



# A FUNCTIONAL ANALYSIS OF TWO 3D-SCANNED ANTIQUE PISTOLS FROM NEW ZEALAND

## UN ANÁLISIS FUNCIONAL DE DOS PISTOLAS ANTIGUAS ESCANEADAS EN 3D DE NUEVA ZELANDA

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### Highlights:

- Preservation of historical machines requires continual maintenance, including replacement of worn or missing parts.
- A combination of 3D scanning and digital models was used to analyze two antique pistols from New Zealand: a converted flintlock pistol and a transitional revolver.
- The method of making and analyzing digital models detailed in this study offers a way to facilitate historical preservation, experimental archaeology, and functional analysis.

### Abstract:

Preservation of historical weapons requires continual and careful maintenance. Digital three-dimensional (3D) scanning can assist in preservation and analysis by generating a 3D computer model. New Zealand presents a special case for historical preservation, owing to the rapid import of European goods in a culture previously unexposed to metalworking. This, and the subsequent British colonization, led to upheaval and war. The most intense conflict between British and Maori forces was in the New Zealand Land Wars of the mid-19<sup>th</sup> century. The primary handheld firearms used in this period were black-powder muzzle-loaders, and the variety of armed factions involved in the war resulted in an eclectic range of weapons used. Two antique muzzle-loading pistols from this period were scanned and analyzed. Insights were gained into the history of double-barreled muzzle-loading pistols and transitional revolvers. The double-barreled pistol was determined to have been a flintlock pistol from a century prior to the Land Wars, later converted to percussion cap ignition. The transitional revolver was an intermediate step between the multi-barrel pepperbox pistol and the "true" revolver, but it remained in use throughout the Victorian era. Both types of firearms were effectively obsolete elsewhere in the world by the time of the Land Wars, but the conflict created a demand for a variety of weapons. While the pistols analyzed in this study are decommissioned and no longer in working order, the 3D models made from the samples afforded a unique glimpse into New Zealand's history. The methodology detailed over the course of the study can be applied to other historical firearms in order to facilitate preservation, investigation, and experimentation.

**Keywords:** historical weapon; 3D modeling; antique pistol; 3D digitization; digital preservation; 3D reconstruction

### Resumen:

La preservación de las armas históricas requiere un mantenimiento continuo y cuidadoso. El escaneo digital tridimensional (3D) puede ayudar en la preservación y el análisis mediante la generación de un modelo informático en 3D. Nueva Zelanda presenta un caso especial para la preservación histórica, debido a la rápida importación de productos europeos en una cultura que no estaba expuesta a la metalurgia. Esto, junto con la posterior colonización británica, provocó disturbios y guerras. El conflicto más intenso entre las fuerzas británicas y maoríes se produjo en la Guerra de las Tierras de Nueva Zelanda a mediados del siglo XIX. Las principales armas de fuego de mano utilizadas en este período fueron los cargadores de pólvora negra, y la variedad de facciones armadas involucradas en la guerra dio lugar a una gama ecléctica de armas utilizadas. Dos antiguas pistolas de carga con boca de este período fueron escaneadas y analizadas. Se adquirieron conocimientos sobre la historia de las pistolas de doble cañón de carga con boca y los revólveres de transición. Se determinó que la pistola de doble cañón era una pistola de chispa de un siglo antes de la Guerra de las Tierras, convertida más tarde en una pistola de percusión. El revólver de transición fue un paso intermedio entre el revolver pimentero de varios cañones y el "verdadero" revólver, pero se siguió utilizando durante toda la época victoriana. Ambos tipos de armas de fuego habían quedado obsoletas en otras partes del mundo en el momento de las Guerras, pero el conflicto creó una demanda de variedad de armas. Aunque las pistolas analizadas en este estudio están fuera de servicio y ya no funcionan, los modelos en 3D realizados a partir de las muestras permitieron dar un vistazo único a la historia de Nueva Zelanda. La metodología detallada en este estudio puede aplicarse a otras armas de fuego históricas con el fin de facilitar la preservación, investigación y experimentación.

