HISTORICALLY ACCURATE:

THE NAVAL GUN SIGHTS AND PERCUSSION LOCKS RECOVERED FROM THE

CONFEDERATE IRONCLAD RAM CSS *GEORGIA*

A Thesis

by

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ABSTRACT

Construction for a 19th-century Confederate ironclad ram known as CSS *Georgia* began in March 1862 after the Ladies Gunboat Association of Savannah, Georgia raised the necessary funds. However, *Georgia* never saw action and spent most of its career moored on the Savannah River. The Confederates intentionally sunk *Georgia* as General William T. Sherman's troops approached Savannah in 1864 to prevent its capture by Union forces. It spent the next 150 years at the bottom of the channel.

The U.S. Army Corps of Engineers Savannah District, in partnership with Panamerican Consultants, Inc., the Conservation Research Laboratory (CRL) at Texas A&M University, and the U.S. Naval History and Heritage Command, organized the recovery of thousands of artifacts and sent many of them to the CRL for subsequent conservation. This vast collection of artifacts includes a set of brass naval instruments known as gun sights. Their use enhanced the accuracy of guns during engagements at sea. Additionally, *Georgia* yielded brass percussion locks that facilitated the instantaneous discharge of naval guns. They represent one of the largest archaeologically recovered collections of naval gun sights and percussion locks from this era.

A brief historical survey of the introduction of guns at sea places the naval gun sights and percussion locks within a broader context. Between the 16th-century and the Civil War, the world's navies placed different kinds of sighting mechanisms on guns and these continued to improve until their culmination in the form of the complex naval gun sights and percussion locks recovered from *Georgia*. The design and use of the *Georgia* gun sights reflects an understanding of the physical properties of a projectile in flight. The evolution of naval gunnery, sighting mechanisms used on guns, and the scientific understanding of the physical properties of a projectile in flight all form a strong basis from which a detailed analysis of the naval gun sights and percussion locks under study can be made. This research sheds more light on aspects of naval gunnery during the Civil War.

To my mother, my father, and my sister.

Siempre para adelante. Para atrás solamente para agarrar vuelo.

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All other work conducted for the thesis was completed by the student independently.

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Historical Background

On 9 March 1862, USS *Monitor* and CSS *Virginia* engaged in fierce combat at Hampton Roads, Virginia in what was the first head-to-head confrontation between two heavily armored ironclad gunboats. The Battle of Hampton Roads first demonstrated the power and destructive potential of ironclad naval vessels. Many recognized the start of a new era in naval warfare, including the Ladies Gunboat Association of Savannah, Georgia, which raised $115,000 for the construction of a gunboat of considerable size (Harrison & Anuskiewicz 1987:74; Still 1971:32-35). News of the Battle of Hampton Roads intensified the apparent need for such a mechanical behemoth of iron and steam by members of this organization (Watts & James 2007:8).

Serious construction efforts began on 22 March 1862 by Confederate soldiers under the direction of the gunboat's citizen-appointed building committee and Major General Henry Jackson at Alvin's Shipyard in Savannah (Watts & James 2007:8). A series of orders on 30 March 1862 first described this gunboat as a "floating battery." When it was completed, it went by many names, including "State of Georgia," "Ladies' Ram," "Ladies' Gunboat," and "Confederate States Steamer Georgia" (Harrison & Anuskiewicz 1987:79). Ultimately, it simply adopted the name "CSS *Georgia*." Its launch took place on 19 May 1862, it made a trial run on 24 July, and took up its final position opposite Fort Jackson on the Savannah River by late October (Watts & James

2007:9). Approximately two years later, the Confederates deliberately sunk it to prevent its capture by General William T. Sherman's Union forces during the siege of Savannah.

Georgia's original function may have been that of a troop transport (Harrison & Anuskiewicz 1987:79). However, the inability of its undersized steam engines to propel such a mass of heavy timber and iron through the strong currents and tides of the Savannah River, relegated it to a "floating fortress." *Georgia* finished its career permanently moored across from Fort Jackson with its guns trained east in defense of the city of Savannah against Union approach from the Atlantic (Baker 1982:5). The original design allowed for an armament of ten heavy guns: four on each broadside and one at each end of the vessel's casemate (Swanson & Holcombe 2007:79). Yet, it apparently carried only six guns when Confederates scuttled it – four heavy and two light guns (Watts & James 2007:13). Once *Georgia* settled at the bottom of the Savannah River, no thorough investigations of the wreck took place until 1979.

Archaeological Excavations of CSS *Georgia*

Gordon P. Watts and Stephen James (2007:14-15) summarized the archaeological excavations that took place at the site of *Georgia* over the years since its sinking. Navy divers briefly examined *Georgia* in 1969 after the contract dredge *St. Louis* struck the vessel the previous year. A decade later, Texas A&M University prepared an archaeological and engineering assessment of the site. The identification and recovery of some ordnance took place during the investigation, such as rifle shells and bolt shots (Swanson & Holcombe 2007:81). The 1979 survey also established a rough morphological plan of the site using bathymetric and acoustic images. The images revealed the site's pedestaled nature with respect to the surrounding dredge channels and pieces of the armor plating, or casemate, extending 7.5 to 9 feet (2.2 to 2.7 meters) from the river bottom. In 1986, the District of Savannah conducted diving operations on *Georgia*'s remains, which resulted in the location of four guns and the recovery of two, along with numerous projectiles.

The common belief was that the location of the wooden hull of the vessel was beneath the sediment under sections of casemate until investigations conducted in 2003 established its absence (Watts & James 2007:109). The main goals of the 2003 investigation included the characterization and delineation of the site, ascertaining the state of preservation, identifying impacts to the site from commercial development and vessel traffic, and suggesting a future course of action to mitigate damage to *Georgia*'s remains (Watts & James 2007:3-4). After the investigations, it was determined that most damage done to the site was a result of historical salvage conducted following the Civil War and ongoing commercial development. Dredging activities posed significant threats to several structural components such as iron casemate, propulsion machinery, propeller and shaft, three guns, and a possible boiler (Watts & James 2007:109). To hinder further damage to the site, a proposal for a comprehensive archaeological investigation and recovery of surviving remains was put forth. (Watts & James 2007:113).

The 2015 archaeological recovery resulted in the identification of thousands of artifacts, among them a fourth gun to add to the three from the 2003 investigation for a total of six guns found at the site (Buddemeier 2015). The complex archaeological project was just the first part of the broader Savannah Harbor Expansion Project

(S.H.E.P.). The removal of all associated artifacts, ordnance, and structural elements was necessary to deepen the channel and accommodate larger ships. Five phases characterized the project: (I) continued archaeological investigation, mapping, and removal of small artifacts, (II) removal of heavier structural elements, such as the casemate, (III) the mechanized recovery of any remaining artifacts, (IV) clearance of the site using different remote sensing methods, and (V) re-deposition and reburial of artifacts and vessel components (U.S.A.C.E. 2014). Of course, as the excavation progressed, the plan was changed to accommodate ever-changing circumstances.

The 2015 archaeological investigation resulted in the recovery of over 140 tons of material (Bynum 2016). Massive chunks of iron casemate, iron machinery, a second 9,000-pound (4,082.3 kg) Dahlgren gun, and hundreds of smaller artifacts associated with the vessel made up the archaeological assemblage. The Conservation Research Laboratory (CRL) at Texas A&M University received about 13,000 out of the more than 30,000 artifacts recovered for further conservation and analysis (Bynum 2016). Among the artifacts sent to the CRL were several small, brass instruments composed of: (1) small and roughly triangular pieces, (2) a long, graduated scale that slid through a type of “box,” (3) and an item resembling a small hammer with a hollowed shaft and/or a hole through its head. After initial analysis, they were determined to be a dispart sight, a tangent sight, and a percussion lock, respectively. Albeit small components of the gun furniture, these items were crucial to the successful operation of naval guns (Tucker 1989:33-41). The first two artifacts (the gun sights) were used simultaneously to aim the naval gun while the third (the percussion lock) was used to fire the gun instantaneously once it was properly trained on its target.

The Present Study

The brass naval gun sights and percussion locks recovered from *Georgia* provide a unique opportunity to gain a deeper understanding of 19th-century naval gun furniture, especially gun furniture used during the Civil War, a period of dramatic technological development. The artifacts display several stamps and other marks on their surface and exhibit slight variations in general appearance. Two of the graduated scales are of the same shape and size, but have different numbers on the scale divisions, while the head of one percussion "hammer" is perforated and the head of another is not.

Modern literature on this type of 19th-century gun furniture is relatively scarce. Additionally, foundries melted down and repurposed most brass materials after the Civil War, making physical examples even less common. The few, precious examples recovered from *Georgia* survived due to their relative inaccessibility underwater. Other sites such as that of USS *Monitor* and the steam-ferryboat-turned-warship USS *Westfield* also revealed some brass gun sights and percussion locks for the same reason. The *Monitor* excavation yielded three gun sights and one percussion lock (Will Hoffman 2015, elec. comm.) while the *Westfield* excavation yielded one gun sight and one percussion lock (Justin Parkoff 2015, pers. comm.). The collection of gun sights and percussion locks recovered from *Georgia* represents one of the largest extant assemblages to date. A total of at least nine gun sights (of both types) and five percussion locks are currently under study at the CRL.

The Civil War was a time of dramatic technological development in ordnance. In 1848, the Navy Bureau of Ordnance and Hydrography ordered all navy guns to carry both a dispart sight and a tangent sight (Tucker 1989:40). This means the Civil War was the first major American conflict that placed serious emphasis on the concept of long-distance accuracy at sea. The brass gun sights and percussion locks from *Georgia* contribute to our understanding of how naval forces from both sides applied this concept in their efforts to outperform each other.

CHAPTER II

HISTORICAL DEVELOPMENT OF NAVAL ORDNANCE

Introduction

It is important to provide the reader with a brief and concise historical survey of gunnery at sea in order to place the gun sights and percussion locks recovered from CSS *Georgia* within a broader context. This will elucidate the practical theory behind their application during naval engagements. Naval guns underwent many changes through the centuries leading up to the US Civil War. This conflict compelled not only artillery experts, but also mathematicians and scientists from different backgrounds to develop new sophisticated methods of operating gun batteries at sea and on land. However, the ship's guns were not always the primary and decisive weapons during naval engagements. The first time guns were used to sea is difficult to know, but naval vessels were certainly equipped with them by the second half of the 14th century (Tucker 1989:2). Prior to this time, ancient civilizations used a variety of different methods to capture or destroy enemy fleets. The ancient Greeks used ramming tactics to cripple and disable enemy triremes. The Romans transferred their land tactics to the sea by using a boarding mechanism known as the *corvus* to engage the crews of enemy ships in hand-to-hand combat (Nagle 2013:132). Medieval fleets incorporated the use of Greek fire and projectiles such as *ballistae*, *catapultae*, and hand-thrown incendiaries characterized naval warfare before the advent of the big guns decided naval engagement (Manucy 1949:2-3; Owen 1873:179).

The 14th and 15th Centuries

Early ship guns were small. They normally weighed from 20 to 40 pounds (9 kg to 18 kg) and the ship's bulwarks served as their firing platforms. During the 15^{th} century, they were composed of several longitudinal strips of iron welded together on a mandrel, the interstices filled with lead, and further reinforced with iron rings or bands. Most were crude predecessors of the 19^{th}-century breechloader because the gun was composed of two basic parts: a barrel and a powder chamber. Initially, guns and gunpowder were not a major component of a naval arsenal. They were slow, cumbersome, and dangerous to fire. In fact, an English naval inventory of 1410 did not list any ships equipped with more than three guns. Additionally, early gunners had little control over aim; thus, making the effects of firing largely unpredictable (Tucker 1989:2-3).

However, this was not always the case, as indicated by a more recent study by Alexzandra Hildred (2011:132). Wide usage of wrought-iron guns was common and they actually outnumbered other gun types until at least 1555. For example, the port side armament of the main deck of *Mary Rose* was found virtually intact and was mostly composed of wrought-iron pieces, numbering at least 12 that fired stone shot and 4 "slings" that fired iron shot. Indeed, the carriage-mounted wrought-iron armament of *Mary Rose* was quite impressive – the wreck site revealed 38 breech chambers and 17 "tubes" or gun barrels. Of the 91 guns included in the *Anthony Roll* inventory of 1546 for *Mary Rose*, only 15 were listed as "*gonness of brasse*" and the rest were made of iron (Hildred 2011:130, 133).

The 16th Century

Naval guns and their shot became heavier towards the end of the 15th century. The weight of guns placed at the forecastles and quarterdecks caused ships to be too top-heavy and unseaworthy. The interior of the hull became a more practical location for heavier naval armaments. Once inside, gunners fired through holes on the sides of ships' hulls known as gun ports, a significant feature invented in 1501 by a French shipbuilder named Descharges (Tucker 1989:5). The advent of gun ports and the placing of guns on the lower (gun) deck of a ship prompted redesign of many vessels. For example, the reconstruction of the English *Henry Grace a Dieu* allowed the accommodation of a double tier of gun ports and 251 guns (Tucker 1989:12). However, only 19 of these were heavy broadside guns.

Cast-bronze muzzle-loading guns appeared around 1500 and had several advantages over the early iron breech-loaders. Bronze was easier to cast, withstood the shock of discharge better than iron, generally weighed less, was safer to use, and could be embellished with designs. Perhaps the only downside was the higher cost of the metal (Tucker 1989:10). However, by the mid-16th century, the advent of the blast furnace improved iron-smelting techniques and made possible the *casting* of iron guns. Even though cast-iron muzzle-loaders were not entirely risk-free, they gradually replaced the less safe wrought-iron breech-loaders due to their strength, reliability, and relatively low cost (Tucker 1989:6). Additionally, improvements in gunpowder from "mealed" to "grained" types increased use of large, cast guns of both metals. Mealed powder burned slowly and yielded lower pressures, therefore it was safe to use with the "barrel stave" construction of early guns. In contrast, grained powder was composed of larger grains and yielded higher pressures, resulting in an increase in velocity of the shot (Manucy 1949:23). Large cast-bronze and cast-iron guns resisted higher pressures better, making them the primary weapons of choice during naval conflicts (Tucker 1989:8).

The 17th Century

Serious efforts at categorization and classification of different guns began during the 16th century and were in place certainly by the 17th century, especially by Spanish artillerists, who emulated German gunners (Manucy 1949:31-36). Three main categories characterized the classification of guns by the end of the 16th century: culverins, cannon, and perriers. Each category had several subcategories and measurement of gun lengths was in calibers (length of the bore divided by its own diameter). Classification of length included ordinary (mid-size), extraordinary (long), or bastard (short). Culverins were generally large, long-range guns, cannon were medium, mid-range guns, and perriers (adapted from the Spanish *pedreros*) were small, short-range guns (Manucy 1949; Tucker 1989).

Additionally, during the first half of the 17th century, three categories characterized the classification of gun thickness: ordinary or “fortified,” extraordinary or “double fortified,” and bastard or “less fortified” (Tucker 1989:13). Eventually, the economic advantages of iron guns outweighed the numerous benefits of bronze guns and the 17th century saw a continued swing from bronze to iron ordnance. Annual iron production in Sussex, England was between 800 to 1,000 tons by 1600 (Tucker 1989:6). A royal edict ordered English naval officers to accept iron guns supplied by French arsenals in 1674 and iron guns emerged as the predominant ordnance aboard European naval vessels by the end of the 17th century (Tucker 1989:16).

The French largely classified artillery by the weight of the projectile (LeBlond 1746:9). Projectiles generally came in weights of 24 pounds (10.8 kg), 16 pounds (7.2 kg), 8 pounds (3.6 kg), and 4 pounds (1.8 kg). The largest guns commonly cast were 24-pounders, which served as siege guns used to batter and destroy fortifications. Classification of 16-pounders, 8-pounders, and 4-pounders was as culverins or "demi-cannon," "bastard," and *moyenne* (middle-size), respectively. Generally, (English) lengths were 11 feet (3.4 m) for 24-pounders, 10 feet, 6 inches (3.2 m) for 16-pounders, 10 feet (3 m) for 12-pounders, 8 feet, 10 inches (2.7 m) for 8-pounders, and 7 feet, 3 inches (2.2 m) for 4-pounders. Falconets were smaller guns with projectiles of two pounds (0.9 kg) to a quarter of a pound (0.1 kg) and generally had a length of 7 feet (2.1 m) (LeBlond 1746:11; Guérout 2011:124-127).

