LRN 03D0571

Project Number: 48-JLS-0031

ANIMATING AN ELIZABETHAN SUIT OF ARMOR

An Interactive Qualifying Project Report:

Submitted to the faculty

Of

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

By:

Brent Newey

Andrew Smith

Date: April 23, 2003

Approved:

Doctor Jeffrey Forgeng

Abstract

This project's purpose is to construct a multimedia exhibit of "The Herberstein Armor," a German 16th century suit of armor. This includes a research paper, comprehensive website, and a 3D animation providing museum guests a way to view the shape of the armor from all sides. The paper (and corresponding website) details the history of armor, the context in which it might have been used, the process of constructing such a suit, and details about the suit itself.

Table of Contents

Table of Figures 4
Introduction 5
History of Armor 8
Armor Development 8
Armor in the 16th Century 10
The Fall of Armor 12
Armor Collecting 13
Principles of Armor Design 17
The Construction of Armor 23
Components of Late 16th Century Armor in Germany 29
The Helmet 29
The Cuirass 33
The Legharness 36
The Arm Defenses 38
The Military of the Late 16th Century 42
Infantry 42
Cavalry 43
Field Artillery 45
The Herberstein Armor 50
Conclusion 56

Table of Figures

Figure 1: The Herberstein Armor 5
Figure 2: Mail Links 8
Figure 3: Coat of Plates 9
Figure 4: Maximillian Armor 11
Figure 5: An Example of Guild Stamps 16
Figure 6: Demonstration of a Glancing Surface 18
Figure 7: The Armor Hinge 19
Figure 8: Spring-loaded snaps on the back of a Falling Buffe 20
Figure 9: Sliding Rivet and Turning Pin on Tasset 20
Figure 10: Venus at the Forge of Vulcan. Water-driven tilt-hammers and grinding wheels can be seen on the right. 23
Figure 11: Maximillian and his Armorers 24
Figure 12: A Polisher using a Polishing Wheel 27
Figure 13: Gorget 30
Figure 14: Burgonet 31
Figure 15: Side View of Peascod-Style Breastplate 34
Figure 16: Breastplate and Tassets 35
Figure 17: The Legharness 38
Figure 18: Vambrace 39
Figure 19: The Pauldron 40
Figure 20: The Gauntlet 41
Figure 21: A Musket and Musket Rest 43
Figure 22: A Snaphance Lock 45
Figure 23: Cannons and their Relative Sizes 46
Figure 24: Lancers and their Techniques 48
Figure 25: A Pikeman's Stances 49
Figure 26: The Herberstein Armor 50
Figure 27: Gauntlet Decoration. First Lame Has Addorsed Bow and S Motifs, 2nd Has H Bar and Key. The H Bar is Also on the Large Plate to the Left. 54
Figure 28: Addorsed Bow Decoration 55

Figure 1: The Herberstein Armor

Introduction

The tall, combed burgonet, beautiful gilt decorations, and roped edges make this suit of field armor from the Higgins Armory truly majestic. This suit, a perfect example of plate armor at the peak of its technological evolution, was forged in the late 16th century for an Austrian aristocrat named Siegmund Freidrich, Freiherr von Herberstein. The suit will be seen by audiences across the United States as part of Higgins' five year touring exhibition "The Age of Armor" premiering in 2003.

The Worcester Polytechnic Institute IQP team of Brent Newey and Andrew Smith worked together for seven months researching the history of this wonderful piece, and the

period of plate armor it represents. This team's research is presented within a website, and the project culminated with a three-dimensional animation of this armor. Using two-dimensional photography, this team digitally shaped and molded the Herberstein armor.

This suit of armor reflects a craft that had been maturing for two hundred years. Plate armor was developed when mail proved ineffective against new developments in weaponry. Crossbows proved strong enough to puncture the metal rings of mail shirts and leg defenses. First, metal plates were used to supplement mail, and over time, these plates grew until the mail was no longer needed, and the plates became complete pieces of armor. By the end of the 14th century, plate armor had taken form.

Throughout the next two centuries, plate armor evolved. Plate armor often reflected not only the practical purpose of its creation, but was designed to visibly imitate fashion of the period. The breastplate in this suit was made in the German peascod style, with an exaggerated medial ridge, a style that developed through the end of the 15th and beginning of the 16th centuries. The sabatons of this suit were designed to reflect the fashion of the period as well. Sabatons from earlier periods came to long points, much longer than necessary, reflecting the footwear of the period. The mid to late 16th century saw a shift in footwear to a more rounded, shorter shoe, and this is reflected in the footwear of this piece.

The Herberstein suit boasts a number of technological advances that were developed specifically for plate armor. The armor hinge is a good example of a mechanism that was taken from regular culture and adapted for armor. The falling buffe, (folding faceplate) was another example of these technologies. Using "spring loaded" snaps the wearer could easily drop and raise the face defense.

Through closer examination, a few unique attributes of this armor were discovered. The leg harnesses for this armor were not made when the actual armor was made, in the late 16th century, but in the late 19th century by Daniel Tachaux of Paris and gilded by Francois Daubresse.

The suit appears to have been "let out," possibly altered to fit when the wearer gained some weight. There is evidence of this on the breastplate and backpiece where they meet.

It seems that portions of the armor (the gauntlet, for example) may have been constructed of pieces from a number of different sources. Though the etched decoration is almost the same, there are enough differences to suggest they were most likely constructed from the remains of two or three different suits of armor.

History of Armor

Armor Development

There are three fundamental types of armor. These are soft armors (such as leather or padding), mail, and plate. All of these types of armor were used in the Roman empire, but for unknown reasons the making of plate armor fell out of use from 600 to 1250 AD, save for plate helmets (Blair 1958: 20).

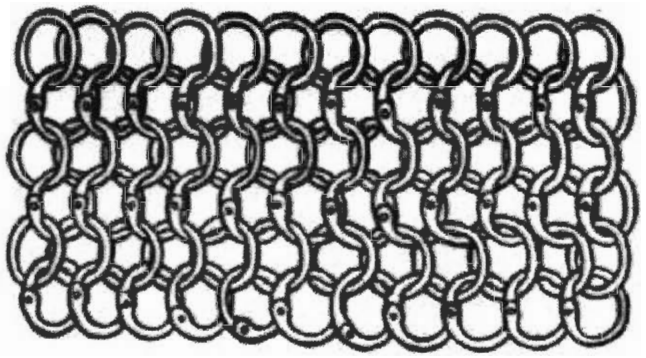


Figure 2: Mail Links

It was during the 13th and 14th centuries that new developments in weaponry were beginning to show major results. Mail armor had difficulty deflecting arrows and halberds, yet many attribute the rapid advances in plate armor to the crossbow, citing the additional power and speed of a quarrel fired from such a mechanism: "tests at Purdue University measured quarrel velocity of 80m/sec…exactly double the velocity of the longbow arrows" (Richardson 1998: 44). Mail armor proved insufficient for dealing with projectiles of such speeds. Additionally, though mail protected its wearer from the slashing of sharp weapons, it did not protect from blunt blows. Despite the fact that the wearer always wore a padded garment under the mail, these blows often bruised and could prove debilitating (Pfaffenbichler 1965: 8).

Figure 3: Coat of Plates

Encouraged by the success of plate used to supplement fabric, leather, or mail, and the general sturdiness of other pieces of equipment made from solid plates of steel, armorers began to fashion breastplates. This introduction worked well, and so the breastplate on high-grade armor was expanded to a cuirass, a covering for the entire torso from the neck to the waist. Eventually, leg harnesses, sabatons (foot armor), pauldrons (shoulder armor), vambraces (arm armor), gauntlets, and helmets all of steel developed and the classical armored knight came into existence. By 1330, plate defenses had been devised for all the parts of the body, and by 1520 plate had reached the peak of its development (Blair 1958: 77). Eventually, munitions-grade plate was made on a mass scale to provide the infantry with the protection plate could provide. Mail, however, was still in limited use until the 17th century (Pfaffenbichler 1992: 56).

Armor in the 16th Century

During the 16th century, a large portion of the production of armor was concentrated in one of three areas of Europe. The Italian city of Milan had always been an influential and prominent armoring force in centuries past, and continued to produce armor during this century. However, as the century opened, armorers in South Germany were doing more business and were exceeding the reputation of the Milanese. Several cities in the German-speaking regions were well known for their armories in this period, including the court armory in Innsbruck, founded by the Emperor Maximillian himself. Many great armorers also hailed from the cities of Augsburg and Nuremberg. It is of general note that the armoring cultures in these two countries experienced a sort of "exchange of ideas" after the Italian Wars, and as the century came to a close, the styles of these two cultures, once very distinguished, had become blurred from this interchange of techniques. Indeed, this sort of behavior was reflective of the trend of armoring all over Europe in this period (Blair 1958: 112-113).

Aside from the two areas listed above, another armory was established in the early 16th century in Greenwich, England, by King Henry VIII. Known as the "Almains", it consisted largely of German and Dutch armorers. It was placed under the care of Martin van Rone, and was exceptionally elitist. Aside from the prohibitive cost of armor produced here, it was exclusively accessible only to the King himself or one to whom he had granted a royal warrant. Because of the cost and high standard to which it was held, this armory consistently produced pieces of exceptional quality throughout the century.

Armor of the first thirty years of the 16th century, referred to as the Maximillian Period, generally reflects the fundamental shifts at the end of the 15th century: the fusion

of German and Italian styles and the development of powerful offensive weaponry. In a decorative sense, they tend to be furnished with what is known as fluting or cresting: the practice of hammering decorative ripples in the armor. This fluting style remained until as late as 1630 in Germany, but evolved during this span of time, becoming smaller and set closer. "It is fairly safe to assume that the narrower and more closely set the flutes are the later the armor is likely to be" (Blair 1958: 116).

Figure 4: Maximillian Armor

Another innovation in the field of armoring that came about at the beginning of the 16th century is that of "pieces of exchange". These sets of armor came with multiple parts that could be mixed and matched to meet the needs of an individual at any given time. The complete set, called a garniture, had as many as 60 separate pieces in the height of its usage in the middle of the century, and could assemble as many as five main sets of field armor, and three sets of tournament armor (Blair 1958: 117).

This period saw a shift in the art of armoring to a separate style of armor designed to meet the needs of the infantry and light cavalry. In the previous centuries, this style of armor was simply a cheaper, less effective version of that made for nobility and heavy cavalry. This is a marked change that takes place at the end of the Italian Wars and may be attributed to the German-Italian fusion of styles.

The Fall of Armor

Advances in other forms of military technology eventually brought about the obsolescence of armor. Some estimate that the origins of the forces that were to bring about the decline of the art of armoring started as early as the 14th century (Blair 1958: 12). While this may be so, the armorer did not see a decrease in the demand for armor for quite some time. Indeed, the 16th century provided a very special opportunity for armorers because of the increased demand for exotic tournament armor and specially made armor for infantry and light cavalry (Ashdown 1967: 275).

Despite the English longbow and gunpowder technologies of the 14th and 15th centuries, heavy armor continued to dominate the battlefield until just before the 16th century. However, even during this period the weaknesses of armor were becoming apparent. Effective uses of pikemen, the success of the English longbow, and the introduction of firearms were all beginning to erode the invulnerability of armored cavalry.

