south cultural fringe – 'a new human highway, the sea route along the Atlantic coasts' – Hawkes ponders who built the island's megaliths, and who comprised a native population of Jersey when explorers arrived from the Iberian peninsular to the south. Given Jersey's geological continental connection, was there a repopulation of the island by settlers from Brittany to the southwest, or did the occupiers come from a newly-established Morbihan centre?

Hawkes's consideration of the movement of peoples, a continental drift of culture into, and out of, the island, is most pertinent when she is summing up archaeologists' ability to find Jersey's ancient peoples from the artefacts they left behind. 'Graves, weapons, tools, and pots, all the surviving material possessions of the prehistoric inhabitants, have been used as documents to tell the story of Jersey from a time when the island was peopled by creatures differing from modern man even in the structure of their bodies, down to the first contact with written history and the humanizing breath of remembered names: gaul, Roman and Norseman.' Hawkes hoped that even if, over the ensuing many thousands of years, the narrative had been lost, 'this chapter has served to show how the patient efforts of modern Jerseymen to recover the relics of former islanders from the soil, has not merely meant the infilling of museum cases, but has provided material for a history, already intelligible, which the future will make better and more vivid'.[22]

Jersey underground

One of the places described and photographed by Hawkes during her research on Jersey was the site of La Hougue Bie (Colour plate 9), which serves here as an unlikely bridge between the island's prehistory and its modern wartime past.[23] The site is best known for its prehistoric burial chamber, or dolmen, which has survived in excellent condition and was, according to Hawkes 'fully famed beyond any other prehistoric monument in Jersey [...] [possibly] one of the finest memorials of its time surviving in Western Europe'. Atop of the dolmen, the ground rises steeply to a medieval building. 'The great circular mound crowned with two medieval chapels' is vividly described by Hawkes, who recounts the 'fantastic framework of medieval legend' surrounding it, involving dragon-slaying and a servant's treachery. She then provides an explanation for the site arising 'among a people cut off by the curtain of time from any knowledge of their prehistoric forerunners, but who felt the need for some heroic explanation of the great monument which stood among their fields'.[24]

However, within a few years of her writing, the inland rural site of La Hougue Bie had an additional feature; a German underground bunker was dug deep into the ground beside the site and concreted in, complete with an entrance door and steps. It survives today as a memorial beside the megaliths as part of Jersey's modern archaeology, and opens up an interesting phenomenon. Given that Jersey's prehistoric monuments were often constructed at exceptional vantage points overlooking the Channel, it is of little surprise that the German gun emplacements, bunkers and other observation posts should follow suit. Thus the visitor to Jersey today will often encounter the curious collision of 4000 years of island occupation at its most attractive coastal viewpoints.

As Hawkes had noted sagely of Jersey's earliest invasions: 'Contact with the outside world was relatively as significant a force in the cultural development of Jersey in prehistoric times as today when she lies an hour's journey from London by air.'

Hawkes's prehistory is still in use today, but the landscape of the sites has altered irrevocably. As noted earlier, the sites of many of the monuments Hawkes described were used in the 1940s as German gun emplacements. Others, such as La Hougue Bie, now share their position with the other vestiges of the war, either visible above ground or concealed underground. In recent years, the value placed on the artefacts of military history, in particular the remains of the Second World War and the Cold War, has given a new currency to the bunkers of the Channel Islands. Unique in being German defences in the British Isles, rather than British defences against the German forces, these have rapidly become assimilated as part of the material culture of the islands. Perhaps there has been more of a focus on preserving this form of archaeology given the context: the vestiges of war – from

Figure 4 The author of this chapter, aged three years (centre), with her mother, Phyllis, left, and a family friend, pictured at the German Underground Hospital (now the Jersey War Tunnels) in 1962. (Allan Finn)

barbed wire to concrete constructions – were being promoted as part of Jersey's tourist attractions long before such defences were protected or similarly promoted in Britain.[25]

As noted above, I have a particular fascination for Jersey's cultural palimpsest: I was born on the island in 1959 and my mother and grandmother both survived the Occupation, the latter choosing to stay rather than be evacuated to the mainland. I grew up, and played, among the remains of the Occupation, notably the site known then as the German Underground Hospital, which is inland at St Peter's (Figure 4). Even at that time the site, now known by its wartime name

Figure 5 Ukrainian slave workers, pictured during the German Occupation, from the Jersey War Tunnels brochure. (Jersey War Tunnels)

of Ho8 or Hohlgangsanlage 8 Tunnel Complex, was an unadorned site on the tourism route: it was a simple and stark reminder of the construction work carried out over three years by prisoners of war, many of whom were injured or died in the process of building the 1 km defence work. Six thousand tonnes of concrete line the tunnels, for which thousands of tonnes of rock was blown out, the raw edges of this now left in poor light as a reminder of the conditions in which the prisoners worked. The Jersey War Tunnels Website states frankly that the workforce 'included hundreds of forced labourers from all over Europe, including Russian and Polish prisoners who were treated little better than animals'.[26] Many of them were labourers of the Organisation Todt, foreign workers who were billeted at a vast seaside dance hall, before facing the appalling conditions at Ho8. The West Park Pavilion was later restored to its prewar glory and has only recently been demolished.

The Germans regarded the Ukrainian Russian workers in particular as literally 'sub-humans' or *Untermenschen*, and the Jersey War Tunnels provide a graphic reminder of their slave conditions (Figure 5). The latest edition of Madeleine Bunting's account reinforces this most forcefully with hitherto untold testimonies of many who worked at

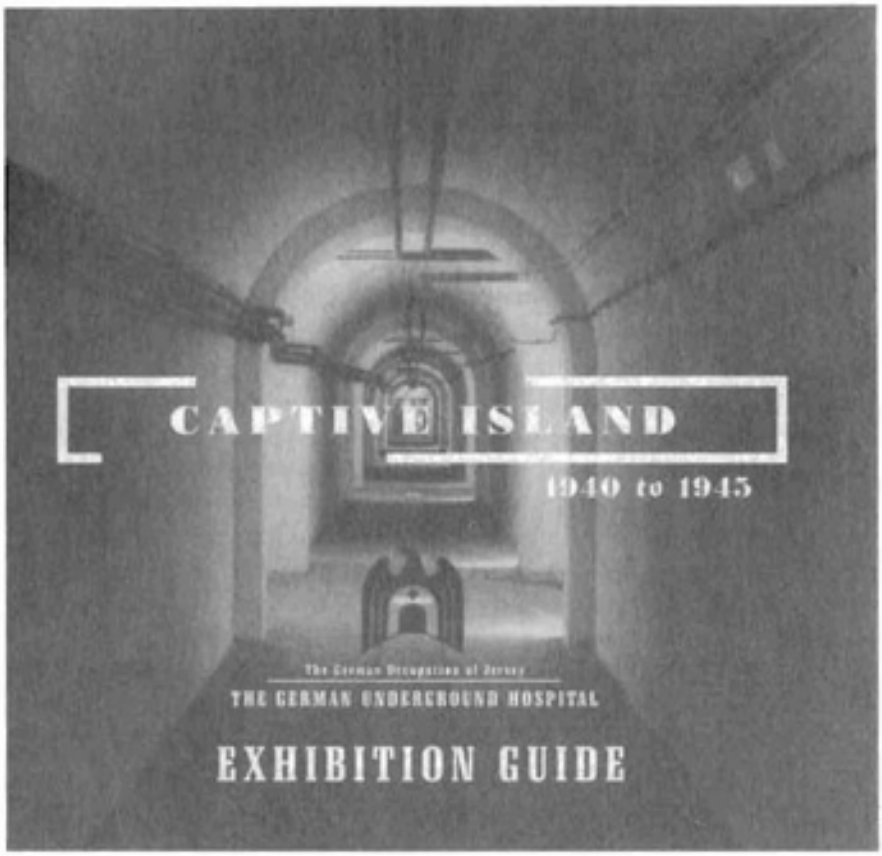

Figure 6 Cover of the Jersey War Tunnels brochure. (Jersey War Tunnels)

Ho8 and on other defence works in the Channel Islands. Ho8 was originally intended to be a bombproof barracks, store and workshop, but it was converted into a casualty clearing station, capable of operating on and treating 500 casualties should there be an Allied invasion of Jersey. Hence it was known locally and generally as the 'German Underground Hospital' until 2003.

Over the years, the original site has been modified, mindful of a need to provide a context for this traumatic episode in history. Its sensitive redevelopment as 'The Jersey War Tunnels', opened in 2001, produced an award-winning visitor attraction that deals with the challenge of providing a narrative to satisfy those who lived through the war on the island and have personal recollections (Figure 6). It also engages the broader public by presenting a lesser-known aspect of Second World War history. It is not the only Occupation exhibition on Jersey, but it is the largest. Its main exhibition space, called 'Captive Island' (Colour plate 10), is sited within an artefact, the galleries of the Ho8 complex. At a cost of £1.5 million, the exhibition used traditional artefact displays and recreated room settings, film, photographs and the latest technology to give a moving account of the Occupation. Visitors are confronted first by the sounds and

atmosphere of prewar Jersey, where visitors – among them Jacquetta Hawkes – were delighted by the Continental ambience of a place so close to home; Londoners, including my grandparents, left the grey of England for this island warmed by the Gulf Stream, many entertaining lavishly in the grand manor houses they built in the undeveloped inland of the island, or in villas overlooking the sea. In 'Captive Island' the jazz of the halcyon days of the 1920s and 1930s gives way to the sound of newsreels and air-raid sirens.

Given the islanders' sensitivity about the Occupation, and particularly wartime collaboration, the *Captive Island* display does not shy away from raising the issue. This has led to an unusual (re)telling of Jersey's wartime story. The reality of the invasion and Occupation is relived in newsreels and tableaux, some using traditional reconstruction techniques, others demonstrating a revisionist approach to Channel Island history, which asks visitors how they would have responded during the Occupation. A life-size tableau asks what they would have done if faced with a German soldier offering an ice cream to their child. Other artefacts include letters to the German command informing on those who possessed strictly forbidden radio sets, or were thought to be planning escape: the informants were sending their fellow islanders to certain imprisonment and possible death.

The Allied invasion of the Channel Islands never came, and the 'hospital' was not required. However, the islands' final liberation, when Germany surrendered on 9 May 1945, brought new dilemmas which are also addressed through the Occupation documents, letters and press cuttings: the end of the war led to swift retribution for those known to have profited during the war years, and many of those women who had had relationships with the German soldiers – some marrying them, some bearing children – are recalled in graphic detail by the use of the name 'jerrybags'. These women were tarred and feathered, and chased through the streets, even as their fellow islanders were celebrating the Liberation.

The Jersey War Tunnel complex is swiftly becoming an island institution, with a wartime research centre, a visitor centre and café – featuring photographs assembled by retired curator Joe Mière, who was imprisoned by the German secret police – a Jersey War Trail, and a Garden of Reflection, which includes plaques dedicated to commemorate the Jersey residents who died as a direct result of the Occupation: some 50 people have been named so far, and research continues. Visitors also walk through the galleries *with* an artefact, a tangible reminder of a human story: in exchange for their ticket they receive a reproduction of an actual Occupation identity card relating to one of the real-life individuals featured in the *Captive Island* (Figure 7).