**Palabras clave:** arma histórica; modelado 3D; pistola antigua; digitalización 3D; preservación digital; reconstrucción 3D

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## 1. Introduction

Historical weapons require specialized care and handling for long-term preservation. As early firearms were handmade, the loss of even a single component can render the device non-functional. Even if the device is not actively used, periodic restoration is still required (Edessa, 2016). This often requires highly specific knowledge about the artifact's composition and construction, which can be difficult to obtain in large collections (Fritsch & Klein, 2018b). Advances in digitized scanning and archiving can improve maintenance, help detect forgeries, increase the accessibility of historic machinery, and facilitate experimental archaeology and analysis (Kumar, Snyder, Duncan, Cohen, & Cooper, 2003; Rojas-Sola & de la Morena-de la Fuente, 2018; Rojas-Sola, Galán-Moral, & de la Morena-de la Fuente, 2018; Neumüller, Reichinger, Rist, & Kern, 2014). Two decommissioned, antique muzzle-loading pistols from New Zealand were disassembled, scanned, and reconstructed for a comprehensive analysis.

## 2. Background

### 2.1. Digital reconstruction

Digital reconstruction offers the potential to record and preserve historical artifacts and architecture. Laser-based three-dimensional (3D) scanners and photogrammetry have been used to record historic architecture and artwork for years (Fritsch & Klein, 2018a, 2018b; Kumar et al., 2003; Menna, Nocerino, Del Pizzo, Scamardella, & Ackermann, 2011; Neumüller et al., 2014; Vrabel, Bellon, & Silva, 2009; Wachowiak & Karas, 2009). Models were made from the digital 3D models, which, in turn, were used to make virtual museum exhibits. Superficial, non-invasive scanning was sufficient for structures and artifacts without internal parts, such as tablets or sculptures (Wei, Chin, Majid, & Setan, 2010; Fritsch & Klein, 2018b; Kumar et al., 2003; Pejić & Krasić, 2016). Related work was conducted using a multimodal combination of technologies for ship hulls (Menna et al., 2011b), a photogrammetric system for a sword (Gil-Melitón & Lerma, 2019), and a high-resolution white-light scanner for dental profiles (Fiorenza et al., 2018).

Devices with complex internal components require either non-invasive scanning or careful disassembly. Even with a successful scan, a high-resolution model must still be made. Small components, such as gears or pins, can substantially increase the time and effort required for the task (Stanco, Battiato, & Gallo, 2011; Rojas-Sola & de la Morena-de la Fuente, 2018). Some components may be missing or degraded, requiring either primary source consultation or experimental reconstruction (Hsiao & Yan, 2012; Estalayo, Aramendia, Matés Luque, & Madariaga, 2019). Such sources, however, may not be available for all artifacts. In certain cases, inferences can be drawn from the device itself (Menna, Nocerino, & Scamardella, 2011; Neumüller et al., 2014). Such is often the case for antique firearms (O'Brien & Garcia, 2005).

### 2.2. Antique guns

Due to the invention of the percussion cap, firearms technology rapidly advanced in the early 1800s. Prior to percussion cap ignition, the flintlock was the dominant

ignition method used in European firearms (Hogg, 1980; The Diagram Group, 2007; Kolesnik & Holubieva, 2018; Kohanoff, 2019). As Europeans had ventured overseas for conquest, commerce, and colonization for centuries by this point, older models of firearms were still in use, and even upgraded (Belich, 2013; Hacker, 1994; Kohanoff, 2019; Jones, 2019; Steyn, 2018; Hackelton, 2019). Caplock firearms converted from flintlock ones still retained signs of the older mechanism, even after removal (Hogg, 1980).

The dominant firearms of the era were single-shot muzzle-loaders (Kolesnik & Holubieva, 2018). In the early 1800s, breech-loading firearms and revolvers were rare (The Diagram Group, 2007). Both were known, but they were unreliable and expensive to produce with the technology and metallurgy of the day. Other technologies, such as multi-shot firearms with superposed loads, multi-barrel firearms, manually repeating firearms and repeating air rifles were known, but they suffered from similar constraints (The Diagram Group, 2007; Hogg, 1980). As such, the most common way to ensure multiple, reliable shots in the same firearm was to include additional barrels.

Multiple barrels increased the weight, cost, and complexity of the firearm. Examples of multiple-barrel firearms include volley guns, which used independent barrels stacked on top of each other, and pepperbox pistols, which are the multi-barrel predecessors of the revolver (O'Brien & Garcia, 2005). The first "modern" revolver is usually considered to be Samuel Colt's Paterson revolver, although Elisha Collier's flintlock revolver predates it by over two decades. As a revolver allowed the discharge of multiple cartridges through a single, rifled barrel, it was lighter and longer-ranged than a pepperbox pistol (The Diagram Group, 2007; Hogg, 1980).

