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Alternative Individual Cartridge Case Identification Techniques

Curtis H. Sedlacek
University of Nebraska-Lincoln, curtis.sedlacek@gmail.com

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Alternative Individual Cartridge Case Identification Techniques

By

Curtis Henry Sedlacek

A THESIS

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ALTERNATIVE INDIVIDUAL CARTRIDGE CASE IDENTIFICATION TECHNIQUES

Curtis Henry Sedlacek, M.A.

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Adviser: Douglas Scott

Individual cartridge case identification is an essential component of historic battlefield archeology. With individual cartridge case identification archeologists are able to track the movement of the combatants as they move across the battlefield, giving a highly detailed view of the past. While useful, current methods of individual cartridge case identification require expensive equipment and extensive training and time to conduct. In this thesis two alternative methods of cartridge case identification are evaluated in order to determine if recent developments in the areas of 3D scanning and statistical analysis can be utilized to develop new methods of individual cartridge case method. The first method tested is the evaluation of three 3D scanners, which have the potential to replace the expensive microscopes currently required for cartridge case identification. The second method tested uses a digital caliper to obtain four different measurements from a cartridge case with the hypothesis that fired cartridge cases have different measurements than unfired cartridge cases. These differences can then be used for individual cartridge case identification. While both these methods show definite
potential, they both require further experimentation and study before archeologists can effectively utilize them.
Dedication

This thesis is dedicated to my wife, Jamie Sedlacek, who has listened to me drone on about cartridge cases and 3D scanners with extraordinary patience for the better part of three years. Without her the work I do would not be nearly as meaningful.
Author’s Acknowledgments

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# Table of Contents

Chapter 1  
**Introduction** page 1

Chapter 2  
**3D Scanner Comparison** page 16

Chapter 3  
**Rush Creek Cartridge Case Analysis** page 33

Chapter 4  
**.22 Caliber Revolver Cartridge Case Analysis** page 49

Chapter 5  
**Conclusion** page 62

Bibliography  
page 70
List of Multimedia Objects

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>13</td>
</tr>
<tr>
<td>1.2</td>
<td>13</td>
</tr>
<tr>
<td>1.3</td>
<td>14</td>
</tr>
<tr>
<td>1.4</td>
<td>15</td>
</tr>
<tr>
<td>2.1</td>
<td>19</td>
</tr>
<tr>
<td>2.2</td>
<td>20</td>
</tr>
<tr>
<td>2.3</td>
<td>22</td>
</tr>
<tr>
<td>2.4</td>
<td>22</td>
</tr>
<tr>
<td>2.5</td>
<td>23</td>
</tr>
<tr>
<td>2.6</td>
<td>24</td>
</tr>
<tr>
<td>2.7</td>
<td>24</td>
</tr>
<tr>
<td>2.8</td>
<td>25</td>
</tr>
<tr>
<td>2.9</td>
<td>27</td>
</tr>
<tr>
<td>2.10</td>
<td>27</td>
</tr>
<tr>
<td>2.11</td>
<td>29</td>
</tr>
<tr>
<td>2.12</td>
<td>30</td>
</tr>
<tr>
<td>3.1</td>
<td>31</td>
</tr>
<tr>
<td>3.1</td>
<td>38</td>
</tr>
<tr>
<td>3.2</td>
<td>41</td>
</tr>
<tr>
<td>3.3</td>
<td>42</td>
</tr>
<tr>
<td>3.4</td>
<td>43</td>
</tr>
</tbody>
</table>
Figure 3.5 page 43
Table 3.1 page 44-45
Figure 4.1 page 50
Figure 4.2 page 51
Figure 4.3 page 52
Figure 4.4 page 53
Figure 4.5 page 54
Figure 4.6 page 55
Figure 4.7 page 56
Figure 4.8 page 57
Figure 4.9 page 58
Table 4.1 page 59
Table 4.2 page 60
Chapter 1 Introduction

Archaeology has often borrowed technology and techniques from other scientific fields in order to answer interesting questions about the past. Frequent use of Global Positioning Systems (GPS) and ArcGIS software from the field of geography (Pratt 2009) are classic examples of this sort of borrowing.

The field of archeology has been quick to adapt in changes when it comes to recording the location of sites and artifacts, but lags behind when it comes to utilizing technology to help with the identification and preservation of artifacts. The development of digital cameras and two dimensional scanners and their subsequent reduction in price have made them an essential part of any archeologists’ tool kit, but these are only a few of the devices that archeologists could be utilizing.

The basic methods of artifact analysis and identification have not changed since the beginning of archeology. An archeologist goes to a collection or finds the physical artifact and conducts an analysis. While the attributes and other information about the artifact are recorded in a digital records system such as, ReDiscovery, the artifact itself is returned to an archival box, placed on a shelf, and most likely never seen again.

The cost of storing these artifacts for perpetuity is very high, and to have them not accessible to researchers, who could conduct further analysis on them, makes the cost seem even higher. Without allowing access to the artifacts archives and museums are paying to store things that have no use.

In order to justify paying ever higher storage costs for artifacts and to further the field of archeology, museums and archives must make them accessible to the public and
to researchers. Understandably, most institutions will be leery of letting researchers take collections out of their facilities, and even more uncomfortable with the public doing the same. The risk of damage to the artifacts makes the unwillingness understandable.

Alternatively researchers often want to be able to conduct their analysis on their schedule and without the travel costs of traveling to a museum that has the collection they are interested in which may be a long distance away. Given that most states are reducing the budgets of state institutions and the increase in fuel costs, collections and artifacts across the country or even out of state could soon become out of reach to archeologists.

A potential answer to this quandary would be the artifacts accessible through the internet. The majority of researchers have internet access and the creation of webpages is no longer the domain of just computer engineers. The method of distribution is the easy part when it comes to making the artifacts accessible. The method of how the artifacts are to be digitized and the form they will be in is where things become much more difficult.

The idea of making the formerly inaccessible available on the internet is not a new one. There are many efforts across the country to digitize and publish historical photographs, documents, maps etc. including at the University of Nebraska-Lincoln and its digitizing of documents related to the Omaha language. While these efforts are important to archeologists, they are limited to two-dimensional (2D) objects such as photographs and maps, while much of what archeologists deal with is 3D objects, such as cartridge cases, projectile points, ceramics, etc.
The answer to this problem is three dimensional scanning. Three-dimensional (3D) scanners, with their ability to capture all the surfaces of an artifact in detail, would be an ideal tool for the digital preservation and distribution of artifact information. While the scans could never replace the actual artifact they would serve many purposes when it comes to analysis.

What has limited the use of 3D scanners in archeology is their cost. Previously 3D scanners could cost hundreds of thousands of dollars which is out of reach for most institutions and the scanners could be difficult to use requiring computer and design specialists to use effectively. Recently, however, the cost of 3D scanners has been reduced to a point where they can now be purchased from anywhere from 500 dollars to 3000 dollars. In addition, they have become easier to use, allowing amateur scanners to get detailed scans.

While 3D scanners have been less expensive they are not all created equal. A range of scanners, with varying costs and methods of recording information must be tested in order to determine which scanner(s) would be the most effective in recording an archeological artifact.

To test 3D scanners of varying cost, scans should be taken of the same artifacts and then compared for level of detail and accuracy. In addition, the ease of use should be recorded as this can be as important as level of detail. For this evaluation cartridge cases will utilized. Another benefit of using cartridge cases for testing the effectiveness of 3D scanners is it can be determined whether or not the scans can be used for forensic cartridge case identification.
Cartridge cases were chosen as the artifacts to be used in the testing of the 3D scanners for the following reasons. Cartridge cases are an important part of battlefield archeology and any 3D scanner used by archeologists must be capable of scanning them. Cartridge cases can be classified in two ways, by class characteristics, and by individual characteristics. Class characteristics are characteristics that allow archeologists to identify the type of cartridge, .44 caliber, .45 caliber etc. and sometimes the manufacturers. Individual characteristics, like extraction marks and firing pin marks, are used to identify which in weapon a cartridge case was fired. These marks are very small and require magnification to be seen.

By testing the 3D scanners using an artifact that has two levels of identification, a more detailed evaluation of the 3D scanners. Some of the 3D scanners may only produce scans that are detailed enough for class identification, while others may produce scans that have the level of detail required to make individual identifications. By evaluating the scanners this way archeologists will be able to understand the level of detail the scanners are capable of in real world terms, rather than just technical terms of nanometers and megapixels.

**Cartridge Case Identification and Archeology**

In order to extract the most information possible from cartridge cases, archaeology has borrowed from the field of forensic science. Utilizing ejection, extractor, and firing pin marks forensic scientists are able to identify which cartridge case is associated with which weapon (Heard 1997). Archaeologists have used this technique in an archaeological context with informative results but it requires expensive equipment.
and highly trained personnel to be effectively utilized (Scott, et al. 1989; Scott and Fox 1987, Laumbach 2009).