Some of those working at the site have personal links with the Occupation through parents or other surviving relatives, or have

PARTICULARS
(NAHERE ANGABEN)

The holder of this Card TURNER Belza Althea
(Inhaber dieser Karte ist)

Residing at Rialian, Bagot Road, St. Saviour
(Wohnhaft)

Born on the 1. 7. 1923
(Geboren am)

Single, Married, Widow or Widower S
(Ledig, Verheiratet, Verwitwet)

Colour of Hair Brown
(Farbe des Haares)

Colour of Eyes Blue-Grey
(Farbe des Augen)

Signature Belza Althea Turner
(Unterish)

Take your identity card to the Sanctuary and find out more about your character in the Joe Mière Collection

Figure 7 The 'ID card' distributed to visitors to the Jersey War Tunnels. (Jersey War Tunnels)

heard the stories of that time directly from those who lived through it. Some will acknowledge the silence of their parents' generation, largely a concern about being misjudged or their actions misunderstood. (Madeleine Bunting's book was not universally well received on the islands, although critically acclaimed elsewhere.)[27]

Considering Jersey's artefacts

Contemplating the remains of the built artefacts of the Occupation, Bunting offers a reminder of the fragile state of nascent modern archaeology, where the past is not yet fully formed as 'history': 'The concrete bunkers are now overgrown with brambles, and the anti-tank barriers serve as seawalls. It is hard to imagine the suffering their construction entailed now, especially on a sunny summer's day, families picnic on their concrete bulk and the beaches are dotted with the brightly coloured towels of holidaymakers. Even the dank, dark tunnels of Guernsey, Jersey and Alderney, used for fuel and ammunition depots and underground hospitals, have almost lost their power to disturb. Having survived the depredations of generations of inquisitive children and memorabilia hunters, several have been converted into highly successful museums, bustling with coachloads of tourists snapping up souvenirs and scones.'[28]

As a journalist and a modern historian, Bunting has performed an act of archaeology, redeeming the nameless in the manner that

Hawkes, 50 years before, urged her fellow excavators to see the individual in a set of bones. Bunting notes: 'A few scraps of graffiti, such as a star of David, or initials scraped into the setting concrete, hint at the hundreds of men and boys who lost their lives building these vast monuments to Hitler's grandiose ambitions. For the last fifty years, most of the individual workers have remained nameless and faceless. Little was known about where they had come from, how many of them were brought to the islands, the conditions of their lives there, how many died or what happened to those who survived the war.'[29]

Bunting, who carried out her initial research in 1992 and 1993, revisited the subject to look in particular at the fate of the Jews on the islands, publishing a revised version of *The Model Occupation* in 2004. She used that opportunity to reflect on how the islanders had responded, and were continuing to respond, to their personal histories becoming public. She notes: 'For many countries occupied by Germany in the Second World War, facing up honestly to their wartime record has been a slow, piecemeal and painful process, because communities were so bitterly divided. What is evident [...] is how far Jersey has come.'[30] Bunting attributes much of this to the Bailiff of Jersey, Sir Philip Bailhache, one of the postwar generation of Channel Islanders, who has spoken openly about the need to acknowledge all aspects of the Occupation, not least the role of the islands in Holocaust history, and the moral dilemmas faced by the islanders who knew of Jews living nearby.[31]

In recognition of this, the collection of artefacts of Jersey's Occupation put on show to the public has been expanded to include items relating to this hitherto buried – and painful – part of the islands' wartime history. The Occupation Tapestry Gallery in the Jersey Museum at St Helier now includes a display of a certificate and a medal awarded to Albert Bedane, an islander who was honoured – 24 years after his death – by the Holocaust Centre in Israel for hiding a Dutch Jewess at his home. When Bedane died in 1980, his heroism was unnoted. Only in recent years was his life illuminated by the president of Jersey's Jewish Congregation, Frederick Cohen, during research for the monograph 'The Jews in the Channel Islands during the German Occupation'.

Bunting, so haunted by the subject to return to it after almost 10 years, also gathered additional stories from Occupation survivors in places as far as Russia, Ukraine and Poland – people 'who were astonished', she writes, 'that anyone was interested in the memories they had buried in their hearts for half a century, and which some of them were telling for the first time'.[32] In this respect these traces of cultural identity, if not as prominent as those of Jersey's thriving Portuguese community, nor as elusive as those of the ancient Iberian

settlers, nevertheless extend the degree to which the Channel Islands are mapped onto the world.

Conclusion

As Julius Caesar's heroic telling of the Gallic Wars has been scrutinised and revised over time, so will re-evaluations of the Occupation continue, with the benefit of multiple stories and the perspectives of both the occupied and the occupiers. But before long, those islanders who lived through the events will no longer be alive to tell their story, to illuminate the artefacts of Occupation contained in homes and museums. These vestiges and remains – from buildings, to documents, to memorabilia – will become part of the interpretational process, to be reviewed and considered broadly, in the larger context of war heritage and military archaeology, and also as micro-histories particular to person, place and situation. As the research centre at the Jersey War Tunnels develops, the range of researchers will add their perspectives to those things behind glass. Those objects that cannot be scrutinised today will have an accruing value which grows out of detachment: the dis-connection of objects allows a reinterpretation which, although sensible to the personal context is, I suggest, less sensitive to it. Over time then, these artefacts of Occupation will gain meaning as the various interpretations – those of the German Occupiers, the islanders, the British mainlanders – offer up their take on the events of 1940–45. There is a poetic resonance to this: the sense of an object offering up a touchstone to many histories is the stuff of artefacts which reach beyond the ascribed meaning and into the realm of the personal and particular. The museum scholar Susan Pearce has noted: 'The object is inexhaustible, but it is this inexhaustibility which forces the viewer to new decisions.'[33]

Unlike what might be regarded as the more traditional artefacts of archaeology, that is those ancient ones that are invested with a history and biography by the archaeologist and the museum visitor, the Occupation material sits in a liminal state: known by those who lived through the event, while also passing into history.[34] When an appreciable time has passed since the events of the 1940s, it will be interesting to see whether the artefacts become more (or less) 'understood' by those working with documents to guide them and, perhaps, the perspective of a revisionist history of the Channel Islands Occupation.

Less conceptually, the wartime bunkers, now seen as significant monuments to be catalogued and conserved, exist today both as tourist attractions and as symbols of five years of islanders living with an enemy with whom they shared a small and bounded landscape. Once the first-hand memories are lost to the present, the memories will join other narratives of those who recorded their stories in journals and books, or had them documented on radio and television, or gave

them in oral history interviews. But what will be missing is testimony from those who have no desire to collaborate with the demands of history. My mother is one of a generation of Occupation survivors who either cannot discuss, or choose not to discuss, those years under German Occupation, and for whom artefacts – and the stories of Hawkes, Bunting and others – have formed my personal past.[35]

Acknowledgments

The author would like to thank John Brooker, Special Collections, J B Priestley Library, University of Bradford, Chris Addy, Collections Manager, Jersey War Tunnels, and Chris Fowler for their help with this chapter.

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13 *The Complete Guide to Jersey* (London: Elliot Stock, 1896), p27
14 Note 13, p29
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18 Note 15, p222
19 Hawkes, J, note 9, p18
20 Hawkes, J, note 9, pp128–9. Hawkes's evidence came not least from a lengthy correspondence with H L Stapleton, on the Jersey finds of Roman and Gaulish coins, and with Stapleton, N V L Rybot of the Société Jersiaise and Derek Allen, on the St Brelades coin hoard.

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23 See http://www.jerseyheritagetrust.org/sites/hougue%20bie/hougue.html. The site's modern intrusions also include a Victorian well and latrine, found during excavations by Mark Patton and George Nash in the 1990s. See http://www.georgenash.freeserve.co.uk/neolithic.html and Patton, M, Rodwell, W and Finch, O, 'La Hougue Bie', excavation report, Société Jersiaise, 1999.
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Barton C Hacker

Objects at an exhibition: reflections on 'Fast Attacks and Boomers'

In April 2000, 'Fast Attacks and Boomers: Submarines in the Cold War' opened for what proved to be a three-year run at the Smithsonian Institution's National Museum of American History in Washington DC. It closed in June 2003. Both submarines and the Cold War were firsts for a major exhibition in the museum. In its final version, 'Submarines in the Cold War' comprised ten sections divided among three major themes, one primarily technological – how submarines work and fight – and two less technologically specific: how nuclear subs interacted with US foreign and military policy and how men and women interacted with submarines.

How some of the objects in the exhibition acquired to my mind special significance is the central concern of this paper. This is very much a personal reflection, but the exhibition was hardly a one-man show. It was, in fact, the work of a sizable team. When I refer to 'we' in my remarks, I'm including not only the two other curators who worked with me but also the project manager, two retired submarine officers who were regular consultants, the design and production team contracted for the exhibition, plus any number of technical specialists and outside advisers.

The Cold War context

The exhibition began with a sweeping photomontage of the Cold War years which featured a video introduction by the veteran broadcaster Walter Cronkite, himself something of a Cold War icon. The largest and most striking images recalled iconic Cold War events such as the Berlin airlift and nuclear weapons tests (Figure 1). Below these images were two photo timelines: one devoted to cultural events of the Cold War years, the other to milestones related explicitly to submarine activities (Figure 2). This curved 12-metre (40-foot) wall provided the context for the exhibition at the same time that it led visitors in. The wall visually displayed the consequences of new technology for the military roles of submarines at every level, from tactics through operations to national strategy and foreign policy. Interspersed among the images several text blocks addressed such broad topics as Cold War origins, the Vietnam wars and the cost of submarines.

Following the Cold War panel into the exhibition brought visitors to a brief survey of the history of submarines before nuclear power,

Figure 1 In July 1946, Operation Crossroads at Bikini Atoll in the Pacific received extensive news coverage. This image of the second test in the series, an underwater shot code-named Baker, quickly achieved iconic status. (US Navy)

told chiefly with graphics and text. Deeper into the exhibition, other sections elaborated aspects of the varied roles of nuclear submarines in underwater research and exploration, as well as their primary Cold War missions – nuclear deterrence, antisubmarine warfare and special operations – using text and graphics. Particularly striking was a chronological set of maps that US Naval Intelligence declassified specifically for the exhibition. Hand-drawn symbols graphically illustrated how Soviet missile submarines gradually retreated during the last two decades of the Cold War from their initial deployments in American offshore waters to an Arctic bastion along Russia's northern coast. Withdrawal reflected in part the growing range of missiles, but even more the increasingly sophisticated and aggressive antisubmarine warfare practised by US forces.

Submarine technology and weaponry

One object was not in the show, physically speaking, but was nonetheless a compelling presence – the submarine itself. Our space was not big enough for an entire submarine. We settled for presenting sections of the interior, with one exception: a three-quarter-scale model of a submarine sail, displayed as if on a diving submarine, dramatically positioned in tense apposition to the Cold War wall. Often misidentified as a conning tower, the sail is quite different. Because conventional submarines were primarily surface ships that hid only briefly under water, they required a bridge, the conning tower. Nuclear submarines, in contrast, spend most of their time under water. The sail

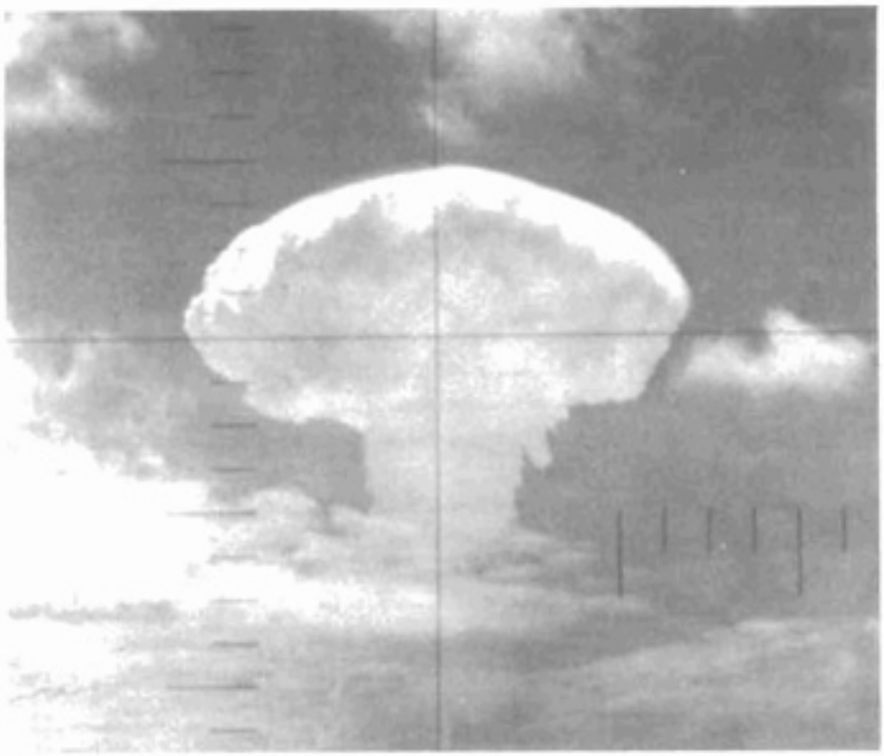

Figure 2 On 6 May 1962, a submerged submarine launched a standard Polaris missile toward Christmas Island in the Pacific in a test code-named Frigate Bird. Just over a thousand miles late and still 11,000 feet high, the warhead exploded as planned. A second submerged submarine observed and photographed the detonation through its periscope, as shown here. This was the only US test of a nuclear missile ever conducted through a complete flight profile from launch to detonation. (US Navy)

serves primarily as a streamlined shroud for the boat's periscopes and antennas. In nuclear submarines, the bridge equivalent is the attack centre in the heart of the ship.