Contrary to popular belief, the advent of firearms did not itself eradicate the use of armor. It was the modernization of this technology and enhancement of training to infantry troops that turned the discovery of gunpowder into a deadly weapon. A good example of this took place in 1544, when German cavalry charged a group of French

soldiers until they were within range, fired in ranks, and fell back to reload. "The manoever…occasioned lances to be gradually but surely replaced by pistols" (Greener 1897: 62-63). These factors led to the general decay of armor on the battlefield during the second half of the 16th century. While armor was rendered cost ineffective and cumbersome by the amount of steel required to stop a bullet, armorers continued for some time to make extremely heavy breastplates designed to repel musket balls. Soldiers, however, began to discard the heavy suits in favor of mobility. According to the account of Sir John Smythe, "…our such new fantasied men of warre doe despise and scorne our auncient arming of our selves both on horseback and on foote…" (Blair 1958: 143). Because of this trend, the first half of the 16th century was the last period in which full armor was worn in the field (Blair 1958: 112).

Armor Collecting

After armor was made obsolete, it eventually gained collector attention as an antique, particularly with the revival of interest in The Middle Ages during the nineteenth century. However, large collections of armor had long been accruing in military armories and private stores and the trade and collection of armor was not entirely a novelty of the 17th century and beyond. Indeed, the largest private collection of armor assembled before the 20th century belonged to Ferdinand, Archduke of Tyrol in the third quarter of the 16th century (Cripps-Day 1925: xxxvi).

In general, armor survived after its heyday as the furnishings of royal estates or private collector's items. The largest collectors during the 17th century existed in France, Germany, and Great Britain. Pieces were acquired at first through inheritance or as gifts, and later through the offices of professional armor dealers.

The collecting of armor also led to a revival in the art of armor reproduction. Starting in the 18th century, this craft took off due to a renewed interest in Gothic styles. Additionally, many existing sets had lost or damaged portions that required replacement, often accomplished by reproducing pieces or mixing similar sets of armor.

Collecting in America began in earnest in the middle of the 19th century. The first American to collect seriously was Carleton Gates, who collected pieces from 1850-1860, and soon other Americans began to develop private collections (Grancsay 1933: 33). Toward the turn of the century, museums began to construct formal exhibitions of armor, starting with the Metropolitan Museum of Art in New York and the Boston Museum of Fine Arts.

The Armorers' Guilds

The armorers' guild, like other guilds of the period, was a small self-governing group of craftsmen. The guild was city independent; each town had its own guilds for each craft, all of which had slightly different rules and regulations from one town to the next. These guilds dictated everything regarding the craft, from style and quality, to armor sale and apprentice hiring.

Charters for armorers' guilds were recorded as early as the late 14th century. These charters imposed very stringent restrictions on the people who would be allowed to make armor, due to the high standards the guild had for any armor bearing its mark. In 1391 a guild charter was written for a mail making guild in Cologne which required an apprentice serve for six years before he could be considered an assistant to the master (a journeyman) (Pfaffenbichler 1992: 26). Regulations set forth in the German town of Nüremberg in 1385 stated that every apprentice must be the son of a citizen of the town, and every apprentice must serve the guild for at least 4 years (26).

Because of the restrictions on masters and the number of people they were permitted to employ, it was not unusual to see the guild masters with larger shops sub-contract work to other, less wealthy masters. These lesser masters often could not afford to wait for the payments of customers, because it often took considerable time to receive payment in full. Wealthy armorers, however, were able to either pay the smaller masters up front, or combine payment with the necessary raw materials, to lessen the cost to the contracted master. It was stipulated in the Nüremberg charter that this contracted master must also be a local citizen (27).

The Augsburg guild provided a much more lenient set of rules for their masters. The guild prospered without regulations until 1562, where changes were made necessary due to a slump in the demand for armor at that time. New regulations set forth in 1562 required that any aspiring master serve four years as an apprentice, then four as a journeyman. The Augsburg guild also required a complete suit of armor for their masters' evaluations. These evaluations were conducted by an elected group of four masters; these masters also inspected and stamped every suit of armor that sold. Armors would be fined if they sold armor that was not stamped by the master's council (28). However, we see today that a great deal of armor still went unstamped.

Figure 5: An Example of Guild Stamps

Principles of Armor Design

The armorers of the 16th century typically adhered to certain principles of design (Ffoulkes 1912: 2). Two of these principles were fundamental to the creation of armor, and were held in the highest regard when armor was designed. The other two principles were not as important, but were still reflected in nearly all armor.

The first of the fundamental principles of armor construction was suitability of purpose. The armorer must keep in his consideration the intended use of the armor. Every type of soldier required slightly different types of armor, dependent on many variables. Nearly all infantry and cavalry armor is thicker in the front than the back and sides, because the front of armor is the most likely location to be struck (Pfaffenbichler, 1992: 63). Infantry armor can be instantly distinguished from cavalry armor by the cuisse, which protects the back of the thigh for foot soldiers (Ffoulkes 1912: 6). Cavalry troops do not need this protection, as their thighs are protected by the flanks of the horse.

This differentiation in armor types was also reflected off the battlefield. Jousting armor, for example, is much heavier on the left side because it is the left that is always struck with the opposing lance.

Glancing surfaces are found on nearly all suits of armor; these curved surfaces were designed to deflect blows rather than to absorb the impact. The most common and easily noticeable glancing surfaces on armor are found on the helm, but nearly every surface is curved with this purpose in mind. The arms of most suits of armor feature lames that overlap downwards, to shed any blows that may come in from above (Ffoulkes 1912: 3-4).

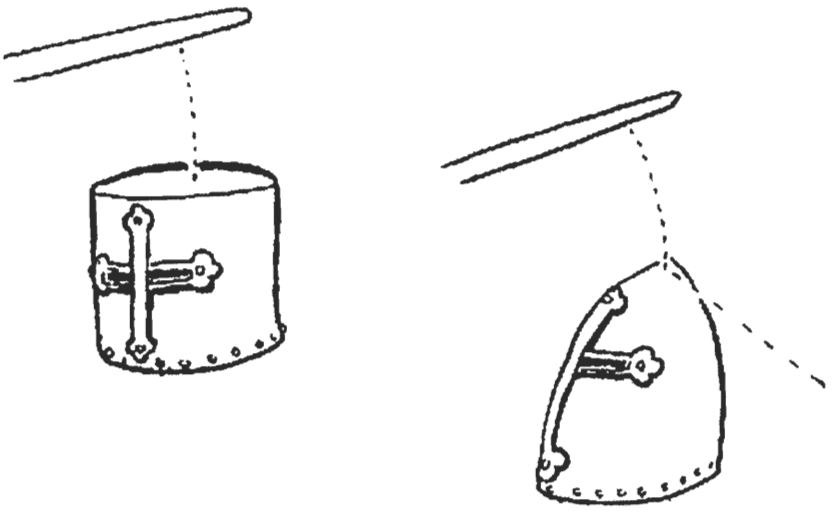


Figure 6: Demonstration of a Glancing Surface

Equally important was the second fundamental principle of the armorers, convenience of use, which often worked hand-in-hand with the functional suitability of the armor. Combatants had to spend a lot of time walking and riding in their armor. It was important for soldiers to remain comfortable, if feasible, and allow for as much range of motion as possible. Armorers often employed techniques such as the sliding rivet to permit range of motion without sacrificing protection (Ffoulkes 1912: 5-7).

Figure 7: The Armor Hinge

The development of the armor hinge is a good example of how constructional methods evolved through use and time, showing application of the two main principles of design. Originally, the armor was simply a normal hinge mounted on the outside of the armor. However, it evolved into a specially designed hinge mounted on the inside of the armor to protect it from the blows of attackers.

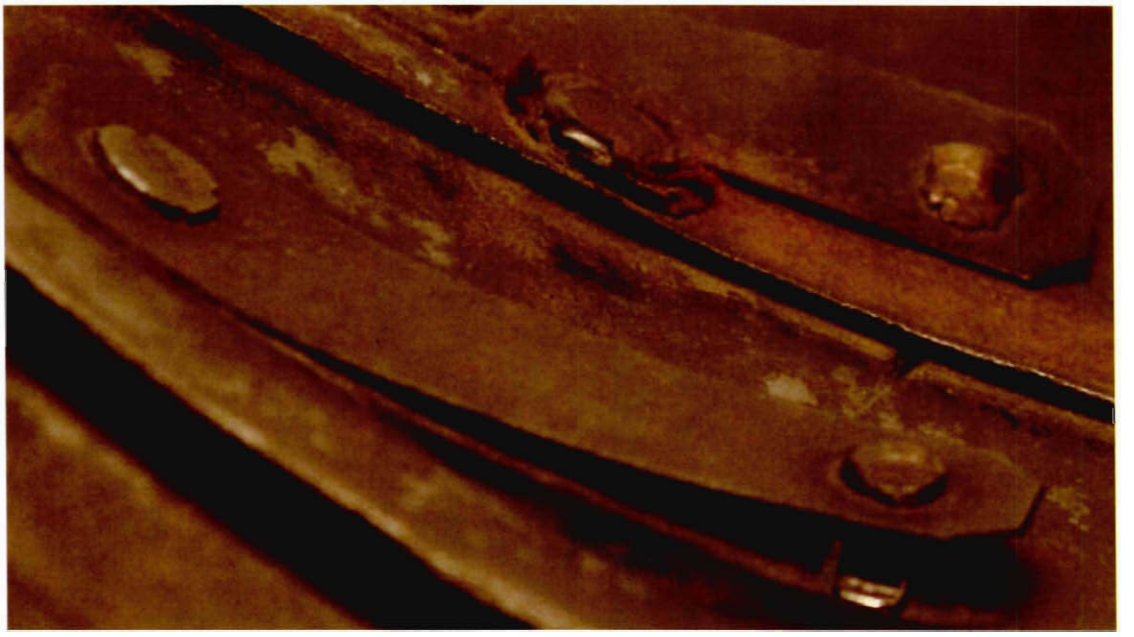


Figure 8: Spring-loaded snaps on the back of a Falling Buffe

Examples of construction techniques in armor that show this application are spring-loaded snaps, the sliding rivet, and the turning hook and pin (Ffoulkes 1912:10).