For forensic scientists, cartridge cases analysis offers a way to solve murders. The marks made on a cartridge case when it is fired from a weapon are as unique as fingerprints and just as useful when it comes to helping to build a case against a murder suspect. For historical archaeologists cartridge cases offer a unique opportunity to examine exactly what happened during a battle. By identifying which cartridge case came from which weapons, historical archaeologists can track the movements of a combat force as it engages in attacks and counter attacks. More importantly, cartridge case identification can allow individual weapons tracking across the battlefield, allowing historical archaeologists a rare opportunity to see the movements and actions of an individual.

Forensic firearm identification has proven itself an important and reliable tool for archaeologists working on battlefields, although, the use of forensic firearm identification techniques remains expensive and time consuming. These techniques require expensive equipment such as comparison microscopes and a highly trained person must use the equipment if the analysis is going to be accurate. In addition, this kind of analysis is conducted in a laboratory and takes a significant amount of time to complete.

This thesis investigates two possible alternatives to the current method of cartridge case analysis. One method, cartridge case measurement analysis, could be used as a field expedient method that allows archaeologists to make basic identification while in the field using a digital caliper and can be accomplished with relatively little training.
The second method, 3D (three-dimensional) scan analysis, could allow the archaeologist to conduct analysis without having the physical cartridge present. This method still relies on the comparison of extractor marks and other physical characteristics but the advantage comes in the form of the archaeologists being able to send the 3D images of cartridge cases to other subject matter experts for analysis without the risk of transporting the artifacts. Another advantage of this technique is that the comparisons could be made without the purchase of a comparison microscope.

The two methods, 3D scanning and digital caliper analysis are two tools that are potentially valuable to archeology as they can help an archeologist to interpret archeological sites and artifacts. These methods are not ends unto themselves, as the data they produce must be interpreted by archeologists in order to be useful.

Definitions

For clarity, terms used in this paper have been defined here:

**Carbine**—a short barreled shoulder firearm.

**Cartridge**—a cylindrical, usually metal casing containing an explosive charge and often a bullet, for a rifle or other small arms (Dictionary.com 2011)

**Cartridge case**—The term “cartridge case” refers to “the ammunition case and primer and does not include the bullet” (Heard 1997, 39)

**Extractor Mark**—The mark left in the extractor groove of a cartridge (Heard 1997).

**Firing pin mark**—The mark left on primer of a fired cartridge case by the firing pin (Heard 1997).
Rimfire ammunition- “In rimfire ammunition, the primer composition is spun into the hollow rim of the cartridge case. Consequently the propellant is in intimate contact with the priming composition. When the trigger is pulled, the weapon’s firing pin crushes the thin rim of the cartridge case, compressing the priming composition and initiating detonation”, firing the cartridge case (Heard 1997, 36).

Brief History of Forensic Firearm Identification

The first use of forensic firearm identification techniques was in 1907 when members of the Frankfort Arsenal were asked to identify which weapons had been fired during the riots in Brownsville, Texas. Using magnified photographs of the firing pin impressions on the cartridge cases found, they were able to determine from which four weapons the cartridge cases came from, but did not have the technology to make use of the striation marks on the bullets themselves (Heard 1997).

Brief History of Forensic Firearm Identification in Archaeology

The first time forensic firearm analysis techniques were applied in an archaeological context was at Little Bighorn Battlefield National Monument in Montana (Scott, Fox and Connor, et al. 1989). This national monument memorializes the famous fight between the United States Army’s Seventh Cavalry and the Sioux and Cheyenne, which took place on June 25-26, 1867. Two hundred and sixty three soldiers were killed here, including Lieutenant Colonel George A. Custer, fighting several thousand Sioux and Cheyenne (National Park Service 2011).

Using firearm signatures on both cartridge cases and bullets, Scott et al. (1989) were able to determine the types of firearms used at Little Bighorn, and more importantly
they were able to identify individual weapons. The ability to identify individual weapon signatures coupled with having precise artifact locations, allowed tracing the movements of individuals across the battlefield (Scott, Fox and Connor, et al. 1989).

In order to identify the unique signature on each cartridge case Scott et al. used microscopic analysis of both extraction marks and firing pin marks. Scott et al. found that this process of microscopic comparison was very time consuming. Each individual cartridge case is analyzed and compared to the other cases, and with 371 individual guns among forty-two firearm types were found. It is easy to see how quickly this type of analysis becomes cost prohibitive and why a less expensive, more expedient but equally reliable way of analyzing cartridge cases is desirable (Scott, Fox and Connor, et al. 1989).

There is a need for less costly option, in terms of both time and money. With faster, cheaper techniques basic analysis of historic battlefields can be completed more quickly, allowing working hypotheses to be altered in the field, which would allow the archaeological investigation to altered if needed to answer new questions.

3D Scanning Method

In archaeology, two-dimensional scanning has been thoroughly embraced. The advantages of being able to preserve a historical document in perpetuity and being able to distribute that document to any interested party are obvious. 2D scanning is also being used in the preservation of languages that may soon disappear.

The Center for Digital Research in the Humanities (CDRH) at the University of Nebraska-Lincoln has been engaged in a project for several years that uses normal flatbed scanners to scan and preserve microfilm of the Omaha language. The scanning of the
microfilm serves two purposes. First, it transfers the information contained in the microfilm to a digital format that can be more easily preserved. Second, once the microfilm has been digitized it is easily made available to researchers and the public on a website created by CDRH, demonstrating the advantage of having a digital scan of historic material (Omaha and Ponca Digital Dictionary 2009).

Upon seeing the benefits of 2D scanning, archaeologists have begun investigating the different ways 3D scanning can help with the preservation and analysis of artifacts (Means 2012). 3D scanning is not a new technological innovation. It has been utilized by the manufacturing industries for years in order to develop and improve on mechanical parts, like in the automotive industry. Similarly it has been embraced by academia in fields like mechanical engineering and graphic design.

The reason archaeologists have begun embracing 3D scanning as a tool is the development of less costly and smaller 3D scanners and less costly more powerful computers with which to render and analyze 3D images. For the most part, 3D scanning has served the same purpose as 2D scanning: preservation. With 3D scanning objects, such as statues or artifacts, can be digitally preserved; while these scans cannot replace the objects themselves, they do provide assurance that the physical destruction of an object does not need to mean that all the information that can be gleaned from the object is lost as well.

While the benefits of 3D scanning when it comes to the preservation of artifacts is obvious, the question remains of whether or not 3D scans can be helpful in artifact analysis particularly when it comes to the field of forensic firearms identification.
The use of cartridge cases for the testing of the 3D scanners is beneficial for two reasons. First, cartridge case analysis is an important part of battlefield archeology, but current methods of identification are expensive and time consuming. The development of a new method of cartridge case analysis would be beneficial for both budgetary and time reasons. Second, cartridge cases are an ideal candidate for establishing which 3D scanner would be most useful for archeologists as the 3D scans must be accurate and detailed enough for analysis of extraction and firing pin marks. If this level of detail can be achieved with cartridge cases then the scanner will be useful for scanning archeological artifacts.

In this thesis, Chapter 2 addresses some of the issues that archeologists face as they begin to utilize 3D scanning technology. In this chapter the 3D scans from three different 3D scanners will be analyzed in an attempt to determine which one would best suited for use in the analysis of cartridge cases. These 3D scanners will be compared on the detail of the scans made, price, and ease of use. In Chapter 5 the results of these tests will be summarized and the 3D scanner that best fits the requirements will be established.

**Caliper Measurement Technique**

A field expedient method of cartridge case analysis is needed as both 3D scanning and contemporary forensic methods require a laboratory, electricity and somewhat expensive equipment.

In an attempt to develop a field expedient method of cartridge case analysis, measurement will be taken from cartridge cases using a digital caliper and then these measurements will be analyzed using a statistical analysis package, like SPSS, to
determine which cartridge cases share similar measurements. While this method still requires the use of a computer and the statistical analysis software that goes with it, laptop and tablet computers still make this method very portable.

In Chapters 3 and 4 this method will be tested for viability and accuracy. Using two independent datasets, several different statistical analysis methods will be utilized to determine which, if any, are the most useful for determining which cartridge cases came from the same weapons. In Chapter 5 the results of these methods will be summarized and whether or not it validates the processes used in the analysis.

Literature Review

Before any topic can be discussed intelligently, an intensive analysis of current literature must take place. Utilizing the resources available, both electronic and physical, an attempt was made find any literature that might discuss the use of 3D scanning or physical measurements to analyze cartridge cases.