A reconstruction of the attack centre inside the exhibition (Colour plate 11) gave visitors a glimpse of the submarine's nerve centre. All the equipment and furnishings came from USS *Trepang*, one of the attack submarines rendered expendable by the end of the Cold War. The Navy allowed us to visit the boat early in the exhibition planning to tag the items we wanted for this exhibit. Complementing this section, three short videos offered glimpses of fast attacks in action. Based on other material that the Navy declassified for this exhibit, they displayed three types of mission: (1) Tracking a Soviet submarine in the Atlantic (re-enactment of a real 1978 mission, with animated depictions of the manoeuvres of the two boats); (2) Observing a foreign surface-to-air missile test (re-enactment of a historic mission illuminated with authentic periscope photography); and (3) Under-hull survey of a US surface ship (a modern-day training exercise amplified with animation and periscope photography). Set against the background of authentic attack-centre equipment and instruments, the videos became extraordinarily compelling.

Displayed in and next to the attack centre were the submarine's electronic systems, including sonar, radar and radio. Sonar – an acronym for *so*und *n*avigation *a*nd *r*anging – is the most important.

Sound is the primary source of information about the world outside the hull of a submerged submarine, detected by instruments and translated into visual data by computers. It allows submariners to locate and track their targets, identify potential threats and determine their own position, all while remaining safely submerged. Active sonar, which bounces sound waves off the target and picks up the reflected echoes, is rarely used because it is too easily detected. Passive sonar detects sounds generated by the target, such as clanking machinery or noisy propellers. To the sonar console on display we added a so-called acoustic workstation. Interested visitors could watch an animated video and hear some of the same sounds that a sonar operator might, then take a brief test to identify the sounds.

Next to the acoustic workstation we addressed submarine power and propulsion. The control panels for power systems – the so-called manoeuvring-room consoles (Colour plate 12), three in all – represented a particularly striking display of submarine workings. During operations, one petty officer would have manned each console, the three supervised by the engineering officer of the watch; they monitored and controlled the submarine's entire nuclear power plant. One console controlled the steam turbines. The centre console was the nuclear-reactor control panel, while the third controlled the electrical system. Heat from the reactor converted water to steam in a closed system. The steam drove the turbines that provided the boat's power, which was fed to the propeller shaft as well as the electrical system.

Displaying consoles like these in public – even most crew members had never seen them – required modifications to protect sensitive classified information about the design and operation of nuclear-powered submarines. Where necessary, scales on instrument faces were modified, instrument labels altered, or instruments repositioned, and some classified nuclear instrumentation was removed. The Navy worked closely with us to keep such changes to a minimum and preserve overall appearances. Our biggest problem was convincing overzealous Navy officers not to clean up the worn spots and coffee rings the consoles had acquired during their active life aboard the USS *Sand Lance*. The relatively small size of the nuclear control panel challenges the common notion derived from civilian nuclear power-plant control rooms of huge and immensely complicated controls. The fact that a nuclear sub is simply another kind of steamship also strikes me as beguiling.

Situated directly behind the model sail were the first of several displays devoted to the new technology of undersea warfare deployed by the United States from the 1960s to the 1980s, including weaponry and ballistic missiles. In addition to models of the several types of ballistic missiles deployed on US submarines, the Navy provided us with both a standard torpedo and a Tomahawk cruise missile (both without their inner workings). More unusual objects on display were

a weapons shipping hatch with hand ratchet; a missile guidance access door, watertight closure and portable crane; and an attack-centre indicator panel (ACIP) and missile-firing key. Unexpectedly declassified for our exhibition were a re-entry vehicle (RV) protective cover and a Trident I missile nose fairing and aerospike.

Living with submarines

We had objectives beyond the technological in this exhibition. It appeared, after all, in a museum of American history, not a museum of science. About a third of the exhibition examined the human impact of technological change on the lives and activities of those who built and maintained subs, the sailors who crewed them, and the families who completed the special community of submariners.

Nuclear submarines challenged conventional ideas of life at sea. Sailors had to learn new skills and adapt themselves to living in a radically confined environment for weeks on end. The changes to life aboard ship were profound. Because a submarine's weight equals its displacement (i.e. its volume), minor changes in equipment weight or volume cannot be so easily compensated aboard a submarine as on a surface vessel, where deck space can be adjusted or draft slightly altered. Everything has to fit within a submarine's pressure hull and that is why a submarine is so inherently crowded. For the same tonnage, a submarine has roughly one-third the interior volume of a surface ship. Cramped quarters are the hallmark of life aboard a submarine.

Regulatory restrictions prevented us from reproducing, to the extent we would have liked, the cramped interior of even large nuclear submarines. The small section showing crew berthing (Colour plate 13) offered visitors a glimpse into the tight little world of the submariner. Just how tight was shown by the stacked bunks from USS *Trepang* on display. The sailor's personal space was limited to his bunk. The shallow bin beneath the mattress was the sailor's only storage space for all his clothing and any other personal items for the duration of a patrol. On a fast attack boat such as *Trepang*, the crowding could be so great that even one bunk might be more than a sailor could call his own. Three men may 'hot bunk', or share two bunks between them, so that when one is on duty another is asleep.

On the back wall of the exhibition we juxtaposed a clothes washer and dryer with a trash disposal unit (TDU) breech (Colour plate 14). In doing so, we intended to impress viewers with some of the complexities of the submarine environment. Finding an ordinary commercial washer and dryer on a nuclear sub should surprise many visitors. We wanted to emphasise, unobtrusively, that not everything was hi-tech. The Navy advisers in fact opposed including these items, just because they weren't anything special. But we thought that was precisely the point: a single, not-very-large washer and dryer serving

an entire 120-man crew for months at a time also seemed to bring home some of the strain of the submarine service. Early in the Cold War, submarines had space for only a single clothes washer that handled less than 4 kg (8 pounds) of dirty laundry. But even when bigger washers could be installed, as later happened, machine time always had to be rationed.

In contrast to the mundane means of clothes washing, trash disposal takes a more exotic turn on a nuclear submarine. Trash disposal, like many other activities that are relatively straightforward ashore, requires special arrangements in a submarine. If you pause to think about the amount of trash you produce in a week, then multiply that by 120 (the crew) and then again by 8 or 9 (two-month patrol), you begin to appreciate how important the TDU is. Trash is tightly compacted in a cylindrical steel-mesh container. A 3 kg (7 pound) weight ensures that it sinks to the bottom of the sea. Since the end of the Cold War, submarines operate under stricter rules about when and where they can discharge trash overboard, and some materials, such as plastics, can no longer be discharged at all. TDU operation can be relatively noisy. When a submarine is rigged for quiet running, trash can accumulate on board for days or even weeks, lest the sounds of disposal alert a potential foe.

One of our concerns about this exhibition in a history museum, as I have already mentioned, was to move beyond the machines themselves to the social systems in which they are embedded. This accounts, at least in part, for the Cold War setting and for our attention to training and maintenance, limited though it had to be in this relatively small exhibition, as well as crew life aboard a submarine on patrol. We believed the families of the submariners were no less important, but getting them into the exhibition ran into considerable opposition from those who felt they really weren't part of the Navy. We strongly disagreed, and a brown grocery bag (Figure 3) was one of our arguments. It bears the slogan, 'Navy Wife. (It's the toughest job in the Navy).' To attract, train and retain people in the all-volunteer military with skills in modern technology, by the mid-1970s the armed forces began to acknowledge the contributions of spouses and families to the military mission. These efforts included slogans on commissary shopping bags, as well as more substantial action.

Figure 3 To attract, train and retain people in the all-volunteer military with skills in modern technology, by the mid-1970s the armed forces began to acknowledge the contributions of spouses and families to the military mission, an important theme in the exhibition. These efforts included mottos on commissary shopping bags, as shown here. (National Museum of American History)

Submarines in the Cold War

Historically, the development of nuclear-powered submarines aroused controversy both within the military establishment and in the public arena, though for very different reasons. Internally, the issues were money and questions about the feasibility both of nuclear propulsion and submarine-launched ballistic missiles. External opposition derived in part from fears of nuclear power, which applied to all nuclear-powered ships. Opposition to ballistic-missile submarines, which led

to demonstrations and picketing outside submarine bases at home and abroad, stemmed from concerns by some members of the public about the morality of nuclear deterrence as national policy.

Preparing our exhibition was not so contentious. The Navy expressed some concern about the label that discussed the cost of submarines, admittedly a complex issue to address in 200 words or fewer. That was worked out. The other issue involved the place of women in the story, which centred on the wives of submariners in the section on life ashore. Here the results were less satisfactory. The problem seemed to be chiefly one of perspective. We wanted to tell the story from the women's viewpoint. The Naval Submarine League representatives saw it from the perspective of the men at sea. They kept trying to make that portion of the exhibition a tale of wives longing for their husbands to return. That women, even Navy wives, might have lives of their own was almost literally unimaginable. Since ex-Navy people ran the production company, we achieved only limited success in imposing our version of the story. If you looked closely at the exhibition, you would have seen that the section on life ashore got short shrift compared with the rest of the exhibition. Our attempt to include in the epilogue some discussion of the prospect of women serving aboard submarines likewise met concerted opposition. This issue we didn't press, accepting the argument that this was not, properly speaking, a Cold War matter.

Overall, though, given the potential problems of exhibiting a topic still fresh in many minds and of much concern to many people still active, we had a remarkably trouble-free exhibition process. Although the physical exhibition has been deinstalled in the National Museum of American History and its future reinstallation at the Naval Historical Museum remains a hostage to fund-raising, a virtual exhibition lives on. At the Website http://americanhistory.si.edu/subs/index.html you can obtain a pretty good idea of what the exhibition looked like.

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Robert Friedel

'The Price of Freedom: Americans at War'

'The past is essentially unknowable, forever lost to us, and in museum displays its material traces are reconstructed into images of time past which have meaning only for the present, in which their genuinely intrinsic relationships to the past are used to authenticate a present purpose. That present purpose, it can be argued, usually has the ideological motive of maintaining the status quo, of showing how smoothly the processes of the past led to the present day, of suppressing dislocation, fragmentation and false starts, and of reinforcing local value systems, of conservation rather than an opening to change and redemption.'

Susan M Pearce, *Museums, Objects, and Collections* (1992), p209

Guns and uniforms... guns and uniforms. The first impression of a visitor to the National Museum of American History's new hall of military history, entitled 'The Price of Freedom', is just that – guns and uniforms. In this exhibition, the trajectory of American military history is followed from the middle of the eighteenth century, when European colonial powers battled each other as well as the native populations for control of North America (Colour plate 15), to the beginning of the twenty-first century, when the world's sole superpower imposed its will on parts of the Middle East through force of arms. The display comprises over 18,000 square feet of exhibits and about 800 objects, only a fraction of which turn out to be guns and uniforms.

Indeed, the list of objects in 'The Price of Freedom' runs from 'accoutrements' (a shovel, for example, Colour plate 16) to 'vehicles' (such as a Vietnam War-era 'Huey' helicopter, Colour plate 17), and encompasses the heroic and famous (George Washington's camp kit, or the stuffed body of General Philip Sheridan's horse, Winchester) as well as the mundane (a Hills Brothers coffee jar, representing Second World War rationing). In much of the exhibition, these objects are surrounded by a sea of images, which themselves range from murals depicting the signing of the Declaration of Independence to television monitors showing anti-Vietnam War demonstrations.

This is an exhibition in which little expense has been spared, few fashions of modern display have been neglected, and no group has been left voiceless. The one thing that is conspicuously missing, however, is a message. There is no introductory statement to tell the

visitor this exhibition's purpose or point of view. All that introduces us to the experience, besides the title, is an expensive-looking display of images, faces and models against which such words as 'death', 'power', 'allies', 'controversy', 'conflict' and 'sacrifice' are projected. Exhibition literature and Web pages help a little, telling us that 'this exhibition examines how wars have shaped the nation's history and transformed American society'. This might serve to alert the thoughtful visitor to the fact that the exhibition is less about military history, in its usual sense, and more about the social meaning of warfare in the American experience. Unfortunately, even this bit of clarification is muddied by the exhibition's actual combination of displays and interpretations. The social 'experience' of warfare is mixed in with some fairly straightforward history of campaigns and battles (although not a great deal) and with much of the basic hardware of death and destruction (lots of guns). The exhibition, in other words, attempts to be all possible things to all possible audiences, and suffers the customary fate of such attempts in avoiding failure by neglecting to give any clear measure of success.

What role do the objects in this exhibition play? Ideally, one answers this question against the background of an exhibition's clear purposes, but this is impossible here. In an exhibition in which historical artefacts play a central role – the display of a collection of guns, for example – we need not demand too much of curators to tell us their intent; the objects convey this themselves. But in a display in which objects are embedded in complicated settings, surrounded by images and reproductions and the like, the challenges of ferreting out the objects' own stories and significance can be formidable. 'The Price of Freedom' does not help us greatly here; we cannot easily determine why we want to see the 'real' things of history, especially as unreal things – models, replicas, videos – carry most of the interpretive burden.