To compete against true revolvers, gunsmiths adapted pepperboxes into transitional revolvers. Transitional revolvers were essentially cut-down pepperbox pistols with a short "barrel" grafted onto the upper part of the frame. The alignment of the cylinder with the added barrel was often imprecise, so a misaligned cylinder could result in the catastrophic failure of the firearm and injury to the shooter (Hogg, 1980). However, such weapons had the advantage of double action, where a single trigger pull would both rotate the cylinder and fire the weapon. This was a distinct advantage over the single-action revolvers of the era, which had to be manually re-cocked before each shot. In addition, transitional revolvers likely would have been cheaper than "true" revolvers. As such, they were common among sailors, settlers, and colonists, as well as some soldiers of the era.

### 2.3. Historical context

Polynesia was among the last locations colonized by European powers, owing to the distances involved and demand for whale oil. Among the Polynesian islands, New Zealand had strategic and economic value. Advantages included its proximity to South Pacific and Antarctic waters for whaling and sealing, as well as its ability to support a large population (Dean & Moss, 2018). The indigenous Maori traded with sailors for firearms, and other weapons were brought by British colonists (Ulrich, 1970; Kohanoff, 2019). These weapons were

used in the Musket Wars and the Land Wars, as well as for unofficial and personal use (Belich, 2013). As such, the South Pacific in the early 1800s was a place of rapid change and instability (Dalton, 1966; Belich, 2013). Despite this, many imported firearms remain intact, if inactive. However, few have been digitally scanned and reconstructed.

**2.4. Motivation**

The New Zealand Land Wars were a series of military confrontations between a well-equipped colonial power and irregular rebel forces. Although consistent victories by indigenous fighters were the exception in the Victorian era, the New Zealand rebels were able to achieve tactical, operational, and even strategic objectives (Dean & Moss, 2018; Belich, 2013). The factions included not only the British military and rebel Maori, but also New Zealand militias, Maori loyalists, and other auxiliary forces (Belich, 2013). In terms of small arms and handheld firearms, the combatants had access to largely similar types of firearms for much of the Land Wars period (Ulrich, 1970; Dean & Moss, 2018). Firearms were provided by sympathizers, the combatants themselves, theft or illegal deals, or acquired through commercial channels. However, the military calculus of the period ultimately favored conventional military forces, often due to logistical and economic reasons (Ulrich, 1970).

With the widespread adoption of breech-loading firearms and repeating rifles, this changed. Even then, such advantages were often incremental, rather than consistently decisive (Dean & Moss, 2018). Due to institutional changes, demographic shifts, and military advances, resistance shifted to non-martial methods (O'Malley & Kidman, 2018; Wirihana & Smith, 2019). An investigation into period weapons could highlight potential differences in the military strategies and outcomes of various factions.

**2.5. Methodology**

The undertaking required a source of antique weapons, a facility, skilled personnel to perform the scan and reconstruction and secure the transport of specimens, and an individual to analyze the reconstructed digital models. Following this, the samples would be returned to their source. Risks included possible damage to historical artifacts, inaccurate reconstruction, and the loss of one or more original components. Age and condition precluded loading and discharge of the antique firearms.

Support was sought from a private collector in New Zealand who possessed well-preserved and partially functional weapons of that era. A 3D scanning company was identified, with equipment precise to sub-millimeter levels. A high resolution was deemed satisfactory enough for Victorian gunsmithing, which was constrained by hand tools and early machinery (Hogg, 1980; The Diagram Group, 2007). The scanning resolution of 0.1 mm was used for each component (Russell, 2016). The 3D scanner used was a REVscan by Handyscan (Creaform, USA).

Component damage to antique parts was a considered risk. To properly handle the antique parts, workers at the facility used rubber gloves to prevent skin oil contamination and minimized direct exposure of each component to ultraviolet light (Stanco et al., 2011). Each specimen was carefully disassembled as detailed in Fig. 1, down to original screws and tacks.