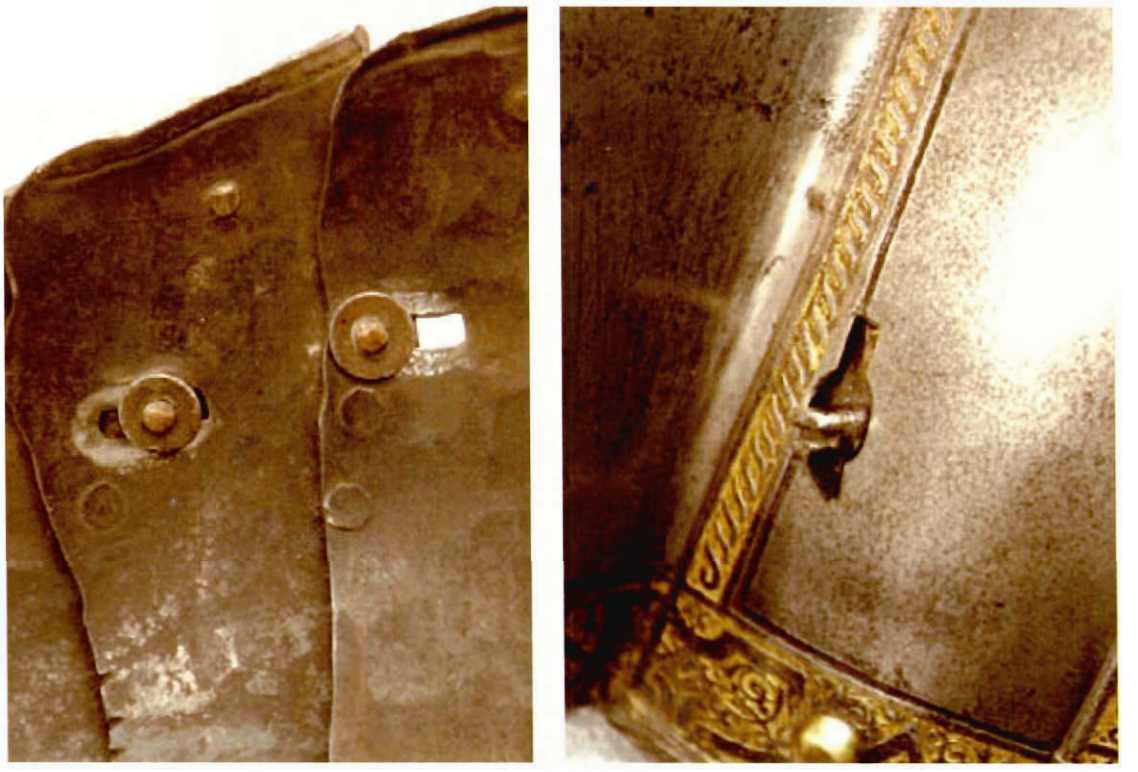


Figure 9: Sliding Rivet and Turning Pin on Tasset

The secondary principles of design consist of recognition of materials and styles, and the subservience of decoration to the primary principles.

Fashion was an enormous influence on armor design and construction. Many individual pieces of armor reflected different aspects of what was modern style. This can be seen in the shapes of the breastplates, or in the evolution of the sabaton. The sabaton moved from a very pointed shape to a very bulbous one. The approach of modeling armor after fashion was even used in rare occasions in designing pieces like the cuisse, which could look skirt-like, or in the pauldrons, which were sometimes puffed like slashed velvet. The recognition of period style and fashion was also true in reverse. New technologies that developed for armor were sometimes reflected in the fashion of the period.

Visors in armor were even sometimes made to resemble animal, bird, or human heads. These "grotesque forms" were intended solely to catch the eye of onlookers (Blair 1958:116).

The subservience of decoration to the primary principles was yet another consideration to be made. Etching, gilding, and coloring, were the most common decorations on armor, as they did not involve a raised surface and did not affect the movement of the piece. Other decorations, such as embossing, were reserved mostly for ceremonial armor, as the relief could negatively affect a knight's motion. The effectiveness of glancing surfaces could be hindered by embossing, which provided places for blades to catch instead of bouncing harmlessly away. Similarly, suits designed with sliding rivets could be impeded by embossing.

Embossing and etching were sometimes employed to create the illusion of lames and false rivets. The creation of this false decoration illustrated the cost of armor. Creating false lames was much cheaper than having actual lames in armor, but looked almost as good.

Figure 10: Venus at the Forge of Vulcan. Water-driven tilt-hammers and grinding wheels can be seen on the right.

The Construction of Armor

The armorers' techniques for building plate armor were refined throughout the time in which plate armor was considered the primary source of protection for a well-equipped soldier, a time that lasted from the early 14th century to the late 16th century.

Before beginning the construction of a suit of armor, the armorer would usually take measurements of the intended owner. Often the armorers would take more measurements than they might need, as it was crucial the armor was made to fit exactly. There are recorded occasions when an armorer from a distant location would be contacted for an armor contract. If it was impossible for either party to travel to meet, the armorer would be forced to build the armor with nothing but a painting to work from. Undoubtedly, this was very difficult.

Once the measurements were taken, the construction of the armor began. Unless the armorer had a large shop, he would order plates of steel from a forger in the area. In exceptionally large shops, the armorer would have a forger, or hammerman, on site, whose sole purpose was the forging of plates of steel. The forger would work with either wrought iron or billets of steel, beating them out to make the actual plates. At first, all work was hand-hammered, but as the armor crafting technology developed, techniques involving a water driven tilthammer were employed to save the hammerman the monotonous job of hammering the steel flat (Pfaffenbichler 1992: 62.) The rolling mill, used to shape pieces of steel, was developed for use by the middle to the end of the 16th century (Ffoulkes 1912: 40).

Figure 11: Maximillian and his Armorers

The armorer would take the plates from the hammerman and begin to form them. First, the plates would be cut into specific shapes using a pair of large cutters fastened to a tree stump for leverage. Then they would file the edges of the plate, and apply their mark somewhere on the piece (Valentine 2000: 4).

There are no specific documents that detail the armor making process, as many of the techniques the armorers used were considered guild secrets. A great deal of the knowledge we have regarding the creation of armor comes from living practice and tradition, surviving armory inventories, and armorers' diaries. The armorer had at his disposal a large number of specialized tools to create different shapes with the newly cut pieces. First, there was a set of anvils that were designed to produce specific shapes when the steel was hammered on them. The "pipe stake" was used for making tubes, presumably for the upper and lower cannon and the greave. The "crest stake" was used in conjunction with the "crest hammer," and was designed for the creation of a crest in the helm. The "visor stake" was used for the creation of visors, and the "cuirass stake" was used to make the cuirass. The "stake for the head pieces" was used with the "hammer for the head pieces" to form helmets. Numerous other hammers have been listed in inventories of armories. These include the "plating hammer," a heavy hammer, much like a sledge hammer, used for beating out plates of metal. There are also a number of small hammers, the "greave hammer," "riveting hammer" (for use creating and placing rivets), and the "boos" hammer, probably for raising or embossing (Ffoulkes 1912: 27; Pfaffenbichler 1992: 62). Other methods were sometimes used in the forming of armor, such as hammering the breastplate piece into a shallow hole in a stump to form

the rounded shape, or a steel ring mounted on a stump to hammer into (Valentine 2000: 5-7).

Steel, or iron with increased carbon content, was likely made in one of two ways. The first of these methods took place before the armor as shaped. The plate of iron was smeared with hog's lard and wrapped it in goatskin. This would then be covered in clay and heated for a very long time (likely a number of days.) Carbon from the goatskin and lard would seep into the iron, leaving it with higher carbon content. The amount of extra carbon in the iron was directly related to the amount of time the iron was heated in with the lard and skin (Pfaffenbichler 1992: 63). The other, more common method for making iron into steel involved leaving a newly made piece of iron in the furnace to expose it to the carbon monoxide gas put off by the burning charcoal. This method, however, left the iron with an uneven carbon composition, so the forger had to fold the iron and reforge it. This method of folding was perfected by the East Asian cultures as well (64).

While some armor was worked hot, most of it was worked cold and frequently annealed (heated and cooled to soften the hammer-hardened metal). Heat was required when the shaping of the piece was finished and the edge was bent over a wire. This bending helped guard against glancing blows being deflected into joints (the rounded edge caught the blade) and served to dull the edge so it was not as sharp (Pfaffenbichler 1992: 62).

Once the armor had been shaped, it would be quenched. Quenching involves heating the armor, then plunging it into cold water. This process serves to increase the hardness of the metal. The faster the armor was quenched, the harder the surface would become. Unfortunately, the quenching process often led to the metal being brittle.

Because of this, the quench was followed up with tempering. Tempering involves heating the armor to a specific temperature (the temperature of the metal could be estimated by its color) and allowing it to cool gradually. Tempering served to reduce the internal stress that had been built up by beating and bending the metal. This internal stress would increase the possibility of the armor cracking if it were struck with a weapon (64).

This two-stage method was only used by the best armorers, who were willing and able to spend a great deal of time on the armor they were creating. A more common one-step method, called slack-quenching, involved heating the armor, then either delaying the quench, or using a less drastic quencher (cool instead of cold water, etc). Slack-quenching was used so the armor could either be kept at a lower temperature while tempering, or not tempered for as long (Pfaffenbichler 1992: 64).

Figure 12: A Polisher using a Polishing Wheel

Once the armor was forged, shaped, and tempered, the pieces were still blackened and rough. The armor was sent to the polisher/millman to smoothen out, take out the small dents, and polish it to a shine. The armor was then sent to the finisher, who put on strappings and linings, padding where necessary, and fashioned leather gloves to attach to the gauntlets. If needed, the armor would be sent finally to the etchers and gilders to decorate before the customer received his piece (Pfaffenbichler 1992: 62). Most of the time, the armorer would be on hand when the customer tried his armor on, to make on-the-spot alterations that may have been impossible to predict when making the armor.

Components of Late 16th Century Armor in Germany

The 16th century saw a substantial change in the styles and usages of various pieces of armor. Some changes were functional, designed to enhance the defensive capability of the armor. Many, however, were purely stylistic, often reflecting trends in clothing at the time.

The Helmet

The helmet of this period was varied in style and function around Europe. For the first few years of the century, the influence of the German-Italian fusion (see Armor Background) could be seen here. The armet, a largely closed helmet constructed in the Italian manner, was being produced in Germany for full suits of armor. It consisted of a pair of cheek pieces that were hinged to the tail of the skull. This type of helmet was used for about ten years, at which point it melded with the development of the close helmet. This melding essentially removed the back part of the helmet, the rondel, and replaced it with a plate guard (Ashdown 1967: 266). Additionally, the rim of the close helmet was hollow, and allowing it to turn on the corresponding rim of the gorget, a defense for the neck.

The close helmet was a particularly effective defense used with a full suit of armor. After the addition of the gorget in 1520, this head piece completely enclosed the head. The gorget consisted of lames of steel riveted at the sides which overlapped upwards. The sliding rivet design allowed the piece to move freely yet continue to offer full coverage (Ashdown 1967: 267). Because of the hollow-rimmed mounting of the

close helmet, the wearer was allowed an exceptional range of motion, while at the same time it could not be knocked askew by an opposing combatant (Grancsay 1986: 130).