Weapons as exhibition artefacts

The most distinctive objects in military history are weapons. These are devices most of us never encounter in our daily lives and which have meanings and uses that are unique to the waging of war. As already stated, 'The Price of Freedom' gives the impression that it is filled with weapons of all kinds and sizes. Many of these, foreign as they may be to our daily experience, are familiar in an iconic sense – swords, muskets, cannon and bayonets are precisely what we picture in the mind's eye when we think of battle, and these mental pictures have been shaped by years of exposure to articles, books and movies. So what can an exhibition attempt to do with these weapons? They can be made part of a chronology, both of warfare and of weaponry itself. They can be analysed as technical artefacts, revealing their working and making. They can inform our understanding of the experience of

Figure 1 American-made composite musket from the Revolutionary War, assembled with a barrel bearing London proofmarks, a lock bearing French marks and the trigger and stock of an American manufacturer. (National Museum of American History)

war, of the material culture of the soldier. Each one of these functions places certain demands on the exhibition and on the visitor.

There is a sufficiency of weapons in 'The Price of Freedom' to provide a sense of how the weapons of war have changed over 250 years. The most prevalent class represented is the shoulder weapon – muskets, rifles, sub-machine-guns and the like. These have clearly changed significantly since the mid eighteenth century, and each conflict in the exhibition is represented by examples of such guns. The shoulder arm or weapon, indeed, would have made a useful thematic thread for this exhibition, suggesting just what museum objects can tell us about the experience of war that other media cannot. In some cases, the Smithsonian collections are remarkably and surprisingly rich, as in the American Revolution. Here we see muskets from all types of combatants – not just colonials and British, but Hessians and French as well. A wonderful example is a 'composite musket', in which parts from British and French guns have been cannibalised to complete an American-made firearm (Figure 1). Here is an object that captures particularly well the improbability of the American war for independence. It is also an object that displays what museums can do best – show us that which is not self-evident about an object but which close study can reveal. It is the London marks on the barrel and the French marks on the lock and American design of the trigger that indicate the mixed parentage of this gun – these are features not obvious to the casual viewer, but which the museum can reveal.

A mock-up of a Revolutionary War musket makes accessible the feel of the weapon, although the fact that we cannot lift it leaves out the experience of its heft, which must have been the most distinctive aspect of the foot soldier's physical experience of carrying his firearm, aside from its recoil on firing. It's too bad that even this limited access to the weapons is missing in the remainder of the exhibition, for the shoulder arm both changes and, in many ways, remains the same, throughout the history covered here. Few single objects could convey so well the relationships between soldiers' experiences as the years move on.

Furthermore, technical changes in shoulder arms can become evocative of different experiences and different values. For example, Sam Houston, the 'father of Texas independence', possessed a rifle with a very unusual breechblock (Figure 2); this so-called 'harmonica lock' carried five shots, which could be fed sequentially into the breech

Figure 2 This rare nineteenth-century Henry Gross rifle with an unusual breechblock belonged to Sam Houston, the 'father of Texas independence'. (National Museum of American History)

by sliding the block across. Nothing is said, however, in the exhibition about the efficacy of this design, why it was so rarely used (something we have to infer), and whether it led to any more successful designs. Still, it is of real interest to learn that a notable such as Houston was ready and willing to use such an experimental gun.

The Houston rifle is in contrast – although this may not be obvious to the visitor – to other nearby examples. A display of a crate marked 'Bibles' is filled with Sharps carbines, of the sort shipped to Kansas in the 1850s by antislavery activists. While this is a nice way of representing the sometimes violent clashes that preceded the outbreak of the Civil War, the display is fake – the Sharps rifles are genuine, but the crate is a prop and weapons of this type were unlikely to have been distributed in this way. The casual manner in which this exhibition shifts from real to fake undermines the value of the authenticity that gives some parts of the exhibition real power.

Another mid-century innovation was the Minié ball, a lead bullet with a hollow at one end (Colour plate 18). When it was fired in a rifle, the ball expanded to fit the rifled grooves of the barrel and thus was spun rapidly as it exited the gun, increasing accuracy. The Minié ball is shown, accompanied by a large cutaway model to show the structural features that made the ball such an effective bullet. This is one of the few places in the exhibition where the technical improvements to weapons are carefully explained (this is done at a few other points, generally for artillery). When the exhibition enters the American Civil War, one of its largest and most complex sections, the Minié ball reappears, with the display of a shattered tree stump (Figure 3), less than two feet high, that was retrieved from the battlefield at Virginia's Spotsylvania Courthouse. There, on 12 May 1864, we are told, a large oak tree was struck by hundreds of bullets, a sylvan victim of a storm of gunfire that struck down some 2000 soldiers. Some of the Minié balls fired that day can still be seen in the tree's remains.

Competition: objects and images

The poignancy of this display is in contrast to much of the Civil War section of the exhibition, where many of the objects – uniforms, swords, camp equipment – have a static and detached character that is put into the shade by some of the sobering photographs (this, after

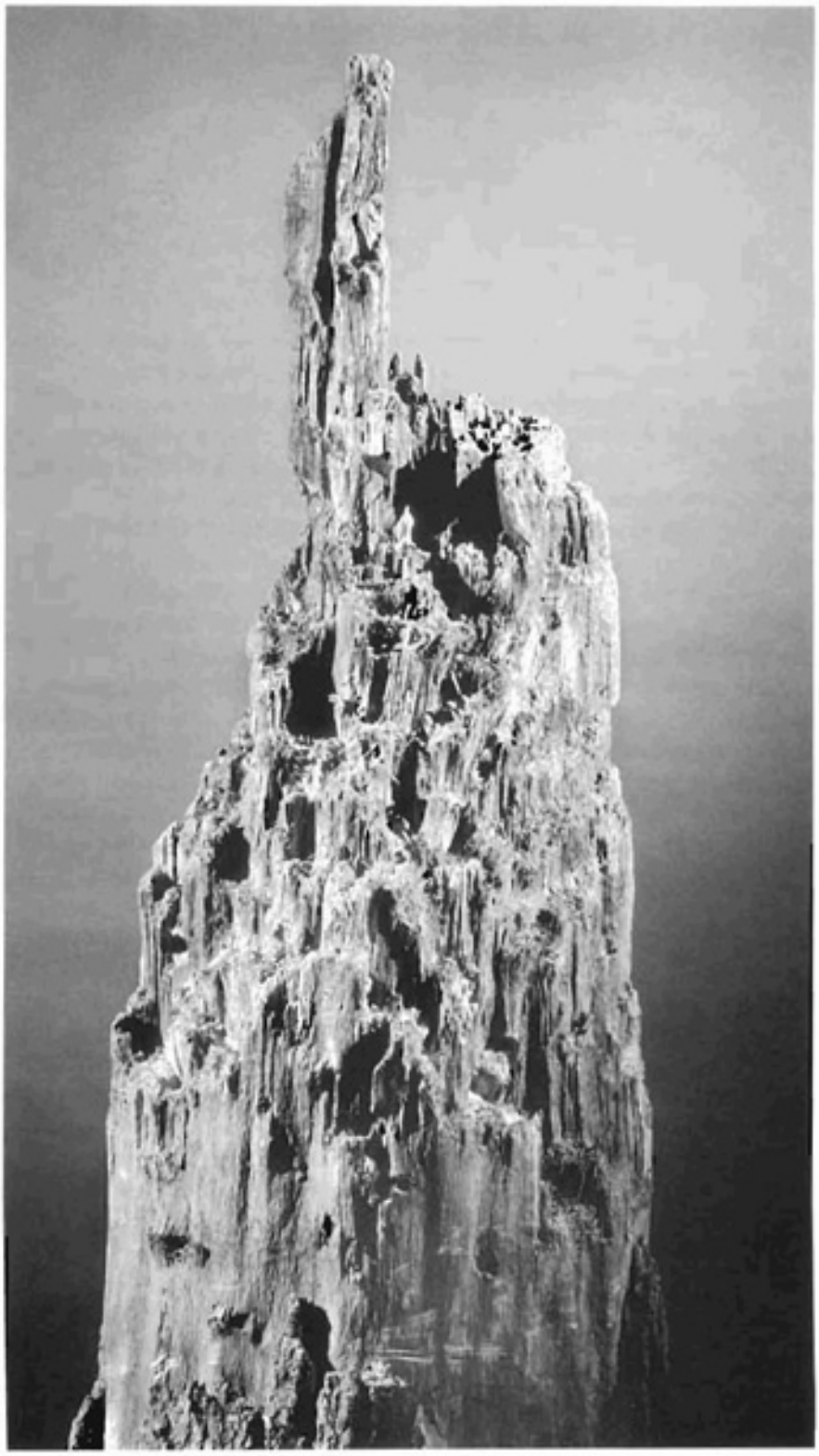


Figure 3 The shattered tree stump retrieved from the US Civil War battlefield at Virginia's Spotsylvania Courthouse. (National Museum of American History)

Figure 4 A nineteenth-century pistol made by Salola, a blacksmith in the Oconaluftee Cherokee settlement of Quallatown, North Carolina. (National Museum of American History)

all, was America's first photographed war) projected on the wall above some exhibition cases. Indeed, the Civil War section, the first that features war photography (itself not more than a half-dozen years old when the war began in 1861), marks an interesting shift in the exhibition. From this point the exhibition's objects and other graphics compete, often unsuccessfully in terms of emotional effect, with the stark images – black and white until the last few decades of the twentieth century – of soldiers and battles.

Flanking the Civil War, in both time and the exhibition, are cases devoted to 'Expansion', which includes the wars with Mexico and Spain and the Indian Wars, both in the East and in the West. Here the firearms are still present, but the display of American arms is joined by a couple of rather interesting additional items. A .28 calibre pistol (Figure 4) made by a Cherokee Indian blacksmith named Salola appears in a section devoted to the removal of Native Americans from the eastern part of the United States. The handiwork does not look exceptional, but that's the point – that white men's arms could be and indeed were manufactured by native people. A bit more unusual in appearance is a 'Homemade Filipino Rifle' (Figure 5) appearing in a case devoted to the Philippine War – the bloody conflict that followed the conquest of the Spanish Philippines by the United States in 1898. This gun is a remarkably crude and unpolished piece of work, but as such it seems particularly fitting to represent the desperate resistance put up by Filipinos against the Americans who had come to 'civilise' them. For nearly three years freedom fighters – insurgents, if you will – fought their 'liberators', at a cost of more than 20,000 Filipino dead and 4200 Americans. This visitor, at least, could not read the candid and straightforward description of this little-discussed episode in American imperialism without drawing chilling parallels with more recent history.

In these two cases, artefacts do in fact go beyond any images and words to convey messages. These messages themselves in fact resist verbalisation, and in the politicised environment in which a national museum has to function, particularly in areas as potentially controversial as military matters, it is particularly important that curators include objects such as these guns that are open to a range