Physical Measurement Literature

This research attempt found that there was no literature dealing with the use of cartridge case measurements to determine if cartridge cases came from the same weapon. There is literature on the measurements of cartridge cases when it comes to reloading. This kind of literature could be valuable sources of information for archaeologists should the measurement technique prove useful.

When it comes to reloading ammunition there is an assumption that cartridge cases could be altered by being fired. This alteration usually comes in the form of the
brass being elongated along the length of the cartridge case and reloading literature deals with shaving the brass back down to proper length before the cartridge case is reloaded.

The lack of literature of about using measurements to identify cartridge cases was expected as the technique is new and unproven.

3D Scanning Literature Review

Unlike the physical measurement technique, there is a large amount of material available about using 3D scanners if not particularly about 3D scanning of cartridge cases. The recent explosion of literature about 3D scanners is related to Moore’s Law. As the number of transistors per microchip has increased exponentially the last few years and the cost of these microchips has decreased, it has become financially feasible for universities and private individuals to purchase 3D scanners and the computers needed to manipulate the resulting images.

With the access to less expensive 3D scanners becoming available, archeologists have been exploring possible uses for them. As mentioned previously, most of these efforts have been focused on the digital preservation of artifacts. An example of this is the working being done at Virginia Commonwealth University by Dr. Bernard K. Means and his students. Working with the Department of Defense Legacy program, Dr. Means has been testing the feasibility of using an inexpensive 3D scanner to ensure Department of Defense compliance with historic preservation laws. The Virtual Curation Unit for Recording Archaeological Materials Systematically (V.C.U.-R.A.M.S.) is using a NextEngine Desktop 3D Scanner (Means 2012).
Figure 1.1

Figure 1.2
The V.C.U.-R.A.M.S. has been testing the NextEngine Scanner by scanning historic artifacts such as tobacco pipe fragments. From the figures above (Figure 1.1 and Figure 1.2) it is apparent that the scanner is capable of capturing many small details on the surface of complex artifact, but a limitation of the scanner is that it does not capture the color of the artifact (Means 2012). Dr. Means’ project has demonstrated the potential for using a 3D scanner for archeological and preservation purposes.

The potential advantage of using 3D scans of cartridge cases has also been recognized by the field of forensic investigation. Several articles have been written about how a database of 3D cartridge cases could be useful to forensic investigators.

Mike Burnett (2010) argues that current cartridge case comparison techniques outdated. Currently 2D black and white photographs or comparison microscopes are used for the comparison of cartridge cases. A 3D scan of a cartridge case would provide potentially millions of exact measurements that would allow for more precise comparison. Burnett also states that 3D scans can more easily manipulated by examiners through things like comparisons of topographical data (Figure 1.3) and z-scale enhancement (Figure 1.4).

Burnett is President and CEO of Pyramidal Technologies Ltd (Pyramidal Technologies Ltd. 2011), which is the maker of ALIAS 3D advanced forensic ballistics analysis systems. The system is accurate to 2 microns, or 1/50th the
diameter of a single human hair and currently the system is under evaluation by several law enforcement agencies, including the Los Angeles Police Department (Jane's Police Product Review 2011).

Dr. Means’ work and the evaluating of 3D scans of cartridge cases by law enforcement agencies lends credence to the fact that 3D scans of cartridge cases are a usable source of information and can be used to identify different cartridge cases, but the question remains whether or not 3D scanning can be made financially and technically feasible for archeologists. The research presented in this thesis will offer some answers to that question.
Chapter 2 3D Scanner Comparison

The idea of preserving and analyzing artifacts through various mediums is not new. Archeologists have been attempting to preserve and share the artifacts they have recovered since the beginning of the field. With the development of digital cameras and the Internet it has become increasingly easier for archeologists to collaborate and share their discoveries.

The advent of digital imaging has not only made the sharing of artifacts easier, it has also made large scale preservation possible, by decreasing the cost of taking two-dimensional images of artifacts and offering an easy way to store them. While these images could not possibly replace the artifacts themselves, they can insure that not all the information is lost if an artifact is lost or destroyed, such as what happened at the Baghdad Museum during the American invasion of Iraq in 2003, or more recently the theft of artifacts from museums in Greece during the recent economic unrest.

Three-dimensional scanning (3-D) is the next step in digital preservation and analysis. 3-D scanning offers an opportunity to gather extremely accurate surface data and the ability to manipulate the images for analysis. As the costs associated with 3-D scanning have decreased archeologists have begun experimenting with how it can best be adapted for use. The use of 3D scanning in archeology is still in its infancy as archeologists experiment with the many ways this technology can be used.

Definitions

For clarity, there must be a common understanding of any terms that might be used in the discussion. Here are definitions of some of the terms that will be used throughout this paper.
Two-dimensional image – A two-dimensional (2D) image is a flat image using only the X and Y (horizontal and vertical) axis, the image has only two dimensions and if turned to the side becomes a line.

Three-dimensional image – A three-dimensional (3D) image adds the Z dimension. This third dimension allows for rotation and depth.

Current uses of 3D scanning in archeology

3D scanning is currently being used by archeologists to map archeological features such as Roman ruins or being used to create virtual museums which can allow people from around the world to view artifacts that they otherwise would not be able to ever see. An example of this is the working being done by Dr. Bernard K. Means and the Virtual Curation Unit for Recording Archaeological Materials Systematically (V.C.U.-R.A.M.S.) at Virginia Commonwealth University. Dr. Means and his team have been experimenting with the NextEngine 3D scanner in order to develop a way to record archeological materials systematically. Working with the Department of Defense’s Legacy Program, V.C.U-R.A.M.S hopes to develop a methodical way of creating 3D digital data and virtual artifact Curation in order to make accessible an extensive catalog of American Indian and historic artifacts. The efforts of Dr. Means and his team is just one example of how 3D scanning is being utilized by archeologists.

3D Scanning and Cartridge Cases

3D scanning technology is not only being embraced by the archeological community but by other disciplines as well. In particular individuals and companies in the field of forensic science, particularly in firearms identification, have begun looking at
how 3D scanning can be utilized. For example, Pyramidal Technologies Ltd. (mentioned in the introduction chapter) has developed a 3D scanner, accurate up to 2 microns, that can be used to scan cartridge cases and those scans can be used for forensic identification by law enforcement. Several other companies are also developing similar systems with the idea that 3D scanners will replace the current system of using comparison microscopes and will allow the development of a nationwide digital database of cartridge cases, which would allow law enforcement to become more effective in tracking weapons and solving crimes.

The move towards 3D scanning for use in identifying of cartridge cases and bullets has several advantages over current methods. First, the scans record extremely accurate spatial information. Second, the scans can be transmitted to other experts to allow for consultation. Third, eventually computer programs can be developed that will be able to use the accurate spatial information to conduct at least preliminary comparisons, reducing the amount of time it takes investigators to identify cartridges and reduce investigation costs.

The downside of 3D scanning in the forensic field is that the 3D scanners capable of producing the accuracy required for forensic level identification are still very expensive and out of reach for most archeological programs. Fortunately for the purposes of archeological investigation it may be not be necessary that 3D scanners be capable of micron level accuracy.
In order to test if more cost effective 3D scanners can be used by archeologists to conduct cartridge case analysis, the results from three different scanners were analyzed to determine which, if any, one could be used by archeologists and be cost effective.

**Breuckmann Smart Scan HE**

The first scanner that was utilized to scan cartridge cases from the Rush Creek battlefield was a Brueckmann SmartScan HE. The scanner is owned and operated by the Center for Advanced Spatial Technologies (CAST) at the University of Arkansas, Fayetteville. Dr. Fred Limp, a research faculty member at CAST, and Katie Simon, a research associate at CAST, were able to scan a cartridge case from Rush Creek (Simon 2011). The cartridge case was Field Specimen (FS) 77, which from a .44 Wesson cartridge.

![Figure 2.1](image)

**Figure 2.1**

The Brueckmann SmartScan HE (Figure 2.1) is a low weight compact scanner that is designed for use in a technical engineering context, for things like quality
inspection. The system is certified according to the VDI/VDE guideline 2634/2 (Breuckmann GmBH 2012). This guideline was developed by VDI/VDE Society of Measurement and Automation and applies to optical 3-D-measuring systems based on area scanning, whose function is based on triangulation and applies to the measuring of three-dimensional objects in a single elementary measuring pass (VDI/VDE-Society of Measurement and Automation 2002).

As seen in Figure 2.2 the resulting scan of FS 77 was disappointing as the surface was not smooth due to the low resolution of the scan at this scale. The point spacing was about 0.06 mm. It was the opinion of Kate Simon that the resolution was too low for useful analysis due to the limitations of the scanner and its 125 mm lens (Simon 2011).