The 18th Century: John Müller's Improvements

During the 18th century, one of the greatest authorities on ordnance was an Englishman named John Müller. Müller believed that up to the mid-18th century no real improvements on the performance of artillery were made because mechanical principles deduced from mathematics, geometry, physics, and experiments during peacetime did not exist (Müller 1780:vi-vii). He made efforts at standardization and characterization of English ordnance and increased gun caliber without substantially increasing the weight. He accomplished the latter by making general alterations on the surface of the gun to save on metal and by lessening the weight of the powder charge to shorten and lighten the gun (Manucy 1949:43-44). Up to that time, and indeed for some time after in some European countries, the general thought was that guns with small calibers, such as culverins, needed to be longer and more fortified to maximize the range of the projectile.

Müller challenged this common practice by modifying bronze and iron garrison, field, siege, and naval artillery. Bronze shipboard guns were to have a bore length of 15 calibers (or 15 shot diameters long), a thickness of metal at the breech $\frac{5}{6}$ the diameter of the shot, and a thickness at the muzzle $\frac{5}{12}$ the diameter of the shot (Müller 1780:54-56). Iron shipboard guns were to have a bore length of 15 calibers, a proportion of 140 pounds (63.5 kg) of iron for every pound (0.5 kg) of shot, a thickness of metal at the vent equal to the diameter of the shot, and a metal thickness at the muzzle being half the diameter of the shot. If guns of these new specifications were loaded with a powder charge that was approximately $\frac{1}{4}$ of the shot's weight, ships could carry more large-caliber guns while simultaneously saving on metal. Saving on metal led to a lighter armament that was no less powerful and since they were shorter guns, it was easier to load them resulting in faster rates of fire. Application of these specifications to the re-armament of *Royal George* resulted in a difference of fifty tons less than the ship's former armament (Müller 1780:55). Müller greatly influenced American gun design during the latter part of the 18th century. In fact, it is thought that his *Treatise of Artillery* of 1757 (of which a pirated edition appeared in the American colonies by 1779) was the only artillery manual available to the Americans during the American Revolution and they adhered to it more than the British did (Tucker 1989:88).

The 18th-century ships of colonial America were usually equipped with foreign-made ordnance because England discouraged filling colonial arsenals with locally made weapons. England placed orders for the construction of vessels in the colonies but provided the naval ordnance once the ships were complete. By the time of the American Revolution, American arsenals were a motley collection of every kind of gun of every caliber from England, France, Spain, and even as far as Scandinavia (Tucker 1989:73-74). During the first two years of the Revolution, 90% of the gunpowder used by American forces originated overseas and more than one hundred ships reached American shores with needed supplies. The chief source of arms for the American cause was France, which nevertheless took every precaution to avoid antagonizing England. The French minister of foreign affairs, Count Charles Gravier de Vergennes, removed French markings from bronze guns in the royal arsenals before giving them to the Americans (Tucker 1989:79).

The 18th Century: The American Revolution

The naval force of the rebel American colonies consisted of the Continental Army's navies at Boston, New York, and Lake Champlain and a Continental Navy made up of new frigates from the frigate construction program, along with many sloops and schooners that served as privateers. The latter was the colonies' biggest naval threat to England. The pieces carried by privateers were mostly small 4-pounders and the largest were usually 9-pounders (Tucker 1989:76). The thirteen frigates that were supposed to form the backbone of the American navy were not intended to carry more than 32 guns and none were supposed to be larger than 12-pounders. However, non-standardization was the general rule for the American navy and it was common for ships to carry more guns whenever possible. The 32-gun frigate *Warren* carried thirty-four guns, including twelve 18-pounders, the heaviest cast for naval use in the colonies during the Revolution (Tucker 1989:81).

Most naval guns used by colonial forces were relatively small. The largest in common use during the Revolution was the 12-pounder and most of the guns employed by England and the colonies at sea during this conflict were of the Armstrong design named for John Armstrong, the English Surveyor General of Ordnance of 1722 (Tucker 1989:85-87). The three main naval gun designers in England during the 18th century were Borgard, Armstrong, and Blomefield. Of these three, Armstrong-designed guns were in use for the longest period and were characterized by their lack of surface embellishment or decorative craftsmanship (Caruana 1997:14). Standardization of their dimensional specifications allowed any foundry to produce them. Armstrong also held a series of tests and concluded the best lengths for 24-pounders to be 9½ feet (2.9 m) (Caruana 1997:13). The basic projectiles used during the Revolution were solid shot; seaborne long guns did not yet fire explosive and incendiary shells during this time (Tucker 1989:92-96).

The 19th Century

Naval guns cast on Müller's specifications were deemed too short by the start of the 19th century. American artillerist Louis de Tousard (1809:194) was one of the first to push for a "uniform system for all kinds of [American] ordnance" during this time. He believed the small size and short barrels of the guns aboard American frigates such as

United States and *Constellation* ran the risk of damaging the side of the ship when fired obliquely because the mouth of the guns remained within the sides of the portholes, risking serious damage from the blast (de Tousard 1809:193). He also strongly recommended forging iron guns using American ore because he deemed it of a superior quality and insisted on holding proper trials to test the locally cast guns. The raw iron ore was processed at Keep Tryst Furnace in Virginia and the pigs were used to cast iron naval guns 18 calibers in length (in contrast to Müller's 15) "from behind the breech ring to the mouth, each caliber weighing 200 lbs. [91 kg] to each pound [0.5 kg] of their shot" (de Tousard 1809:190-193).

The 19th Century: The War of 1812

American guns cast during the War of 1812 continued to follow those of Britain closely in design but there were some differences in ordnance from both countries. American shot tended to weigh less than its nominal weight. Windage, the difference between the diameter of the bore and the diameter of the shot, tended to be greater on British guns ($\frac{1}{20}$ the bore) than windage on American guns ($\frac{1}{25}$ the bore) (Tucker 1989:137). The Congreve gun design made its debut during this conflict. Named after Lieutenant Colonel William Congreve, this design appeared only in one size: a 24-pounder 7 feet, 6 inches (2.3 m) in length and 41 cwt in weight (approximately 4,100 pounds or 1,860 kg). The exterior was relatively smooth and possessed a single-curved breech. Congreve also introduced an improved carriage that allowed four men to work the 24-pounders. Prior to his improved design, 13 men worked the same gun on a common naval carriage. The advantages of this carriage came from the trucks working on a perfectly plane slide, which made it easier to handle and a new kind of truck lever that was more powerful and with better casters being "fixed in the true direction for traversing" (Congreve 1811:6, 41). The production model for this gun design had the first ring cascable (a loop at the base of the breech through which breeching rope was passed to check recoil during fire) (Congreve 1811:7-9), a raised sight on the reinforce ring to improve accuracy, and a plain tapered muzzle. This gun may have inspired the gun designs of the famous Lieutenant John Adolphus Bernard Dahlgren later during the 19th century (Tucker 1989:137-138).

The 19th Century: The Advent of Shells

Solid shot fired from smoothbore muzzle-loading guns characterized most naval warfare prior to the mid-19th century. However, up to this time, ship construction had developed at a faster pace than naval artillery. Naval ordnance was not strong enough to sink these monstrous sailing ships. Improved framing and planking methods and the intrinsic porosity and elasticity of wood had made ships capable of withstanding constant pounding from solid shot. Ship hulls proved practically impenetrable during the Battle of Trafalgar of 1805 when gunfire did not sink a single ship of the line (Luraghi 1996:57). The answer to increased hull strength arrived during the 1820s, when explosive shells joined the fray.

Round, solid shot left smooth, circular holes on the sides of wooden hulls that were relatively easy to patch. Shells were intended to lodge on the side of the enemy ship's hull and explode shortly after, creating large, irregular holes that were sometimes impossible to patch and were very likely to lead to the sinking of the ship (Tucker

2002:3; Dahlgren 1856:15). Experiments with shells fired from naval guns had taken place since the 18th century but numerous difficulties led to unsatisfactory results. Solutions to the various problems came with the publication of *Nouvelle force maritime* in 1821 by Colonel Henri Paixhans, an artillerist from Metz, France and one of the staunchest advocates of this type of projectile (Tucker 2002:3; Luraghi 1996:57). Paixhans created a gun and a carriage steady enough to withstand the massive report created by the heavy charges required to launch large projectiles with enough initial speed to penetrate the side of a ship's hull and explode inside. These new guns first proved their worth in 1824 when only 16 shells were required to sink the 80-gun French ship of the line *Le Pacificateour* at Brest, France. Raimondo Luraghi dramatically summarized the impact of these guns on naval warfare when he wrote, "by the firing of his shells he [Paixhans] had, at one stroke, sunk all the world's navies" (Luraghi 1996:57-58).

The Civil War

By the time the Civil War began, a dramatic race in innovation and sophistication of naval armaments was underway. The principal ordnance innovator in the US Navy before and during the Civil War was Commander John Dahlgren. He produced bronze boat howitzers at the Washington Navy Yard in 1844 as well as cast-iron guns, shell guns, rifled guns, percussion locks, and other weapons for the navy (Olmstead et al. 1997:83). A howitzer was a mid-size, mid-range gun that was lighter and easier to move than a mortar but shot larger projectiles than a regular gun of a similar weight. According to Dahlgren, King Frederick of Prussia first demonstrated the full extent and use of the howitzer's capacity during the second and third quarters of the 18^{th} century (Dahlgren 1856:5). After he demonstrated the advantages derived from the howitzer, an increase in the casting of this type of gun took place in the European mainland. Howitzers cast under Dahlgren's specifications were of bronze and appeared as 12- and 24-pounders, 3.4-inch (8.6 cm) 12-pounders, and 4-inch (10 cm) 20-pounders. However, Dahlgren's legacy comes mostly from his heavy, smoothbore, muzzle-loading ordnance. The 9-inch (22.9 cm) bore was the most common broadside carriage-mounted gun in the US Navy during the Civil War. These heavy pieces exhibited a smooth exterior, curved lines, and had the appearance of soda bottles (Olmstead et al. 1997:83). Their design placed the greatest weight of metal at the breech, the point of greatest strain. The Dahlgren design was composed of several sizes: the 32-pounder, 8-inch (20.3 cm), 9-inch (22.8 cm), 10-inch (25.4 cm), 11-inch (27.94 cm), 13-inch (33 cm), and 15-inch guns (38.1 cm). A massive 97,300-pound (44,135 kg) gun with a 22-inch (55.9 cm) bore also existed but never saw action during the war. Dahlgren guns fired both shot and shell (Tucker 2002:3-4; Manucy 1949:32).

There were attempts to introduce 32-pounders into smaller vessels. However, the slight frame of these vessels hardly offered the necessary support these guns required. To decrease the weight of the gun, it was necessary to maintain a certain relationship between the weight of the gun and its projectile. This was done by casting hollow shot, which allowed the caliber of the gun to remain the same while achieving practical weight proportions for its use on smaller ships. The disadvantages of this system were evident in the diminished density of the hollowed shot. A projectile with a lower density did not overcome the natural resistance of the atmosphere as well as a projectile with a higher density, increasing the inaccuracy of the shot due to deviations during its flight. The size of a hollow shot fired from a gun of 8-inch caliber sometimes was enough to compensate for its loss of density but hollow shot fired from guns of smaller calibers were not effective (Jeffers 1850:115-116).

Dahlgren also made an unsuccessful attempt to produce a series of standardized rifled guns destined for withdrawal from naval service in 1862. Instead, the most distinguished maker of US rifled ordnance during the mid-19th century was Robert P. Parrott, a former army ordnance captain and superintendent of the West Point Foundry Association. His gun and namesake first appeared as 2.9-inch (7.4 cm) 10-pounders, 3.67-inch (9.3 cm) 20-pounders, and 4.2-inch (10.7 cm) 30-pounders. The size and caliber of the Parrott rifle increased to 5.3-inch (13.5 cm) 60-pounders, 6.4-inch (16.2 cm) 100-pounders, 8-inch (20.3 cm) 150-pounders, and 10-inch (25.4 cm) 300-pounders during the Civil War and both the Army and Navy used them. Rifled guns tended to be particularly fragile prior to the introduction of the Parrott rifle. Closer tolerance and an increased strain on the gun increased its chances of bursting. Parrott solved this problem by placing a wrought-iron spiral-wound band around the breech of the cast-iron tube. Upon cooling, this band contracted and gripped the breech, allowing it to withstand the explosion of the powder charge. By 1864, Parrott guns, from 3.67- to 8-inch size, represented about one-fifth the inventory of US Navy guns (Tucker 2002:5-6).

Lieutenant John Mercer Brooke was the primary ordnance designer for the Confederacy. Guns produced in the South followed standard US Navy patterns and included 32-pounders, 10-inch, and 11-inch smoothbores and 6.4-inch, 7-inch, and 8-inch rifled guns. Brooke also experimented with wrought-iron bolt shot. After conducting experiments with this type of projectile, he found that an 85-pound (38.6 kg) shot could penetrate 3 layers of 8x2-inch (20.3x5 cm) iron plates backed by an oak layer 17 in. (43.1 cm) thick if loaded with a 12-pound (5.4 kg) powder charge (Brooke 2002:115). The Southern 8-inch rifled gun was one of the best pieces of ordnance used by either side during the Civil War. This gun was slightly thicker than a Parrott rifle and differed in that it had not one, but two and even three series of wrought-iron bands placed around the breech of the cast-iron gun tube (Tucker 2002: 6-7).

Conclusion

Naval guns underwent many significant changes and modifications from the barrel-stave construction of the 14th century to the heavy and powerful Civil War guns of the 19th century. Everything from their placement on a ship to the type and thickness of the metal to the weight of the powder charge was under constant modification to gain the advantage in battle. Developments in other aspects of naval gunnery, such as methods of priming and improvements in accuracy, were just as crucial in establishing and maintaining naval superiority.

CHAPTER III

IMPROVING THE ACCURACY OF GUNS

The Gunner’s Quadrant

The earliest mode of improving the accuracy of naval guns by using an aiming device concerned the angle of elevation of the gun set by using the gunner’s quadrant (Figure 3.1) invented in 1545 by Niccolò Fontana Tartaglia, an Italian mathematician of the Republic of Venice (Manucy 1949:75; Owen 1873:172).

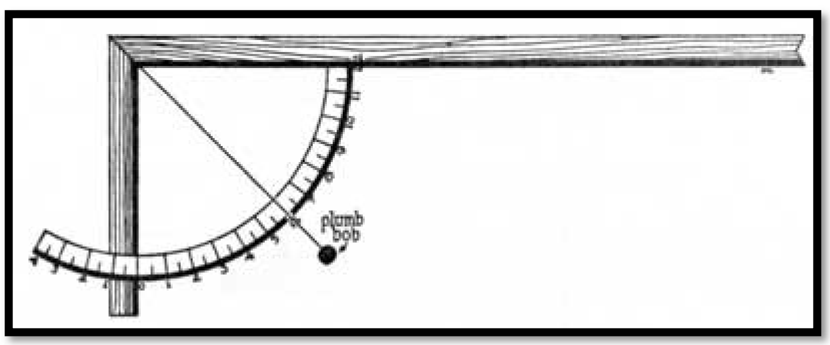

FIGURE 3.1. Gunner's Quadrant (Manucy 1949:75).

However, Luis Collado (1592:38), a Spanish mathematician and historian from Andalucía, cited a book written by Daniel Sanbech before Tartaglia was born, in which “Iohan (Johann) of Monte Regio” used an instrument called a *triangulis* to measure ranges of shot based on different degrees of elevation. According to Collado, the *triangulis* was marked with the same degrees found on Tartaglia’s quadrant. The shape of the gunner’s quadrant was like that of a carpenter’s square with a graduated quarter circle connecting the two arms. A plumb bob dangled from the angle of the square and displayed the gun’s angle of elevation when the long arm of the instrument entered the bore of the gun. The mathematical theory behind the use of the gunner's quadrant was simple and is still in use today (Manucy 1949:75).

During the 16th century, the basic understanding was that a gun fired at a 45-degree elevation would send its projectile about ten times farther than a gun fired at zero elevation (i.e. level barrel). Therefore, the quadrant should be marked into at least ten equal parts. Once gunners established the range of a gun raised to 45º and the range when the barrel was horizontal, it was theoretically possible to estimate the approximate range corresponding with all the marks in between. The gunner could achieve the desired range simply by raising the gun until the line of the plumb bob was over the proper mark on the instrument (figure 3.2).