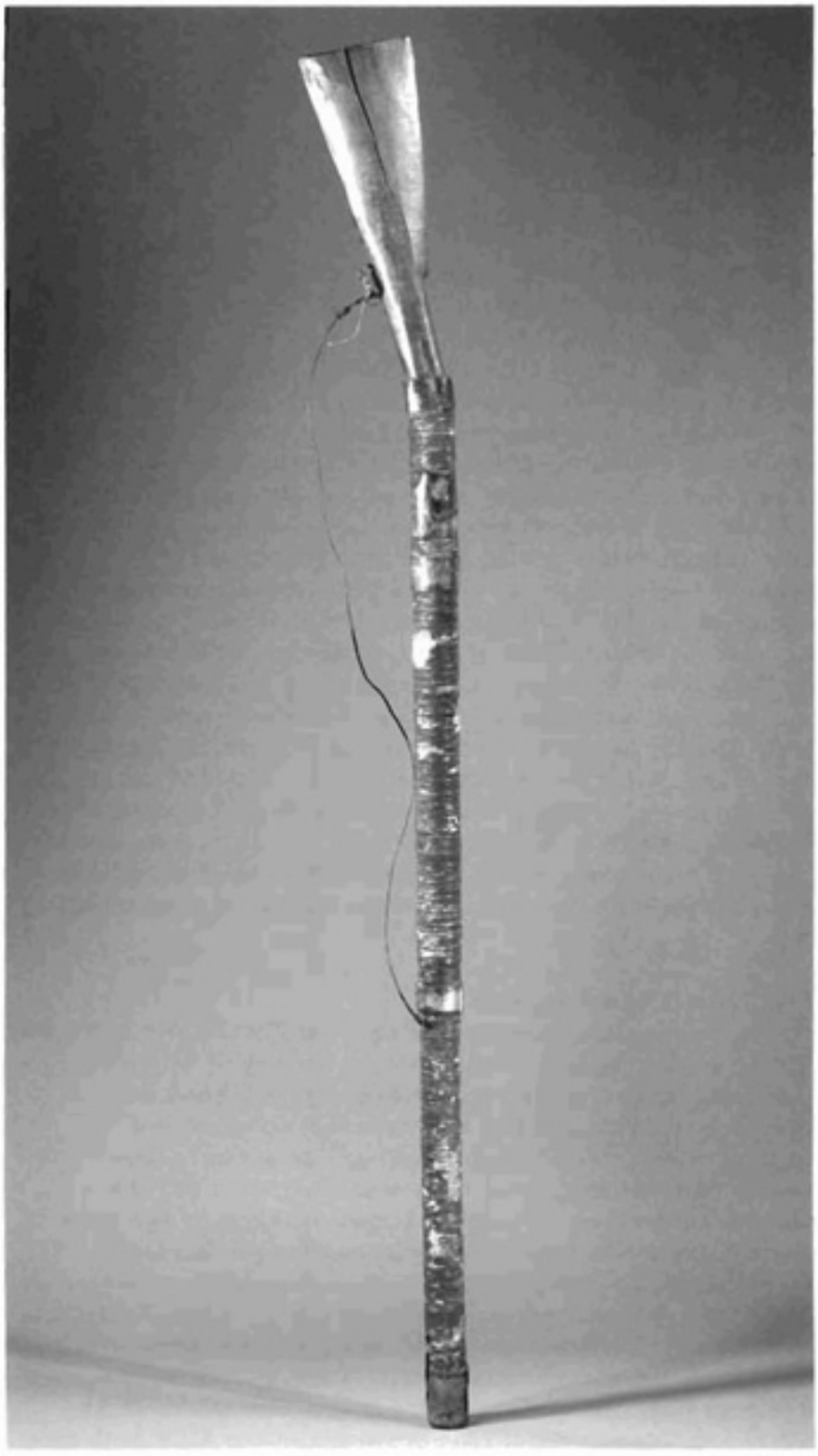


Figure 5 The 'Homemade Filipino Rifle' appearing in a case devoted to the Philippine War. (National Museum of American History)

of interpretations, depending on the political vantage point that is brought to them. Salola's pistol and the Filipino insurgent's rifle are objects as foreign to their makers as they are unconventional to their eventual American possessors. They bear eloquent if mute testimony to the cultural conflicts that are frequent but neglected features of American wars.

The second half of the exhibition covers the wars of the twentieth century and after. The First World War actually gets fairly short shrift, contained in a small exhibition area between the large Civil War and Second World War sections (in fact, the visitor passing from one to the other may easily miss it). The scale of the Second World War is appropriately overwhelming. Particularly significant here is the great attention given to the home front and the support personnel. The weapons are there, but their prominence is much diminished by the message of total mobilisation and the implications this had for life throughout American society. Large military objects are plentiful, from a full-size jeep suspended from the ceiling to parts of aircraft and some large guns. But more striking are the tableaux with soldiers in their barracks, women factory workers, a USO (soldiers' entertainment) stage, and the like. Here is a mixture, often hard to differentiate with precision, of real artefacts and props, reinforcing the impression throughout this exhibition that the artefacts are indeed often no more than props for vignettes that carry the real messages. That jeep hung from the ceiling, for example, cannot be inspected (except for the underside), but can be little more than decoration or symbol. The largest single object in the exhibition, a 'Huey' helicopter used in the Vietnam War (Colour plate 17), can be seen much more clearly, but it too is essentially a stage set, a setting for mannequins, video presentations and other depictions of the experience of modern jungle war.

The artefact as background

Herein lies the puzzle that runs through 'The Price of Freedom' – how are the artefacts to be more than settings, decorations or symbols, particularly as they appear with stark photographic (after 1860, at least) and cinematic (after 1939) images that document war and sacrifice more eloquently and evocatively than any three-dimensional object? This exhibition, better than most, illustrates a dilemma in which many modern museums find themselves: how do you make artefacts speak effectively to audiences much more accustomed to receiving messages from pictures, words and moving images? How do you do this, especially, when the images are of a particularly familiar and affecting type? One approach is to design an exhibition so that the artefacts are not incidental pieces but are clearly more prominent and more significant than supporting images. This exhibition does this in a few places – the displays of prisoner-of-war items, both from

the Civil War and from Vietnam, are good examples: here, the objects, small as they are, are the unambiguous focus. Oddly enough, when the objects are large – the Vietnam helicopter, for example – this focus is diminished by the imagery and other props nearby.

Large objects do not have to suffer this fate. Upon exiting 'The Price of Freedom' one sees, across an empty space, just past a garish shop devoted to toys, trinkets and booklets, a much older exhibition, the American gunship *Philadelphia*. In a quiet space, surrounded by labels that tell the artefact's story as well as the tale of its rescue, lies the oldest American warship. Despite its quaint understated display, this boat, raised in 1935 from Lake Champlain, where it was sunk in a battle with the British just a few months after the Declaration of Independence was signed, attracts visitors and tells a powerful story – just as we would wish a museum object to do.

'The Price of Freedom' highlights one of the core dilemmas of the general-history museum: the temptation to convey large and complicated stories, filled with many possible interpretations and meanings, by constructing a putatively 'objective' and 'balanced' image of historical events and circumstances. Such objectivity, as Susan Pearce pointed out in the epigraph to this article, is an illusion, but it is still a meaningful goal. This goal is meaningful and honest, however, only when it is carried out with the objects of the past as the primary actors on the historical stage. If these objects become only bit players, as in this exhibition, then the conservative, ideological weight of the exhibition, even if intentionally kept implicit, overwhelms everything else.

Barton C Hacker and Margaret Vining

European military history museums: a personal electronic and bibliographic survey

We have divided this compilation into three parts: (1) an annotated list of selected European military museums, with Websites, arranged by country; (2) a partially annotated list of general military museum Websites; and (3) an annotated bibliography of publications on military museums. In Part 1 we focus on traditional military museums of relatively broad scope that we believe to be of particular importance or interest, not only to the general public and military historians, but also to museum professionals, historians of technology and art historians. We daresay that scholars of many other stripes might find a visit to such museums instructive. One sociologist of our acquaintance certainly did. In addition to the selected museums, we have, where possible, suggested Websites that identify (and in many cases link to) other military museums in the same country.

With a few exceptions, Part 1 does not include museums centred on single units (e.g. regimental museums), branches (e.g. tanks), topics (e.g. Cabinet War Rooms), events (e.g. D-day) or other relatively narrow topics. It also excludes, again with some exceptions, naval museums, military aviation museums, and arms and armour collections (whether independent or in art museums); such museums require lists of their own. Museums and collections of this kind are included in Part 2, which lists Websites of a more general nature than those addressed in Part 1. Those interested in military museums may find these sites, which we have partially annotated, useful for further exploration. Finally, Part 3 offers a brief annotated bibliography of recent publications on military museums.

Part 1: List by country of selected European military museums

Austria

Heeresgeschichtliches Museum (Military History Museum), Vienna, http://www.hgm.or.at. Although focused on the military history of the Habsburg Empire from the sixteenth century to the First World War, Vienna's oldest museum houses some of the world's finest collections of militaria, with notable holdings of arms and armour, firearms, artillery, and military art.

For other Austrian (and Austro-Hungarian) military museums, see the section of the Links list from 'Austro-Hungarian Land Forces

1848–1918', by Glenn Jewison and Jörg C Steiner, which covers military museums and archives in Austria and Hungary: http://www.austro-hungarian-army.co.uk/links.htm.

Belgium

Musée Royal de l'Armée et d'Histoire Militaire (Royal Museum of Army and Military History), Brussels, http://www.klm-mra.be. Centred on the military history of Belgium since the eighteenth century, with wide-ranging collections of arms, uniforms, flags and military art, this traditional military museum especially emphasises the world wars.

Musée d'Armes de Liège (Arms Museum of Liège), http://www.museedarmes.be. Founded by the city and its gun manufacturers in the late nineteenth century, this museum is devoted entirely to the history of small arms from the fourteenth century to the present. At the time of writing it was undergoing renovation, its collections inaccessible.

For other Belgian military museums, see Belgium in ABCollection: Militaria: Military Museums Directory, http://www.abcollection.com/eng/museum/summary.php.

Bulgaria

Natsionalen Voyennoistoricheski Muzey (National Museum of Military History), Sofia, http://www.md.government.bg/nvim/_bg/index.html.

For other Bulgarian military museums, see Balkan Military History: Bulgaria Military History Tour, http://members.aol.com/balkandave/frmcon.htm.

Czech Republic

Voyenský Historický Ústav (Military Historical Institute), Prague, http://www.militarymuseum.cz. In addition to military historical exhibits at its headquarters, the institute maintains the new military historical museum (moved from Schwartzenberg Palace) in the Mihulka Powder Tower at Prague Castle, which now relies on up-to-date storytelling through vignettes.

For other Czech military museums and memorials, see CZeCOT: Tourist Server of the Czech Republic: Military, http://www.czecot.com/?id_tema=28. See also Prague, Heart of Europe: Museums, http://www.heartofeurope.cz/museum_6.html.

Denmark

Tøjhusmuseet – Dansk Forsvarsmuseum (Arsenal Museum – Danish Armed Forces Museum), Copenhagen, http://www.thm.dk.

For other Danish military museums, see Danish Military Historie: Museums, http://www.milhist.dk/index_uk.htm.

Finland

Sotamuseon julkaisuja (Military Museum of Finland), Helsinki, http://www.mpkk.fi/en/museum.

For other Finnish military and naval museums, see Maanpuolustuskor keakoulu: Sotamuseo, http://www.mpkk.fi/fi/sotamuseo/. See also Royal Swedish Academy of War Science: Finland: Museums, http://cgi.kkrva.se/eng/mwi/finland/museums.shml; and List of Finnish museums, http://www.axishistory.com/index.php?id=157.

France

Musée de l'Armée (Army Museum)/Musée National d'Armes et d'Histoire Militaire (National Museum of Arms and Military History), Paris, http://www.invalides.org/. Located in the Invalides, the French Army Museum mixes very impressive but traditional displays of Napoleonic War memorabilia and straightforward accounts of later wars, with an exotic presentation of oriental arms and armour as *objets d'art*, a remarkable display of large-scale models of fortified cities, and a stunning exhibit of the history of artillery through models.

For descriptions and links to other French military museums, see the section on France in ABCollection: Militaria: Military Museums Directory, http://www.abcollection.com/eng/museum/summary.php.

Germany

Militärhistorisches Museum (Military Historical Museum), Dresden, http://www.milhistmuseum.de. Formerly the Saxon Army Museum, the German Military Historical Museum and the East German Army Museum, this museum took its present identity after reunification. A temporary exhibition hall is open to the public while a splendid new facility is under construction, scheduled to open in 2008.

Bayerisches Armeemuseum Ingolstadt (Bavarian Army Museum in Ingolstadt), near Munich, http://www.bayerisches-armeemuseum.de.

Wehrgeschichtliches Museum Schloss Rastatt (Military History Museum in Rastatt Castle), Rastatt, near Karlsruhe, http://www.wgm-rastatt.de.

For descriptions and links to other German military museums, see the section on Germany in ABCollection: Militaria: Military Museums Directory, http://www.abcollection.com/eng/museum/summary.php.

Greece
Polemiko Mouseio (War Museum), Athens. No Website identified, but see the illustrated description under museums at the Hellenic Ministry of Culture Website, http://www.culture.gr. Founded in 1975, this museum devotes considerable space to premodern military activities, from prehistory through antiquity to Byzantine and Turkish rule, before turning to the wars of independence, the Balkan wars and the world wars.

For other military museums in Greece, see the Website Hellenic Army Military Museums, http://www.army.gr/n/e/archive/museums/.

Hungary
Hadtörténeti Intézet és Múzeum (Museum of Military History), Budapest, http://www.militaria.hu.

For other Hungarian (and Austro-Hungarian) military museums, see the section of the Links list at 'Austro-Hungarian Land Forces 1848–1918', by Glenn Jewison and Jörg C Steiner, which covers military museums and archives in Austria and Hungary: http://www.austro-hungarian-army.co.uk/links.htm.

Italy
For military museums in Italy, see Italian Kits: Museums, http://www.italiankits.it/museums.html. See also the Website Military Museums in Rome, http://www.liveinrome.com/museums/military_museums.htm.

Luxembourg
Musée National d'Histoire Militaire (National Museum of Military History), Diekirch, http://www.nat-military-museum.lu. Primarily devoted to the Battle of the Bulge.

For descriptions and links to other Luxembourg military museums, see the section on Luxembourg at ABCollection: Militaria: Military Museums Directory, http://www.abcollection.com/eng/museum/summary.php.