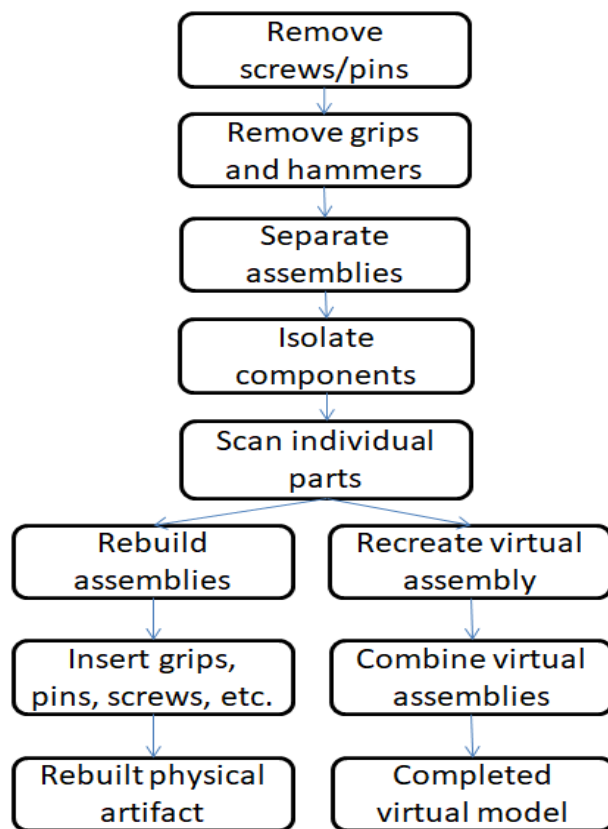


Figure 1: Process to disassemble, scan, and reconstruct each pistol.

As shown in Fig. 2, each component was affixed inside the scanner (3D). Lasers mapped the object in three dimensions. From the rotational map, a model of the shape and texture features at 0.1 mm was generated. The conditions in the scanner were sufficient to preclude the reflectiveness of any component from affecting the resulting model. Simulated “restorations,” i.e., a model without wear and corrosion, were similarly generated for each part. The process revealed information about both artifacts.



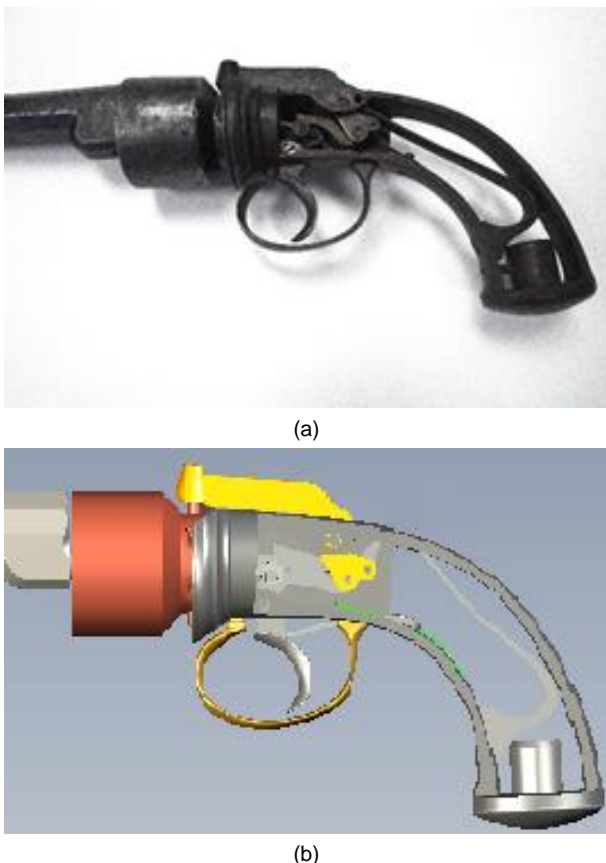
Figure 2: Frame of transitional revolver in the 3D scanner.

Each scanned component was used to make a 3D model, preserving original detail and dimensionality as much as possible. In addition, erosion and stress were estimated, and two digital models of each sample were made: the sample as scanned, and an estimated reconstruction model of its original form. Both models were saved

in STEP format, a format widely used in computer-aided design (CAD) (International Standards Organization, 1994). Both the scanned artifact and the reconstructed artifact were saved as separate meshes in the same file, using Creo 5.0 software (PTC, Boston, USA).

STEP format allows the simultaneous storage of multiple “meshes” in relation to each other. A “mesh” can be made visible or hidden based on the desired details. In the case of the reconstruction, each mesh corresponded to a different component or layer of detail (a reconstruction of a worn or damaged component, for instance). In this way, a single STEP file could store multiple details about one assembled object and its components (ISO, 1994).