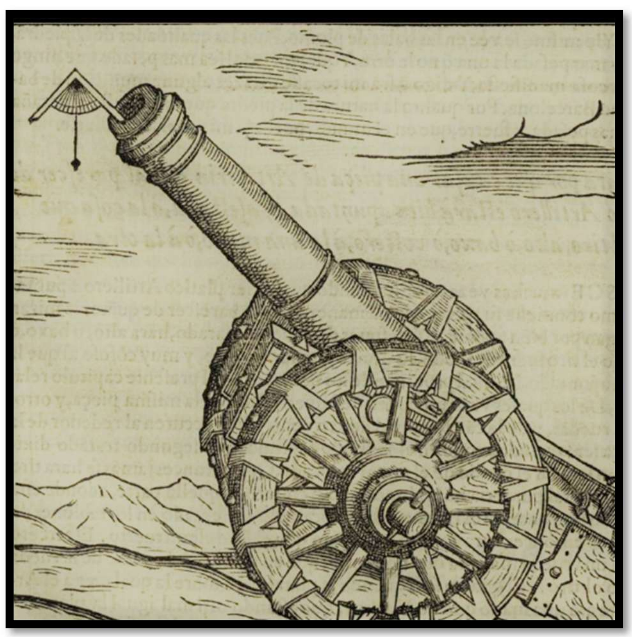

FIGURE 3.2. Gun showing placement of gunner's quadrant (Collado 1592:38).

Collado (1592:38) explained this system and held experiments with a 20-pounder culverin measuring his distances in "paces." At zero elevation (i.e. point-blank range) the gun sent the projectile 200 paces. At a 45-degree elevation, the projectile traveled approximately 2,000 paces. To calculate the range of the gun when raised to each mark in between, the quotient of the difference of these ranges divided by the number of marks (in this case, 10) was added to 200 or subtracted from 2,000 as the gun was raised or lowered. Raising or lowering the gun to a specific position on the gunner's quadrant would then increase or decrease the range of the projectile by approximately 180 paces. However, a poor understanding of the effects of air resistance on the trajectory of a projectile resulted in inconsistencies between theory and experimental results (Manucy 1949:76).

Adjusting for Difference in Thickness

Bronze and iron muzzle-loading guns are thicker at the breech than they are at the muzzle; thus, what a gunner sees when he aims a gun by following the surface of the barrel is *underneath* the actual area of impact. This is because the outer surface of a muzzle-loading gun tapers from the breech to the muzzle while the bore stays horizontal. Beauchant (1828:10) calculated that aiming for the gun ports of a ship 100 fathoms (182.9 m) distant by using the outer surface of the gun would cause the shot to go 18 to 20 feet (5.5 to 6.1 m) above the intended target. To overcome this problem, the bore had to be parallel to the gunner's line of sight. The 17th-century Spanish gunner made use of a technique then known as *matar el vivo* or "killing the live one" to achieve this. When the *bore* was level, a 4-pounder falconet ranged approximately 250 paces. When the *top of the gun* was level, elevation of the bore slightly increased. Therefore, the range increased to approximately 440 paces. The difference between the top of the gun and the bore was the *vivo* and its elimination led to a line of sight parallel with the bore (Manucy 1949:76).

The Spanish gunner inserted a pick into the vent at the breech down to the bottom of the bore and marked the depth. He then took that same pick to the muzzle and stood it up in the bore to mark the height of the muzzle. The difference between the two marks, with an adjustment for the base ring (which was higher than the vent), was calculated and fixed using a small wedge of proper size (Manucy 1949:76-77). Archaeologists working at the 1715 Spanish Douglass Beach Wreck in Florida recovered a brass "gunner's bar" (Figure 3.3) now being conserved by the Florida Bureau of Archaeological Research (Jessica R. Stika 2017, elec. comm.). The surface of this artifact appears to be graduated and its application seems appropriate for the operation of killing the *vivo*.

FIGURE 3.3. Spanish gunner's bar from Douglass Beach Wreck Site (Courtesy of Florida Division of Historical Resources).

French gunners of the 18th century overcame the same problem by placing a small piece of wood near the muzzle of the gun (Le Blond 1746:20). This early instrument was concave on one side to fit nicely on the round surface of the gun and made up for the difference in thickness at the breech and at the muzzle. Known simply as a "sight-piece," it made a gunner's line of sight parallel to the bore. Even though the sight-piece was level with the upper part of the breech, the shot struck slightly lower than the area the gunner aimed for. This happened because the diameter of the bore was smaller than the diameter of the breech (Le Blond 1746:21). As a result, the gunner simply had to raise the gun to a point "half the diameter of the breech higher" and the shot would strike precisely the point aimed for.

Gunner's Level

As late as the mid-19th century, common practice for training a gun on a target required the location of the centerline at the top of the gun, marking it with chalk or filed notches, and using those as a sighting line. To locate this centerline, gunners used a gunner's level (Figure 3.4). This instrument was similar to a gunner's quadrant. It also resembled a carpenter's square, had a quarter circle connecting the two arms, and a plumb bob dangled from the angle of the square. However, a third arm connected the ends of the arms of the gunner's level and formed a triangle. This third arm was the base of the triangle and the plumb bob dangled at its midpoint. The gunner placed the instrument first on the base ring, then on the muzzle. When it was level above both points, the plumb bob was theoretically on the centerline, which was subsequently marked (Manucy 1949:77).

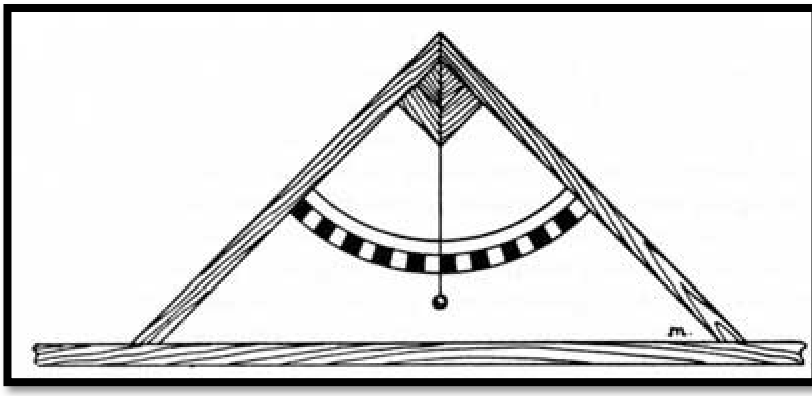

FIGURE 3.4. Seventeenth-century gunner's level (Manucy 1949:77).

Müller was much more in favor of using the gunner's level, or "perpendicular," a single time and marking the line of direction with a permanent slit or cavity at the breech and a "button" at the muzzle. Even though this line might not have marked the true center of the gun, the gunner would be able to correct his mistake by adjusting the piece *in relation to* the false centerline. Müller cited gunnery experiments in France in which gunners shot too far to the left of their intended target after they marked their initial centerline. They did not place the perpendicular on top of the gun again to attempt to locate the proper centerline. Instead, they simply adjusted their aim by gauging their margin of error after the first shot and registered hits on most subsequent shots (Müller 1780:149).

Müller's Rejection of the Gunner's Level and Gunner's Quadrant

In his *Treatise of Artillery*, Müller raised some doubts concerning the function of the perpendicular when the centerline was marked with chalk. He described a process in which gunners trained a gun on a target with the use of both the gunner's quadrant and the gunner's level. The perpendicular helped the gunner locate the centerline of the points described above. Once found, the gunner's quadrant entered the bore and application of the proper degree of elevation of the gun followed, which depended on the distance to the target (guessed by the gunner). Finally, the elevation of the gun increased or decreased according to whether the shot was too short or too long. However, Müller recognized the fact that no gun "is ever turned so true, that the outside corresponds exactly with the inside" due to the nature of the tools and heaviness of the work of casting ordnance (Müller 1780:148-149). Thus, it was reasonable to assume that an instrument applied on the outside of the gun would yield an inaccurate centerline due to differences with the inside of the gun. He also pointed out the obvious problem of not placing the perpendicular precisely in the same spot when the gun was shifted laterally or vertically, providing the gunner with different lines of direction and confusing him (Müller 1780:149).

Despite offering possible solutions to the problems gunners faced when trying to locate the centerline of a gun using the perpendicular, Müller thought the instrument should be rejected along with the gunner's quadrant. Concerning the latter, he pointed out the inherent disadvantage of relying too much on the gunner's quadrant to determine proper degree of elevation. The gunner would never learn to judge distance by eye – an important skill when in the midst of a battle's confusion. A gunner with the ability to gauge the approximate distance of an enemy line or ship without a gunner's quadrant or a perpendicular would be able to raise and train the gun appropriately and at a moment's notice because his "gunner's eye" would be well-developed. The gunner's quadrant had its merits but these were easier to appreciate in time of peace when there was no enemy battery to contend with (Müller 1780:150).

Müller's Rules of Projections

One of Müller's greatest contributions to the science of ballistics were his rules of projectiles. These rules were established mainly to be used when operating mortars, as they allowed the gunner to solve for range, time of flight, or degree of elevation if the distance to the target was approximately at or under 1200 yards (1,097 m). However, he recognized the establishment of these rules happened under certain controlled conditions: the charge was the same and the only variable was the elevation of the gun. Additionally, the rules were deduced from the theory of bodies moving through a non-resisting medium, which would not be the case for projectiles fired from a gun – air offered considerable resistance to projectiles during flight (Müller 1780:156). Nonetheless, the four rules for horizontal ranges were as follows:

> I. *The range of a body projected with an angle of 15 degrees is half the range of that body, if projected with the same force with an angle of 45 degrees*.
>
> II. *The range of a body projected with an angle of 45 degrees is equal to the square of the time of its flight expressed in seconds multiplied by 16.1 feet.*
>
> III. *If a body be projected with the same force, but with different angles of elevations, the horizontal ranges are as the sines of angles double those of the elevations respectively*.

> IV. *The times of the flights of the same body, projected with the same force, with different degree of elevations, are to each other as the sines of the angles of elevations* (Müller 1780:156-157).

An example of Rule II at work follows. If a gun was raised to 45° and fired a shot that traveled for 12 seconds before it struck a target, the first thing to do to calculate the approximate range is find the square of 12. The square of 12 is 144 and this number would be multiplied by 16.1 feet (4.9 m). The product of these two numbers is 2318.4 feet (706.6 m). When this is converted to yards, the approximate range of a mortar raised to 45° and firing a shot that had a 12-second flight time is 772.8 yards (706.6 m). If the goal was to achieve a desired range, to calculate the necessary degree of elevation, Rule III was consulted. At 20° of elevation, the approximate range of a projectile was 200 yards (182.9 m). If the desired range was 300 yards (274.3 m), the first step in calculating the proper degree of elevation was doubling 20 to get 40. The sine of 40° is 64278. If the sine for double the degree of elevation needed to reach 200 yards is 64278, by simply calculating for ratios, the sine of the angle double the required one for 300 yards must be 96417 (expressed as $\frac{200}{64278} = \frac{300}{96417}$). This is the sine of an angle of 74°, 37 minutes. Half of this angle and the proper elevation of a mortar if the goal is 300 yards is 37°, 18.5 minutes (Müller 1780:157-158).

Point-Blank

True fixed gun sights on naval ordnance were virtually unknown prior to the 19th century (Tucker 1989:37). Dispart sights similar to those mounted on the muzzles of modern rifles were used sparingly during the 17th century but because typical naval engagements were yardarm-to-yardarm encounters, there was no pressing need to improve the accuracy of guns (Manucy 1949:76; Tucker 1989). Accuracy depended on proximity to the enemy vessel and ranges were rarely above point-blank. In fact, Admiral Horatio Nelson rejected an 1801 proposal for a set of gun sights saying, "The best and only mode I have found of hitting the enemy afloat is to get so close that whether the gun is pointed upwards or downwards forward or aft…it must strike its opponent" (Tucker 1989:37).

The definition of point-blank range varied over time and with each country. Müller defined point blank range as that distance between where the shot was fired and where it first touched the ground when the gun was level. The ranges of that same piece fired horizontally would vary according to the weight of the powder charge. Therefore, he redefined point-blank range as that range achieved under the above circumstances with the powder charge commonly used in battle (Müller 1780:152). He also conceded to the variation in point-blank ranges for guns of different calibers and sizes and deemed it necessary for the gunner to know the approximate ranges for guns of every class. During the 18th century, the US Navy defined point-blank range as the distance to a point at which a shot, fired from a level gun loaded with a full service charge, crossed the horizontal plane on which the trucks of the gun carriage stood. The French defined point-blank range as the distance between where the shot was fired and where it crossed the horizontal plane on which stood the gun's line of metal. In 1850, point-blank range for an 18-pounder was approximately 275 yards (251.5 m) and 400 yards (365.8 m) for a 32-pounder (Tucker 1989:37).

Calculating Distance

Methods of calculating the distance to an enemy ship evolved through the years. Considerable improvements in guns and powder compelled gunners to make accurate distance measurements. With improved ordnance and accurate distance measurements, keeping an enemy ship within range while simultaneously staying out of theirs was a possibility. Müller formulated a chart of distances at sea (Figure 3.5) based on the height of ships above water.

Yds.	Yards	Miles.	Yds.	Yards	Miles.
1	3735	2.12	26	19048	10.82
2	5278	3.00	27	19410	11.03
3	6470	3.67	28	19767	11.23
4	7470	4.24	29	20107	11.42
5	8353	4.74	30	20460	11.62
6	9150	5.20	31	20800	11.82
7	9863	5.60	32	21133	12.00
8	10566	6.00	33	21459	12.20
9	11206	6.36	34	21780	12.38
10	11800	6.70	35	22100	12.55
11	12390	7.04	36	22413	12.73
12	12940	7.35	37	22720	12.91
13	13468	7.65	38	22895	12.97
14	13977	7.94	39	23329	13.20
15	14468	8.22	40	23631	13.40
16	14942	8.49	41	23919	13.59
17	15402	8.75	42	24209	13.75
18	15850	9.00	43	24500	13.92
19	16283	9.25	44	24780	14.08
20	16706	9.49	45	25059	14.24
21	17118	9.72	46	25336	14.40
22	17521	9.95	47	25610	14.55
23	17915	10.18	48	25880	14.70
24	18300	10.40	49	26148	14.85
25	18678	10.61	50	26414	15.00

FIGURE 3.5. Muller's chart (Muller 1780:xxxix).

He assigned ships heights from 1 yard (0.9 m) to 50 (45.7 m) "deduced from the roundness of the sea's surface," calculated the mean diameter of the earth in English yards which "gives 7.1447018 [sic] for its logarithm; to which adding continually the logarithm of the height, gives the logarithm of the of the distances in yards" (Müller

1780:xl). The basic principle was that a seaman would always have some idea of the height of his position above the waterline within his own ship. To that height, he adds the approximate height of the part of the ship that is underwater. When those two heights are added together, the above distance chart is consulted to check the corresponding distances in yards and then in miles to the opposing ship. For example, if a sailor knew that his position above the waterline was 15 yards (13.7 m) and he guessed that the part of his ship below the waterline was at 7 yards (6.4 m), he would add both measurements to make 22 yards (20.1 m). He would then consult the chart for the corresponding distances for 22 yards: 17,521 yards (16,021.2 m) or 9.95 miles (16 km) (Müller 1780:xl).

In his *Sea Gunner's Vade-Mecum* (1812:39-40, 43-45), Robert Simmons laid out another mode of gauging distance to and height of another ship at sea, the latter was important because it let the observer know the class to which the other ship belonged. Mast heights were approximately the same for ships of each class, regardless of their nation of origin (Tucker 1989:41). Simmons observed that by using Hadley's quadrant to take angular heights, the angle corresponding to the height of another ship as seen from the quadrant's telescope will read 45° if the distance between the observer and the ship is equal to the ship's perpendicular height. One may also go backward and forward until the angle reads 45°. The basis for this technique lies on the geometric principle of diagonally cutting a square in half. A table for gauging the distances between ships of the line at sea, furnished by Admiral William Waldegrave for *Steel's Treatise on Naval Tactics*, was used in tandem with Hadley's quadrant. When a ship of the line was spotted at sea, Hadley’s quadrant was adjusted to ascertain the angle made from the observer’s eye to the “maintop-gallant-mast hounds or rigging” of the other ship. Once the angle was established, the gunner consulted the table. On the table, the rate of the ship (which an experienced gunner or captain would know) is found on the topmost row. It is followed down its corresponding column to the degree closest to that shown on the quadrant, and, on a parallel left-hand column, the distance between the enemy ship’s mainmast and the observer would be shown in fathoms or miles (Figure 3.6).

A TABLE for finding the distance of Ships in the line.