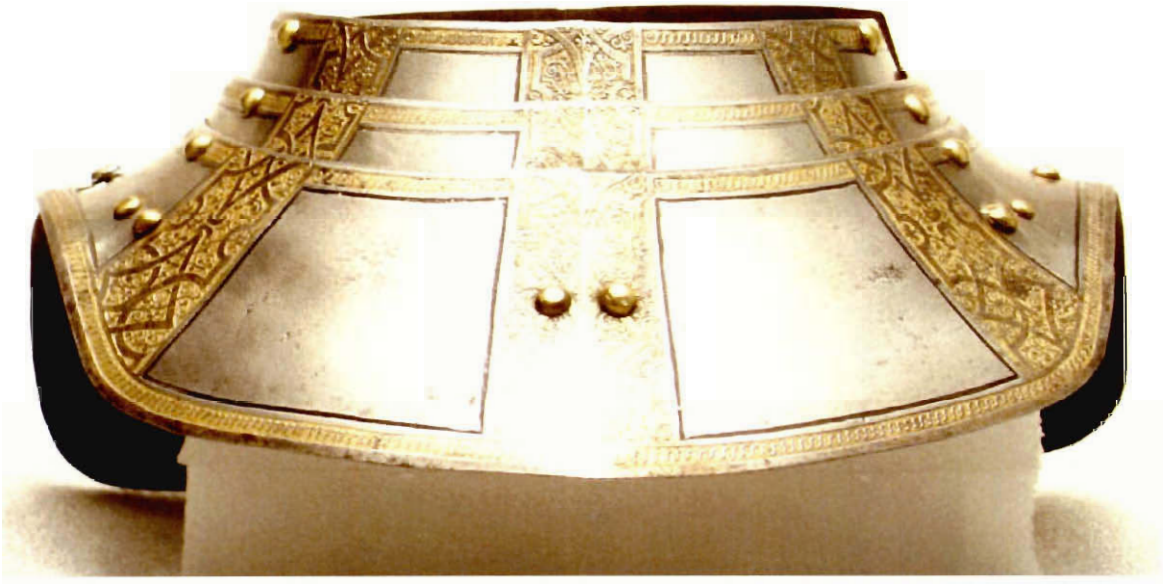


Figure 13: Gorget

In general, the close helmet during the first few years of the century had either a flat, broad comb or no comb at all. However, the comb became more prominent on head-pieces over time and after 1530 the comb was usually quite large, especially in the second half of the century.

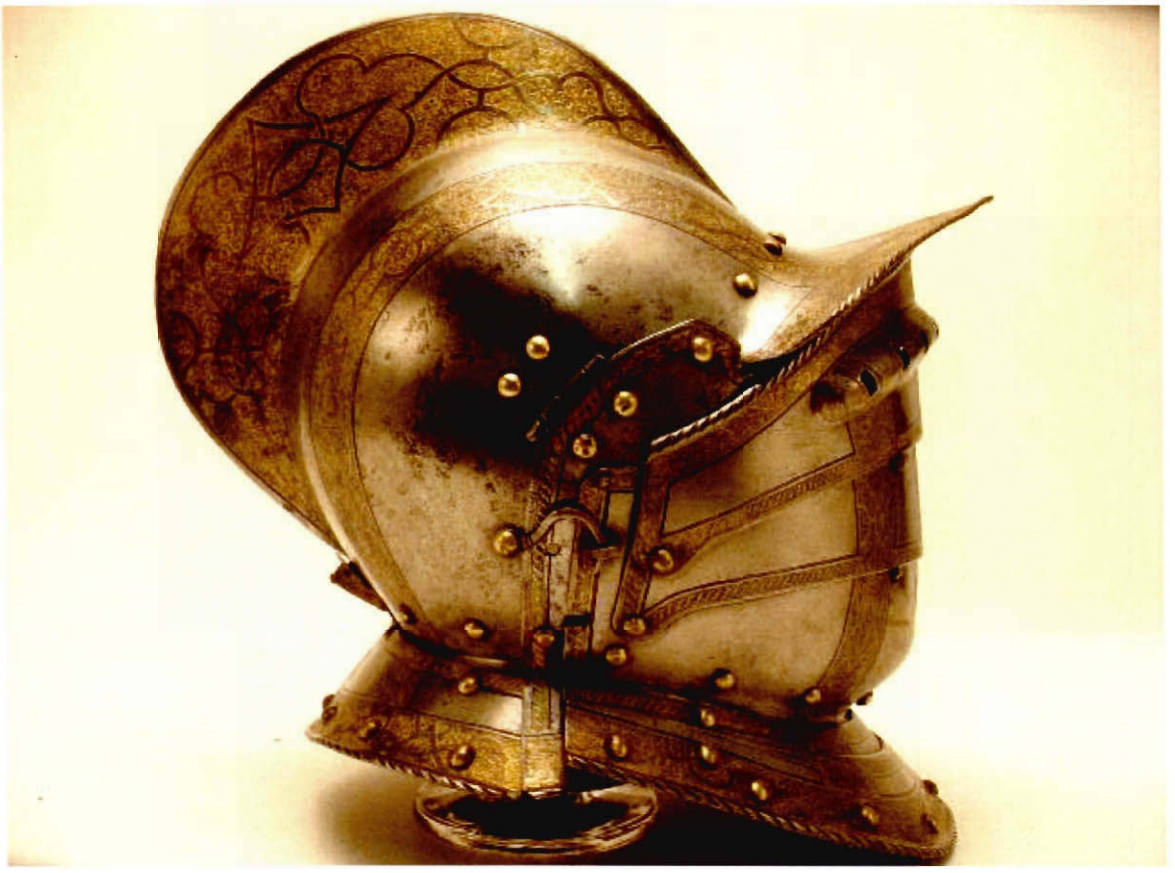


Figure 14: Burgonet

Another type of helmet developed for the infantry and light cavalry was a close-fitting open helmet known as the burgonet, as demonstrated by this piece. This helmet covered the cheeks but sometimes left the front of the face exposed. The brim comes to a sharp point extending beyond the visor. At the base of the large comb is located the triangularly-shaped plume holder. It is generally thought to have been derived from the sallet (Blair 1958: 136). This style of helmet generally comes with a buffe (see below). The morion, or "kettle-hat", was also sometime used by infantry. It comprised a down-turned brim that curved up to a sharply pointed brim at both the front and rear, and was completely open-faced. It was primarily used by archers and musketeers, because of the visibility it afforded.

To protect the eyes and maximize defense of the upper face, the visor was originally constructed of a single piece, often of the bellows style. This style consisted of a set of semi-circular lames that were connected in ridges. The lames would have holes punched in them for visibility and ventilation. However, as the century progressed, the visor separated into two distinct pieces.

The front of the face defense, below the visor, is called the buffe. During this period, buffes often accompanied both close-helmets, as part of the helmet itself, and burgonets, as either part of the helmet or attached to the breast plate. A form of the buffe that was easy to remove also appeared on many pieces. It was called the falling buffe, and consisted of a set of lames that could slide along each other (the concept of this motion can be related to that of a collapsible antenna on a remote-control device).

The helmet for this suit is furnished with a falling buffe of three lames, which are pivoted at the sides. The falling buffe's primary purpose was to provide adequate protection for the lower face, while being easy to drop when necessary. This example is secured with spring-loaded catches (Grancsay 1931: 74). The comb is of exceptional size, as can be seen in Figure 2. At the base is a brass plume holder, also evident in Figure 2 where the comb ends at the back. Also, note the pivoted hook located on each side for securing the buffe (see below for an explanation of the buffe), (Grancsay 1931: 74).

Some helmets during the early part of this century attempted to approximate wild beasts in their appearance. Known as grotesque forms, the visors on these sets of armor might simulate bird or animal masks, or even that of a human face. To accompany the headpiece, the entire armor would be etched in imitation of the style of dress at the time.

The Cuirass

As with the helmet, a variety of forms developed for the armor of the body during the 16th century. Each was designed for use by a different type of fighting men. These defenses developed naturally out of a need for varying levels of mobility and protection among the units, much as helmets balanced the need for protection with visibility.

During the preceding century, the most common piece of munitions-grade body armor was the jack. Essentially a coat of plates, the small plates of steel were stitched into canvas and sometimes reinforced by strips of plate. The better-equipped foot soldier would come to battle wearing a breastplate or cuirass.

Infantry armor changed beginning in the early 1500s to the corslet, a type of light half-armor with much more defensive plating. In its entirety, it consisted of a collar, breastplate, back plate, tassets, vambraces, and gauntlets. This shift in the amount of plate in munitions-grade armor may be one reason why armorers were commissioned with a great deal of work in this century.

Cavalry, too, saw a change in their outfit. Light cavalry were now outfitted with defenses primarily for the body (cuirass, collar, spaudlers, gauntlets, and short tassets), and heavy cavalry a type of "three-quarters" armor, fully protecting everything from the knees upward. Cavalry breastplates also came with a lance rest, which for obvious reasons was not included on infantry breastplates.

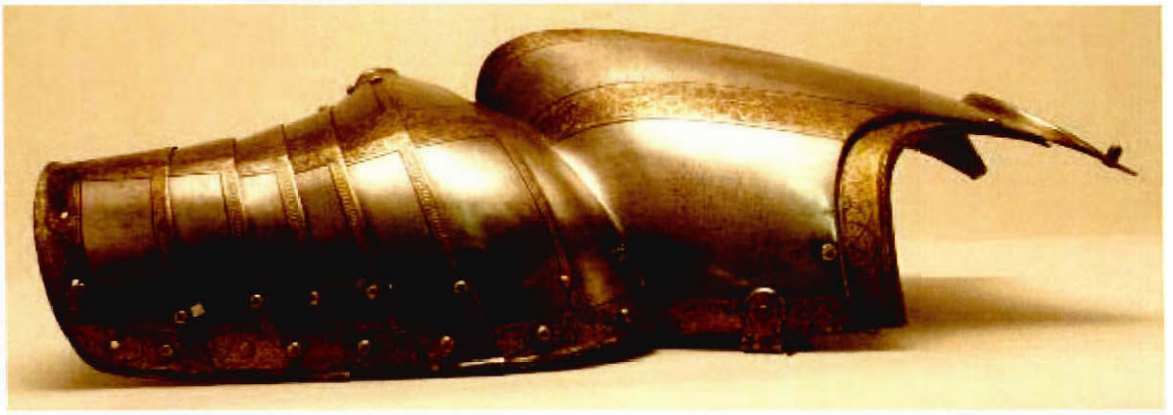


Figure 15: Side View of Peascod-Style Breastplate

The German breastplate during this period is primarily described as globular during the first part of this century. This form is used almost exclusively until 1530, at which point it developed a low medial ridge along the center of the abdomen. After 1530, two distinct styles began to evolve. The first saw medial ridge develop and drop into an exaggerated point, reaching its peak length in the 1550s and 60s, and was known as the 'peascod' style. The second followed more Italian lines and become longer and flatter.

Our example follows the peascod style, and has a vertical mid-ridge. To secure it to the back plate, a hinged iron strap is used with a chain and peg. Otherwise, this piece is fairly typical of the styles listed above.

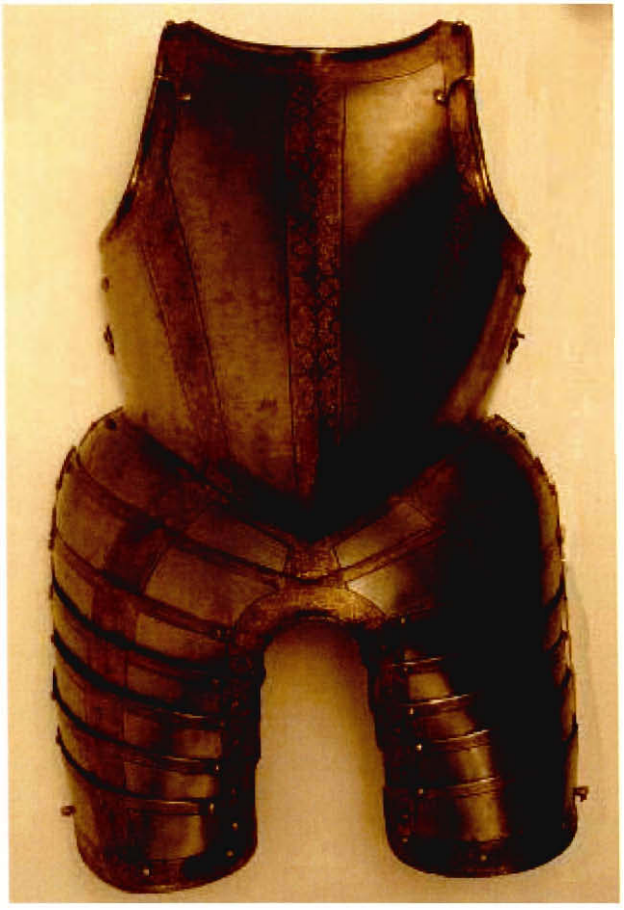


Figure 16: Breastplate and Tassets

The back plate complements the breast plate, forming a complete shell of steel for the body. While many sets of munitions-quality armor did not include a back plate, it was a standard feature of all full sets of armor. Secondary defense plates around the waist sometimes accompanied the back plate, but there was no standard in this matter. Where the tassets are on the front, the back plate sports the culet. The general style of a back plate of this period is embossed slightly at the shoulders and flanged where it meets the culet. During the first half of the century, this culet consisted of many lames, but this slowly degenerated and after 1560 usually consisted of but a single lame.