Disassembly began with the removal of externally accessible pins and screws. If necessary, they were gently drilled or hammered out. The larger external components, such as the hammers and grips, were removed first, as shown in Fig. 3. Assemblies of smaller components, such as the trigger, mainspring, and hammer, were removed from the frame. As summarized in Fig. 1, the artifacts were eventually reduced to separate, individual components. Each component was placed in the scanner, and virtual reconstruction was conducted for each individual assembly. Comparisons to the physical counterparts were performed when necessary.



**Figure 3:** Comparison of partially dissembled pistol and computer model: a) View with wooden grips removed; b) Computer model with cylinder highlighted for visibility.

Reassembly of the artifacts was performed in the opposite order of the disassembly. To ensure secure delivery, a private courier service was used for sample transportation. Upon completion, the digital models were sent to an independent expert.

The expert was familiar with Victorian militaria, including the Napoleonic period, the American Civil War, and the New Zealand Land Wars. The expert searched for comparable examples of each firearm in other collections, the published literature, auction catalogs, and archival information. In addition, the expert also had direct experience in the collection, restoration, and preservation of military antiques. The findings of each sample were reported.

### 3. Results and discussion

#### 3.1. Overview

Two antique and decommissioned firearms were acquired from a private collection in New Zealand. The first was a double-barreled caplock pistol that had been converted from flintlock. The second was a caplock transitional revolver. The scanning process used a resolution of up to 0.1 mm. The reassembled units were then returned to the private collection. Following this, the digital models were analyzed. Discussing each component in the model down to screws and pins would be excessive, so only the major parts and assemblies of each pistol were covered.

#### 3.2. Double-barreled pistol

Shown in its entirety in Figure 4, the first pistol is almost three centuries old; it was originally fabricated as a double-barreled flintlock pistol. The orientation of the two barrels in over-under configuration is less common than the side-by-side positioning, but it is not distinctive of a particular nation or gunsmith. However, the caliber of the pistol provides evidence of its origins (Hogg, 1980).

In the late 1700s, the Royal Navy adopted the Sea Service pistols, some of which were chambered in 0.54 caliber (~13.7 mm). From the 1700s to the end of the Napoleonic Wars, the British heavily used the 0.54 caliber Sea Service pistols in their wars with the French. Like other flintlock firearms of the era, Sea Service pistols were converted to caplock in the early 1800s (Hogg, 1980). Even in the era of revolvers, such weapons could be found widely among colonists, sailors, and as unofficial military sidearms (Urlich, 1970). The virtual model is shown in Fig. 5.

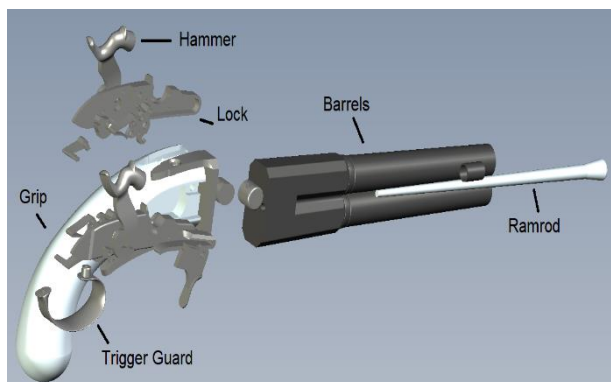


**Figure 4:** Exterior of the double-barreled pistol, converted from flintlock to percussion cap ignition.



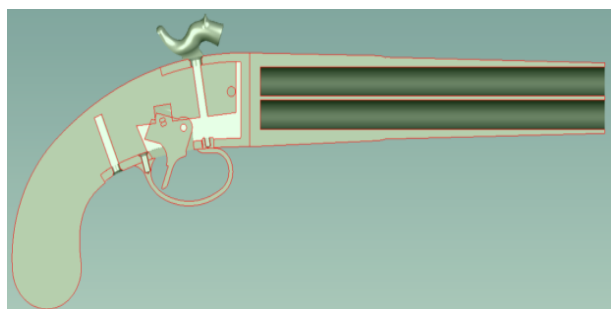
**Figure 5:** Complete virtual model of double-barreled pistol.

The pistol bears a superficial similarity to others. The famous Anglo-Swiss gunsmith Durs Egg made over-under flintlock pistols in a similar design, although with different grip styles (Garth Vincent *Antique Arms & Armour*, n.d.). Non-firing commercial replicas are modeled after a similar but distinct “turn-over” pistol (Denix, n.d.). The fictional character Lirianne in *Pathfinder*, a tabletop roleplaying game, uses similar over-under muzzle-loading pistols, although their appearance and mechanism vary depending on the artist (Frasier, 2011). The main components are shown in Figure 6.