Guns.	100	90	80	80	74 L.	74 S.	64	60	50
Distance in Fathoms.	Angle.	Angle.	3 decks Angle.	2 decks Angle.	Angle.	Angle.	Angle.	Angle.	Angle.
50	31° 50½′	30° 45′	29° 57′	35° 43′	31° 13′	30° 16′	27° 50′	26° 45½′	25° 34½
100	16 21½	15 43½	15 23½	16 49	16 7½	15 34½	14 4½	13 28½	12 5½
150	11 3½	10 37	10 18½	11 25	10 48½	10 26	9 30	9 5½	8 39
200	8 18½	7 59	7 44½	8 29½	8 7½	7 50	7 8	6 49½	6 29
250	6 39	6 23½	6 12	6 50	6 30	6 16½	5 42	5 27	5 11½
300	5 32½	5 18½	5 9½	5 39¾	5 24½	5 13½	4 44½	4 32½	4 19½
400	4 9	3 59½	3 52½	4 15	4 3½	3 55	3 34	3 24	3 14
500	3 19½	3 11½	3 5½	3 24	3 15	3 8	2 51	2 44	2 36
600	2 46	2 39	2 35	2 50	2 42½	2 36½	2 22¼	2 17	2 10
700	2 22¼	2 17	2 12½	2 25½	2 19	2 14	2 2	1 57	1 51
800	2 5	1 59	1 56	2 8	2 2	1 58½	1 46¼	1 42½	1 37½
900	1 51	1 46½	1 43½	1 53½	1 48	1 44½	1 35	1 31	1 27
1 mile	1 38	1 34	1 31½	1 40½	1 36	1 32½	1 24	1 20½	1 17
2 miles	0 49	0 47½	0 45¼	0 50½	0 48	0 46½	0 42	0 40	0 38
3 miles	0 33	0 31½	0 30½	0 33½	0 32	0 31	0 28	0 27	0 25½
4 miles	0 24½	0 23½	0 23	0 25½	0 24	0 23¼	0 21	0 20¼	0 19¼

FIGURE 3.6. Chart showing angles of elevation and corresponding distances to ships (Simmons 1812:44).

The Advent of 19th-Century Gun Sights

Orders given in 1848 instructed the fitting of all US Naval guns with a pair of gun sights: a dispart sight on top of the gun in the area known as the second reinforce and a tangent sight, a graduated scale that moved in a vertical plane, at the breech of the gun. Commander J. A. Dahlgren graduated the tangent sight scales for guns of every class shortly after this order (Dahlgren 1856:39). Colonel Jure of France first proposed the idea of using both a dispart sight (Figure 3.7) and a tangent sight (Figure 3.8) together.

FIGURE 3.7. Dispart sight recovered from CSS *Georgia* (photo by author).

FIGURE 3.8. Tangent sight recovered from CSS *Georgia* (photo by author).

Under his system, the tangent scale had six principal divisions and each represented one cable length, or approximately 608 feet (185.3 m) (Tucker 1989:39). Shortly after the introduction of this system, the English followed suit but graduated their tangent scales in degrees, rather than range or charge. William Nicholson Jeffers, a passed Midshipman of the US Navy, deemed British gun sights undesirable because of their graduation in degrees. This necessitated consultation of a range table to find corresponding ranges to different degrees of elevation, which was impractical in the middle of a battle. (Jeffers 1850:146-148).

The basic concept behind the use of a dispart sight was not new. Since the 17th and possibly the 16th century, attempts at correcting for the difference in thickness at the breech and at the muzzle of a gun took place. The difference between the diameter of the breech and the diameter of the muzzle was calculated and divided by two. The resulting quotient represented the proper height of the sight placed at the muzzle. This created a line of sight "perfectly parallel" to the bore of the piece as long as the gun was "truly bored" (Simmons 1812:142; Beauchant 1828:10). Dispart sights did not come into general use until the beginning of the 19th century and became permanent fixtures on the muzzle of the gun by the middle of the century. Additionally, US naval guns cast with sight masses already in place were common. These masses indicated the location of sights on the surface of the gun (Tucker 1989:40).

On the other hand, tangent sights were used when the enemy ship was beyond point-blank range. When the range increased, the gun had to be elevated, effectively blocking the enemy ship from the gunner's line of sight (Jeffers 1850:143). Lowering the gun would reveal the position of the enemy ship but its range would obviously decrease. The tangent sight, sliding through a metal box fixed in place at the breech of the gun, solved this problem. Once raised, the gunner would look through the notch at the top of the scale, rather than along the gun's line of metal, effectively obtaining a direct view of the enemy ship despite the increased elevation of the gun (Jeffers 1850:137). This view was known as an artificial line of sight. This line of sight was a straight, imaginary line that ran from the tangent sight notch, through the top of the dispart sight, and ended at the intended target. Once all three points were "connected" by this line, the gunner would pull the lanyard and the gun discharged instantly thanks to the new percussion locks and mercuric fulminate primers adopted during this period (Jeffers 1850:139).

Conclusion

Tangent and dispart sights were unique to each gun because each gun had a different dispart, caliber, projectile, and appropriate powder charge, which resulted in ranges attainable at different degrees of elevation. The information on the different possible ranges determined the graduated reading on the tangent scale. Dispart sights proved very useful during close-quarter, quick-firing battles. Tangent scales were crucial during long-distance engagements and were indispensable on the breech of the gun with the advent of more powerful artillery capable of greater ranges of fire. In fact, British Lieutenant Theophilus Samuel Beauchant (1828:15) once said, “A ship is about as complete without a rudder as a gun without a tangent scale.”

CHAPTER IV

PHYSICAL PROPERTIES OF A PROJECTILE IN FLIGHT

Introduction

The 19th century was a time of significant progress in applied scientific theory to numerous commercial and military endeavors. Within the scope of the latter, the practical application of various scientific laws was partially evident in the realm of gunnery. The naval gun sights recovered from *Georgia* reflect an understanding of the physical properties of projectiles in flight. Therefore, it is important to grasp these scientific concepts as they were understood during the 19th century.

The Right Triangle

The most fundamental principle of any projectile fired at sea towards a target at a range greater than point-blank is the formation of an imaginary right triangle (Figure 4.1).

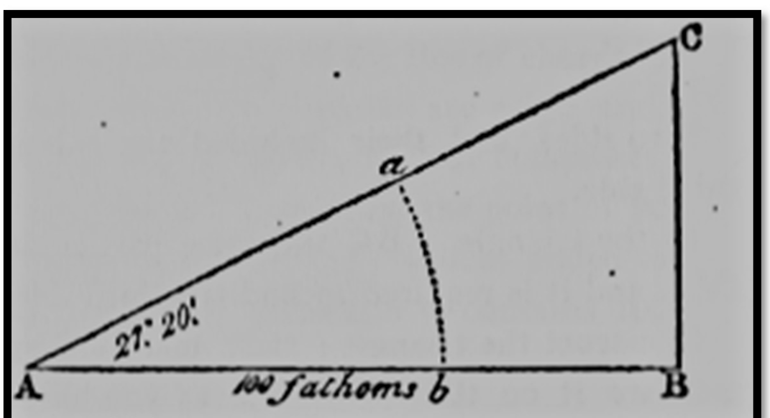

FIGURE 4.1. Triangular principle when firing guns at sea (Simmons 1812:40).

The base of the triangle formed the distance between the gun and its target. The height of the triangle was a line perpendicular to the base and represented the altitude of the target, which was usually the main topmast head, main topgallant head, or the main topmast crosstrees of a ship (Simmons 1812:40-41; Beauchant 1828:18-19). The third and longest side of this triangle was the hypotenuse, formed by an imaginary diagonal line connecting the highest point of the triangle with the gun at its base. This line was known as the "prolongation of the axis/bore" of the gun raised to a given elevation (i.e. angle of elevation) (Jeffers 1850:135, Plate I, figure 24; Robinson et al. 1939:254, figure 1101) and would have been the trajectory of the projectile had there been no outside factors influencing its flight, such as gravity or atmospheric resistance (Simmons 1812:90; Owen 1873:207).

Gravity

The force of gravity acts with equal intensity upon all bodies at motion or at rest but it varies in intensity at the surface of the earth according to latitude. Within the same latitude, it varies with elevation. This is because the attractive force of gravity is proportional to the masses of the bodies but inversely proportional to the squares of their distances from the earth (Ward 1861:15). When a body is set in motion, it begins with a velocity of zero. At the end of the first second of time, it will have acquired a velocity, v. If no outside factors act upon the body (i.e. if it remains in freefall) by the end of the next second, the body will have acquired a velocity of $2v$. The spaces fallen through in given intervals of time increase as the *squares of the times* (Ward 1861:19). Therefore, all objects suspended in midair will eventually begin to fall towards the center of the earth and cover 16 feet (4.9 m) in the first second, 64 feet (19.5 m) by the end of the next second, and so forth (Simmons 1812:91; Jeffers 1850:12, 16-17). This basic principle of the action of gravity upon bodies was considered when the striking or terminal velocity of a projectile nearing the end of its flight was calculated. The projectile achieved terminal velocity when the resistance of the air it encountered as it fell through the atmosphere became equal to the pull of the force of gravity (Owen 1873:207).

The influence of gravity on a projectile was considered a permanent force because it was continuous throughout the duration of its flight (Ward 1861:16). The line described by the flight of the projectile was "represented by a polygon of an infinite number of sides, that is, a curved line convex towards the direction of the impulsive force" (Jeffers 1850:18-19). This curve was called the trajectory. It was roughly in the form of a parabola and was the result of the continual deflection of the projectile away from a straight-lined course by the force of gravity (Simmons 1812:90). Its parabolic form compelled early mathematicians to use a principle known as the "parabolic theory" to calculate the flights and ranges of shot they believed ought to take place in artillery practice (Ward 1861:20). This theory held its ground for a long time by virtue of its extreme simplicity until Sir Isaac Newton demonstrated it to be erroneous in the beginning of the 18^{th} century (Jeffers 1850:123).

The Parabolic Theory

Figure 4.2 illustrates the parabolic theory. The diagram places the naval gun at point *a*, several feet above the horizontal plane *bc*. The reasoning behind this initial placement is due to guns being placed several feet above the horizontal plane of the earth when they are aboard naval vessels. When a shot fired from point *a* is impelled by a charge of powder, it will initially travel in a horizontal direction towards point *d*. If no external factors influence the flight of the projectile, it will continue to travel in the direction of point *d* and cross equal spaces in equal times forever. At the end of the first second of time, it will be found at *1"*, at the end of the second equal space of time at *2"*, at the end of the third at *3"*, and so forth (Ward 1861:18).

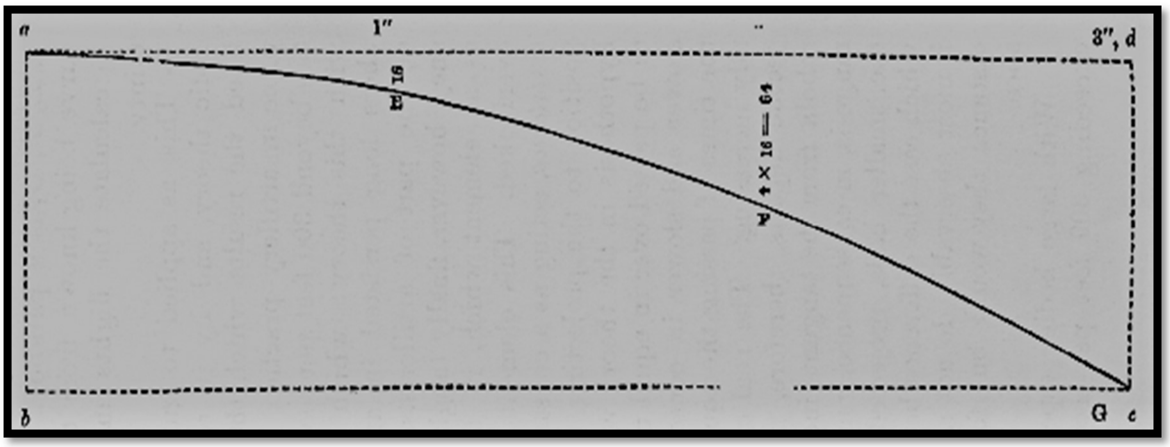

FIGURE 4.2. Eighteenth-century illustration of the parabolic theory (Ward 1861:19).

However, gravity begins to act upon the projectile immediately after it exits the bore of the gun. The projectile is drawn towards the earth with an accelerated velocity, creating the curve *EFG*. As mentioned earlier, a body suspended in the air will be pulled towards the center of the earth and cover approximately 16 feet (4.9 m) during the first second. Therefore, the projectile will be at point *E*, 16 feet below the plane *ad*, after the first second. Since the spaces covered by bodies pulled by the force of gravity are as the squares of the times, at the end of the second equal space of time, the projectile will be found at point *F*, 64 feet (19.5 m) below the plane *ad*. This pattern will continue until the projectile finds itself at point *G*. Because the ordinates *E1"*, *F2"*, and *G3"* are as the spaces *a1"*, *a2"*, and *a3"*, this curve is considered a parabola. Once the parabola was formed, all its properties were known because they could be easily calculated (Ward 1861:19-20).

This theory would also indicate that if the gun was placed at point *G*, turned 180°, and fired at the same angle of elevation, or angle of departure/extension of the bore (Robinson et al. 1939:254), to create the curve *GFE*, the projectile would continue that curve until it landed at a point creating a horizontal plane twice the length of the plane *cb*. This would create the other half of the original curve and all its points would exactly mirror the points on *GFE*. Point *a* would be located on the summit of the curve and its vertical axis would be located on the center of amplitude (i.e. midpoint of the new horizontal plane created). The lines formed by the point of departure and the point of arrival of the projectile would make equal angles with the horizontal plane and all points on these lines would match with each other. The velocity of the projectile would be the same in the two branches of the curve at the same height and the final velocity would equal the initial velocity. The angle giving the greatest range would always be 45° (Jeffers 1850:122).

Inadequacy of the Parabolic Theory

According to this theory, if two bodies are fired with the same velocity and at the same angles of elevation they should achieve the same range, all other factors being equal (i.e. the intensity of the impulsive force of the powder charge and the influence of gravity). However, even if equal force is applied, a ball of cork will not achieve the same range as a ball of lead. This is because the parabolic theory assumes a projectile will describe its trajectory through a *non-resisting medium* (Müller 1780:156; Simmons 1812:90; Jeffers 1850:19). Air acts against a body in flight in the form of atmospheric resistance. This was, and indeed still is, a major consideration in the art of gunnery, especially towards projectiles fired at high velocities. A vertical "wall" of condensed air formed in front of high-velocity projectiles during flight, which greatly influenced their trajectories (Jeffers 1850:20). The only time the parabolic theory differed little from the actual trajectory described by a projectile was when the latter was considerably dense, was fired at short range, and achieved a low velocity. Beauchant (1828:6) did not believe the parabolic theory was applicable with velocities over 400 feet per second (121.9 m/s). Ward (1861:20) and Owen (1873:209) reduced this velocity to approximately 300 feet per second (91.4 m/s). The resistance of the atmosphere is greatly diminished at low velocities because the body in flight does not increase the length of the column of condensed air formed before it (Jeffers 1850:19-20; Simpson 1862:315). However, gunnery dealt with velocities considerably greater than these, making the parabolic theory largely irrelevant.

Atmospheric Resistance

The column of condensed air created when the projectile traveled at very high velocities increased friction between air and the surface of the shot. If the velocity increased up to a certain point, the resistance of the condensed air column also increased, which led to the creation of a partial vacuum immediately behind the projectile as air was displaced. This vacuum was immediately filled with the displaced air and created eddies which favored the motion of the projectile (Jeffers 1850:20). The displaced air met the posterior of the projectile and exerted less pressure upon it than the air anterior to it. Both pressures together would place the shot in a state of equilibrium – the force on one side would balance the other and the difference between them would be the measure of atmospheric resistance of the projectile (Ward 1861:21-22). However, if the projectile achieved a considerable velocity, the displaced air will not fill the vacuum left in its wake until after the projectile had passed (Jeffers 1850:110). Ward (1861:21) and Owen (1873:210) calculated this velocity at 1,600 feet per second (487.7 m/s). Velocities greater than 1,600 feet per second would slow the increase of atmospheric resistance because the pressure formed before the projectile would not be balanced by a pressure formed behind it (Jeffers 1850:20; Ward 1861:21; Owen 1873:210). Despite the decrease in the rate of atmospheric resistance, the projectile would still be met with the utmost retarding force of the atmosphere. Therefore, Ward (1861:21-22) did not recommend firing a cannonball at a velocity over 1,600 feet per second.