This back plate is shaped to fit the shoulder blades and has hinged iron straps. The culet, being from the year 1560, naturally has but one lame. It is detachable using a

keyhole perforation on either side. These fit over the turning pin on the back plate. There is also an extension plate that is riveted to each side of the back plate (Grancsay 1931: 74).

The tassets, a hip-level defense suspended from the bottom of the breastplate, were often attached directly to the breastplate and could not be removed. This was not universal, however, and there were still some that were attached by leather straps, buckles, and hinges. There is often a separate plate just for this purpose, as in this example. During the early parts of this century, German tassets were constructed all of one piece. In general, however, all tassets of the middle and late 16th century are laminated, consisting of many lames of steel. Infantry tassets extended to just above the knees during the early 1500s, and fastened there around the thighs with straps, buckles, and leather thongs. By the 1530s, the poleyns (see below) were sometimes attached to the tassets as well, but as the century progressed the tassets gradually became shorter again.

In general, the full suit of armor was completely developed by the beginning of the 16th century. Hence, all the pieces of the armor are simply improvements or changes on old designs. One unique piece that developed during this century, however, is the codpiece. This defense covered the genitals of the wearer with a cup-like protection with thick padding on the inside (Blair 1958: 123). It came into use during the 1510s and was put on suits of armor until as late as 1570.

The Legharness

Few changes were made to the defense for the legs during this period. The most important changes took place in the area of the foot defense. There is little to note about the poleyns, defenses for the knees, or the greaves, defenses for the shins, as they

changed little from the form taken in previous centuries. Of most significance is the appearance of the three-quarter suit, designed for cavalry, which did not extend below the knee.

The armor that defends the thigh area, called the cuisse, changed a little during this century, especially in Germany. For most of the later part of the century, the cuisses are in two pieces which are joined horizontally. Also of note, the hinged side plates of these cuisses started to become incorporated into the main plate, eventually becoming smaller and finally disappearing altogether by the second half of the 16th century.

On the other hand, the sabaton, a defense for the foot, changed a great deal. In previous centuries, these pieces were generally long and pointed, often much longer than necessity dictated. During the 1500s they became shorter and broader, sometimes excessively so, before narrowing down and forming an oblong shape, much like the shoes of modern garb. These changes are generally attributed to fashion, and do not reflect any competitive advantage. In general, the lower parts of the legharness were not used by cavalry in this century. Indeed, infantry pieces were often found without them as well, restricting their usage to the upper class.

The legs on the piece presented here are fairly typical of a suit of armor from the second half of the century. However, it should be noted that the greaves and sabatons are reproductions. The work was done by Daniel Tachaux of Paris and gilded by Francois Daubresse. The reproduction, however, is generally correct.

Figure 17: The Legharness

The Arm Defenses

The German vambrace (a word used to describe the entirety of the defense for the arms) was often permanently joined, and thus the three parts that generally comprise it (lower cannon, couter, and upper cannon) are rarely found apart. Sometimes, the entirety of the vambrace is also connected to the pauldrons or spaudlers (shoulder armor).

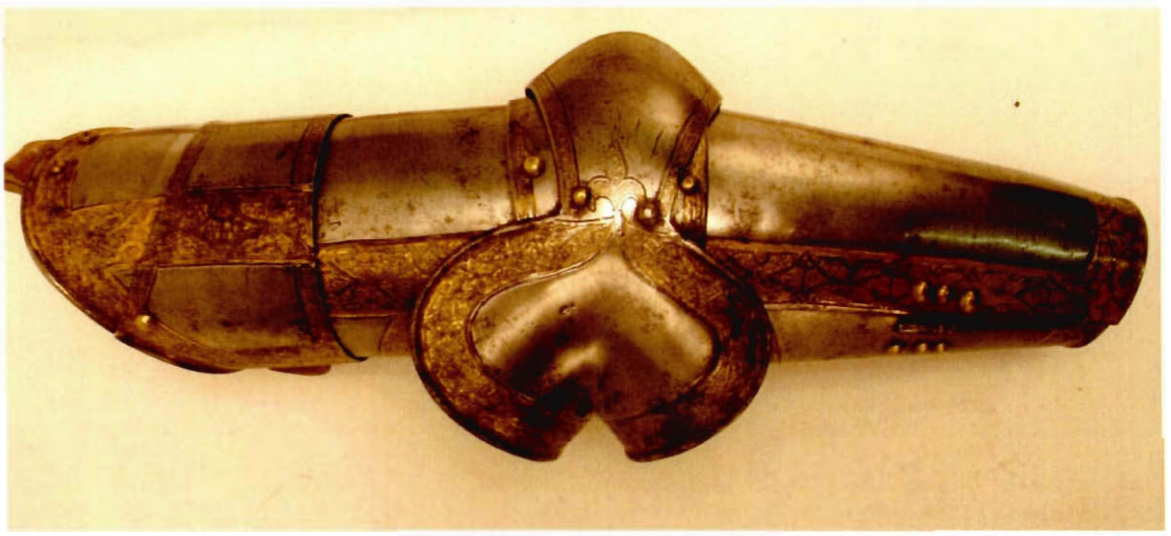


Figure 18: Vambrace

Blair (1958: 126) defines the two general forms of shoulder defense as follows. The spaudlers are considered to encompass any of the small, cap-like defenses for the shoulders, and pauldrons the large forms that also cover part of the breast and back plates. For purposes of simplicity, the term pauldrons will be used here to refer to all shoulder defenses, as spaudlers generally are not used after 1560. The distinction between the two terms is in what suits they were for. Pauldrons most often were used for full suits of armor, while spaudlers supplemented partial suits for infantry and cavalry.

The pauldrons of this century are all generally of moderate size. They are constructed of narrow lames that overlap upwards or downwards (no set rule) from a broad central lame. The lames are connected using either sliding rivets or leather straps to allow for freedom of movement.

The vambrace and pauldrons (not spaudlers) of this suit are very typical of the period. The pauldrons consist of five lames secured by straps and sliding rivets, although they are beginning to lose some of their mobility. Also note the rotating cannons on the upper arm.

Figure 19: The Pauldron

The couter of this piece consists of three lames with inner and outer heart-shaped flanges (Grancsay 1931: 74). In most German pieces earlier in this century, couters were large and shell-like, and after 1515 the couter was of the "bracelet" type, completely encircling the joint. Such is the case with this piece, and commonly of all German pieces in this century (Blair 1958: 125).

In the early sixteenth century, "mitten" style gauntlets gained great popularity. About thirty years after this trend started, however, it died, and armorers returned to making gauntlets with individual fingers. Gauntlets are almost always decorated as the rest of the armor (Blair 1958: 127-128).

Figure 20: The Gauntlet

The Military of the Late 16th Century

The Italian wars early in the 15th century yielded some interesting changes in the way armor was made for the common foot soldier. Developments after the Italian wars led to armorers producing light harnesses for use specifically by infantry and light or medium cavalry (Blair 1958: 112). Before this time soldiers either wore cheap imitations of the armor their superiors wore, or quilted or leather armor with a kettle hat (118).

Infantry

The infantry of the 16th century military were separated into light and heavy foot soldiers. The light infantry occupied the area behind the heavy footmen. Light infantry soldiers were provided with a sword or rapier, depending on their preference or what was available to them, and a dagger of arbitrary size. The light infantry soldiers wore a burgonet and corselet (breastplate, backplate, and tassets). This left their arms and legs uncovered by plate, though they usually wore heavy cloth or leather on their legs (Webb 1965: 90).

Heavy infantrymen held the main line of defense (or offense) with a range of multi-purpose weapons. The pike was the preferred weapon of the heavy infantrymen because of its versatility against both mounted and foot soldiers. Traditionally made of good light wood, the pike varied in length from 15 to 20 feet. Pikemen also carried either a sword or rapier, which they would use either in melee combat once their lines were broken, or in conjunction with a planted pike against mounted foes (Webb 1965: 87-90). The heavy infantrymen were equipped with a collar, corselet, vambraces, gauntlets, and an open helmet. The infantrymen were fully clad in armor, with the exception of their legs (Blair 1958: 118-119).

The infantry were used primarily as shock troops to smash through the front forces of the enemy after the initial shooting, and leave them in complete disarray.

By the late 16th century, firearms had made their way into the military structure, with harquebuses, calivers, and muskets being the most prevalent firearms carried by infantry. All three of these weapons were matchlocks. With the harquebus and caliver being so similar, they were often confused for each other. In general, the term harquebus is used to describe the longarms used on horseback, the caliver for a light footman's firearm. The musket, however, was so heavy it could not be accurately aimed without assistance, and therefore required a musket rest (Webb 1965: 92). Most musketeers did not have any armor, though some wore morions (which would not impair their vision).

Figure 21: A Musket and Musket Rest

Cavalry

The cavalry units, just like the infantry, were separated into light and heavy cavalry, with a separate category for cavalry troops armed with firearms. The light and medium cavalry units, known as light horse, light staves, or javelins, carried a light (10-15 ft) lance, and a sword (Webb 1965: 115). The light cavalry units were armored with a

cuirass, short tassets, a collar, spaudlers, gauntlets, mail sleeves, and an open helm. Like most other troops, this left their legs uncovered (Blair 1958: 119).

The heavy cavalry, known as the lances or demi-lances, formed the main component of mounted troops (Blair 1958: 119). These soldiers carried a 12-18 foot lance, and a pistol if available (Webb 1965: 115). The cavalry units were clad in "three-quarters" armor which consisted of a cuirass, pauldrons, vambraces, gauntlets, tassets, cuisses, and either an open or closed headpiece. Once again, their lower legs were left unprotected. It is interesting to note the breastplate did not have a lance rest, because the lance carried by the cavalry soldier was considered a light lance (Blair 1958: 119).

The light, medium, and heavy cavalry units were used in conjunction with the infantry as shock troops.