**Figure 6:** Exploded assembly of the double-barreled pistol showing major component parts.

The caliber of the pistol, as well as its apparent conversion, suggests a transition in social class as well as purpose. It was likely initially commissioned by a British officer or wealthier individual for use as an unofficial sidearm (Hogg, 1980). The caliber choice may be due to its intended use as a naval officer’s weapon, but its owner may also have been a civilian sailor or army officer. It was likely chambered in 0.54 caliber to facilitate ammunition procurement through the use of a common bore size (The Diagram Group, 2007). As shown in Fig. 7, the addition of a second barrel to the weapon, which increased its cost and complexity, suggests that the user desired the capacity for a rapid follow-up shot.



**Figure 7:** Bisected view of the double-barreled pistol.

Given the age, caliber, and style of the pistol, it likely saw action in the Napoleonic Wars as a flintlock. Like other military surpluses, it was upgraded and later rendered obsolete. The pistol later arrived in New Zealand, where British colonists, foreign sailors, and the Maori equipped themselves with whatever firearms they could acquire (Belich, 2013; Ulrich, 1970; Dean & Moss, 2018). As the first permanent European settlement in New Zealand was in 1815, the pistol may have arrived in New Zealand prior to the Treaty of Waitangi in 1840. However, it is probable

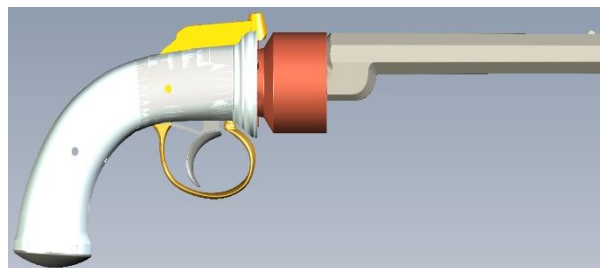
the pistol arrived in the 1830s or later, when Britain performed large conversions of flintlock firearms to caplock (Ulrich, 1970; Hogg, 1980). Figure 8 shows the converted hammer and lock up close.



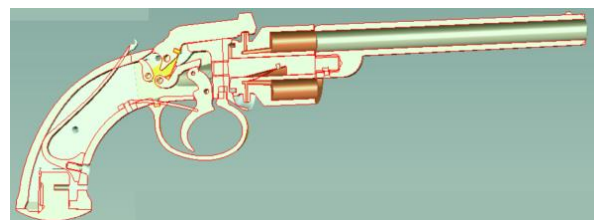
**Figure 8:** Close-up of double-barreled pistol.

### 3.3. Transitional revolver

The second pistol is a transitional revolver in 0.442 caliber (approximately ~11.2 mm), shown in its entirety in Figure 9 and bisected in Figure 10. The revolver cylinder has six chambers and is rotated by a double-action trigger. Before use, black powder and a bullet would be inserted into each cylinder, and a percussion cap would be placed on each of the “nipples” on the cylinder. When the trigger was pulled, the hammer would be raised and then dropped onto an unfired percussion cap, once the cylinder was rotated. The spark from the percussion cap would ignite the primary charge and expel the bullet from the chamber (The Diagram Group, 2007).



**Figure 9:** View of transitional revolver's virtual reconstruction.



**Figure 10:** Bisected view of transitional revolver.

Transitional revolvers were used until they were displaced by “true” revolvers, which were later replaced with cartridge-firing revolvers (The Diagram Group, 2007). Transitional revolvers and pepperbox pistols were seen as cheaper alternatives to “true” revolvers, and they were present across British colonies, including Australia and New Zealand (O’Brien & Garcia, 2005).

The bar hammer, as shown at the top rear of the pistol, is similar to other transitional revolvers and pepperbox

pistols, such as others designed by the American gunsmith Ethan Allen ([The Diagram Group, 2007](#)). As such, the weapon was likely manufactured between the 1840s and 1860s, and it probably arrived in New Zealand shortly afterward. Transitional revolvers were used in the American Civil War and the colonial wars of Britain, France, and Europe ([Hogg, 1980](#)). As such, there is a chance the pistol may have been present in New Zealand during the Land Wars ([Urlich, 1970](#)).