Naval engagements were a time of stress and constant physical activity, requiring quickness of thinking. A gunner did not have time to sit and solve complicated geometric and algebraic problems and come up with the best way to prepare, load, train, and fire his gun at the enemy ship. Additionally, numerical errors are rarely absent from long calculations and long calculations are an inherent characteristic of theoretical systems – even if results were achieved in the comfort of home and away from the heat of battle. These theoretical systems were insufficient even then, as velocities and ranges with balls of different diameters and densities fired with various proportional charges of powder at different angles of elevation could not be determined by theory alone (Ward 1861:22). The result was often a mystification of "what is wished to make plain and simple to those not versed in mathematics" (Beauchant 1828:5) The best way to form reliable and readily available data for the artillerist was to create good experimental tables of ranges of every species of ordnance, discharged from several different classes of guns, at different angles of elevation, under varying circumstances (Beauchant 1828:6-7). Results also differed despite the similar conditions under which two guns were fired. Causes for the varying trajectories or ranges of projectiles fired under similar circumstances may not be initially evident. This was yet another justification for close observation and reasoning following extensive experimentation (Ward 1861:17).

Three Principles of Atmospheric Resistance

The general effects of atmospheric resistance on different kinds of projectiles were condensed into three main principles during the 19th century. First, large balls have greater range than small balls of the same density and initial velocity. Second, heavy or dense balls have greater range than those less dense despite being projected with equal velocity and elevation. Third, if balls with equal diameters and densities described their trajectories at different velocities, those with low velocity will range farthest *in proportion* to the velocity (Simmons 1812:92-94, 99; Jeffers 1850:19-21, 114, 117; Ward 1861:22). Essentially, from these three main principles, it followed that: resistance acted with greater effect in retarding small shot than large shot, shot of little density than shot of great density, and, in proportion to their range, shot of high velocity than shot of low velocity (Ward 1861:23).

In the first instance, the resistance to small shot is greater than to large shot because the absolute resistances they both met were proportional to the squares of the diameters of the shot. The forces of shot to overcome resistance were proportional to their weights, and their weights were proportional to the cubes of their diameters (Owen 1873:210-211). Therefore, as shot increased in diameter, their force to overcome atmospheric resistance increased faster than the resistance itself increased; thus retarding small shot more than large (Ward 1861:23). Experiments held in 1786 by Dr. Charles Hutton, English mathematician and surveyor, came to the same conclusions: "That the resistance of the air is nearly as the surface; the resistance increasing but a very little above that proportion in the greater surfaces" (Owen 1873:225). Ward (1861:23-24) illustrated this concept with shot of different diameters: one of three inches (7.6 cm) and another of six inches (15.2 cm). They corresponded with a 3-pounder ball and a 24-pounder ball. Resistances to this type of shot were as the squares of 3 and 6 (9 and 36), the ratio being 1 to 4. Their forces to overcome resistance were as their weights, which are as the cubes of their diameters, 27 to 216, the ratio being 1 to 8. The larger shot met with a resistance four times greater than the smaller but had eight times the power to overcome it. Therefore, it was retarded in its flight only half as much as the smaller shot.

In the second instance, dense shot is less retarded than lighter shot of equal diameter because if the surfaces are equal, then the resistance depended solely on the overcoming force of the shot, which corresponded to its weight. The total weight of a body is represented by a ratio compounded of its mass and of the intensity of gravity at the place where it is situated. The weights of equal volumes expressed the density of matter (Jeffers 1850:17) and although gravity acts with greater intensity on dense objects, these have more force to counteract atmospheric resistance. However, if dense shot were fired with very low velocities, they did not outrange lighter shot fired at higher velocities (Ward 1861:24).

In the third instance, shot of low velocities are retarded less than shot of high velocities because there was less rarefied air in the rear end of the slower projectile. This resulted in a smaller difference between the pressure in front of the projectile and the pressure behind it. Being that the measure of atmospheric resistance was the difference between the two pressures, a smaller difference meant less atmospheric resistance (Ward 1861:24). According to Owen (1873:210), atmospheric resistance varied as the cube of the velocity of a projectile and he devised a formula to calculate the measure of the resistance: d^2v^3 (where d is the diameter of the shot and v is its velocity). If a 68-pound (30.8 kg) round shot with a diameter of 8 inches (20.3 cm) fired with a velocity of 1,580 feet per second (481.6 m/s) experienced a resistance of 1,000 pounds (453.6 kg), then a 100-pound (45.4 kg) shot with a diameter of 9 inches (22.9 cm) fired with a higher velocity of 1,650 feet per second (502.9 m/s) would experience a higher atmospheric resistance equivalent to 1,441 pounds (653.6 kg). This was calculated by using the ratio $1{,}000 : R :: 8^2 : 9^2$ (Owen 1873:211).

Causes of Deviation

Jeffers (1850:109, 111) believed a spherical figure to be the most advantageous shape for projectiles fired from artillery. A spherical form is the only form that admitted the great velocities impressed upon projectiles. The surface of a sphere was a minimum with respect to its volume, which decreased the resistance of the atmosphere. Finally, the centers of gravity and of figure are less removed in a sphere than in any other figure, making the consequences of irregularity less numerous (Jeffers 1850:109). However, all projectiles acquire a motion of rotation upon being fired and a projectile in the shape of a sphere is not exempt from the resulting deviation from the vertical or the horizontal planes. Vertical or lateral deviation of a sphere was greater if the centers of gravity and of figure did not coincide (i.e. if the sphere had irregular mass).

To better understand the causes of deviation, it is necessary to begin by understanding windage and its effects. Windage was the difference between the diameter of the shot and that of the bore (figure 4.3).

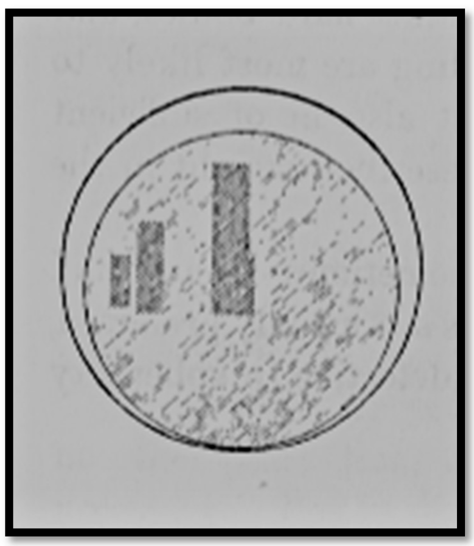

FIGURE 4.3. Eighteenth-century illustration of windage ring (Ward 1861:84).

In 1861, new shot for the navy had a fixed windage of $\frac{1}{10}$ to $\frac{2}{10}$ of an inch (2.5 to 5.1 mm) for all calibers (Ward 1861:83-84). Shot had to be cast with a smaller diameter than the bore to allow for want of sphericity, to allow for the formation of rust on the shot and in the bore, and to allow for the expansion of shot, which was about $\frac{1}{70}$ the diameter at white heat (Ward 1861:84). The space left between the bore of the gun and the shot was called the "windage-ring," was in the form of a crescent, and its area was the difference between the area of the circular cross-section of the shot and of the bore (Ward 1861:86-87).

The inherent disadvantage resulting from the necessity of a certain degree of windage manifested itself in what gunners called "balloting" (Ward 1861:86). When the powder charge was ignited, the shot would bound from side to side or up and down (figure 4.4) as it traveled along the bore of the gun. This caused the projectile to leave the muzzle in an upwards, downwards, or lateral direction, which influenced the accuracy of fire because the shot would deviate to the right, left, up, or down during the course of its flight (Ward 1861:88-89). If the shot impinged upon the left side of the bore upon leaving the gun, it would have taken a rotary motion from right to left on a vertical axis *b*, as shown in figure 4.5. Immediately upon exiting the bore, the shot would deviate to the right towards *d* because it struck the left side of the bore last. The initial velocity of a projectile is its greatest velocity (Owen 1873:193), therefore the air at *c* is greatly condensed and offers considerable resistance to *p*, or to the motion of rotation. The air at *r* is rarefied and offers little, if any, resistance to *s*. As a result, the resistances at *p* and at *s* are not equal and the tendency of the shot to deviate towards the right is upheld during the first part of its trajectory (Ward 1861:90).

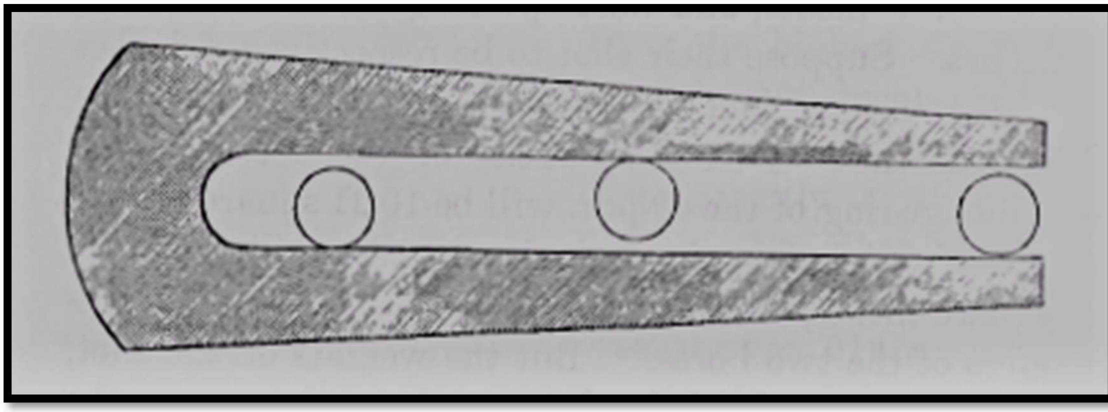

FIGURE 4.4. The shot bounds up and down the bore (Ward 1861:86).

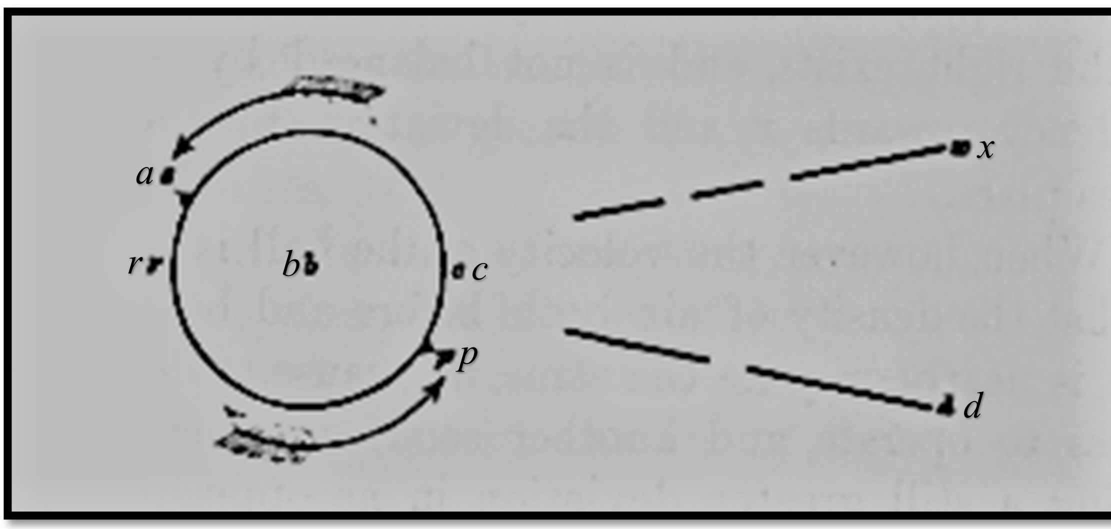

FIGURE 4.5. The motion of rotation of a spherical shot and its deviation (Ward 1861:89; letters repeated for clarity by author).

The velocity of shot was reduced during the latter part of its flight, therefore the density of the air in front and behind the shot was closer to being equal, which canceled the deviation towards *d* (Ward 1861:90; Owen 1873:233-234). The shot still revolved from left to right on a vertical axis *b*. The right side of the shot moved *in conjunction* with that of the shot's progression, or trajectory. The left side of the shot had a motion of rotation *in opposition* to that of the shot's progression. This led to a decreased velocity of rotation on the left side which resulted in least resistance. A shot surrounded by air of nearly equal densities on all sides tended to deviate to the side of least resistance, or towards *x*. The opposite would happen if the shot hit the opposite side of the bore right before it exited (Ward 1861:90-91). Additionally, if the shot struck the bottom of the bore right before it exited, the axis of rotation would be horizontally perpendicular to the trajectory, and the motion of rotation of the shot would be from above downwards. The increased pressure would be above and the decreased would be below, effectively decreasing the range of the shot. If the shot struck the top of the bore last, the impact would have the opposite effect on it, and it would ultimately increase the range of the shot (Jeffers 1850:158; Owen 1873:238).

When the projectile was perfectly spherical but not homogeneous, or homogeneous but not perfectly spherical, the centers of gravity and of figure did not coincide. Figure 4.6 illustrates the effects different centers of gravity and of figure had on the motion of rotation of the projectile. The point *G* represents the center of gravity and *C* the center of figure. The impulsive force of the powder charge was applied to the mass and passed through the center of gravity. The atmospheric resistance acted upon the center of figure. These forces tended to generate a certain motion of rotation in which the center of figure *C* rotated around the center of gravity *G*. The resistance of the atmosphere was oblique to the impulsive force of the powder charge, which resulted in a deviation from the intended trajectory. Atmospheric resistance influenced the center of gravity to a greater degree than the center of figure and gave the trajectory a slightly undulating form (Jeffers 1850:155, 159).

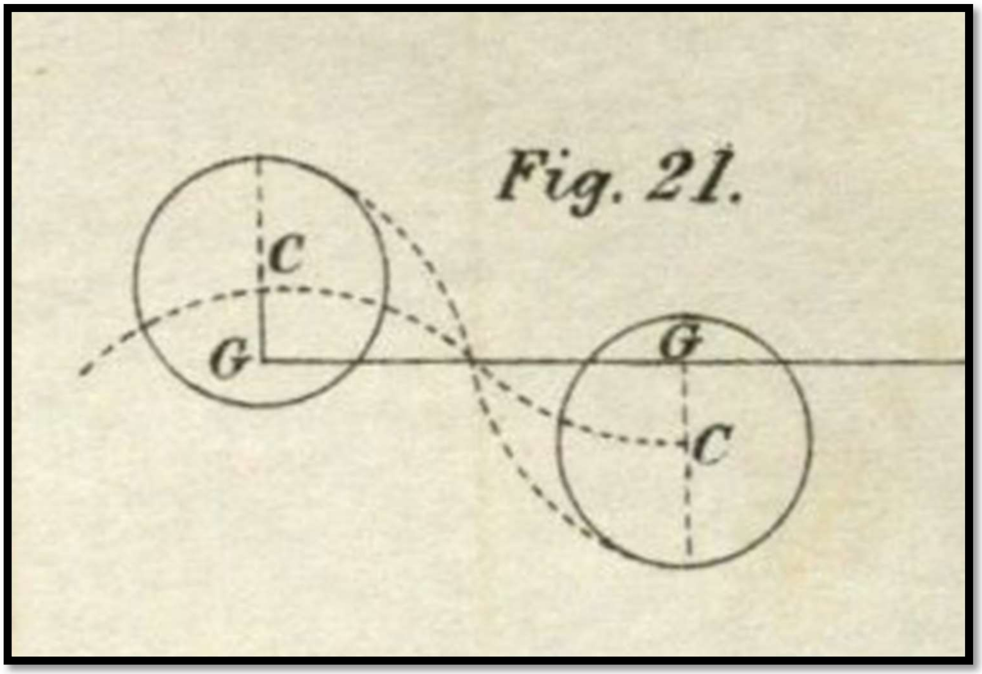

FIGURE 4.6. Eighteenth-century illustration of deviation (Jeffers 1850:Plate 1, figure 21).

The rotation of the earth had an appreciable influence on shot fired at an elevation. The principal effect of the rotation of the earth on the horizontal deviation of a projectile, away from the vertical plane passing through the axis of the gun, was the tendency of the shot to go to the right (Jeffers 1850:150). Therefore, for projectiles fired in the northern hemisphere, the deviation was toward the south when shot was fired towards the east, towards the north when fired towards west, towards the east when fired towards the north, and towards the west when fired towards the south. The range of the projectile increased when it was fired from west to east and decreased when fired east to west. These effects would be reversed for projectiles fired in the southern hemisphere (Jeffers 1850:151; Owen 1873: 232).

It was impossible to know the axis of rotation of spherical shot during the mid-19th century. Gunners had no way to predict what part of the bore the shot would strike upon leaving it. Therefore, Ward (1861:92) suggested no allowance in aim to adjust for deviations be made and to simply sight for the enemy ship to the best of one's ability. The only time some allowance in pointing was required was when a strong wind blew continually with little to no variance in direction. Further, when the axis of rotation coincided with the line of flight, there would be no deviation in its trajectory except for the superior density of air beneath a falling body that resulted from the force of gravity. This coincidence was rarely achieved by smooth-bored artillery and was reserved for rifled bores, such as Parrott rifles, hence the noted superior accuracy of rifled ordnance.