The Netherlands
Koninklijk Nederlands Leger- en Wapenmuseum Generaal Hoefer (Royal Dutch Army and Weapons Museum), Delft, http://www.legermuseum.nl. Commonly known as the Legermuseum and housed along a canal in the formidable seventeenth-century Armamentarium (Arsenal), this exciting museum combines solid permanent exhibitions with innovative temporary shows.

Norway

Forsvarsmuseet (Norwegian Armed Forces Museum), Oslo, http://www.mil.no/felles.fmu/. Centrally located in Oslo at the former Akershus fortress, this relatively modest museum exhibits Norwegian military history from the Vikings to the present quite conventionally.

Poland

Lubuskie Military Museum, Letnica, http://free.polbox.pl/l/leszekch/. Displays aircraft, helicopters and heavy military equipment. Also links to a number of other Polish military museums.

Wielkopolskie Muzeum Wojskowe (Polish Military Museum), Poznań, http://www.mnp.art.pl/oddz4.html.

Muzeum Wojska Polskiego (Polish Military Museum), Warsaw, http://www.muzeumwp.pl.

Portugal

Museu Militar (Military Museum), Lisbon, http://geira.pt/mmilitar/. This one-time artillery museum occupies the site of a former shipyard gun foundry and arsenal; although its collections have expanded and the building has been refurbished, it remains a fairly conventional military museum with stronger than usual artillery holdings.

Romania

Muzeul Militar National (National Military Museum), Bucharest, http://muzeu.mapn.ro/. Like most military museums, the Romanian version is chronologically organised, covering the full sweep from antiquity to the present, with excellent displays and dioramas, and unusually fine large-scale maps.

Russia

Tsentral'niy Muzey Vooruzhennykh Sil (Central Armed Forces Museum), Moscow, http://www.armymuseum.ru.

Serbia

Vojni Muzej (Military Museum), Belgrade, no Website located.

Spain

Museo del Ejército (Army Museum), Madrid, no Website located. Situated in an elegant old building, this was a classic military museum of the old school. But no longer. The army museum is now in the process of transferring itself to the Alcázar, the old hilltop fortress in Toledo, while the old building is now part of the Prado.

Sweden

Armémuseum (Royal Army Museum), Stockholm, http://www.armemuseum.org/. Open again after years of renovation, this museum sets a new standard for museum storytelling, though perhaps at the expense of displaying real objects. It offers a chronological account of Swedish military history, relying chiefly on life-size tableaux to dramatise such activities as recruiting, foraging, families, field repairs and fighting.

For other Swedish military and naval museums, see Royal Swedish Academy of War Science: Sweden: Museums, http://cgi.kkrva.se/eng/mwi/sweden/museums.shtml.

Switzerland

For Swiss military museums, see Schweitzer Armeemuseum: Military Museums and Collections in Switzerland, http://www.musee-armee.ch/.

United Kingdom

Imperial War Museum, London, http://www.iwm.org.uk. Contentious name and weird location (it occupies the one-time Bethlehem Hospital (Bedlam) for the Insane) aside, this is one of the great military museums, a pioneer in expanding its scope to deal with the larger social implications of military affairs. It commemorates and displays objects related to Britain and the Commonwealth in the world wars of the twentieth century and in later conflicts.

National Army Museum, London, http://www.national-army-museum.ac.uk. This is the other half of British military history, the story of the British army to the First World War, emphasising the experience of the soldier and featuring an exceptional military art collection.

Royal Armouries, Leeds, http://www.armouries.org.uk/. Formerly in the Tower of London, the Royal Armouries has now acquired a large new building, where its extensive collections of arms and armour can be displayed and where special exhibitions can be mounted to good effect.

For descriptions and links to other United Kingdom military museums, see A–Z of [British] Military Museums, http://www.army.mod.uk/ceremonialandheritage/museums/. See also UK Directory: Military Museums: 'Naval and Maritime Museums in the British Isles', by Martin H Evans and Janet West: http://www.cus.cam.ac.uk/~mhe1000/; and http://www.ukdirectory.co.uk/Library/Category681880.html, which includes naval and aircraft museums.

Part 2: Selected general military museum Websites, including Websites for naval, military aviation, and arms and armour collections

ABCollection: Militaria: Military Museums Directory, http://www.abcollection.com/eng/museum/summary.php. Directory of military museums and exhibitions related to military history, located in France, Belgium, Luxembourg, Germany, and Great Britain, most with Websites.

Academie des Armes Anciennes, http://www.academie-des-armes-anciennes.com/. Detailed discussion of several museums.

Aerofiles: Museums and Public Access Displays, http://www.aerofiles.com/museums.html. Includes US and Canadian museums, civil air as well as military.

Aircraft and Aviation Museums, http://www.fleetairarmarchive.net/Museums/Museums_aircraft2000A-Z.htm.

Aircraft Museums, http://www.travelcentre.com.au/travel/Aviation/aircraft_museums.htm.

The AirNet Web Site: Aviation Links: Aviation Museums (not UK or US), http://homepage.ntlworld.com/airnet/museums.html. Includes civil as well as military aviation, with separate links to UK and US museums.

American Society of Arms Collectors, http://www.americansocietyofarmscollectors.org/museums. American and European museums.

Arms and Armor, http://www.armor.com/2000/links.html. Includes links to a number of arms and armour museums and collections in Europe and America.

Aviation Museums of the World, http://www.airaffair.com/Library/museums.html.

Danish Naval History: Maritime Links – Maritime and Naval Museums, http://www.navalhistory.dk/Common_files/LinksSider/usLinksMilitary.htm. Emphasis on Danish and Scandinavian museums, but worldwide in scope.

DMOZ Open Directory Project: Reference: Museums: Military, http://dmoz.org/Reference/Museums/Military/.

European Maritime Museums Sites, http://www.maritimemuseums.net/europe.html.

Frazier Historical Arms Museum (Louisville, KY): Related links section, http://www.frazierarmsmuseum.org/links.html. Includes

museums with important arms and armour collections, as well as other resources.

Militaria on the Web: Military Museum Guide, http://www.arbeia.demon.co.uk/museums/index3.htm.

Military Aircraft Museums, http://www.richard-seaman.com/Aircraft/Museums/.

Military.com Museum & Memorial Guide, http://www.military.com/Resources/ResourceSubmittedFileView?file=museums_museum_guide.htm.

Military Museum Resources, http://www.cbel.com/military_museums/.

Military Museums and History Links, http://www.qmmuseum.lee.army.mil/links.html.

Military Museums and Memorials in the Yahoo Directory, http://dir.yahoo.com/Arts/Humanities/History/By_Subject/Military_History/Museums_and_Memorials/.

Military World, Links to Museums, http://www.militaryworld.com/dir/History/Museums/. Primarily US.

Mother of All Maritime Links: John's Nautical Links List, page 32: Museums, Museum Ships & Preservation Efforts, http://www.boat-links.com/linklists/boatlink-32.html.

Museums, http://home.planet.nl/~whitestar/museums.htm. Listing of European military museums that display vehicles.

Museums of Weapons and Military History, http://users.swing.be/sw017995/museum.htm.

Naval and Maritime Museums: Europe, http://www.bruzelius.info/Nautica/Museums/mmeu.html.

Naval and Maritime Museums List, http://www.bb62museum.org/wrldnmus.html.

Olive-Drab Military Museums, http://www.olive-drab.com/od_history_museums.php3.

Veteran and Military Museums and Memorials, http://members.aol.com/veterans/warlib6m.htm. Links to a large number of Websites, primarily US and Canada.

War and Remembrance – WWII Memorials to Visit in Europe, by James Martin, http://goeurope.about.com/cs/germany/a/warmemorials.htm. With links to sites all over the continent.

War Museums: Place of Remembrance throughout Europe, http://www.warmuseums.nl/.

War Museums Itinerary, by Elisabetta Corselli, http://www.museumland.com/Itguerra/. Interesting short reviews of war, naval, air and other military-relevant museums.

World Wide Web Virtual Library: Naval and Maritime: Museums, http://vlnavmar.usnaweb.org/museums.html.

Part 3: Select bibliography of European military museums

Humbert, J M and Dumarche, L, *Guide des Musées d'Histoire Militaire: 400 Musées en France* (Paris: Charles-Lavauzelle, 1982)

Kavanagh, G, *Museums and the First World War: A Social History* (Leicester: Leicester University Press, 1994)

Kristy, B H, 'Museum collections as historical sources', in Higham, R and Mrozek, D J (eds), *A Guide to the Sources of United States Military History: Supplement IV* (North Haven, CT: Archon Books, 1998), pp543–80. A broad bibliographical survey that expands in several directions the earlier reviews in the same series by Lundeberg, qv.

Lundeberg, P K, 'Military museums', in Jessup, J E and Ketz, L B (eds), *Encyclopedia of the American Military: Studies of the History, Traditions, Policies, Institutions, and Roles of the Armed Forces in War and Peace*, (New York: Charles Scribner's Sons, 1994), Vol. 3, pp2133–57. Although now somewhat dated, provides a useful discussion and substantial bibliography that goes beyond specifically American museums.

Lundeberg, P K, 'Museums collections as historical resources', in Higham, R and Mrozek, D J (eds), *A Guide to the Sources of United States Military History: Supplement III* (Hamden, CT: Archon Books, 1993), pp374–426. Unlike the author's earlier essays in the series, this essay is not limited to American museums and includes a far larger bibliography.

Robertson, I G, 'Museums, military', in Corvisier, A (ed.), *A Dictionary of Military History and the Art of War*, trans. Turner, C, English edn revised, expanded and ed. by Childs, J (Oxford/Cambridge, MA: Blackwell, 1994), pp540–3. Describes the changing functions of military museums.

Thwaites, P, *Presenting Arms: Museum Presentations of British Military History, 1660–1900* (London/New York: Leicester University Press, 1996). A substantial discussion of the broad problems in exhibiting military history as well as specifically British issues; includes a list of museums and bibliography.

Westrate, J L, *European Military Museums: A Survey of Their Philosophy, Facilities, Programs, and Management* (Washington DC: Smithsonian Institution, 1961). Although outdated in detail, the broad discussion remains worthwhile.

Wise, T and Wise, S, *A Guide to* [British] *Military Museums and Other Places of Military Interest*, 8th edn (Knighton, Powys: Imperial Press, 1994)

Wood, S, 'Museums, military', in Holmes, R (ed.), *The Oxford Companion to Military History* (Oxford: Oxford University Press, 2001) pp668–9. A concise survey of the history of military museums.

Jan Piet Puype

Arms on display: core business or illustrations? A commentary on the presentation of arms and armour in museums[1]

Some historians working in military museums, because they have ambivalent feelings towards weapons, or maybe because they feel it is the decent thing to do for the general public, allow themselves to be carried away when making their choices for the displays and when creating texts and captions. To mention an early example from my own experience, in 1974 the Rijksmuseum in Amsterdam organised a special exhibition on Dutch firearms of the seventeenth century. The excellent display and main treatment of this subject were in my view marred by the unnecessary inclusion of wooden blocks in which the penetrative power of bullets fired by old firearms was shown.[2]

I am not saying that such effects should *not* in principle be dealt with, but when doing this we must prevent a judgment of value creeping in and blocking our capacity to look at a firearm in a neutral, objective manner. It is one of the recognised issues in museums of arms and military history, indeed in many other museums. Collections should be cared for by specialists capable of dealing with arms in an open-minded and unbiased fashion.[3] Emotions about the effects of arms on human beings inevitably influence our capacity to study them as objects; they make it difficult to sustain technical interest in them and they make it almost impossible to deal with arms as a hobby, for use in sport or as desirable objects to collect.

Time and again curators of institutional arms collections are put under pressure – not only externally but also and notably from within! – to show what is named the 'shadow side' of arms or the 'dark side of war'. Very recently, my own Legermuseum (the Dutch Army Museum) held a temporary exhibition on the Kalashnikov, the well-known assault rifle. There was a lot of discussion in the preparatory stage of the exhibition and some of the staff were of the opinion that we should also display Somalian boys and other child soldiers using this rifle. As it turned out, the presentation itself was a pure arms exhibition, save for a sensational video presentation at the beginning showing the so-called darker side of its use. Nonetheless, many versions of the Kalashnikov were to be seen and there were many kinds of explanatory technical material including instruction films and trials by the Soviet army.

However, the chief poster used to promote this exhibition went too far in my eyes. It featured one of the aforementioned young rascals with a 'Kalash' and ostentatiously holding a cigarette between his lips so as to suggest, as it were, his casual attitude towards killing human beings. At the opening event of the exhibition, the inventor, the crafty old General Kalashnikov, was present too. He was very contented, he said, with the exhibition, but frowned when seeing the poster as well as the video presentation mentioned earlier. Asked about this, the general commented that it was impossible for him to feel responsible for the use of his rifle by many terrorists and so-called freedom fighters, saying: 'I designed this weapon during the war mainly out of patriotism. My country was in great distress and I have dedicated all my knowledge and abilities to do my bit in reaching our final victory.'