The revolver's composition, shown in Figure 11, offers clues about its history. The caliber of the weapon suggests British manufacture, or a gunsmith trying to accommodate British military standards. The 0.442 caliber was also known as 54-bore to Victorian gunsmiths. The Beaumont-Adams revolver in 54-bore was the standard British Army sidearm from about 1850 to 1880 ([Hogg, 1980](#)). Such a caliber would simplify ammunition procurement in a remote colony. Faded engravings are also present, though they are not depicted in the model.

The complex, double-action mechanism is shown in Figure 12. Such actions were not uncommon in the relevant era ([Hogg, 1980](#)).

While difficult to prove conclusively, a possible manufacturer was S. W. Berry of Woodbridge, Suffolk in the UK, a gunsmith active from 1840 to 1860. The name indicates possible Welsh heritage ([Garth Vincent Antique Arms & Armour, n.d.](#)).

A transitional revolver with a similar finish, size, and style was sold at private auction, although the caliber was different. The pistol possesses an octagonal, smoothbore barrel with a single "front post" sight, suggesting that it was only accurate at point-blank range. Given the low cost and ease of acquiring ammunition, such a weapon would have been useful to a sailor, settler, or soldier as a sidearm, should their primary weapon fail ([Dean & Moss, 2018](#)). Given the rapid spread of British settlements in New Zealand during the same period, such a weapon would have been a typical example of its category ([Hogg, 1980](#)).

### 3.4. Additional considerations

The scanning process facilitated internal and external analysis, but there are other considerations. First, both pistols use leaf springs, as opposed to coil springs, due to the metallurgy of the time ([Hogg, 1980](#)). Metal fatigue was readily visible in both pistols' leaf springs, as visible in Figure 12. Small parts, such as those pictured in Figure 13, required careful handling.

Second, such firearms were intended to be used with period-appropriate black powder, rather than modern propellants, which generate at least three times as much energy and pressure. Attempting to use modern gunpowder in such a firearm would result in catastrophic failure and, potentially, lost fingers. Even when black-powder muzzle-loaders dominated the battlefields, more fatalities were caused by infected gunshot wounds than by the instant impact of the gunshot itself ([Hogg, 1980](#); [The Diagram Group, 2007](#); [Reilly, 2016](#); [Zellem, 1985](#); [Thivierge, 2017](#)).

Third, the lack of rifling and sights on both firearms are typical of the period, where "hip shooting" was commonplace, especially at point-blank range ([Hogg, 1980](#); [The Diagram Group, 2007](#); [Dean & Moss, 2018](#)).

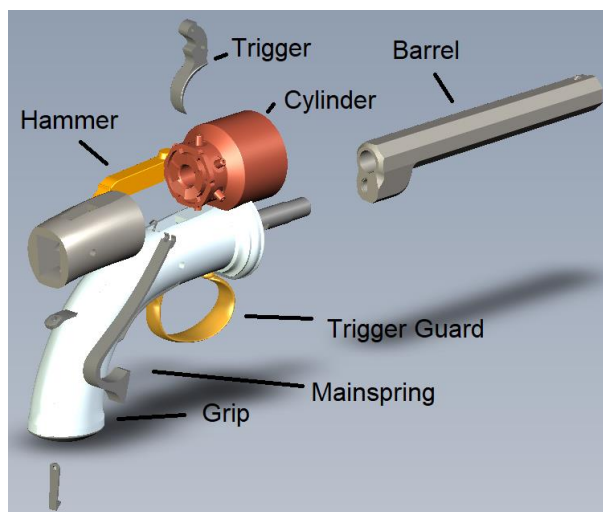


Figure 11: Exploded view of major components in the transitional revolver.



Figure 12: Grip, trigger, hammer, and mainspring of the transitional revolver.



Figure 13: Small metal components from the transitional revolver, including trigger assembly components and leaf spring.

The effective range, power, and accuracy of these firearms were greatly reduced, even compared with later Victorian designs.

Due to the hand-fitted nature of many of the parts and conversions, disassembly required great care. Reassembling the pistols after scanning, both the originals and *in silico*, required careful handling and adjustment. Replicating the process on other antique machines will require similar care.

### 3.5. Closing remarks

Of the two samples, the double-barreled pistol is clearly the older gun. The external components indicate a conversion from flintlock to percussion cap ignition. The transitional revolver was more widely used earlier in the 1800s, but effectively obsolete by the middle of the 19<sup>th</sup> century. Even by the intense period following First Taranaki War in 1860, both firearms would have been effectively obsolete (Dean & Moss, 2018).