Conclusion

Generally, the smoother the surfaces of shot, the less their windage and eccentricity, and the greater their accuracy, other things being equal (Jeffers 1850:154; Ward 1861:92; Owen 1873:233). These considerations had to be made when the gunner wanted to "fire with unusual deliberation and accuracy" (Ward 1861:92). Additionally, the contemporary gunnery treatises recommend that the heaviest side of the shot should be put next to the charge. Hollow shot deviated more than solid shot because the center of figure was always at a different point than the center of gravity and because of the considerable difference in density. Hollow shells typically contained an explosive charge that was ignited shortly after it lodged in the side of the enemy ship. The variable position of this charge within the shell also influenced the deviation from its trajectory (Jeffers 1850:160). The deviations produced by the friction of the atmosphere were in proportion to the times in which that friction operated. Essentially, if two projectiles covered the same range at different speeds, the angle of deviation would be greater for the slower projectile (Ward 1861:93). By the beginning of the 1860s, it was generally accepted that high powder charges that fired larger and denser shot at very high velocities were essential to accuracy, especially at long ranges. The larger and denser shot were less readily influenced by the causes of deviation, retained their velocities longer, and covered the distance between the gun and its target less time (Ward 1861:93).

CHAPTER V

ANALYSIS OF NAVAL GUN SIGHTS AND PERCUSSION LOCKS

***Georgia*'s Ordnance**

The earliest inventory of the guns on board *Georgia* was compiled on 23 April 1863. Its battery was composed of four starboard guns, four port guns, two guns on the spar deck forward and aft, and one mounted in the bow (Swanson & Holcombe 2007:79). Table 1 illustrates the classes of guns and their location on the ironclad.

Table 1: 1863 Inventory of Guns on CSS *Georgia* (Swanson & Holcombe:79-80)

No. 1 Starboard	8-inch shell
No. 2 Starboard	32-pounder rifle
No. 3 Starboard	8-inch shell
No. 4 Starboard	8-inch shell
No. 1 Port	9-inch shell, Dahlgren pattern
No. 2 Port	32-pounder rifle
No. 3 Port	32-pounder rifle
No. 4 Port	9-inch shell, Dahlgren pattern
Spar Deck Forward	24-pounder (Made by A. N. Miller of Savannah, Georgia)
Spar Deck Aft	6-pounder (presented by Ladies of Rome, Georgia)
Mounted in Bow	32-pounder rifle

The 32-pounder rifles had a caliber of 6 inches (15.2 cm) and had a single band to withstand the strain on the gun from the powerful pressure from the explosion of the powder charge. Two of the 32-pounders were of 66 hundredweight (cwt; 7,392 pounds or just under 3,353 kg) and the other two were of 58 cwt (6,496 pounds or 2,946.5 kg). All three 8-inch guns fired explosive shells. Two were of 55 cwt (6,160 pounds or 2,794.1 kg) and the third was of 56 cwt (6,272 pounds or 2,894.9 kg) (Swanson & Holcombe 2007:82-83). The 9-inch shell guns were smoothbores of the Dahlgren pattern and were of 93 cwt (10,416 pounds or 4,724.6 kg). Changes in *Georgia*'s ordnance took place after this initial inventory. A series of loans reduced the complement of guns to nine. By the end of October 1863, only five guns were left on board *Georgia*. Some of the 32-pounders and all the 8-inch shell guns were given to the Army before the end of the year and *Georgia*'s battery consisted solely of 32-pounder rifles and Dahlgren smoothbores by the start of 1864 (Swanson & Holcombe 2007:80).

The Gun Sights and Percussion Locks

The following figures represent the gun sights and percussion locks recovered from *Georgia*. The dispart sights are shown first, followed by the tangent sights, and ending with the percussion locks. Basic measurements and a brief description follow the figures. These images are referenced throughout the chapter.

CSSG 2994.8

FIGURE 5.1. CSSG 2994.8 - Dispart Sight (photo by author).

Height: 2.0 in. (5.1 cm), W. of base: 1.3 in. (3.3 cm), L. of base: 4.0 in. (10.2 cm)

Typical dispart sight. Stamp on the base reads: NO. 289 32 OF 32.

CSSG 1855.6

FIGURE 5.2. CSSG 1855.6 - Dispart Sight (photo by author).

Height: 2.0 in. (5.1 cm), W. of base: 1.8 in. (4.6 cm), L. of base: 3.9 in (9.9 cm)

Typical dispart sight. Stamp on the base reads: 112.

CSSG 1856.14

FIGURE 5.3. CSSG 1856.14 (1 of 2) – Tall Dispart sight (photo by author).

Height: 2.4 in. (6.1 cm), W. of base: 1.4 in. (3.6 cm), L. of base: 3.9 in. (9.9 cm)

Typical dispart sight. Tallest in the collection. Stamp on base reads: 714.

CSSG 1856.14

FIGURE 5.4. CSSG 1856.14 (2 of 2) – Short Dispart Sight (photo by author).

Height: 2.0 in. (5.1 cm), W. of base: 1.7 in. (4.3 cm), L. of base: 3.9 in. (9.9 cm)

Typical dispart sight. Has 111 stamped on base.

CSSG 1881.28

FIGURE 5.5. CSSG 1881.28 - Dispart Sight Cover (photo by author).

Max. height: 3.9 in. (9.9 cm), Max. length: 6.3 in. (16.0 cm)

Dispart sight cover. Distorted shape. Stamp at base reads: US WNY 112. Stamp at the top reads: 112.

CSSG 2997.3

FIGURE 5.6. CSSG 2997.3 - Percussion Lock (photo by author).

L. of shaft: 3.2 in. (8.1 cm), L. of shaft opening: 1.4 in. (3.6 cm), Diameter of "hammer head": 1.3 in. (3.3 cm), L. of iron "nipple": 0.5 in. (1.3 cm), Diameter of iron "nipple": 0.6 in. (1.5 cm)

Sliding lock. Axial bolt traveled the length of the opening in the shaft. The "hammer head" seems to be damaged by explosion from the vent.

CSSG 1335

FIGURE 5.7. CSSG 1335 - Percussion Lock with Base (photo by author).

Lock measurements:

L. of shaft: 3.4 in. (8.6 cm), L. of shaft opening: 1.4 in. (3.6 cm), Diameter of “hammer head”: 1.3 in. (3.3 cm), Diameter of “hammer head” opening: 0.4 in. (1.0 cm)

Sliding lock with perforated “hammer head.”

Base measurements:

L.: 5.1 in. (13.0 cm), W.: 2.9 in. (7.4 cm)

Typical percussion lock base. Contains three fastener holes for attachment to gun.

CSSG 2012.1

FIGURE 5.8. CSSG 2012.1 - Percussion Lock with Base (photo by author).

Lock measurements:

L. of shaft: 3.5 in. (8.9 cm), Diameter of “hammer head”: 1.3 in. (3.3 cm), Diameter of “hammer head” opening: 0.4 in (1.0 cm), L. of iron “nipple”: 0.8 in. (2.0 cm), diameter of iron “nipple”: 0.7 in. (1.8 cm)

A stamp on the top surface of the shaft is not entirely visible. Perforated “hammer head.”

Base measurements:

L.: 5.2 in. (13.2 cm), W.: 3.0 in. (7.6 cm).

Base has a stamp that reads: 714.

CSSG 2994.6

FIGURE 5.9. CSSG 2994.6 - Percussion Lock with Base (photo by author).

Lock measurements:

L. of shaft: 3.4 in. (8.6 cm), Diameter of “hammer head”: 1.4 in. (3.6 cm), Diameter of “hammer head” opening: 0.4 in. (1.0 cm)

Opening in shaft is not visible or not present. Head is perforated.

Base measurements:

L.: 3.8 in. (9.7 cm), W. 0.9 in. (2.3 cm), Thickness: 0.6 in. (1.5 cm)

Stamps on base read: NO. 112 55. Mark on the inside face reads: XIII.

CSSG 2156.3

FIGURE 5.10. CSSG 2156.3 - Percussion Lock with Base (photo by author).

Lock measurements:

L. of shaft: 3.5 in. (8.9 cm), Diameter of "hammer head": 1.3 in. (3.3 cm)

Lock with no perforation on "hammer head." Stamps on the shaft read: J A D US.

Base measurements:

L.: 4.0 in. (10.2 cm), W.: 0.9 in. (2.3 cm), Thickness: 0.6 in. (1.5 cm)

Base has stamp that reads: 111

CSSG 2160.9

FIGURE 5.11. CSSG 2160.9 - Tangent Sight Scale (photo by author).

L.: 11.3 in. (28.7 cm), W.: 0.6 in. (1.5 cm), W. of head: 0.9 in. (2.3 cm), L. of head: 0.7 in. (1.8 cm)

Typical graduated tangent scale. Graduations are: 340, 700, 900, 1100, 1300, 1500, and 1700.

CSSG 1892.3

FIGURE 5.12. CSSG 1892.3 – Assembled Tangent Sight (photo by author).

W. of “box”: 2.4 in (6.1 cm), diameter of screw hole: 0.2 in. (0.5 cm), W. of tangent scale: 0.6 in. (1.5 cm), L. of tangent scale: 10.5 in. (26.7 cm)

Typical tangent sight. Stamps on scale read: NO. 58, 8 IN. OF 55 CWT. Lowest graduation on scale is 260. Largest graduation on scale is 1860. Screw to secure tangent scale still there. Maker’s mark on the side of the tangent “box” reads: DANIEL EDWARDS, MAKER, NEW ORLEANS

FIGURE 5.13. CSSG 1892.3 – Maker's Mark (photo by author).

CSSG 1972.1

FIGURE 5.14. CSSG 1972.1 – Tangent Sight Cover (photo by author).

Max. width: 2.7 in. (6.9 cm), Max. length: 11 in. (27.9 cm)

Distinct shape. Narrow section is slightly bent. Stamp on top reads: NO. 79

CSSG 1856.10

FIGURE 5.15. CSSG 1856.10 - Assembled Tangent Sight (photo by author).

W. of "box": 2.3 in (5.8 cm), diameter of screw hole: 0.3 in. (0.8 cm), W. of tangent scale: 0.6 in. (1.5 cm), L. of tangent scale: 10.5 in. (26.7 cm)

Typical tangent sight. Tangent scale slightly bent. Largest graduation is 1860. Stamps on the head read: 8 IN. SHELL, 7 LBS. LEVEL. Stamps on "box" read: NO. 112 8 IN. 56 CWT.

CSSG 1874.5

FIGURE 5.16. CSSG 1874.5 - Assembled Tangent Sight (photo by author).

W. of “box”: 2.4 in (6.1 cm), W. of tangent scale: 0.6 in. (1.5 cm), L. of tangent scale: 10.9 in. (27.7 cm)

Has a slightly different appearance from the other tangent sights. The head of the scale is perforated with a small hole. Graduations are in degrees. Stamp on scale reads: NO. 3 OF 66- and then it cuts off. Stamp on “box” reads: NO 3 OF 6600.

CSSG 978

FIGURE 5.17. CSSG 978 - Tangent Sight "Box" (photo by author).

L.: 5.75 in. (14.6 cm), W.: 2.5 in. (6.4 cm), Diameter of screw hole: 0.3 in. (0.8 cm), W. of scale opening: 0.7 in. (1.8 cm)

Box has two fastener holes at the sides towards the front.

CSSG 2997.4

FIGURE 5.18. CSSG 2997.4 - Tangent Sight "Box" (photo by author).

L.: 5.8 in. (14.8 cm), W.: 2.5 in. (6.4 cm), Diameter of screw hole: 0.3 in. (0.8 cm), W. of scale opening: 0.5 in. (1.3 cm)

Shape resembles that of the sight boxes from previous tangent sights except for CSSG 978. No damage, marks, or stamps.

CSSG 1850.17

FIGURE 5.19. CSSG 1850.17 - Tangent Sight Cover (photo by author).

L.: 12.3 in. (31.2), W. of "strap" opening: 0.3 in. (0.8 cm), W. of "strap" area: 2.6 in. (6.6 cm)

Extremely distorted. Stamp on outer edge reads: 27 CWT

Matching Gun Sights with Guns

The gun sights recovered from excavations of CSS *Georgia* include as many as 4 dispart (front) sights and 8 tangent (breech) sights. The collection of dispart sights consists of four sights (CSSG 2994.8 [figure 5.1], 1855.6, and two with the number 1856.14 [figures 5.3 and 5.4]) and one dispart sight cover (CSSG 1881.28 [figure 5.5]). However, the marking on the cover reads: US WNY 112 (figure 5.5). This number is the same as the number on the base of one of the dispart sights: 112 (figure 5.2). Therefore, even though there are five pieces associated with dispart sights, only four sights have been found because one sight and cover go together. It was standard practice to place covers over dispart and tangent sights when they were not in use (Tucker 1989:40). The collection of tangent sights consists of two covers (CSSG 1972.1 [figure 5.14] and 1850.17 [figure 5.19]), two sight "boxes" (CSSG 978 [figure 5.17] and 2997.4 [figure 5.18]), one graduated tangent scale (CSSG 2160.9), and three nearly complete tangent sights consisting of both box and scale (CSSG 1856.10, 1892.3, and 1874.5). No markings on sight covers or boxes match the numbers on the scale or on the nearly complete tangent sights.

An idea of the composition of *Georgia*'s battery is given by other markings on these artifacts. Three of the nearly-complete tangent sights are marked with the type of gun on which they were mounted. The front of sight box CSSG 1874.5 (figure 5.16) reads: NO 3 of 6600. This can represent the manufacturing number or, more likely, the type of gun on which the sight was mounted. Two of the 32-pounders on board *Georgia* in 1863 were of 66 cwt (7,392 pounds or 3,353 kg) and this tangent sight might have belonged to one of them. The front of the sight box of sight CSSG 1856.10 (figure 5.15) reads: 8 IN. 56 CWT. The head of the graduated scale reads: 8 IN. SHELL…7 LBS. The bottom of the graduated scale of sight CSSG 1892.3 (figure 5.12) reads: 8 IN OF 55 CWT.

When these markings are combined with the documentary evidence, they strongly support the interesting assertion that even though the 8-inch shell guns on board *Georgia* were given to the Army in 1863, the sights corresponding to these guns were kept. When dispart and tangent sights were placed on a gun, they could only be used for that specific gun and did not admit to being transferred to other guns *without readjustment* (United States Navy [USN] 1852:63). Tangent sights were graduated with degrees of elevation and/or distance to the enemy ship in yards. The distance marked on the face of the tangent scale had to match the actual range of the gun for the system to work (Ward 1861:118). For example, if a gun was to be loaded with a powder charge of 7 pounds but the powder was deficient when compared to another powder charge of the same weight loaded to another gun of the same type, it was imperative for the gunner to go out of his way to increase the charge of the first gun. This allowed the ranges to equalize and the tangent sights to indicate the proper elevations for each charge and distance (USN 1852:2-3). The gunners on *Georgia* might have been planning to calibrate new guns to the tangent sights they already had.

Out of the entire collection of gun sights, three artifacts have number 112 engraved on their surface: the dispart sight cover (figure 5.5), dispart sight CSSG 1855.6 (figure 5.2), and tangent sight CSSG 1856.10 (figure 5.15). It is very likely they belong to the same system of sights mounted on the 8-inch shell gun because the US Navy Bureau of Ordnance and Hydrography had made it mandatory for guns to be equipped with a dispart sight at the second reinforce of the gun and a tangent sight at the breech since 1848. Although Confederate naval ordnance was differed from Union naval ordnance in some ways, their systems were still based on standard US Navy systems because many naval officers, including John Mercer Brooke, a distinguished artillerist and US Navy veteran of twenty years' service, defected to the Confederacy when the Civil War began and took their experience, knowledge, and skills with them (Tucker 2002:6; Brooke 2002: viii-ix, 13-14). Further, because it was preferable to conduct naval engagements at long distances during the first half of the 19th century (Ward 1861:122; Holley 1865:203-204) and the new system of tangent and dispart sights was deemed revolutionary and indispensable by anyone who placed any value on long-range accuracy (Beauchant 1828:15-17; Jeffers 1850:143), this system was used and developed by southern gunners as well as their northern rivals.