![Figure 2.2](image)

While the general shape of the cartridge case is clearly apparent none of the diagnostic marks (ejection marks and firing pin marks) are visible on the scan, making it useless for cartridge case identification. Simon did suggest that a more accurate scan
might be possible with a different lens but project funds did not allow for the purchase of more accurate lens (Simon 2011).

The results of this scan show that the Brueckmann SmartScan HE make it unsuitable for both class and individual cartridge case identification.

**DAVID Laserscanner**

The next 3D scanner utilized for this project was the DAVID-Laserscanner 3.3. The scanner is capable of picking up surface details of less than 0.2 mm in optimal conditions (DAVID Vision Systems GmbH 2009).

This scanner is considerably less expensive than other 3D scanners at a cost of €399 ($526) for a starter kit. The starter kit contents include DAVID Laserscanner Pro Edition 3 software, high resolution 2 megapixel webcam (Logitech Quickcam 9000 PRO), webcam stand, red line laser module with adjustable focus, calibration panels (four different sizes), user manual. To utilize the software requires a Windows PC, and 2 available USB ports. DAVID also recommends a 2 GHz CPU, 1 GB RAM, and 3d graphics card (DAVID Vision Systems GmbH 2009).
The figures (Figure 2.3 and Figure 2.4) above are of a one Euro coin. The figure on the left is a 2D digital photo; the figure on the right is the 3D scan using the DAVID-Laserscanner (DAVID-Laserscanner 2012). The DAVID-Laserscanner result contains a lot of detail on it, like the outline of Europe and lines and stars near the outline of Europe but it also has a rough texture at the top of the coin, and a long scratch mark across the coin towards the bottom. Without having the coin that was originally scanned, it is not known if the rough texture or scratch is on the physical coin or if it is a result of the
scanning, but the level of detail shown does bode well for the DAVID-Laserscanner’s potential for cartridge case identification.

The DAVID-Laserscanner system is different from the Brueckmann SmartScan HE in that it uses a handheld laser, webcam and background calibration panels. The webcam is calibrated to the calibration panel which allows the software to establish a three-dimensional space in which the software knows where everything is located (Figure 2.5). After calibration the object is positioned between the calibration panels as shown in the figure on the left. Then the scanning process is started using the red line laser to “sweep” down the object repeatedly until the 3D scan is formed. The object can then be rotated and the process repeated until all sides of the object have been scanned. It is then possible to “stitch” the scans together to create a complete 3D model of the object (DAVID-Laserscanner 2012).
The figure on the left (Figure 2.6) is the view from the webcam after scanning has taken place. This view and lighting conditions are used at the end of scanning in order to get a photo surface of the object that the software then lays over the 3D figure. This is important as accurate representation of the colors and surface will allow for easier identification of diagnostic marks.

Figure 2.7 shows the results of the experiments with the David-Laserscanner. From top left the scans go from 1\textsuperscript{st} attempt to 4\textsuperscript{th} attempt. Obviously there is a learning curve to scanning objects using the DAVID-Laserscanner.

A disadvantage of this system, unlike the Brueckmann SmartScan HE and NextEngine scanner, is that it does not automatically adjust to the
lighting conditions where the scan is taking place and the scanner must be calibrated before use, which can be time consuming and must be done carefully. Poor calibration can lead to degraded scans. In addition, the lighting must be extremely dark for the scanning of an object and then extremely bright for the photo capture, precluding from using this scanner in the field or in any place other than a controlled environment.

The fourth and final result in Figure 2.7 is of high enough quality to be used for class identification as the general characteristics are all visible. However, while an unfired cartridge case was used for this scan, it is apparent that the level of detail will not be enough for individual cartridge case identification.

In an effort to improve image clarity two different digital cameras were used. One was 2 megapixel Microsoft webcam; the other was an 8 megapixel camera on a Motorola Droid Razr. The use of different cameras produced no noticeable improvements in image quality.

**NextEngine Scanner**

As discussed previously Dr. Means and the V.C.U.-R.A.M.S. have been using the NextEngine 3D Scanner HD. The scanner is a compact scanner (Figure 2.8) that uses twin arrays of four 10 mW lasers and twin 3.0 megapixel CMOS figure sensors to take a 3D scan of an object. The scanner has a dimensional accuracy +0.005” in in Macro Mode and +0.015” in Wide mode and it can be used in ordinary office lighting. The scanner comes with ScanStudio HD which is the
software used to run the scanner and complete the scans, but faster and more powerful software is available from NextEngine for additional cost. The scanner can take multiple shots of a large object and using the software that comes with the scanner a person can put the 3D figure together (NextEngine 2012). For smaller objects NextEngine has developed the MultiDrive. This is two axis programmable robot onto which a small object can be placed and the device will automatically rotate the object as needed for a complete scan without the need for human involvement, reducing scanning time and scan errors (NextEngine 2012). The scanner can take figures quickly, requiring about two minutes per view. The number of views needed depends on the size and composition of the object being scanned.

The scanner is occupies the midrange on prices for 3D scanners at $2,995. The additional software HD PRO, which increases scanning speed and helps with manipulating software, has a cost of $995. While this is more expensive than the DAVID-Laserscanner, the tradeoff is that more of the processes are automated and controlled by the computer making scanning easier to do and with less of learning curve.

In addition, the NextEngine scanner can be used in just about any lighting conditions, unlike the DAVID-Laserscanner. Dr. Means and his team have demonstrated this as they have used the scanner in the field at the location of the Battle of Third Winchester near Winchester, PA (Means 2012).
Figure 2.9 (Courtesy of the Virtual Curation Laboratory at Virginia Commonwealth University) is several photographs of a historic tobacco pipe fragment while Figure 2.10 (Courtesy of the Virtual Curation Laboratory at Virginia Commonwealth University) is 3D scan of the same tobacco pipe created using the NextEngine scanner.

The decorative details can on the tobacco pipe fragment can clearly be seen on the 3D scan (Figure 2.10) which lends credence to that the NextEngine scanner should be further explored as a possible tool for the identification of cartridge cases.

After contacting Dr. Means, several .44 Wesson cartridge cases from Rush Creek were sent to V.C.U.-R.A.M.S with the intent that Dr. Means and his team would use the NextEngine scanner to create 3D scans of them for analysis. After some technical difficulties were sorted out Dr. Means was able to perform several scans of a cartridge case.

For the first attempt at scanning the cartridge Dr. Means covered the cartridge case in boron nitrate powder (email to author, April 7, 2012). Boron nitrate powder was used because of the high sheen of the metallic cartridge case. Objects with a high sheen can be difficult to scan because of the diffusion of the laser as it hits the objects surface.
Figure 2.11

Figure 2.11 (Courtesy of the Virtual Curation Unit at Virginia Commonwealth University) is the result of the scan of the cartridge case with NextEngine scanner using boron nitrate powder. While the image has not yet been processed, which gives it a bumpy appearance, the ridge of the label (indicated by the red arrow) put on the artifact for sorting purposes is clearly visible. The fact that this ridge is visible indicates that small details are visible on scans created by the NextEngine scanner.
Figure 2.12

The scan shown in Figure 2.12 (Courtesy of the Virtual Curation Unit at Virginia Commonwealth University) is of a cartridge case without any powder on it. The scan is close in quality to the scan of cartridge case covered in boron nitrate powder, but the label is no longer visible.

The scan of the boron nitrate covered cartridge case looks to be the most promising in creating a scan that can be used for individual cartridge case identification.

Conclusion
The use of 3D scanning technology in archeology will only increase as the technology becomes less expensive and easier to use. The potential that 3D scanning has to assist archeologists in analyzing and preserving artifacts cannot be ignored. 3D scanning is the future of cartridge case identification in both forensics and in archeology.

The Brueckmann SmartScan HE with a 125 mm lens did not prove to be a useful tool when it comes to cartridge case identification. This can be expected when tools are repurposed for something other than their original use. The lack of detail combined with its high cost makes the Brueckmann SmartScan HE unsuitable for the purposes of this study.

The DAVID-Laserscanner is a mixed bag. While it is inexpensive compared to the NextEngine and Brueckmann SmartScan HE scanners, it comes with a steeper learning curve and is more complicated to operate, requiring perfect lighting conditions for the most accurate scans. In addition, while directions for the software can be helpful they lag behind the current version of the software which can lead to problems.

The DAVID-Laserscanner may be the best option for archeological departments that do not have the funds for the NextEngine scanner, but want to experiment with 3D scanning artifacts. The DAVID-Laserscanner may also be useful for the scanning of broken artifacts. The individual pieces of an artifact can be scanned then reassembled digitally allow archeologists to view the complete artifact without the risk of damaging the artifacts.