Relative obsolescence did not preclude their use in the ensuing conflicts. Such weapons would have been available on the colonial frontier as surplus, or commonly used by settlers and sailors. A handful of British officers and enlisted troops furnished their own private sidearms, often preferring weapons better suited to colonial conditions (Dean & Moss, 2018; Ulrich, 1970).

By modern metrics, the deficiencies of both the double-barreled pistol and transitional revolver are evident. While the particular samples analyzed in this study are decommissioned, even functional, period-accurate reproductions would be impractical for any purpose except re-enactment, experimental archaeology, historical exhibition, cultural events, and perhaps muzzle-loading target shooting (Hogg, 1980; The Diagram Group, 2007).

These weapons' performance in target sports would be extremely limited by their inaccuracy. The complex loading procedure, archaic ignition method, limited ammunition capacity, short effective range, constraint to black powder as a propellant, and innate inaccuracy greatly limit their efficiency as weapons (Perdekamp et al., 2013; Hogg, 1980; Hejna, Šafr, Zátoková, & Straka, 2012).

Even in countries where period-accurate reproductions are exempt from the licensing requirements of their modern counterparts, they are almost entirely unused in suicide, violent crime, or murder (Hejna et al., 2012; Perdekamp et al., 2015). Contemporary firearms, even improvised and illicit ones, offer far greater lethality, range, power, ammunition capacity, and convenience (Hogg, 1980; Gojanović, 1995; Lee & Meng, 2011). Even at the peak of muzzle-loading pistols' usage, long arms, artillery, and arguably melee weapons were far more efficient killing tools (Leoni, 2014; Hogg, 1980; The Diagram Group, 2007). The efficiency of these weapons paled in comparison with the deadliness of disease, sepsis, and infection, which were the most common complications resulting from injury with firearms. It was not uncommon for those struck by such weapons to make a full recovery, even with the limited medical technology of the Victorian period (Zellem, 1985; Reilly, 2016; Thivierge, 2017).

Regardless of the samples' shortcomings as weapons, the analysis shed light on their possible origins and history.

Such firearms could have been used by almost any faction in the Land Wars, whether British, Pakeha (European-descended) New Zealander, or Maori (Dean & Moss, 2018; Ulrich, 1970). They represented key evolutionary steps between the flintlock weapons of the Napoleonic period, the percussion cap weapons of the Victorian period, and the cartridge firearms of later designs (Ulrich, 1970; The Diagram Group, 2007). While relevant to military technology, the samples also represent enduring pieces of New Zealand's history.

The analysis was made possible by the use of 3D digitization and reconstruction. The successful reconstruction of even small pistol parts suggests that 3D digitization and digital reconstruction may be useful in the analysis of other mechanical artifacts (Rojas-Sola & de la Morena-de la Fuente, 2018). Indeed, other Victorian machines, such as pocket watches and music boxes, possessed even smaller, more precise parts (Wachowiak & Karas, 2009). Other antique firearms possess small, hand-fitted parts, which can complicate restoration and preservation (O'Brien & Garcia, 2005). 3D digital recording and reconstruction could greatly facilitate not only Napoleonic and Victorian military history, but also provide insights in to the combatants by analysis of their weapons (Hacker, 1994). While documentation may be lacking for colonial wars, the weapons themselves can tell about those that used them (Dean & Moss, 2018).

## 4. Conclusions

The use of 3D digital recording can facilitate the preservation, analysis, and reconstruction of historical objects such as ships (Menna et al., 2011a). However, precise care is necessary for correct reassembly. This analysis was able to discern important details about the design, history, and use of two antique firearms. First, as the lock of the double-barreled pistol shows, many old flintlock firearms found a second life after conversion to percussion cap. Second, the double-action mechanism and rapid-follow up shots of transitional revolvers potentially made them appealing, despite their lack of formal military adoption.

Due to their age and corroded state, the weapons analyzed in this study cannot be discharged safely, but the application of 3D scanning enabled the researchers to provide new insights into an aspect of New Zealand's colonial history. The models constitute a cultural resource and will be made available to other scholars. It is hoped the process can be replicated with other machines, so original works of craftsmanship and antique machines can be preserved for posterity.

The models are available at <https://github.com/jnu-ose-biomedical-ultrasound-lab/historicalMachines>. The converted flintlock is 'nzModel1.stp' and the transitional revolver is 'nzModel2.stp'.

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