The third cavalry type, the shot-on-horseback, was divided within itself into two subtypes, the pistoleers and harquebusiers (argoletiers). In general the shot-on-horseback soldiers all wore the same or similar armor. This armor consisted of a burgonet, collar, cuirass, pauldrons, and a gauntlet for their bridle hand, leaving their shooting hand free. The pistoleer would carry three pistols as his primary offense, one mounted on his person, and two on the horse. The argoletier wielded a harquebus with a snaphance lock. Both the pistoleers and argoletiers carried a sword and dagger for secondary defense, and both carried with them the materials to reload their pistols while remaining on horseback (Webb 1965: 117).

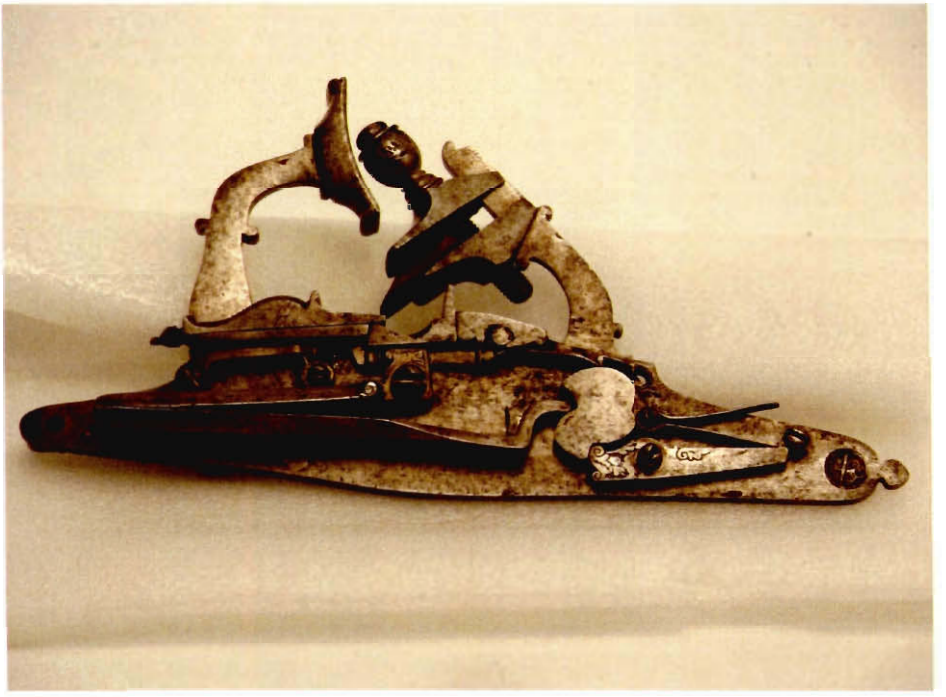


Figure 22: A Snaphance Lock

Field Artillery

Field artillery was used with nearly all armies. The unreliability of the cannons made them difficult to aim, and because of their unpredictability they had to be positioned on the flanks of their army even with their front line to make sure their cannonballs did not inadvertently fall on friendly troops. Because of this, the artillery was very vulnerable to enemy cavalry. Often, the artillery would be unable to shoot a second time (142-143).

Double (Great) cannons and demi-cannons were used to penetrate walls (130). These cannons were so large they required upwards of 20-24 animals to draw them (128). Quarter-cannons and culverins were used defensively against oncoming enemies, often mounted on walls to fire on troops below. The sakers, falcons, and falconettes were used as field pieces (130). The cannoneers designed multiple forms of shot to put in the

cannons. Usually, the cannons fired iron or stone cannonballs, but sometimes the cannoneers would pack the cannons with bags of musket balls, or chain-shot, a pair of smaller cannon balls connected by a chain.

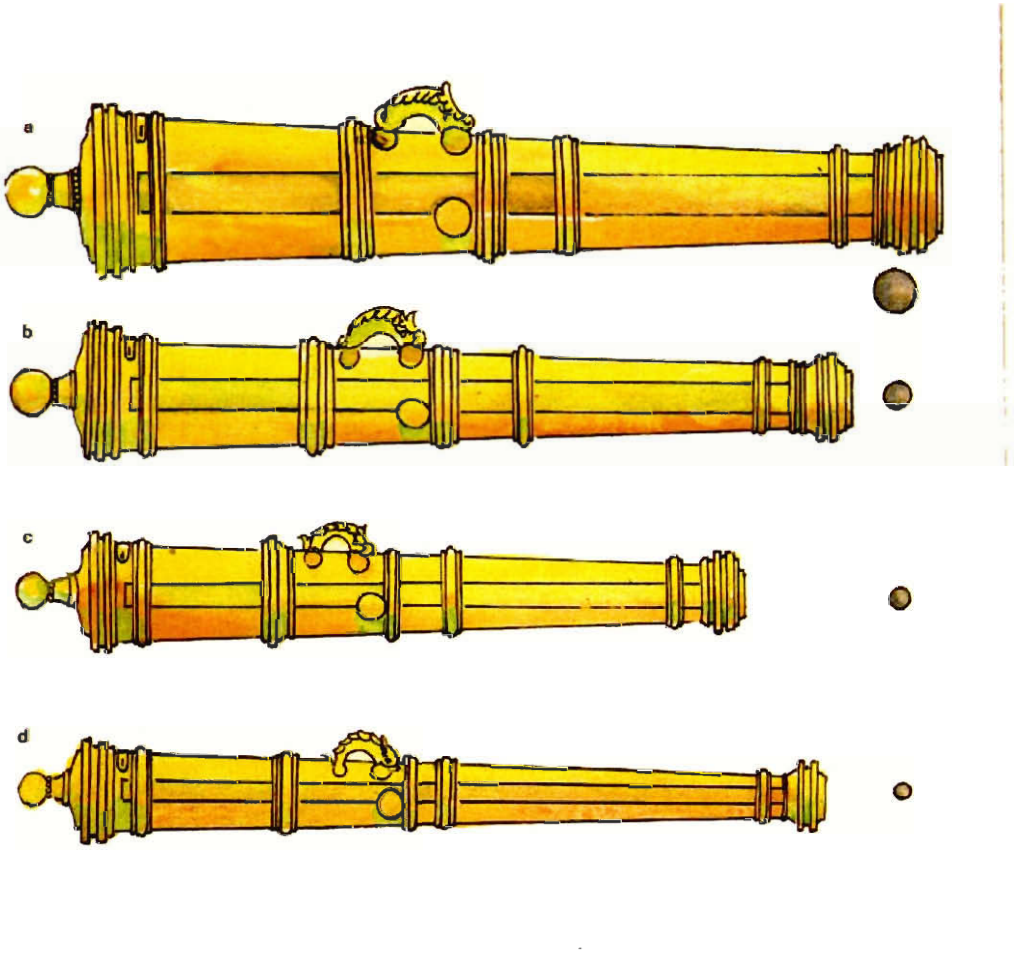


Figure 23: Cannons and their Relative Sizes

A – Cannon
B – Demi-Cannon
C – Culverin
D – Saker

Military Tactics

By the end of the 16th century, the previous dominance held by the cavalry had been replaced with the less expensive, more plentiful pikemen and light infantry. Cavalry grew increasingly scarce, and eventually held a secondary position behind the harquebusiers, calivermen, musketeers, and heavy infantry.

Elizabethan military tactics are often compared to the tactics of the armies of ancient Rome. At the beginning of a battle, the calivermen would move to the front and fire volleys into the enemy troops, much like the bowmen and sling bearers did in Roman times. These cursory blows were called the "skirmishes of forlorn hope," and were intended to "overwhelm and pursue the enemy, or provoke him to move the assault" (Webb 1965: 100).

There were two main methods used to keep the volley of shots continuous. The first involved an alternating front line, where the front line would fire a shot and exchange places with another line of shooters. While the first line was reloading, the second line was shooting, and vice versa. The second of these tactics involved the troop of firearms-men marching in a circle, as a soldier reached the closest point to the enemy they shot their weapon, and as they continued around the circle reloaded, so they were ready when they came close to the enemy again (101). The attackers either broke the enemy lines or were forced to retreat when the enemy advanced; the calivermen never fought in close quarters (102). While these soldiers were shooting from the front lines, musketeers either shot from arbitrarily placed stationary squares, or formed a half circle and shot over the front line troops in volleys (101).

If the enemy troops showed any signs of giving in, the shooting skirmishes would be immediately followed by a charge from the heavy infantrymen with swords in a frontal assault, accompanied by the medium and heavy cavalrymen (99).

The cavalrymen had a two-fold purpose. Primarily, they were intended to break through enemy lines and create confusion and disarray (Webb 1965: 119). Their secondary goal was to deal with the cavalry of the enemy. The cavalrymen could either aim their lance with a slight upward angle to attack the heads of mounted enemy soldiers, or aim their lance parallel to the ground in an attempt to unhorse them. A more crude method of eliminating enemy mounted troops involved aiming the lance at a slight downward angle, with the intent of piercing through the chest of the horse. This method could also be used to strike an infantryman in the face (116). If the enemy was using pikemen, horse would not be employed against them, as horses were not cheap, and it was an unnecessary risk (118).

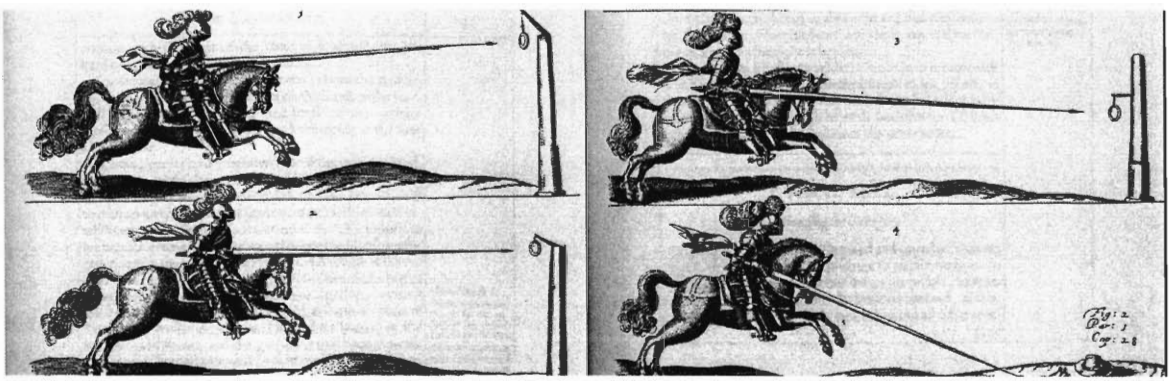


Figure 24: Lancers and their Techniques

If the enemy troops did not give in, but rather attacked, the calivermen and harquebusiers would move to the back, and the pikemen would move to the front.

When being assaulted by troops on foot, the pikemen would stand sideways, with their pikes held shoulder high for stabbing, piercing attacks at the enemy. The same

weapon could be used effectively against horse by planting the butt of the pike into the ground in front of their rear foot. Presented with a line of pikemen, a mounted enemy would be unable to penetrate without serious danger to his beast (87-88). During the assault, the first four ranks of pikemen were so close together, if anyone were killed or wounded, they could be replaced without a break in their ranks (103).