The NextEngine scanner produced very interesting results. The quality of these initial scans (Figure 2.11 and Figure 2.12) is of high enough quality to see the outline of
the label put on the artifact. With further testing and processing, the NextEngine scanner seems the most likely of the three scanners to produce a scan of high enough quality to conduct individual cartridge case identification.

While both the DAVID-Laserscanner and the NextEngine scanner have definite potential for future use in archeology in both artifact preservation and cartridge case analysis, it would seem that the technology is still too immature for everyday use. However, given the continued research by people like Dr. Means and his team it seems likely that 3D scanners and the techniques in using them will reach the quality level needed in the near future.
Chapter 3 Rush Creek Cartridge Case Analysis

In order to test the feasibility of making cartridge case identification s using a digital caliper, the Civil War era battle at Rush Creek was selected. This analysis was carried out by comparing four measurements taken from one cartridge case to another, using several different statistical analysis methods. The analysis of the cartridge cases from Rush Creek would ultimately prove inconclusive but the knowledge gained from this experiment would allow for the creation of a more sophisticated experiment which would determine with confidence whether the technique will be useful to archaeologists.

History of Rush Creek

In order to give a historical context to the analysis, here is a brief background to the Rush Creek Battlefield site. On November 29, 1964, 725 men of the First and Third Colorado Volunteer Calvary, under Colonel John M. Chivington, conducted an attack on a camp of Cheyenne and Arapahos near Sand Creek Colorado, even though the camp consisted mostly of women and children. The Cheyenne and Arapahos also believed they were under the protection of the federal government, represented by the troops at nearby Fort Lyon (Vandervort 2006; Scott 2000).

The Colorado Volunteer Calvary began their assault with a barrage of artillery shells, and then followed by a cavalry charge from two sides. The shelling and the charge sent the Cheyenne and Arapahos running to a nearby creek bed. The cavalry later shelled the creek bed, killing 150 people (Vandervort 2006).

The cavalry soldiers then proceeded to scalp and mutilate the bodies as they burned the native camp to the ground. On December 22, they rode into town displaying
the scalps and genitals of the Cheyenne and Arapaho that they had killed (Vandervort 2006).

The people living near the incident called it the Sand Creek Massacre and it incited immediate action from the Cheyenne and Arapaho, who (along with sympathetic Sioux) began attacking white settlements. When word of the massacre reached Washington D.C., it provoked a strong reaction with many people calling for an investigation into the events that took place. Congress and the military formed a commission to investigate, but it failed to hold anyone accountable for the “battle” and Chivington resigned his commission before he could be court-martialed (Vandervort 2006).

A direct result of the Sand Creek Massacre and the lack of punishment meted out to those who the Native Americans held responsible was the battle at Rush Creek. The battle at Rush Creek was an encounter between a large Native American group (consisting of Cheyenne, Lakota, and Arapaho) and the Eleventh Ohio Volunteer Cavalry and Seventh Iowa Calvary, commanded by Lieutenant Colonel William O. Collins. This encounter occurred on February 8-9, 1865 in Morrill County, Nebraska (Scott, Bleed and Bilgri 2010).

The Native American group of 2,000 to 3,000 individuals had made camp at Rush Creek and staged several attacks on a nearby telegraph station, Mud Springs Station. The formation of this group and the attacks it conducted were revenge for the November 29, 1864 Sand Creek Massacre. The purpose of these attacks on Mud Springs was to obtain horses and livestock that were at the station and to harass the soldiers stationed at Mud
Springs. The soldiers at Mud Springs sent word by telegraph about they were under attack by hostile natives which lead to about 200 soldiers being sent from Fort Laramie and Fort Mitchell to reinforce them (Scott, Bleed and Bilgri 2010).

After Mud Springs Station was secure, Lieutenant Colonel Collins departed with 160 mounted soldiers, several army wagons and a 12-pound Mountain howitzer in pursuit of the Native American attackers. The Native American group, meanwhile, were staging a strategic withdrawal northward, moving across the frozen North Platte river on the night of February 7th (Scott, Bleed and Bilgri 2010).

On February 8th a rearguard left by the Native group spotted the Union cavalry heading their direction. The warriors of the group again crossed the North Platte in order to engage with the Union cavalry and slow their advance. When faced by the Native attackers, the Union cavalry dismounted, and made a defensive perimeter utilizing temporary breastworks and deployed their cannon (Scott, Bleed and Bilgri 2010).

According to oral reports, the cavalry soldiers used a ten man cavalry charge in an attempt to break up the Native American attack and force them to scatter. The soldiers were able to wound one Native American and then were repulsed back to their lines after the Native American counter attacked, killing three soldiers in the process (Scott, Bleed and Bilgri 2010).

In order to stop the Native American counter attacks the cavalry soldiers fired their Mountain Howitzer loaded with canister shot. They succeeded in stopping the Native American counter attack but failed to kill any of the attackers. This was the major engagement of forces on February 8th with the fighting ceasing at nightfall. Fighting
picked up again on February 9th with Native Americans continuing to harass and take shots at Union troops, keeping them behind their breastworks (Scott, Bleed and Bilgri 2010).

By the end of the day on February 9th the Native American community of women and children had moved far enough away to be safe from the Union forces, allowing the Native warriors to slowly disengage from Union forces and escape from them. The volunteer cavalry stayed in place until the next day when they struck their defensive works and moved back to their originating forts (Scott, Bleed and Bilgri 2010).

Archaeology at Rush Creek

Douglas Scott et al. discovered the Rush Creek Battlefield through archaeological research in 2008. While researching and investigating violent encounters that took place between a Native American group and Union troops stationed at Mud Springs telegraph station, archaeologists, Dr. Peter Bleed and Dr. Douglas Scott became interested in following the combatants of Mud Springs to Rush Creek. Initial attempts to find the site were unsuccessful until 2008, when the University of Nebraska-Lincoln (UNL) Summer Field School in Archaeology was able to devote part of a day to search for the battlefield (Scott, Bleed and Bilgri 2010).

The field school participants, guided by local rancher Pete Peters and Morrill County historian Bill Vogler, were able to locate a probable location for the battlefield at a confluence of Cedar Creek (known as Rush Creek in the 1860s) and the North Platte River. Using a search pattern that prioritized areas of highest possible return and utilizing metal detectors, the searchers were able to locate two isolated .44-caliber bullets
and a group of .56-caliber Spencer and .44-caliber Wesson cartridge cases on a small rise. To the investigators this concentration of artifacts suggested that this was probably a fighting position that was connected to the Rush Creek battle (Scott, Bleed and Bilgri 2010).

In 2009, Dr. Scott and Dr. Bleed, along with the UNL Summer Field School in Archaeology, were able to return to the site to conduct a 10 day survey of the site. The surveying was done with metal detectors used by student operators who walked transects at 5 meter intervals. Scott et al. recovered 150 artifacts during the 10 day survey, including many cartridge cases and bullets (Scott, Bleed and Bilgri 2010).

Along with the analysis that was conducted of all artifacts collected at Rush Creek, a more detailed analysis of the cartridge cases took place in the form of firearm identification analysis which not only allowed the determination of which type of firearm a cartridge case was fired in using firing pin marks and extraction marks (Scott, Bleed and Bilgri 2010).

**Weapon of Choice- Wesson Carbine**

The Wesson carbine was developed by Frank Wesson and was one of the earliest carbines designed to use a metallic cartridge with a patent being awarded in 1859. His .44 proprietary rimfire cartridges were popular during the war. Frank Wesson was originally based in Worcester, Massachusetts and then moved to Springfield, Massachusetts. His distance from Washington may explain why the United States Army did not buy as many Wesson carbines as they did others (Whisker 2002).
.44 Extra Long Cartridge Cases

Ballard developed the .44 Extra Long cartridge which could be adapted to several rifles such as Remington and F. Wesson .44 caliber weapons (Barnes 2003). At Rush Creek, a large number of .44 Extra Long cartridge cases found had multiple firing pin marks on them, indicating misfires. This may indicate, but does not prove, a quality control problem during manufacturing, particularly in regards to the priming of the cases (Scott, Bleed and Bilgri 2010).

Hypothesis

The hypothesis for this research is that by analyzing four different measurements taken from each cartridge case it would be possible to determine whether a cartridge case had been fired and which cartridge cases had been fired in the same gun.

Materials and Methods

The measurements of .44 Wesson Extra Long cartridge cases from the Rush Creek Battlefield were taken using a Mitutoyo 500 Digimatic Digital Caliper. Four measurements were taken from each cartridge case; mouth diameter, total length, base diameter, and rim diameter each of these measurements was taken three times to control for measurement error. The averages of those three measurements were used in the analysis. In addition, the same four measurements were taken from four unfired .44 Wesson Extra Long cartridges in order to determine what if

Figure 3.1
any differences could be seen in the average measurements between unfired and fired cartridge cases.