Dispart sight CSSG 1855.6 (figure 5.2) had a base-to-apex height of 2 in. (5.1 cm), which further supports the assertion that it was meant to work in tandem with tangent sight CSSG 1856.10 (figure 5.15). Dispart sights compensated for the difference in the diameter of the bore and the gun. The height of the dispart sight had to equal this difference to make the line of sight parallel with the axis of the bore. Additionally, due to the taper of the gun from the breech to the muzzle, its height depended on its position on the surface of the metal: it increased the closer it was to the muzzle and vice versa. Nineteenth-century dispart sights were located on the second reinforce on a plane perpendicular to the axis of the trunnions (Ward 1861:112). Further, the markings on tangent sight CSSG 1856.10 (figure 5.15) closely match the specifications of one of the 8-inch shell guns that formed part of *Georgia*'s battery. This gun fired an 8-inch shell, was No. 1 on the starboard side (faced upriver), was of 56 cwt, and was commonly loaded with a 7-pound (3.2 kg) powder charge (Dahlgren 1856:33, 61; USN 1866:xiii; Swanson & Holcombe 2007:82). According to the inventory of 1863, the year 1846 was inscribed on the face of the right trunnion and the cascabel had initials: F.P.F. 111. Therefore, this 8-inch shell gun, the specifications of which are noted on the 1863 inventory and on the tangent sight CSSG 1856.10, was likely one of the 186 8-inch chambered shell guns of 55 cwt produced by Alger, Fort Pitt, and West Point foundries from 1846 to 1852, allowing for a very slight variation in weight (Olmstead et al. 1997: 42; Swanson & Holcombe 2007:82). Otherwise, it follows the characteristics of guns of this class close enough to justify using their dimensions and measurements for comparison (figure 5.20).

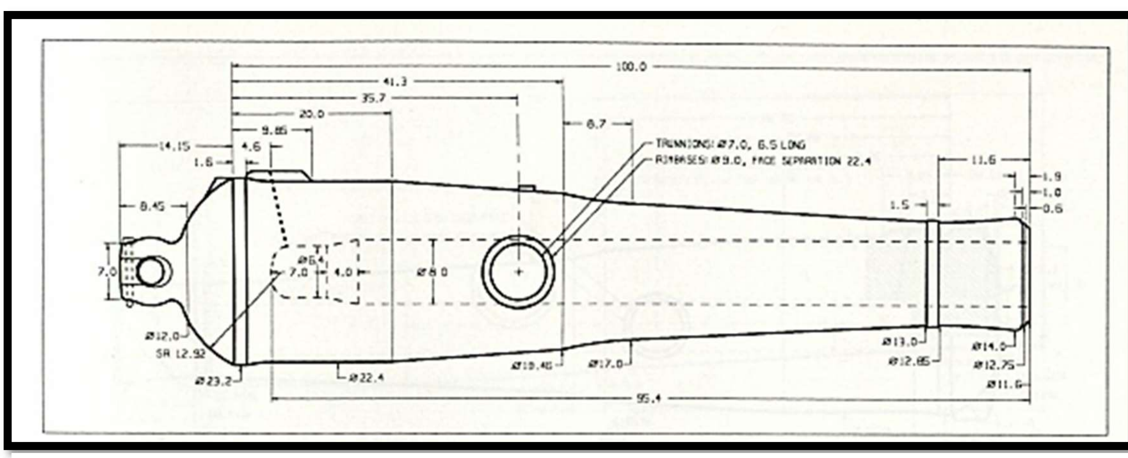

FIGURE 5.20. Eight-inch chambered shell gun (Olmstead et al. 1997:41).

Chambered shell guns of the 1846 8-inch class were typically 100 inches (254 cm) in length from the base ring to the face of the muzzle (Olmstead et al. 1997:41). As previously mentioned, the height of the dispart sight was equal to the difference between the diameter of the gun and the bore. To find this height, the diameter of the muzzle at the dispart sight was subtracted from the diameter of the breech and divided by two. The diameter of the gun at the breech of the 1846 8-inch class was 23.2 inches (58.9 cm) and 19.6 inches (49.8 cm) at the second reinforce, where the dispart sight was located (allowing for a slight increase in diameter at the muzzle since figure 5.10 provides a diameter slightly forward of the dispart sight mass on the surface of the gun). The difference of these diameters is 3.6 inches (9.1 cm). When this is divided by 2, the answer is 1.8 inches (4.6 cm). Dispart sight CSSG 1855.6 had a height of 2 inches (5.1 cm) when it was measured.

The form of graduation on the tangent scale may also indicate the guns to which they belonged. The highest graduation located at the bottom of the tangent scale of sights CSSG 1892.3 (figure 5.12) and CSSG 1856.10 (figure 5.15) reads: 1860. The highest for tangent scale CSSG 2160.9 (figure 5.11) reads: 1700. Method of graduating tangent scales varied through time and with different countries. The French, who were the first to adopt the system of using a tangent sight and a dispart sight together (Jeffers 1850:138, 146), marked the tangent scale in cables' lengths. However, they marked the same ranges on tangent scales regardless of the type of gun they were mounted on. There was no variation according to the true caliber and uniqueness of each gun. Therefore, the system was relatively ineffective and drew many objections. The English graduated their tangent sights in degrees. This required a readily-available table of ranges to see the distances that corresponded to each degree of elevation marked on the tangent scale. Jeffers thought this system was very inconvenient, as the consultation of a book or range board during the heat of battle was hardly practical (Jeffers 1850:146). Graduating the tangent scales by ranges in yards corresponding to degrees of elevation for different calibers and weights of guns was more common during the 1860s (Ward 1861:118). The tangent sights recovered from *Georgia* were graduated in yards to represent the effective range of the gun they were mounted on. Only one tangent scale out of the four recovered is graduated in degrees (CSSG 1874.5).

The tangent sights with 1860 marked as the highest range on their scales belonged to the 8-inch shell guns of 55 cwt on board *Georgia*. The highest marked range on a tangent scale was judged to be the greatest effective range at which a certain gun could be used and still maintain penetrative power, even if the gun was capable of longer ranges (Jeffers 1850:145; Ward 1861:38-39). The 8-inch shell guns of the type on board *Georgia* ranged approximately 1,866 yards at 6° of elevation (USN 1852:133; Dahlgren 1856:33; USN 1860:lxix; USN 1866:xiii). The highest range marked on tangent scale CSSG 2160.9 (figure 5.11) is 1700. When tables of effective ranges at different degrees of elevation for the guns on board *Georgia* are examined, only the 9-inch shell guns of the Dahlgren pattern have a range of exactly 1,700 yards as the maximum effective range marked on the tangent sights (USN 1860:lxx; USN 1866:xiv). This tangent scale is the only component of tangent sight CSSG 2160.9 and its graduations are the only clue we have that it belonged to a 9-inch Dahlgren gun on board *Georgia*.

Method of Graduating Tangent Scales

In geometry, any section of the circumference of a circle is known as an arch. When a line touches an arch of a circle without cutting through it, it is called a tangent line or *tangential*. The tangential is perpendicular to the radius of the circle and its length is limited by a line drawn from the center of the circle through its other end. This line is known as the *secant* (Simmons 1812:22). Tangent sights or tangent scales derived their names from this geometric principle. They touched the circular, curved surface of the chamber of the gun and were perpendicular to the radius of the imaginary circle formed by this arch.

If the length of a gun represented the radius of a great circle, the face of the muzzle would be at the center, a section of the circumference (arch) would be represented by the rounded outer surface of the breech chamber, and the tangent sight scale would work as the tangential of the circle. If this radius was raised to 1° and a triangle was made by using the original, horizontal position of the radius as the base and the new position as the second side, the third side of this triangle would be formed by a straight line connecting the first two at the breech of the gun. This line would be part of the tangential and its length would be equivalent to the length of one division on the tangent sight scale (Beauchant 1828:13).

The 8-inch shell guns of 55 cwt on board *Georgia* had an overall length of 100 inches (Olmstead et al. 1997:41-42). First, this length was converted to 8.3 feet (2.5 m). Once the length in feet was obtained, it was multiplied by 0.22, as this is the tangent of 1° to 1 foot. The product was 1.826, or the length, in inches, between each division on the tangent sight scale (Beauchant 1828:13; Ward 1861:117-118). However, the lengths between the divisions of the tangent scales of sights CSSG 1856.10 (figure 5.15) and CSSG 1892.3 (figure 5.12) are much smaller. This is because the radius of the circle one must work with is not the length of the gun, but the length of the distance between the dispart sight and the tangent sight (Beauchant 1828:13-14). When the tangent sight was raised, the line of sight began at the bottom of the notch at the head, passed through the apex of the dispart sight at the second reinforce, and ended with the target to be hit (Beauchant 1828:16; Jeffers 1850:136-137; USN 1860:82; Ward 1861:116-117). Therefore, rather than the total length of the gun, the distance between the dispart sight and the tangent sight of the 8-inch shell guns must be used as the radius of the imaginary circle. This length was listed as 35.7 inches (90.7 cm), or approximately 3 feet (0.9 m) (Olmstead et al. 1997:41). When this length was multiplied by 0.22, the product was 0.66. The lengths between each division on the scales of tangent sights CSSG 1856.10 and CSSG 1892.3 must be 0.66 inches (1.7 cm) for them to function correctly. Indeed, when the lengths between the divisions on the tangent scales of these sights were measured, they proved to be about $\frac{2}{3}$ of an inch, or 0.66 inches.

Maker's Mark: The Daniel Edwards Foundry

An interesting feature of tangent sight CSSG 1892.3 (figure 5.13) is a maker's mark engraved on the side of the sight box through which the tangent scale passes through. The maker's mark reads: DANIEL EDWARDS MAKER NEW ORLEANS. This is interesting because the city of New Orleans was not a major manufacturing center prior to the Civil War and did not begin to experience any degree of prosperity in this industrial venture until after the war. (Walker 1900:511). Instead, the economy of New Orleans revolved around commerce and trade, which kept most of the population employed. In 1835, the port of New Orleans achieved about $54 million in commerce and by 1840, some 400 steamboats plied the Mississippi River (Walker 1900:512).

The manufacturing enterprises that did exist in antebellum New Orleans devoted themselves almost exclusively to repair work or turned out goods that could not be easily found anywhere else. Of these, the foundry business was the leading industry of the city during the mid-19th century and had been the oldest and most successful for a very long time (Walker 1900:523). These early foundries were originally designed for the repair of such machinery that was broken, could not be used, or was too heavy to be shipped back to its original place of manufacture (Walker 1900:513). One of these early foundries was known as the Daniel Edwards Foundry – the only one of that name in New Orleans (Warsaw Collection of Business Americana [WCBA], Foundries ca. 1827-1926: Manufacturers and Distributors, ca. 1827-1924:box 1, folder 29).

The Daniel Edwards foundry was established in 1846 by Daniel Edwards, an Englishman brought up in the foundry business of Liverpool, England (Morrison 1885:95; Walker 1900:525; Huber et al. 2004:143). Mr. Edwards was the sole proprietor for a few years until he was joined by his son, James D. Edwards, and the firm changed its name to Daniel & James D. Edwards Foundry. It became the James D. Edwards Foundry upon the death of the founder in 1859 (Morrison 1885:95; Walker 1900:525). In 1884, James D. Edwards made a partnership with Mr. Leon F. Haubtman, who had been associated with the business as superintendent of works for 20 years, and the name of the business was changed yet again to Edwards & Haubtman (Morrison 1885:95). Haubtman retired in 1893 and the business was turned over to Daniel Edwards, grandson of the founder, giving the business its original name yet again (Walker 1900:526).

By 1860, the foundry boasted of the work produced by its facilities and claimed it was "superior to any other house in the South or West". Its services included work in chimneys, juice boxes, fire beds, ash pans, heaters, filterers, sheet-iron pipe, and copper, tin, and pewter worms for distillers. It also provided "every description of brass work of my [the founder's] own manufacture" (*The Louisiana Courier* 1858:16). Under the Edwards and Haubtman partnership of 1884, the business was regarded as expert in the construction and repair of steamboat and sugar-making machinery, the former providing plenty of work due to the tendency of ships' boilers to fall out of order (Morrison 1885:95; Walker 1900:514). Andrew Morrison (1885:96) claimed the Daniel & Haubtman Foundry occupied the largest premises of anybody doing similar work in the South and hired an average of 60 workmen and as many as 200 during the busy season. Any metalwork of copper, sheet-iron, or brass stamped with the firm's name (such as the gun sights recovered from CSS *Georgia*) was preferable to any other (Morrison 1885:96). By the end of the 19th century, the foundry employed from 200 to 250 workers and was engaged in business with Mexico, Cuba, and Central America. They turned out an average yearly output of $750,000 and specialized in the production of sugar machinery (Walker 1900:526; Huber et al. 2004:143).

The dispart sight and cover marked with the number 112 may have been manufactured at the same foundry as tangent sight CSSG 1892.3 because they were both part of the same system of sights mounted on the same 8-inch shell gun. Additionally, tangent sight CSSG 1892.3 is identical in almost every feature to tangent sight CSSG 1856.10 (figure 5.15) and they both belonged to the same class of gun. Therefore, they might also share the same place of manufacture. There was only one foundry in New Orleans named for Daniel Edwards during the majority of the 19th century. It is reasonable to assume that a maker's mark with this city listed as its business location on a brass artifact, a metal in which the business specialized, indicates the source of at least four components of the gun furniture of *Georgia*'s battery. Further, because the 8-inch shell guns were likely produced by the Fort Pitt and West Point Foundries in Pittsburgh, Pennsylvania and West Point, New York according to marks on their cascabels, their gun sights might have been replacement pieces produced after these guns were acquired by the Confederacy.

The Function of Naval Gun Sights

A naval gun had to be raised to an appropriate degree of elevation to achieve the necessary range to strike a distant object at sea. The degree of elevation was a measure of the angle formed by the lower surface of the gun and the horizontal plane on which the trucks of the carriage stood. The angle of projection or departure was formed by the bore of the gun and the horizontal plane. Therefore, it was slightly greater to the angle of elevation because the bore was inside the outer surface of the gun. Jeffers (1850:22) cautioned against confusing both angles when preparing tables of ranges. The projectile departed from the axis of the gun but the quoin, used to adjust elevation, was marked in degrees of elevation *of the lower outer surface of the piece*, with which it made contact.

In fact, the degrees marked on the quoins were the same as those marked on the tangent scale if the latter was marked in degrees (USN 1852:118). The mean difference between both angles ranged between a minimum of 10’ and an extreme of 34’ (Jeffers 1850:22).

Extensive experimentation determined effective ranges of shot and shell under varying conditions. The degree of elevation, powder charge, weight of the gun and projectile, height of the carriage above the water, and distances in yards were marked on tables of ranges for guns of each caliber (USN 1852:133). These ranges were marked on the tangent sight and the difference in diameter of the bore and outer surface of each gun was calculated and used to make a dispart sight of proper height. Before both sights could be used effectively, the exact placement of the dispart sight on the surface of the gun had to be determined.

Two adjustments were needed to place the dispart sight exactly in the correct spot: it had to be in a vertical plane perpendicular to the axis of the trunnions and its apex had to create a line of sight parallel to the axis of the bore (Ward 1861:112). The vertical plane had to cut the muzzle and base ring into equal parts. Once this plane was established, the points on the surface of the gun where the plane cut through had to be marked with permanent notches. Figure 5.21 below illustrates this process. The gun was placed on skids *e* and *f* on the plane *gh*. A rectangular, wooden frame *abcd* was placed over the gun with one leg resting on each arm of the trunnions. A spirit level was placed on top of the wooden frame (*bc*) and the skids were adjusted until *bc* was level. If *bc* was level, then *ik*, the axis of the trunnions, was also level (Ward 1861:113)

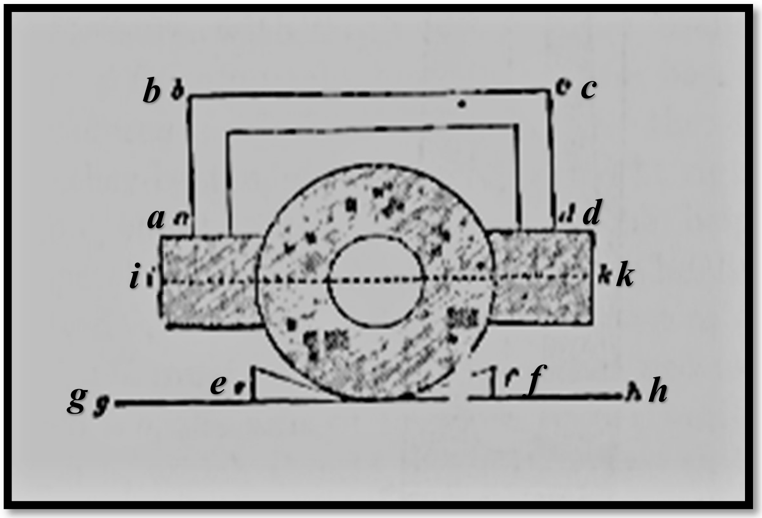

FIGURE 5.21. Eighteenth-century diagram showing how to level the trunnions (Ward 1861:113; letters repeated for clarity by author).