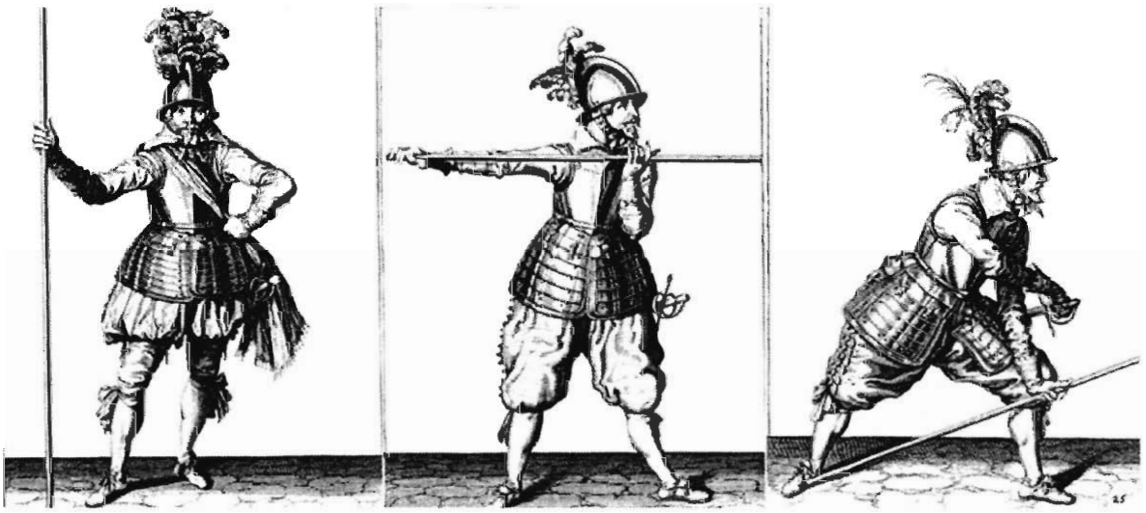


Figure 25: A Pikeman's Stances

Figure 26: The Herberstein Armor

The Herberstein Armor

The armor exhibited here is believed to have been made in 1560. It had previously belonged to New York socialite Oliver H. P. Belmont (1858-1908), and later to Clarence H. Mackay (1874-1938) from whose estate Higgins purchased it in 1940.

Belmont was not only an avid collector but involved himself in many other affairs, including a variety of athletic clubs, law, and yachting. His estate, Belcourt Castle, and collection were purchased with money inherited from his father, August Belmont. Notable among his decorative interests were suits of armor, horses, and medieval and renaissance architecture.

Mackay lived in the East Hills area of Roslyn, Long Island. Mackay inherited his father's money as well, constructing an estate known as "Harbor Hill". The Mackay

estate had a very large armory built as the heart of the house (Grancsay, 1931). His legacy also is the Mackay trophy, "the oldest award presented exclusively to flying officers of the U. S. Air Force" (Aeronautical Systems Center History Office). After his death, his estate was demolished to build housing developments.

The Herberstein suit contains elements from at least two harnesses, one of which may have been made for Siegmund Friedrich (d. 1621), lord of Herberstein, to judge by similarities with armor elements in the von Kienbusch Collection (Philadelphia Museum of Art). Most of the elements would have been for medium or light cavalry use, or heavy infantry; the greaves and sabatons, used by heavy cavalry, were added in the nineteenth century.

The burgonet helmet for this suit is furnished with a detachable falling buffe of three lames, which are pivoted at the sides. The occularium is dotted with several oblong slits, and the visor above comes to a point, overlooking the occularium and buffe by several inches. The lames are secured with spring-loaded catches (Grancsay, 1931: 74). The comb is of exceptional size, reaching a maximum distance from the helmet of 3" and having a total circumference of 18". At the base of the helmet is a modern brass plume holder where the comb ends at the back. Also, there is a pivoted hook located on each side for securing the buffe (Grancsay, 1931: 74). The total size of the helmet is 18 1/8" from the furthest point back to the visor, and 8 ¼" wide from side to side. It is 12 5/8" in height.

The gorget for this piece consists of three lames connected by leather strips to accommodate the movements of the neck. As an elliptical shape, its widest point has a radius of 5 7/1". This narrows to 4 ¾" around the front and back of the neck. The total

height of the gorget is 4 3/8". At its smallest point, these figures reduce to 3" and 2 ¾", respectively.

The vambrace and pauldrons (not spaudlers) of this suit are very typical of the 16th century. The pauldrons consist of five lames secured by straps and sliding rivets, although they are beginning to lose some of their mobility. It is held to the body using leather straps. There is also a bolt along the left pauldron, possibly for the besagews. The pauldrons are 6 1/8" long from neck to shoulder, with a width of 9 3/8". It is 12" from the highest point on the shoulder down the length of the arm to the opposite end.

Each vambrace comprises a set of rotating cannons on the upper arm approximating a total length of 8 ¼", a couter of moderate size (7" wide at the elbow, 4 ½" at the joint), and a lower cannon of 8 1/8" in length. In particular, the couter of this piece consists of three lames with inner and outer heart-shaped flanges (Grancsay, 1931: 74). In most German pieces earlier in this century, couters were large and shell-like, and after 1515 the couter was of the 'bracelet' type, completely encircling the joint. Such is the case with this piece, and commonly of all German pieces in this century (Blair, 1958: 125). The vambrace has been refurnished with new leather straps.

The breastplate of this piece follows the peascod style, and has a vertical mid-ridge. The depth of the breastplate at its highest point, the medial ridge, is 7 ½". It is 15 3/8" wide and 24 ¼" long. To secure it to the back plate, a hinged iron strap is used with a chained pin. On the lower edge of the breastplate is some of the original leather. Because leather decays easily, this is generally uncommon.

The back plate is shaped to fit the shoulder blades and has hinged iron straps that secure the back plate and breastplate over the shoulders. The culet, being from the year

1560, naturally has but one lame. It is detachable using a keyhole perforation on either side. These fit over turning pins on the back plate. There is evidence here that the suit was refitted for a larger midsection, most notable on the sides of the back plate, where extra metal has been used to provide more girth. The back plate is 7 7/8" deep, 13 ½" wide, and 14 7/8" long.

The tassets consist of six lames. There is evidence that the tassets have been modified to accommodate the cuisse in the patterns of holes in the tassets. Much of the leather has been replaced. Additionally, the washers in the tassets are different. Where most washers in the suit are polygonal in shape, these washers are completely round. This implies that they were added to the tassets sometime after the 16th century.

The legs on the piece presented here are fairly typical of a suit of armor from the second half of the century. Each cuisse is 8 ¾" in length, 6" in width, and is approximately 2 5/8" deep. The greaves and sabatons are "restorations" (i.e. modern pieces made to complete the suit). The work was done by Daniel Tachaux of Paris in the nineteenth century and gilded by Francois Daubresse. The reproduction, however, is generally correct. The sabaton, greaves, and cuisse are inseparable, and the entire unit is 17 ¼" long, with a width of 4 7/8". The greaves are generally as deep as they are wide, being relatively circular. The length of the sabaton is 11 ¾".

The gauntlets of this piece contain several points of interest. Each is based on of a long hand-piece of vague hourglass form. At the point where the knuckles begin there are six overlapping lames, the last of these conforming to the shape of the knuckles. The left gauntlet has four fingers remaining, but the right gauntlet no longer has these. Upon careful inspection, the decoration upon the gauntlets is not uniform. It can be inferred

that these gauntlets were consolidated using two original pairs. One of these is in the same motif as the rest of the suit (see below), but the other has bowed ridges that are closer together and contain a pair of crescent shapes across it. This motif appears elsewhere as well, but is not generally as common. The individual fingers have a variable amount of lames. The pinkie has 5 lames, the ring 6, the middle 8, and the index 7. These individual lames bear a stair-like pattern of etching.

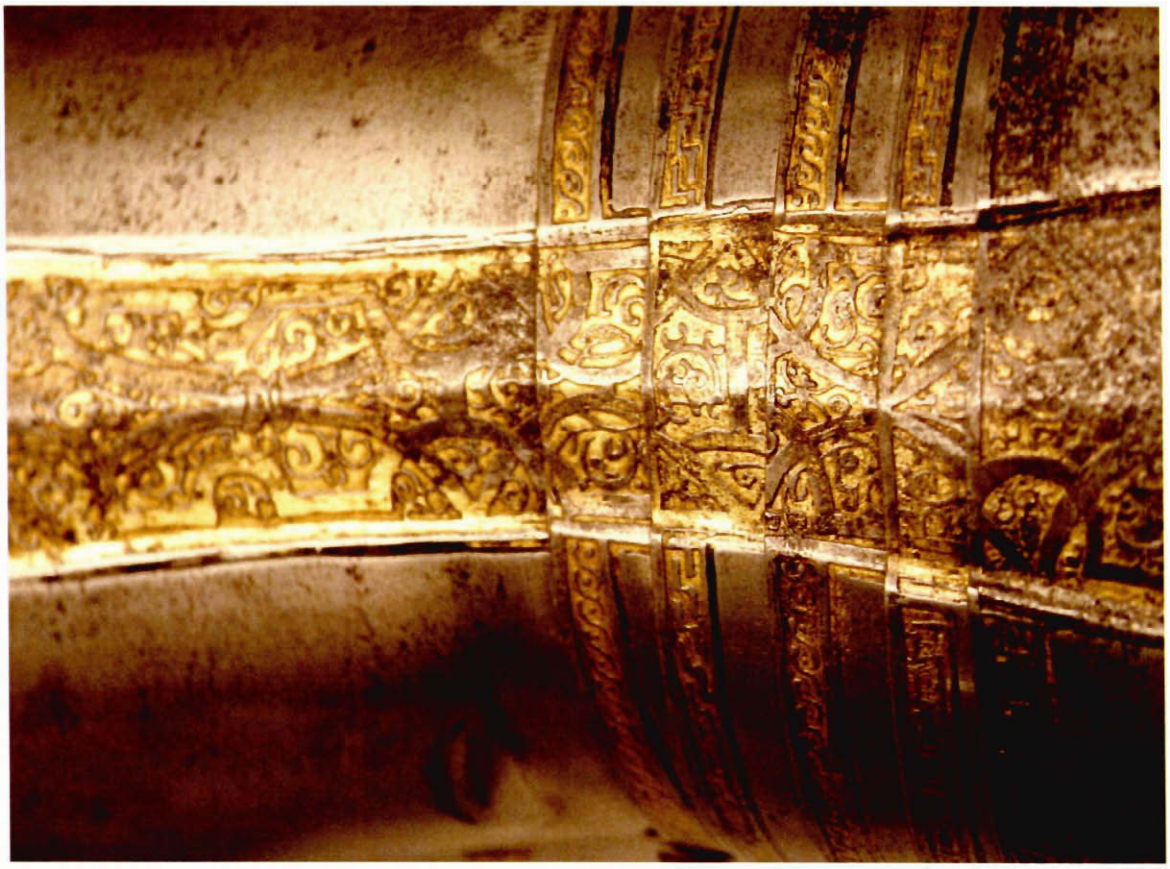


Figure 27: Gauntlet Decoration. First Lame Has Addorsed Bow and S Motifs, 2nd Has H Bar and Key. The H Bar is Also on the Large Plate to the Left.