Measurements were taken in a standardized procedure in order to increase consistency and reduce error. For each variable, the firing pin mark was used as the initial measurement point, then the cartridge case was rotated 90 degrees and the second measurement was taken. The cartridge case was then rotated 45 degrees and the third and final measurements were taken.

Between each cartridge case the digital caliper was zeroed and all measurements were taken by the same researcher to reduce error. In order to reduce bias, the researcher was intentionally not informed which cartridge cases were from the same weapon. That information was added after the measurements were taken but before the statistical analysis took place.

Data Set

The collection used to test these hypotheses met several requirements. First, the collection was available and easily accessible for research. Second, the collection possessed cartridge cases from a time period during which battle was common so the technique, if successful, can be applied easily to other archaeological sites. Third, the collection must have already had its cartridge cases forensically identified with their associated weapon type and more importantly identified with the weapons in which they were fired in order to determine whether any patterns recognized in the test were actually accurate. Dr. Douglas Scott (Scott, Bleed and Bilgri 2010) had previously forensic
techniques to individually identify the cartridge cases in the Rush Creek collection, for both weapon type and individual weapon association.

The .44 Extra Long cartridge cases were selected for examination primarily because there were sixty one complete cartridge cases (complete meaning having all four attributes that were to be measured) collected in 2009 at Rush Creek which gave a large data set.

The removal of eleven cartridge cases from the data set was necessary as they were damaged in such a way as to make the taking of all four variable measurements was impossible. Primarily the damage was in the mouth diameter area, which was expected as this is the weakest point of the cartridge case after it has been fired. This left a data set of 50 .44 Wesson Extra Long cartridge cases which were used in both the fired-unfired analysis and the individual weapon identification analysis.

Two different statistical methods were utilized for this analysis. For the comparison of fired and unfired cartridge cases the statistical method binary logistic regression was used because the data were not normally distributed and the data could be divided into two groups. In addition, binary logistic regression would allow for the comparison of all four variables at once (Drennan 2010).

For the comparison of cartridge cases to identify individual weapons the Kruskall-Wallis non-parametric one-way analysis was chosen as the data were not normally distributed. Use of the Kruskall-Wallis analysis allowed for a comparison of all four variables at the same time, each weapon could be compared to every other weapon and it met the other assumptions of the Kruskall-Wallace one-way analysis (Drennan 2010).
Average Mouth Diameter

It was assumed that the mouth diameter would have the most variation as the mouth of the cartridge is where the force of the explosion is directed when the cartridge case is fired.

![Histogram of Average Mouth Diameter](image)

Figure 3.2

The histogram (Figure 3.2) shows that the data for average mouth diameter are not normally distributed. The data have a unimodal distribution and are skewed to the right with several outliers. That most of the data points cluster to the center does not bode well for identifying individual cartridge cases as the mouth diameter measurement was assumed to be the larger and more “unique” as this is where the force of the explosion exits the cartridge case.

Total Length

It was assumed that the measurements taken from each cartridge case would be consistent from case to case with little variation as this variable should not have been affected much by the firing of the case.
From the histogram (Figure 3.3) it is apparent that this assumption was also false.

The data have a bimodal distribution with several outliers and is skewed to the left.

**Rim Diameter**

It was assumed that the rim diameters would vary from cartridge case to cartridge case due to the nature of rim fire cartridge cases. The firing pin on a rim fire cartridge pushes out some of the metal when it strikes the cartridge case, altering the circumference of the rim for each cartridge case.
This is seen in the histogram (Figure 3.4) which shows the data as evenly distributed without any outliers or skewness.

**Base Diameter**

![Histogram of Base Diameter](image)

**Figure 3.5**
For the average Base Diameter measurement it was assumed before data collection that these measurements would all be very similar as the base is strong point in the cartridge case since it is a fold in the metal. Being stronger it would not be as influenced by explosion when the cartridge case was fired.

The histogram (Figure 3.5) shows the distribution of the data is unimodal and nearly evenly distributed, with no skewness, and one outlier. This would seem to confirm that the explosion of the cartridge case only minimally influenced the base diameter measurement when it was fired.

Results of binary logistic regression

For comparing the differences between the measurements of fired and unfired binary logistic regression was used.

Table 3.1

<table>
<thead>
<tr>
<th>Observed</th>
<th>Fired_Unfired</th>
<th>Predicted</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td>Step 1</td>
<td>Fired_Unfired</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>Overall Percentage</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. The cut value is .500
Binary logistic regression is testing the to see if the odds of being fired versus unfired are different dependent on a series of predictors, in this case the four measurement variables (e.g., Average Length, AvgRimDiam).

The result of the binary logistic test (Table 3.1) shows that there are no significant differences between the dimensions of fired and unfired cartridge cases.

Results of Kruskall-Wallis one-way analysis of variance

The Kruskall-Wallace one-way analysis of variance was used because it tests the mean of ranks between groups based on continuous outcomes. It revealed significant differences between individual weapons in Base Diameter ($P < 0.023$) and between Total Length ($P < 0.034$). There were no significant differences found between weapons in Mouth Diameter or Rim Diameter. Post-hoc pairwise comparisons revealed only one significant difference between weapons 4 and 7.
Fired versus Unfired

The results of the binary logistic regression test (see Table 3-1) seem to show that there is no statistical difference between fired and unfired cartridge cases, but this cannot be taken at face value due to the limited amount of data available for the unfired cartridges.

A larger sample size is needed before this model can be rejected with confidence. This could prove problematic as the ammunition was only manufactured for a limited period of time (Barnes 2003). It may be possible to use more recent cartridge cases but this could prove just as problematic as the ammunition is no longer manufactured.

Another issue with analysis is possible sampling error and data collection error. The variation seen in Total Length could have several possible explanations. It could be variation in the manufacturing process as machine tools during the Civil War were not to the standard of today’s manufacturing processes. Different manufacturers using different equipment could also explain the variation. The Wesson rifle was more forgiving of ammunition that was not manufactured to exact standards then weapons used today.

Individual Weapons

An examination of the Kruskall-Wallis one-way analysis shows that there were significant differences between weapons in Total Length and Base Diameter but the post hoc comparison only showed significant differences between weapons 4 and 7.

There are several possible reasons for these results. First, the differences found in both Total Length and Base Diameter could be the result of the manufacturing process.
There were several manufacturers of .44 cartridges during the Civil War and each one could have made them slightly different either by design or unintentionally because of the imprecision of machine tools. The manufacturers of the cartridge cases at Rush Creek are unknown, but when dealing with cartridge case collections where the manufacturers are known it could be possible to control for this variation.

Second, sampling error may be an issue. The data set was small to begin with and was made even smaller once the misshapen cartridge cases were removed and all the weapons which only had one data point were removed. This data set may be too small for significant differences to appear in analysis.

Third, there may be a data collection error. The data was collected with a digital caliper which can only measure to thousandths of a millimeter. The changes in a cartridge case may be so minute as to not appear at that resolution.

Additionally there is always a chance of human error in reading and holding the caliper. Attempts to control for error were made by standardizing the testing procedure but it is impossible for a human being to do the exact same technique repeatedly without any error.

**Conclusion**

While this experiment was inconclusive about whether or not this manual measurement technique would be an effective way to individually identify cartridge cases with others that were fired in the same gun, it does provide important information for a second experiment. Another experiment will be conducted to confirm whether cartridge
cases are altered at all by the act of being fired in order to determine if further research into identifying individual weapons using measurements is worthwhile.
Chapter 4 .22 caliber Revolver Cartridge Case Analysis

In this chapter, cartridge case measurement analysis is conducted between fired and unfired .22 caliber cartridge cases and between chambers of a seven chamber pistol. The purpose behind this comparison is to understand if there is a statistically significant difference in the measurements between fired and unfired cartridge case. If there is a difference it would lend credence to the idea that measurements of cartridge cases could be used to identify individual weapons.

Hypothesis

The hypothesis for this experiment is that by analyzing four different measurements taken from each cartridge case it would be possible to determine whether there is a statistically significant difference between fired and unfired cartridge cases.