The special problems of military museums

These and other critical remarks below illustrate the dilemmas we often face in museums. The pressure by certain parties to 'show the dark side of war' will in my estimation always be a constant factor in our profession. As I stated above it comes mainly from within, and it is practically always justified by the perceived or purported demands of society, that is, the potential visitors. What these other parties in fact want is to turn our museums into war museums. They '...wollen den totalen Krieg!' But as soon as you change your institution into a war museum – or a 'peace museum' for that matter – the arms shown will inevitably be saddled with a psychological load (a fitting term for firearms) which inhibits their being presented in terms of their design and technical characteristics, their changes and tactics and so on, except in the case of such elements being employed to point to the ultimate destruction of human beings. In such an approach the typology of a weapon is out of place. A historian working in a military museum told me recently: 'If I want to tell the story of the revolver, I need only one revolver!', adding, as if to rub it in, '...and if I have seen one revolver I've seen them all.'

If it were my own task to show the development of the revolver I would show it in a 'typology' of all its versions, together of course with a good explanation of why all the changes came about. A historian of the sort just mentioned considers the weapon merely as illustration, whereas in my view the weapon should be dealt with as a phenomenon first and then be placed in an explanatory context.

The historical component, preferably in chronological order of course, is always propagated by historians. But it is *just one of several* components that make up the context of weapons on display. What about a context of arms manufacture? What about the makers? What about a context on use? Let's not kid ourselves by those who say that in practice it would not matter so much, for there will often be a blend of the 'historical' and the 'typological' approaches. However,

they are in principle totally different! For an army museum, weapons, beside uniforms, are 'core business', not 'mere illustrations'. The Legermuseum has a lot of collections of various kinds, but uniforms and arms are the two main components of its collection. In the basic display of our museum they form the two leitmotifs, despite the conspicuous tanks, vehicles, flags and paintings. Over the years the Legermuseum has amassed a large number of arms. Why can we not show them in all their different aspects?

Of course the message of a war museum and that of an army or arms museum are not diametrically opposed. There are areas where they touch or even overlap. Below I shall give some examples of how some contemporary museums have resolved the dilemma between regarding the weapon as an object and as a horrible instrument of destruction.

Arms: interpretation of functionality and application

As far back as 1979 a well-known Dutch journalist wrote an article[4] about the deteriorating condition of the buildings of the Legermuseum in Delft, the so-called Armamentarium. They contained the extensive study collection of the museum, which then still had its main premises in Leiden. The following quotation from the article conveys the reasons why it is important to collect and care for arms in museums:

> Few people, except a small circle of collectors and specialists, are aware that Delft has a world-famous collection of musical instruments. The particularity of that collection is not its size – it is large, but there do exist larger ones, for instance in America, England, France and Italy. What makes the collection in Delft exceptional is its diversity. It contains rare artefacts of extremely diverse natures and origins. It is probably the best all-round collection of musical instruments in the world.
>
> This fabulous Dutch collection is housed in two beautiful 17th-century buildings in Delft. However, now be aware of something unbelievable: practically no money has been made available for the upkeep of these buildings for such a long time now that the collection is doomed. During a heavy rain shower the interior offers the alarming sight of rows of spoiled Amatis, Guarneris and Stradivariuses, mirrored in the flooded floors. Cases full of valuable wind instruments are covered with plastic sheets while the rainwater is gushing through the ceiling and everything is caught as best it may in buckets and tubs. On the upper floor, where enormous organs, concert pianos, bassoons and tubas are displayed, the walls have saltpetre beards. During last winter snow blew inside and was even found in the organ pipes.
>
> Under these circumstances, upkeep is hardly possible any more. The valves of the wind instruments are turning green; the violins and cellos are affected by fungus. For the cleaning of a clarinet or an oboe and to make it damp-proof a specialist needs almost an entire day, but this collection contains hundreds of them and it is almost impossible to even begin such a project. In this manner one of the most valuable and

exceptional collections of the world is slowly going to the dogs. How is this possible? What is the reason that such a national monument of the instrument-maker's art is being treated with so much indifference?

The reason is that we are not dealing with musical instruments *but with firearms*. Those musical instruments were only a metaphor. But apart from that, everything else I've said is all true. A unique collection in Delft is indeed growing mouldy and turning green. However it doesn't consist of clarinets and oboes, but of machine guns and rifles. It is not organ pipes which had snow blown into them, but gun barrels. Those soaked instruments were not Amatis and Guarneris, but Albini-Carcanos and Gatlings, and it should be clear what statement I am making with this representation, namely that one is not worse than the other. If it is worth the trouble to keep exceptional products of a technology for posterity, then this goes as much as for firearms as for musical instruments.

Among firearms, too, there are works of art and the criteria this is judged by are the same as for other instruments, irrespective if they are musical instruments, astronomical clocks, Greek temples or steam locomotives. Those criteria have nothing to do with their application, no matter how unpleasant it may be. The tendency to see firearms as horrible things because they are used for a horrible purpose is based on the same misconception as finding a Stradivarius to be an ugly thing if played out of tune. A more or less similar difficulty exists in architecture: must we find a building ugly because it is being used as a prison or, even stronger, because it was designed as a prison? Something similar is valid for firearms. Machine guns are machines and among machines they are often the most beautiful, the most ingenious in existence and made with the utmost care. What quickly comes to mind is the word functionality.

There exists in this field a hardly recognised but essential difference between *functionality* and *application*. The functionality of a machine lies fully within the terms of the working of the mechanism and has nothing to do with what the person who uses it is thinking. Someone might try to bash in somebody else's head with a violin and the mechanism of a racing car does not become ugly when someone uses it to rob a bank. The aesthetic appreciation bears on the quality of the mechanism, not on the designer's or the user's motives.

The value of this article, besides of course that nice metaphor at the beginning, is its emphasis on considering the weapon as an object. In a display it should be detached from its effect on human beings – and animals one might add – and detached from war. Such detachment allows one to really come to grips with the weapon's characteristics, its development and its technical and aesthetic quality. These two sides of the coin, the 'historical' approach and the 'typological' approach, should be treated separately in the museum display. They can be integrated in the display, but not in one theme. Let us look at how different museums have approached this problem.

The Legermuseum, Delft, the Netherlands

I have already mentioned the Legermuseum's Kalashnikov exhibition. In a corner of a very large display case containing almost 30 variants of the rifle, there were two blocks of gelatine into each of which a Kalashnikov bullet had been fired. The bullets were now visibly buried in the material, the intention being of course to show their effect on human flesh. One still wonders what the makers of this exhibition were trying to tell the visitor. Since something similar was shown nowhere else in the museum, it might just appear that of all the firearms on display only the Kalashnikov was deadly. As a message, it is also patronising – the wagging finger that says 'You realise that these weapons are deadly!' – as if the average visitor, meaning someone who is not a firearms specialist, would be totally ignorant of this fact in the first place.

It would perhaps be far more effective to dedicate a special display in our basic (so-called 'permanent') exhibition to a separate theme about the penetrative power of bullets and other projectiles through the centuries. Preferably, it should be treated in a broader way, showing different kinds of projectiles, those intended to neutralise the opponent, or indeed kill him, but also those projectiles intended not to kill in the first place, for instance rubber bullets – which in close encounters can kill just the same – or the many sorts of non-lethal weapons now under development. We could also enter into wound ballistics. But not place two gelatine blocks in *one* case in *one* exhibition about *one* particular weapon.

The lessons I have learned from these examples from my own museum are that if you want to show the so-called two sides of weapons, you must do so in a balanced way, and certainly not mix them, for then the museum conveys the wrong message, both to people who like arms and to people who do not.

The Wehrgeschichtliches Museum, Rastatt, Germany

Another example in this discussion is provided by the Historical Army Museum in Rastatt in Baden-Württemberg, Germany. Its basic display is a pure example of one conceived by a military historian[5] classically educated to regard written documents as the historian's sole sources. The museum is housed in the Baroque castle of Rastatt and covers, among other subjects, the military history of the German *Kleinstaaten* relative to Prussia.

The galleries in the WGM are built up in a severe chronological succession. Each gallery has the *Didaktik* on one side and objects selected as illustrations to the historical tale on the other. The explanatory area uses one entire wall and offers texts and images. In every gallery, a map is shown, sometimes with battle maps added. All maps have been specially made for the display, meaning that all non-essential information could be left out. With each map is a well-

designed, explanatory thematic text dealing with strategic and tactical aspects. Then follows a table summing up the events in that period. Portraits, both reproductions and originals, of the various leading players take up the remainder of the explanatory wall.

Although the texts are kept as concise as possible, they inevitably result in a lot of text taken all together. The objects, as I have said, serve as illustrations to the theme and thus are placed in the correct historical context. However, the perceived distance between the macro level (the explanation) and the micro level (the objects) remains too large – simply because they are totally different among themselves. The risk is that that the average visitor will either read the thematic texts and take the objects for granted, or will concentrate on the objects and just glance at the texts. As in so many historical museums, the display is a sort of picture book and as such, in my view, less effective than a book available in the museum shop.

In a frank discussion, the director explained that during the years he had been building up his museum galleries and bringing his concept to life, he had slowly come to reconsider his approach. There was the practical factor that his storage space was still full of objects, but the main factor which forced him to reconsider was that the museum *hardly got any visitors*.

He recognised that despite the many rare and interesting objects already on display in the 'historic' galleries, the museum barely catered for visitor categories that are important but unlikely to produce large numbers – such as collectors, specialists and other kinds of particularly interested people. He explained that he wanted to tie these specialists to his museum, not only to increase the number of visitors, but also to link them more or less permanently to his institution because he needed their expert opinion and the acquisition potential of the objects they collected.

In this way the concept of study collections (*Studiensammlungen*) was born. These collections are intended to be parts of the museum's permanent display. The director filled these study galleries with large numbers of objects and brought in collectors and other specialists on a temporary basis. They carefully and knowledgeably selected the many 'sleepers' from storage and put them on display in a typological manner. Since there was a lack of expertise among the museum staff and because the museum was always short of money, the project took many years to come to fruition. Three such study collections are now in place and exactly one year after the opening of one on the history and development of badges of rank (mainly in the form of hundreds of shoulder pads, but also including sword knots and tassels), the third study collection was opened (Figure 1).[6] It is about military swords and shows over 200 pieces that, together with explanatory material, have been put into rows of narrow display cases which can be viewed from both sides. They hold about 30 swords each, horizontally

placed parallel to their scabbards. Wishing to put as many swords as possible in the cases, the creators of the exhibition placed the swords with their hilts alternating to the left and the right. It is true that this arrangement forces the visitor to constantly change his or her viewing position, but for somebody interested in the objects this is only a minor nuisance.

With this approach the Rastatt museum has killed two birds with one stone. More visitors can now be expected. The number of collectors of militaria should not be underestimated, and they can now see a large number of pieces which otherwise would have remained in storage.

Figure 1 The permanent study collection of swords at the Wehrgeschichtliches Museum in Rastatt, Baden-Württemberg, Germany. (Photograph taken by Eveline Sint Nicolaas on the day of the official opening of the display, 24 September 2004)

The Schweizerisches Landesmuseum, Zürich, Switzerland

The third museum worth mentioning is the Swiss National Museum in Zürich and the large exhibition 'Waffen werfen Schatten' ('Arms Throw Shadows') held in 2003. From a professional museological viewpoint, one can greatly admire its approach. For a museum of its kind it has a colossal arms collection, about 12,000 items, most of which are hafted weapons, primarily halberds (as one would expect in a country like Switzerland). From 1898 until a few years ago, a large mass of these weapons had been on permanent display in the largest hall of the museum, the *Ruhmeshalle* or 'Hall of Fame'. As befits nineteenth-century notions, the display concept was that of large numbers of martial trophies – so-called panoplies – although it had been renewed a number of times.[7]

The Hall of Fame was finally discarded in 2003 in favour of a temporary exhibition in which no fewer than 1600 swords, hafted weapons and firearms – and armour (!) – were suspended from the ceiling in such a manner that together they formed an enormous cupola with all the offensive ends – the points and muzzles – of the arms pointing towards the visitor, giving him or her an overwhelming feeling of threat from the inherent offensive power. Added to this feeling – and no doubt intended to deepen it – were musical sounds and, almost inevitably, a display of Jacques Callot's prints about the cruelties and miseries of war.