The decoration of the suit falls into two categories. Both have a curving pattern where the primary lines bow to the center before coming back to the edges, set against an ivy-styled background. However, one of these patterns has a crossbar that connects the bowed section of the decoration, and one of the patterns has the bows addorsed back-to-

back. Generally, the crossbar pattern is also associated with a key motif across smaller sections of the armor, and can be found along the arms, legs, and restored greaves and sabatons. The addorsed crescent pattern is usually found with an S motif, and can be found on the entire corslet, the pauldrons, and the gorget. Interestingly, the helmet seems to have a different pattern, in which the bowed markings are interlaced. This is associated with the S motif.

Figure 28: Addorsed Bow Decoration

Conclusion

The work for this project was completed through extensive research and electronic work. Divided into three terms, the process began in the first term through research and drafts of the research document. This document would eventually become the primary focus of the project paper and a website devoted to information about the particular suit of armor. There were many times when the list of resources gathered in the pre-qualifying project proved insufficient. Thus, many more sources were obtained and assimilated into the document. Additionally, photography for the armor began for use in the website and as a starting place for the animation.

During the second term of work, the framework for the website was constructed, the draft was revised and updated significantly, and the animation process begun. Also during this time, logistical issues such as contacting publishers of books from which we pulled figures, and supplementing our photography archive.

The final term saw a coming together of the work into a final project paper, website, and animation. A majority of the animation work was done this term. Starting from the photographs, we resized the images, constructed outlines of each piece, and aligned them. From there, we could mold primitive shapes into the desired forms by moving the vertices of the shapes through a variety of techniques. Textures were applied and the suit animated through the inverse kinematics system of 3D Studio MAX.

Some things could have been done differently to save time on the project, and some additional equipment might have made the task significantly easier. The importance of having the images taken from the photography sessions soon became apparent, and so there were times when we had to go back and retake some pictures, or

correct outlines during the animation process. A wide-angle camera would have been optimal to take the pictures to prevent problems with the perspective of the camera when constructing the shapes in 3D Studio MAX. However, the quality capabilities of the camera given us left nothing to be desired. Another useful tool for animators is a laser-scanner. While this machine is expensive, it simplifies the animation process considerable, providing three dimensional shapes rather than forcing the animators to construct them manually.

In the future, this work could be expanded in several ways. Because of time constraints, the animation does not represent every moving part within the suit of armor. So, the intricacies of movement with an individual piece are lost. Future teams could break these objects up and enhance the complexity of the inverse kinematics to produce more accurate results.

Otherwise, the amount of information provided on this suit of armor and its background is quite extensive, and so there is little more to be explored in that department. However, any future work on similar pieces, specificities of any of the general background information (armor development, collecting, military tactics, etc.) could tie-in very well with our piece, and many such works could eventually provide a wealth of online information about the Higgins collection.

Glossary

Armet – A helmet that can be closed around the head so that the weight of it is transferred to the shoulders rather than the head.

Baviere – The piece of armor that protects the lower part of the face.

Besagew – A disc that protects the armpit.

Caliver – A long-arm weapon usually used by calivermen on foot. Often confused with the harquebus, but very slightly smaller.

Close helmet – A descendant of the armet. This style of helmet was most popular in the 16th century.

Coloring – The act of adding color to a piece of armor. Bluing was the most common form of coloring.

Couter – A defense for the elbow.

Cuirass – An entire defense for the upper body, covering the area from the neck to the waist, drawn from the French word "cuirie", meaning breastplate (Oakeshott 1961).

Cuisse – Defense for the thigh, comparable to the upper cannon for the arms, but missing the plate on the inside of the thighs to allow for riding.

Etching – A form of decoration such that the metal is etched with a design.

Embossing – A form of decoration where the designs on the armor are actually raised relief. Usually only on decorative or ceremonial pieces.

Gauntlets – Defense for the hand, originally constructed of leather with reinforcing plates, but later made entirely of a plate of steel underneath which was a leather glove.

Gilding – The application of gold to a design.

Globose – A "round and fat" version of the breastplate, as opposed to a thinner, flatter one.

Gorget – A piece of armor protecting the neck, found in nearly every style of armor from the late 13th century (Tarassuk and Blair 1979).

Greaves – Defense for the calf, comparable to the lower cannon for the arms.

Harquebus – A long-arm firearm, usually used by an argoletier on horseback. Often confused with a caliver.

Lame – A narrow plate. These are often overlapped to achieve a better defense with flexibility than a single plate.

Legharness – The entirety of the defense for the lower body. This piece is also known as a "jamb".

Lower cannon – A small pair of plates enclosing the forearm.

Matchlock – A type of ignition device for a firearm where a burning wick comes in contact with a priming pan when the trigger is pulled in order to ignite the gunpowder.

Occularium – The aperture in the visor cut to allow the wearer to see.

Pauldrons – The defense for the shoulders, covering a section of the breast and back as well.

Poleyns – Defense for the knee, comparable to the couter for the arms.

Rolling Mill – Essentially a large, strong rolling pin. Used to roll out and smoothen flat pieces of iron.

Roundel – A plate defense that protects the base of the neck.

Sabaton – This is a broad-toed foot guard that replaced the Solleret in the 16th century.

Snaphance – A form of ignition system for a rifle very similar to the flintlock.

Solleret – A long, narrow piece of armor for the foot, often pointed and of exorbitant length. It is constructed of multiple lames of plate riveted together and kept in place by two straps passing under each foot.

Spaudlers – A defense for the shoulders, small and cap-like.

Tilthammer – A water driven hammer that repeatedly moved up and down. Used when smoothing a piece of metal once it had been roughly formed.

Upper cannon – A pair of plates enclosing the upper arm.

Vambrace – Originally this term referred to the defense for the forearm, but was expanded to include the entirety of the arms (Oakeshott 1961).

Bibliography

Ashdown, Charles Henry. (1967) *European Arms and Armour*. New York, New York, The United States of America: Brussel and Brussel.

Bicalho, Alexander; Montiero, Alex; Murray, Chris; Woods, Catalina. (2000) *Mastering 3D Studio Max R3*. Alameda, CA. Sybex Inc.

Blair, Claude. (1958) *European Armour: Circa 1066 to Circa 1700.* London, England: B.T. Batsford Ltd.

Cripps-day, Francis Henry. (1925) *A Record of Armour Sales.* London, England: G. Bell and Sons Ltd.

Ffoulkes, Charles. (1912) *The Armourer and His Craft.* London, England: Methuen & Co. Ltd.

Flint Institute of Arts in the DeWaters Art Center. (1968) *The Art of the Armorer.* Flint, Michigan, The United States of America: Flint Institute of Arts.

Gardner, J Starky. (1897*) Armor in England.* London, England: Seeley and Co. Limited.

Grancsay, Stephen V. (1933) *The Bashford Dean Collection of Arms and Armor.* Portland, Maine, The United States of America: The Southworth Press.

Grancsay, Stephen V. (1961) *Catalogue of Armor: The John Woodman Higgins Armory.* Worcester, Massachusetts, The United States of America: Unpublished.

Grancsay, Steven V. (1986) *Arms & Armor.* New York, New York, The United States of America: The Metropolitan Museum of Art.

Greener, W. (1897) *The Gun and its Development*. New York, New York, The United States of America: Charles Scribner's Sons.

La Rocca, Donald J. (1984) *Kienbusch Centennial.* Philadelphia, Pennsylvania, The United States of America: Philadelphia Museum of Art.

Laking, Sir Guy Francis. (1920) *A Record of European Armour and Arms through 7 Centuries; Volume III; Chapter 23.* London, England: G. Bell and Sons Ltd.

Mowbray, E. Andrew. (1990) *Man at Arms; Volume XII.* Lincoln, Rhode Island, The United States of America: Man at Arms Magazine.

Peterson, Harold L. (1975) *How Do You Know it's Old.* New York, New York, The United States of America: Charles Scribner's Sons.

Pfaffenbichler, Matthias (1992) *Medieval Craftsmen – Armourers.* Toronto, Canada: University of Toronto Press.

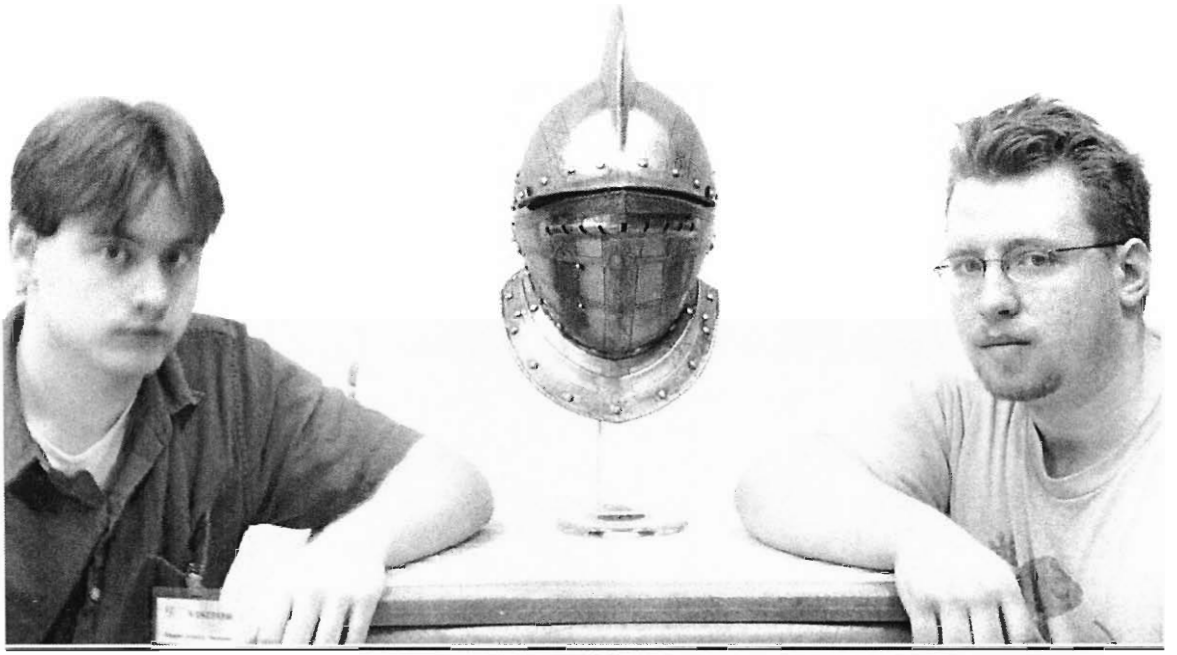
Richardson, Thom (1997), *Royal Armories Yearbook Volume 2.* Great Britain: The Trustees of the Armories.

Steed, Paul (2002) *Modeling a Character in 3DS Max.* Plano, Texas, The United States of America: Wordware Publishing.

Valentine, Rob (2000) *The Art of Making Armour.* Baltimore, Maryland, The United States of America: American Literary Press.

Webb, Henry J. (1965) *Elizabethan Military Science*. Madison, Wisconsin, The United States of America: University of Wisconsin Press.

About the Authors



Brent Newey and Andrew Smith are Computer Science majors at Worcester Polytechnic Institute.

Brent Newey is from New Gloucester, ME. At the time of this writing, he was completing his final term at WPI and would graduate with the class of 2003. Hobbies include writing, gaming, juggling, programming, and medieval arms and armor.

Andrew Smith is from Pembroke, NH. At the time of this writing, he was completing his junior year at WPI and will graduate in the spring of 2004. His hobbies include reading, writing, computer graphics and animation, gaming, and, of course, medieval arms and armor.