Material and Methods

The weapon used for the testing was a seven shot Young American Double Action made about 1885. The ammunition used was manufactured by CCI and was .22 caliber CB (reduced load) cartridges. While it was determined that the weapon was safe to be fired for testing, it was determined by the investigator that reduced load ammunition would be used as it would reduce the stress put on the revolver.
The measurements of the .22 caliber cartridge cases, fired and unfired, were taken using a Mitutoyo 500 Digimatic Digital Caliper. Four measurements were taken from each cartridge case; mouth diameter, total length, base diameter, and rim diameter each of these measurements was taken three times to control for measurement error. The averages of those three measurements were used in the analysis. In addition, the same four measurements were taken from five unfired .22 Extra Long cartridges in order to determine if what if any differences could be seen in the average measurements between unfired and fired cartridge cases.

Measurements were obtained in a standardized procedure in order to increase consistency and reduce error. For each variable, the firing pin mark was used as the initial measurement point, then the cartridge case was rotated 90 degrees and the second measurement was taken. The cartridge case was then rotated 45 degrees and the third and
final measurements were taken. Between each cartridge case the digital caliper was zeroed and all measurements were taken by the same researcher to reduce error.

Data Set

The collection used to test this hypothesis met several requirements. First, the cartridge cases came from a historic .22 caliber pistol. Second, the .22 caliber pistol was available for use and the investigator could collect the cases. According Douglas Scott three cartridges were fired in each chamber as this is a statistically valid approach that is used in current forensic cartridge case identification (email to author, April 10, 2012).

All of the cartridge cases are complete (meaning they had all four attributes that were to be measured), though two of cartridges were misfires. The two misfired cartridge cases will not be utilized in the comparison. The five unfired cartridges used for comparison were taken from the same ammunition box as the fired in order to control for manufacturer differences.

Average Mouth Diameter

![Histogram of Mouth Diameter](image-url)

**Figure 4.2**
For Mouth Diameter, it was assumed that the mouth diameter would have the most variation between the fired and unfired cartridges due to the mouth of the cartridge is where the force of the explosion is directed when the cartridge case is fired.

The histogram (Figure 4.2) shows that the data is normally distributed and runs the range from 5.625 mm to 5.75 mm, with the average being 5.7 mm. The data has a unimodal distribution. The normal distribution does not bode well for the idea that there will be significant differences between the mouth diameter of fired and unfired cartridge cases.

This does not bode well for the identification of different revolvers on the same battlefield as the measurement for mouth diameter may be different enough to appear as unique weapons rather than from the same revolver.

The above histogram (Figure 4.3) provides a visualization of the mouth diameter data for the unfired cartridge cases. The data are unimodal with an outlier on the lower end. The average, 5.67 mm, is lower than the average of the fired cartridge cases, 5.7
mm. This lends credence to the idea that the mouth diameter of the fired cartridge cases was altered by being fired.

**Total Length**

It was assumed that the measurements taken from each cartridge case would be consistent from case to case with little variation as this variable should not have been affected by the firing of the cartridge.

![Figure 4.4](image)

The histogram (Figure 4.4) shows a variation in length of the fired cartridges. The data have a unimodal distribution with an outlier on the lower end. Besides the outlier the rest of the data are normally distributed.
From the histogram (Figure 4.5) the total length of the unfired cartridges is not normally distributed and is unimodal. In comparing the two histograms, it is apparent that the firing of a cartridge case extends the total length as the total length of unfired cases ranges from 10.20 mm to 10.24 mm, while the length of fired cartridge cases ranges from 10.42 mm to 10.50 mm. Whether this variation is helpful in identifying which chamber the cartridge case was fired in will be determined later.
Rim Diameter

It was assumed that the rim diameter would not vary from fired cartridge case to fired cartridge case as the cartridge cases all come from the same pistol, just different chambers. It was assumed that there would be a noticeable difference between fired and unfired cartridge cases due to the nature of rim fire cartridge cases. The firing pin on a rim fire cartridge pushes out some of the metal when it strikes the cartridge case, altering the circumference of the rim for each cartridge case.

This variation is seen in the histogram (Figure 4.6) as the data is close to being within normally distribution with no outliers or skewness, though the data are bimodal.
The histogram (Figure 4.7) shows that the data is close to being normally distributed with no outliers or skewness and it is unimodal.

A comparison of the two histograms reveals that all the fired cartridge cases have an average rim diameter greater than the smallest average rim diameter of the unfired cartridge cases. This demonstrates that the firing of the cartridge case alters the rim diameter measurement. However, the alteration of the cartridge caused by firing is very slight in some cases, with the smallest rim diameter of an unfired cartridge case being 6.88 mm and the smallest rim diameter of fired cartridge case being 6.9 mm.
With the this small amount of variation it could be that average rim diameter is not a good candidate for being used to identify cartridges cases fired in different weapons, or in this case, different chambers of the same revolver.

**Base Diameter**

It was assumed that these measurements would all be very similar as the base is a strong point in the cartridge case because of the fold in the metal. Being stronger it should not be as influenced by the explosion of the cartridge case when it is fired.

![Histogram showing average base diameter of fired cartridge cases](image)

**Figure 4.8**

The histogram (Figure 4.8) shows the average base diameter of the fired cartridge cases. The data are bimodal with two outliers on right side and it is not normally distributed.
For the average base diameter of unfired cartridge cases (Figure 4.8) the data are bimodal, and are not normally distributed. The variation between the cases is extremely small, with the standard deviation being 0.004.

The small variation between the base diameters of unfired cases, unlike the variation between other attributes of unfired cartridge cases, could be the result of the mechanical process of folding the metal. In addition there is a need for the cartridge to fit precisely at that point as the fold also produces the rim portion of the cartridge case which is used to hold the cartridge in the chamber.

**Results of Mann-Whitney U test**

The Mann-Whitney U Test was used to compare the difference between fired and unfired cartridge cases, as the dependent variable of the analysis was ordinal, fired or unfired and because the data was not normally distributed.
The results of the Mann-Whitney U test show that null hypothesis should be rejected and that the differences between fired and unfired .22 caliber cartridges are statistically significant.

This is in contrast to the analysis of the .44 caliber cartridge cases found at Rush Creek, where no significant differences between fired and unfired cases was found (Table 3.1).
Results of Kruskall-Wallis one-way variance

The Kruskal-Wallis one-way variance is a nonparametric test that can be used on ordinal data. Also the test is not sensitive to outliers which will of help with this dataset.

Table 4.2

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>Test</th>
<th>Sig.</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 The distribution of Avg_BaseDiameter is the same across categories of Fired_Unfired.</td>
<td>Independent-Samples Kruskal-Wallis Test</td>
<td>.024</td>
<td>Reject the null hypothesis.</td>
</tr>
<tr>
<td>2 The distribution of Avg_Mouth_Diameter is the same across categories of Fired_Unfired.</td>
<td>Independent-Samples Kruskal-Wallis Test</td>
<td>.010</td>
<td>Reject the null hypothesis.</td>
</tr>
<tr>
<td>3 The distribution of Avg_RimDiameter is the same across categories of Fired_Unfired.</td>
<td>Independent-Samples Kruskal-Wallis Test</td>
<td>.010</td>
<td>Reject the null hypothesis.</td>
</tr>
<tr>
<td>4 The distribution of Avg_TotalLength is the same across categories of Fired_Unfired.</td>
<td>Independent-Samples Kruskal-Wallis Test</td>
<td>.001</td>
<td>Reject the null hypothesis.</td>
</tr>
</tbody>
</table>

Asymptotic significances are displayed. The significance level is .05.

The results of the Kruskall-Wallis one way variance test show that there were statistically significant differences between fired and unfired cartridge cases in all four categories of measurements, Base Diameter, Mouth Diameter, Rim Diameter, and Total Length, just like the Mann-Whitney U test.

Conclusion

The fact that two different statistical analysis methods show significant differences reinforces the conclusion that, in this specific case, there are differences between fired and unfired cases.
This difference means that the first part of the original hypothesis is accurate. However it cannot be assumed that this will be true for all historic weapons or even for other .22 caliber historic revolvers. This method of cartridge case identification is only in its infancy and further testing is require before overarching statements about differences between fired and unfired cartridge cases can be made.

With that in mind, this testing did reveal that there is a need for more exploration in this area as it could potentially yield an effective and easy way of individual cartridge case identification.
Chapter 5 Conclusion
Measurement Analysis

The identification of cartridge cases forensically has provided an invaluable resource to the field of historic archaeology (Pratt 2009). From its first use at Little Bighorn National Monument to its use at Rush Creek, forensic analysis has allowed archaeologists to get a much more detailed understanding of battlefields. The ability to track individual weapons (and possibly individuals) as they move across the battlefield has increased the resolution with which archaeologists can view a battlefield to a level previously unheard of.

This high resolution view of the past does come with a tradeoff. The forensic analysis of cartridge cases requires hours of training and specialized equipment in order for it to be conducted effectively. A quick Amazon search shows that lower end comparison microscopes can go for $1,800 which is a lot of money to a small anthropology department (Amazon.com 2011).