Figure 5.22 represents a section of the same gun, with level trunnions, at the base ring. Points *abc* represent the outer surface of the gun and *def* represents a square with an attached plumb bob.

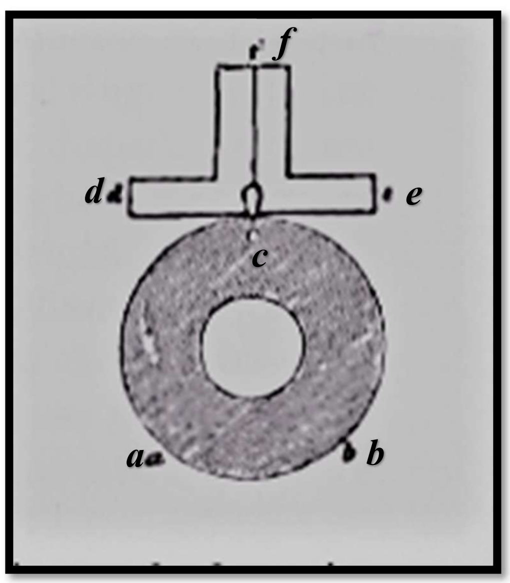

FIGURE 5.22. Locating the vertical plane (Ward 1861:113; letters repeated for clarity by author).

By adjusting the square so that the plumb bob touches the base ring at *c*, a vertical plane at right angles with the base ring is created. The notch marking the location of this plane is made at the meeting of the plumb bob and the point *c* at the base ring. The same square is then placed on the muzzle and the placement of the notch is determined in the same manner. These two notches are joined by a line representing the vertical plane along which the dispart sight is placed (Ward 1861:113-115).

Once the placement of the dispart sight was determined it was fitted to the gun and ready to be used in tandem with the tangent sight. The basic geometric principle behind this system of training naval artillery was that of equal angles when a straight line cut through two parallel lines. This process is illustrated by figure 5.23. Diagonal line *AB* represents the axis of the bore of a gun. When this line cuts through planes *CD* and *EF*, it creates angles *a* and *b* at the corresponding points of intersection. Point *C* represents the top of the tangent sight. The point of intersection of line *AB* and plane *CD* represents the apex of the dispart sight. Plane *CD* represents the line of sight created with the tangent and dispart sights. Angle *b* represents the degree of elevation of the gun. Angle *a* represents the artificial angle of sight formed by the line of sight with the surface of the gun (Jeffers 1850:23). A variety of angles is formed when two parallel lines are intersected by a diagonal line. The universal rule concerning these angles is: adjacent outer angles always combine to form 180° and opposite inner angles are always equal. Therefore, because angle *b* and angle *a* are both opposite inner angles, the angle of elevation of a gun must be equal to the artificial angle of sight created by the gun sights (Simmons 1812:25).

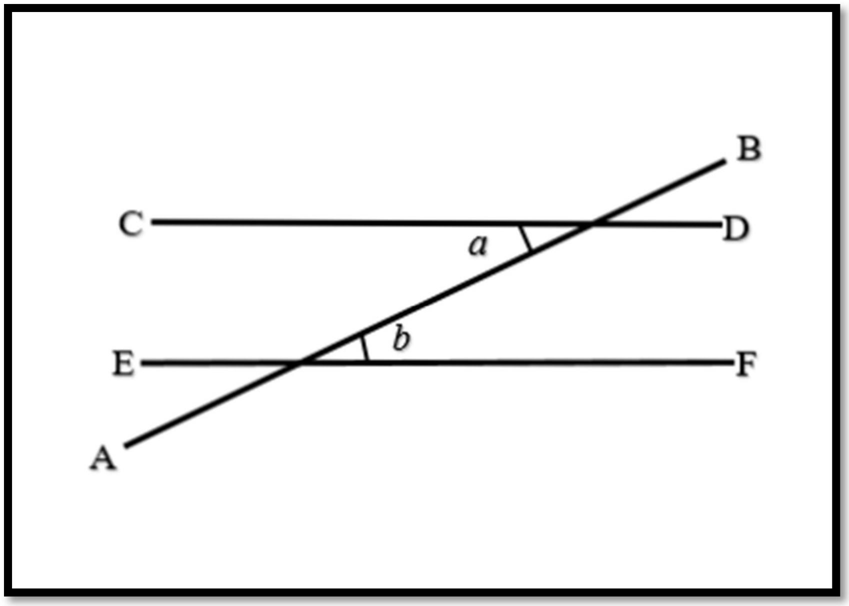

FIGURE 5.23. Diagram showing angular relationships when firing a gun (diagram created by author).

When the "Captain of Division" of a battery of naval guns (USN 1860:82) calculated the approximate distance to an enemy ship, he instructed the gunners to raise their tangent scales to that same distance marked on their surface. After this was done, the quoin, marked in degrees of elevation, was adjusted so that the gun was raised to the proper degree of elevation recorded on the table of ranges. Once the quoin was raised and the tangent sight was adjusted, a line of sight had to connect the notch at the head of the tangent sight with the apex of the dispart sight and the enemy ship at the waterline (USN 1860:46). This process was easy to execute in calm weather. During adverse weather and heavy swells, the gun had to be raised to the proper elevation and the correct angle of sight had to be created by the sights first. Once this was done, the gunner had to wait for the opportune moment to fire – preferably when the ship was top of a wave (USN 1860:82, 86).

Instantaneous Discharge: The Percussion Locks

The opportune moment to fire a naval gun on a rolling and pitching ship was notoriously ephemeral. Even if everything was in place, the entire process would be ruined if a gunner was not able to discharge the gun *precisely* when all three major points were connected by his line of sight. The constant movement of the sea and the target, the deviations of the projectile caused by the wind, the weight of the projectile, and the balloting of the shot against the inside of the bore, compelled many to consider naval gunnery an art rather than a skill. The difficulty of mastering this art was ameliorated when the ability to provide instant communication of fire to the powder charge was achieved (Jeffers 1850:138-139). Gun-firing mechanisms underwent many changes and modifications prior to the 19th century. Initially, guns were fired using a slow match wound around a two and a half foot (0.7 m) wooden staff known as a linstock. Port fire or quick match was introduced before the end of the 17th century. This was a short length of flammable material that freed the crew from the task of laying a powder train to the vent. By the beginning of the 19th century, the quill tube was the primary mode of priming used. Flintlocks on naval guns provided a very fast rate of fire and were adopted by the Royal Navy in 1790 after they proved their worth in 1782 during the Battle of the Saints against the French. They were adopted by the French Navy in 1800 (Jeffers 1850: 139; Dahlgren 1853:9-13; Tucker 1989:29-33).

The effectiveness of fulminate of mercury as a primer for gunpowder was first demonstrated with rifles and muskets on land before it was used as a primer for naval guns. This material rendered loose powder obsolete because it did not require fire for ignition. All it needed was friction. It ignited when struck with a sharp blow and since it did not require fire, it was reliable in all weather conditions. Fulminate of mercury was initially in the form of a wafer laid over the touchhole and later transitioned into a sheet metal cup or percussion cap placed over the iron nipple fitted to a percussion lock, such as those recovered from *Georgia*, which amount to a total of five: CSSG 2997.3 (figure 5.6), CSSG 1335 (figure 5.7), CSSG 2012.1 (figure 5.8), CSSG 2994.6 (figure 5.9), and CSSG 2156.3 (figure 5.10). Percussion caps became the regulation primer for the US Navy for some time (Simpson 1862:292). The initial conundrum concerned the damage sustained by the lock from the blast that emanated from the vent as the propellant ignited in the gun's breech. Percussion locks underwent two major changes to overcome this problem. The first was a hammer with an open slot in the shank that allowed it to be quickly withdrawn from the touchhole after setting off the primer, as CSSG 2997.3 (figure 5.6). The second was simply a hammer with a perforated head through which the hot gases from the vent passed without harming the lock, as CSSG 1335 (figure 5.7) and CSSG 2994.6 (figure 5.9). (Dahlgren 1853: 51-53; Tucker 1989:33-34).

The first design was patented by Enoch Hidden, who was first listed in the New York City directory as a "gunsmith" in 1813. His occupation was changed to "Cannon Lock Maker" by 1842. He continued to work under this title until 1851 when he advertised "Brass & Bell Foundry" (Gaede 1998:111). Hidden was most concerned with creating a percussion lock that would be moved out of the way of the vent after igniting the primer. He obtained his first patent for a gun lock on 14 January 1831 and it was described as having a spring-driven hammer that rose vertically from the vent by a counter spring to avoid the blast. Three years later, on 20 August 1834, he received his second patent and his first substantial order by the Ordnance Department (Gaede 1998:113-114).

Hidden's greatest achievement did not come until 29 April 1842 when he patented the design for a sliding lock. This lock had an elongated slot in its shank through which traveled an axial bolt. One quick pull of the lanyard caused the head to strike the vent and, as the lanyard was still being pulled, instantly slide out of the way of the explosion by the movement of the axial bolt along the shank (Figure 5.24) (Simpson 1862:295). This lock was adopted by the British and modified by Colonel William Dundas in 2 October 1846. Enoch Hidden sold all the rights of his patent to the Navy on 3 April 1848 for $1,200 (Gaede 1998:117).

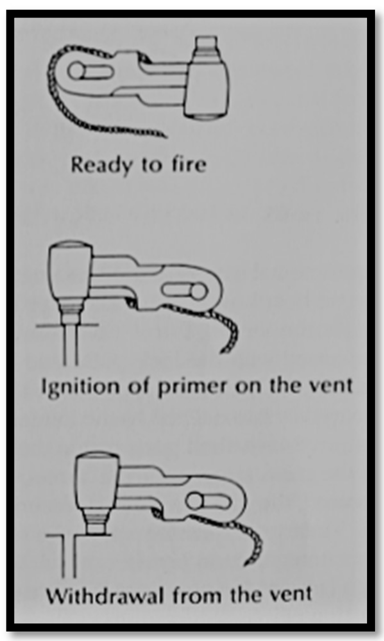

FIGURE 5.24. Motion of Hidden's Patent Sliding Lock (Tucker 1989:36).

Hidden had attempted to use a gun lock with a perforated head since 1831. However, this lock also had a counter-spring attached close to the hammerhead to instantly rebound away from the vent and the perforation was added merely as an auxiliary means to escape the erosion caused by the blast (Dahlgren 1853:29-30). Dahlgren proposed making a lock that remained over the vent after ignition of the primer and avoided the blast by the perforation alone. The first trials with this lock were held on United States frigate *Cumberland* and the lock was fitted on an 8-inch shell gun of the main deck battery. However, "so imperfect were the mechanical means at disposal" that these experiments produced no results. A second attempt was made in 1847 and the results were so satisfactory that the lock was subsequently used on pieces of the new experimental battery. This included all classes of naval ordnance and the then-experimental 9-inch and 11-inch shell guns. Dahlgren's lock also became the established percussion lock for the boat-howitzers of the US Navy (Dahlgren 1853:32).

The Advantages of Naval Gun Sights

The system of using a tangent and dispart sight adopted during the mid-19th century did not guarantee a hit. Yet, by creating tables of ranges and using the artificial line of sight and proper degree of elevation to strike a distant target, while supplementing the process with instantaneous discharge by using primers composed of fulminate of mercury and efficient percussion locks, the chances of success were infinitely greater than they would be if the gunner depended entirely upon his own judgement without the aid of any instruments (Ward 1861:117).

One of the greatest advantages of the tangent sight was the ease with which a battery was placed under the control of a commander. His presumed superior judgement in estimating the distance to another ship at sea, coupled with his unobstructed vision from an elevated position on the quarterdeck, allowed him to communicate the proper adjustment to the tangent sights and elevation of the gun to those on the gun deck. The men working the guns below had obstructed views of the target due to smoke and the general confusion during the heat of battle but were more likely to strike the enemy, or at least come very close to doing so, because the commander did the work of many pairs of eyes. Gunners were solely responsible for setting the gun and tangent scales properly. Once the guns of the battery were fired, the commander observed the results and communicated any necessary adjustments to those working the gun decks (Ward 1861:119).

Before naval batteries were under the control of one skillful leader for want of good sighting and ignition implements, inaccuracy in naval gunnery was exhibited in conflicts at sea all over the world. When the frigates USS *United States* and HMS *Macedonian* met in battle during the War of 1812, they fired a total of 50 broadsides, or 2,500 shot. Yet, only 100 hits were recorded by both vessels combined: 95 on *Macedonian* and 5 on *United States* (Ward 1861:120; Simpson 1862:485-487; Tucker 1989:41). This inefficiency in accuracy happened despite the close range at which the ships were engaged. Another example of bad gunnery happened during the Greek War of Independence at the Battle of Navarino of 20 October 1827. The battle was fought at anchor at exceedingly close range and yet the 74-gun ship *Albion* did not sink a single ship despite firing a total of 52 tons of shot in the form of 98 broadsides or 4,000 balls (Ward 1861:120).

Even though “gallant men” preferred to engage an enemy at close range, the results were not always satisfactory. Yardarm-to-yardarm engagements did not prevent the unnecessary expense of large quantities of ammunition and, before the advent of steam, opposing winds could prevent a vessel from closing in with an enemy in the first place. Therefore, the constant application of scientific principles to the arts of war was of utmost importance, as it compensated for any deficiencies in resources, marine or otherwise, of any nation (Ward 1861:122-124). Tangent sights reduced the amount of guess work a gunner had to resort to when gauging distance and training his gun. An artillerist trained in the use of tangent sights was aware of the proper force required to move a projectile with sufficient initial velocity to reach a target. This information was translated to the tangent sights in the form of effective ranges marked on the scale. The gunner was assisted by every aid at his disposal and the only factors with a negative influence on accuracy were those which the gunner had no control over (i.e. deviations caused by the movement of a ship and by balloting, atmospheric resistance, and the force of gravity). Less was left to chance and the practical gunner, with vague and general ideas upon the subject of the principles of gunnery, was only successful by accident (Jeffers 1850:144-145).

CHAPTER VI

CONCLUSION

Summary

The CSS *Georgia* was one of the largest ironclad rams built by the Confederacy during the American Civil War. Construction began in 1862 and the ironclad served as a floating battery until 1864, when it was intentionally sunk by the Confederates in response to US Army General William Tecumseh Sherman's approach to Savannah by land. Although it did not get an opportunity to test its mettle in battle, *Georgia* does provide historians and nautical archaeologists with a wealth of clues and information on American naval history. Excavations and investigations at Savannah have provided the Conservation Research Laboratory at Texas A&M University with a vast collection of artifacts for conservation and analysis.

This collection of artifacts includes brass instruments known as gun sights and percussion locks. These were used in tandem to provide a greater degree of accuracy and instant discharge of the gun during naval engagements. Instruments of this type are relatively rare in archaeological settings because brass instruments like these were typically melted down and repurposed after the Civil War. The group of brass naval gun sights and percussion locks recovered from *Georgia* represents one of the largest ever recovered from a Civil War site. Their study facilitates a better understanding of the principles of gunnery during the mid- to late-19th century.

Before gunnery at sea was firmly established, it underwent many transitional periods. Changes in the number of guns on board a ship, lengths of guns, amount and what type of powder used, and the physical characteristics of projectiles constantly shaped the nature of naval batteries and engagements. Accuracy and methods of ascertaining distance at sea underwent constant improvement in the 19th century. Instruments to assist gunners in their efforts at superior accuracy steadily developed before coming to an apex in sophistication during the Civil War.

An understanding of the scientific principles of different types of projectiles in flight was reflected in the design of 19th-century naval gun sights. To know the approximate point of departure and arrival of a projectile and mark the tangent scales accordingly, artillerists had to be aware of all the factors acting for and against the projectile's trajectory. These included atmospheric resistance, lateral and vertical deviation, the force of gravity, and the eccentricity of a shot or shell.

The design of the tangent and dispart sights recovered from *Georgia* were based on different geometric principles unique to each gun. These principles were reflected in the dimensions of the sights, such as the height and positioning of the dispart sight and the length between each division on the tangent scale. Examination of these dimensions and of the markings present on the gun sights help determine the guns they were mounted on, as each sight was specifically made for each gun.

Future Research

The final field recovery of the remains of *Georgia* will take place during the summer of 2017. This may result in the discovery of the rest of the gun sight assemblage. *Georgia* had as many as 11 guns on board when the first inventory was created in 1863. Even though changes in ordnance took place over the next several months, two of the gun sights recovered in the 2015 investigation belong to 8-inch shell guns, and the only time this class of gun was on board *Georgia* was during the time the original inventory was completed. The discovery of more gun sights can help us learn more about the components of *Georgia*'s battery, which was designed to defend the city of Savannah against the overwhelmingly superior force of the Union Navy.

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