In itself, such a display is acceptable for its sheer impressive magnitude and for the fact that our Swiss colleagues conceived it in the first place. I already stated that I appreciated it as a museological experiment. The museum asserted that the old *Ruhmeshalle* display was 'sensational and seeking to achieve effect' in the negative sense, but in my view the 'Arms Throw Shadows' approach was just as sensational and seeking to achieve effect. Besides, one can wonder if it is the task of a national museum to use its arms collection just for a single goal, speaking out against war and leaving the many other aspects of these arms unattended.

The statement in Zurich was based on only (one of the aspects of) application, namely that arms are horrible instruments of death. The museum was silent about the functionality of arms and, indeed, about their true role in establishing and guarding Swiss independence.[8]

Conclusions

It is hoped that my somewhat ex-cathedra statements, based on a lifetime of museum experience with arms, can help in conveying that arms have the same basic qualities as any other museum object and that they too have their own information potential. Arms should not be used in a museum to present a single message or a desired political statement. Their information potential is multifaceted and one should carefully differentiate between the functionality and application and all

their related aspects in order that the one does not negate or confound the other.

Notes and references

1 This chapter is an edited and abridged version of a paper presented at the annual ICOMAM symposium for 2004, organised by the Royal Netherlands Army and Arms Museum (or Legermuseum) in Delft, the Netherlands, on 25 and 26 November 2004. ICOMAM is the International Committee of Museums and Collections of Arms and Military History, of which the author is the secretary. The subtitle chosen for the chapter was the title of the symposium theme. More information on ICOMAM can be found on its Website: http://www.klm-mra.be/icomam. The author is grateful to Barton C Hacker and Margaret Vining, both specialists in military history at the National Museum of American History, for their willingness to read an earlier draft of this article.

2 See the catalogue of this exhibition: Kist, J B *et al.*, *Dutch Muskets and Pistols: An Illustrated History of Seventeenth Century Gunmaking in the Low Countries* (London: 1974). This being a pure arms catalogue, the authors wisely did not include the wooden blocks in it.

3 On problems in methodology, dating, biasing factors and uncontrollable variables in arms historical research, see: Puype, J P, *Proceedings of the 1984 Trade Gun Conference: Part 1, Dutch and Other Flintlocks from Seventeenth Century Iroquois Sites* (Rochester, NY: 1985), pp2–9. The same problems, as well as those of the methodology in cataloguing arms, are dealt with in Puype, J P, *The Visser Collection: Arms of the Netherlands in the Collection of H. L. Visser: Vol. 1, Catalogue of Firearms, Swords and Related Objects, Part 1*, pp27–30.

4 Kousbroek, R, 'Het vuurwapen als kunstwerk: waardevolle collectie in Delft met ondergang bedreigd' ('The weapon as a work of art: valuable collection in Delft doomed'), *NRC Handelsblad* (17 August 1979)

5 Dr Joachim Niemeyer, who recently went into retirement.

6 The study collection of swords was opened on 24 September 2004 by Niemeyer's successor, Dr Kai Uwe Tapken. The display was designed by Dr Michael Gordon of Munich, a recognised specialist on edged weapons, who also selected all the swords.

7 The Schweizerisches Landesmuseum has produced a brochure entitled *Waffen werfen Schatten: Sonderausstellung in der Ruhmeshalle: 6. Mai bis 13. Juli 2003*, in which the history of the displays and the concept of this temporary exhibition is explained.

8 The exhibition was conceived under the supervision of the curator responsible, Dr Matthias Senn.

Colour plate 1 The gun barrel, dated to about 1470, shown in Figure 1, page 11. (Ruth Brown)

Colour plate 2 Gun barrel detail, showing marks. (Ruth Brown)

Colour plate 3 Vincent Sabini's crucifix made from the German bullet that wounded him on 7 June 1917 at Messines, Belgium (page 80). Height 4 cm. (Nicholas J Saunders)

Colour plate 4 Pair of corseted trench-art artillery-shell-case vases, decorated with Art Nouveau roses (page 82). (Nicholas J Saunders)

Colour plate 7 Bullet crucifix on a tripod of German Mauser bullets (page 88). The memorial plaque shows the Menin Gate Memorial to the Missing at Ypres, Belgium, and thus dates the piece to 1927 or later, indicating this was a postwar souvenir made for battlefield pilgrims and tourists. (Nicholas J Saunders)

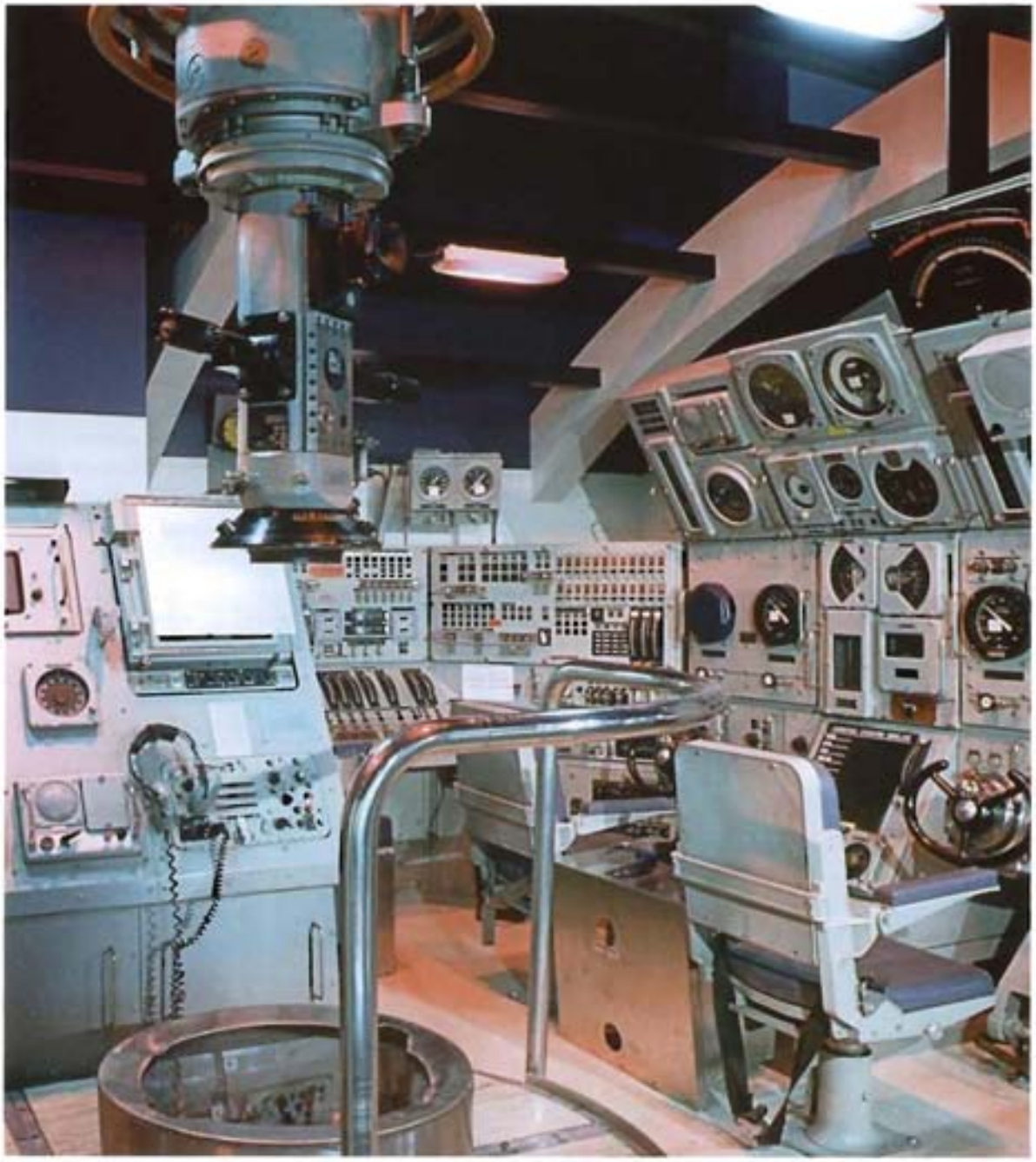
Colour plate 5 A post-war commemorative dinner gong made from a 75 mm artillery-shell case, decorated with the Sphinx, inscribed 'Egypt' and 'Lincolnshire', and mounted on a wooden frame engraved with '1919' (page 83). (Nicholas J Saunders)

Colour plate 6 An enamelled artillery-shell-case vase (page 86). Painted blue on white, it depicts a snowy battlefield scene and is inscribed 'Yser. 1914-1918' and signed 'H.J.'. (Historial de la Grande Guerre, Péronne)

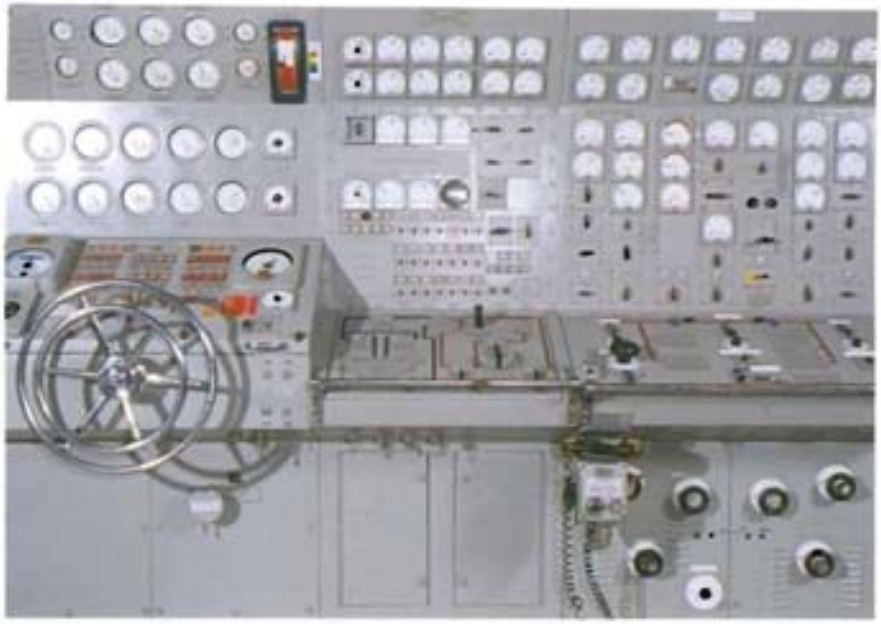
Colour plate 8
A German bunker visible on the cliff top at Jersey (page 122). (Christine Finn)

Colour plate 9
La Hougue Bie dolmen, with medieval site above; beneath to the right, out of sight, a Second World War German underground bunker (page 130). (Christine Finn)

Colour plate 10 Interior of the Jersey War Tunnels visitor attraction in the Ho8 complex: a domestic scene from the 'Captive Island' installation (page 133). (Jersey War Tunnels)



Colour plate 11 The brain of a submarine is its attack centre (page 143). Into this critical location flow data from the boat's sensors and status reports for evaluation; from it issue the commands that direct the submarine and its weapons. The commanding officer normally stands near the periscopes, one of which is purely optical, while the other includes electronics that allow it to function as a video camera. (National Museum of American History)



Colour plate 12 From left to right are the control panels for the submarine's steam turbines, nuclear reactor and electrical systems (page 144). These so-called manoeuvring-room consoles were seldom seen by most crew members and to the best of our knowledge have never before been displayed in public, albeit somewhat altered for security reasons. (National Museum of American History)

Colour plate 13 One exhibition theme was life aboard a nuclear-powered submarine on patrol, which often lasted many weeks without ever surfacing (page 145). One source of stress was the very cramped quarters, as this section of the USS Trepang*'s crew berthing in the exhibition shows. (Courtesy Peter B Boyne)*

Colour plate 14 Disposing of trash, like many other activities that are relatively easy ashore, required special equipment in a submarine, while dirty laundry was handled much more conventionally. To impress visitors with this contrast, we juxtaposed a highly specialised trash disposal unit (TDU) with an ordinary washer and dryer from the USS Trepang *(page 145). (Courtesy Peter B Boyne)*

Colour plate 16 An 'entrenching tool' (shovel) used by American soldiers in the First World War (page 149). It was carried on the soldier's back. (National Museum of American History)

Colour plate 15 A British field gun surrendered to American forces under the Convention of Saratoga in 1777 (page 149). (National Museum of American History)

Colour plate 17 The Bell UH-1 'Huey' helicopter used in the Vietnam War, displayed in the NMAH exhibition 'The Price of Freedom: Americans at War' (pages 149, 156). (National Museum of American History)

Colour plate 18 The Minié ball, a mid-nineteenth-century lead bullet with a hollow at one end (page 152). When fired in a rifle, the ball expanded to fit the grooves of the barrel and thus acquired a rapid spin, increasing accuracy. (National Museum of American History)

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