Developing alternative, less expensive techniques will allow more archaeologists to achieve at least some of the data that is attained from forensic analysis techniques. These alternative techniques may not be as accurate as forensic analysis or replace their use in the courtroom, but they could allow for a better understanding of sites more quickly and allow archaeologists to make the determination whether or not they wish to use more expensive and time consuming analysis tools.

In this thesis two alternative methods of class and individual cartridge case identification were tested in order to determine if they would be effective in either type of identification.
3D Scanner Comparison

3D scanning needs to be embraced by the field of archeology. The ability to preserve artifacts in a digital format and then make those artifacts available to other archeologist is a too invaluable tool to ignore. The benefits of 3D scanning, increasing accessibility to artifacts and allowing for detailed analysis, are clear in theory. However without analysis of the effectiveness of the many 3D scanners available informed decisions cannot be made by archeologists looking to use the technology. In this thesis 3 of the available 3D scanners were tested using scans of cartridge cases and the effectiveness of these scanners was determined by whether the scans were enough to conduct class cartridge case identification or individual cartridge case identification.

In the comparison of 3D scanners, the Brueckmann SmartScan HE with its high cost and low resolution scan would not be a very effective purchase for the scanning of small artifacts including cartridge cases, which is understandable as the scan is intended for scanning items much larger. While the scanner was found ineffective for scanning small artifacts, further testing should be conducted to see if it is capable of producing detailed scans of larger artifacts before its possible use is completely discounted.

The DAVID Laserscanner, on the other hand, produced very useful results when it came to level of detail, but there is a steep learning curve when it comes to effectively using it. The DAVID Laserscanner uses a webcam, a specific background, and a red line laser and requires specific lighting condition to be utilized effectively.

As seen in Figure 0.0 which shows the learning curve of scanning. The four scans shown in the figure are a sample of 15 attempts to get a detailed and useful scan of the
cartridge. The reason it took so many times was the lack of directions that came with the scanner and reasons stated above needing optimum lighting in order to do the scan.

While the final scan was highly detailed, it is not yet detailed enough to show the extraction marks needed for forensic identification, which makes it not very useful in that respect, but the quality of the scan could be high enough for other artifacts. In addition, the quality may be able to be increased with further practice, and possible equipment improvements like a higher resolution webcam, and software upgrades from DAVID-Laserscanner.

The analysis of the NextEngine scanner resulted in mixed results. While scans of cartridge cases were not available for analysis due to technical difficulties, it is apparent from scans of other artifacts that the NextEngine scanner is capable of producing high quality scans that are detailed enough to be used for analysis.

Due to the lack of cartridge case scans the NextEngine scanner cannot be recommended for use in individually identifying cartridge cases. However, once its technical deficiencies are overcome, the NextEngine scanner is probably the ideal candidate for use in scanning artifacts.

This recommendation comes from its automated scanning features and ability to produce high quality scans in any lighting conditions. While the scanner still requires some practice to be used most effectively the learning curve is much lower than the DAVID-Laserscanner. While the scanner is not exactly cheap ($2,995) its cost does not put it out of reach of most archeological departments or historical institutions. In addition, while it may be more expensive than some comparison microscopes, it can be
used for multiple purposes such as the scanning and digital reassembly of pottery fragments, while a comparison microscope can only be used in individual cartridge case identification.

**Cartridge Case Measurement Analysis**

The cartridge case measurement analysis portion of this thesis was based on the hypothesis that when cartridges are fired, the cartridge cases are altered in a measurable way that is unique to the weapon in which they were fired. This unique signature can be used to identify in which weapon a cartridge case was fired allowing for individual cartridge case identification without the need for other forensic techniques. Four attributes of cartridge cases were selected to be measured to test this hypothesis: rim diameter, base diameter, total length and mouth diameter. The measurements were collected using a digital caliper, a low tech tool requiring little training to operate.

After collection the measurements were tested for two things using various statistical analysis methods. First, the measurements were analyzed to determine if there were any statistically significant differences between fired and unfired cartridge cases. Second, the measurements from each fired cartridge case were compared to each other to determine if any measurements were significantly similar to each. Based upon the hypothesis, cartridge cases that were fired in the same weapon would have similar measurements that would indicate that they were fired in same weapon without having to conduct forensic individual identification.

This hypothesis was initially tested on cartridge cases taken from the Rush Creek battlefield. This collection was chosen because the cartridge cases associated with it had
already been sorted by individual weapon using current forensic individual identification techniques. The fired cartridge case measurements were compared to unfired cartridge case measurements to determine if the difference in measurements was statistically significant. The results of the binary logistic regression used to compare fired and unfired cartridges showed there were no statistically significant differences between fired and unfired .44 Wesson cartridge cases.

Even with those results a comparison of the fired cartridge cases was conducted in order to determine if any patterns emerged that could be used for individual cartridge case identification. This analysis was conducted using a Kruskall-Wallis one way analysis of variance. The results showed a statistically significant difference between total length and base diameter in collection of cartridge cases. However, further investigation showed that this difference was only statistically significant between cartridge cases associated with weapon 4 and weapon 7 and was not statically significant in a pattern that would indicate that the difference could be used to individually identify cartridge cases.

Some possible issues with the analysis of the Rush Creek cartridge cases was the small size of the collection and that the cartridge cases could have been by several different manufacturers, each with its own understanding of what the sizes of a .44 caliber cartridge constituted.

In order control for these problems, a second experiment was designed. This experiment was based the same hypothesis that fired cartridge cases have different measurements from unfired ones and that these different measurements are unique to the
weapon in which they were fired. In order to control for differences in manufacturing, cartridges from the same manufacturer and the same box of ammunition were used for the testing. Further only one weapon, an 1885 seven shot Young American Double Action revolver, was used. While the hypothesis of the test was the same the Rush Creek testing, the primary focus of the testing was determine if there were statistically significant differences between fired and unfired cartridge cases.

The comparison of the fired and unfired cartridge cases was conducted using a Mann-Whitney U test was showed that the difference between fired and unfired cartridge cases was statistically significant for all four measurements. This difference proves that the first part of the hypothesis was correct, but only in the case of an 1885 seven shot Young American Double Action revolver.

While the testing of the revolver shows that there are statistically significant differences between fired and unfired cartridge cases the testing only applies to this specific case. Further testing is required before this difference can be assumed to happen with other cartridge cases and other weapons as well.

In addition, while the testing determined that differences between fired and unfired cartridge cases exist in some cases, it did not answer the question of whether or not this difference is unique to each weapon and can be used for individual cartridge case identification.

In order to answer this question, further testing is required. The next logical experiment would include the use of several weapons, at least four, of the same caliber and the same manufacturer, and the cartridge cases would also be from the same
manufacturer, preferably the same box of ammunition. Several cartridges would then be fired in each weapon and the resulting cartridge cases would be collected and identified which weapon fired them.

The collected cases would be analyzed using the measurement methods described previously and then the appropriate statistical analysis would be conducted in order to determine if the measurements of a fired cartridge cases were unique to the weapon in which they were fired.

Conducting an experiment requires that several obstacles be overcome. First, the gathering of four historic firearms of the same make and model could be difficult give the rarity of period weapons. Another factor would be that many historic weapons are not fit to be fired and many collectors and institutions will not be too keen on risking these weapons for this experiment. Second, historic ammunition is quite valuable and many collectors would not be willing to let it be fired. Reloaded ammunition could possibly be used but things like the type of powder used, the quality of copper, even the lead used for the bullet must be taken into consideration as these could all have an effect on how the cartridge cases are altered by being fired.

**Overall Conclusion**

The current methods of artifact identification and storage are limiting future research. With technology available today, these artifacts can be made available in a digital format to researchers and the public alike.

The 3D scanners tested here show that technology has reached a point where it can effectively used to conduct artifact analysis and make the artifacts available to
everyone. The caveat being that like any new technology there will be certain growing pains when it comes to implementing it effectively, but these problems are not insurmountable. Adopting this technology could also lead to the development of new and better ways to conduct analysis, for example, individual cartridge case identification.

Individual cartridge case identification is an important part of battlefield, and while current methods are effective, they are costly and time consuming. Further experimentation is needed to develop alternative ways to individually identify cartridge cases. In this thesis two different ways, high tech ways using the latest in 3D scanning technology, and a low tech way using a simple digital caliper, were analyzed for their potential to yield positive results when it comes to individual cartridge case analysis.

Both of the methods analyzed in this thesis are still too immature for everyday use by archeologists, but they both have the potential to one day become an essential part of archeology. Archeologists must continue to experiment with new and different ways of conducting their trade in order become more effective. Just because archeologists study the past does not mean that our methods must also remain in the past.
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