SFSA CAST IN STEEL 2025

George Washington's Alte Presentation Broadsword

Technical Report

Saint Martin's University – Brotherhood of Steel

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1 Introduction

The ability to form metals into various shapes and tools is a very important skill of engineering. As some of the strongest materials that engineers can manipulate, metals, especially steel, are used in daily life. The Cast in Steel competition is a great way for engineering students to demonstrate their understanding of manufacturing processes through their own creativity in designing and forming the designated project. SFSA has created this competition to encourage students to learn about making steel products using the casting process and applying the latest technology available.

This technical report details the challenge requirements of the 2025 Cast in Steel competition (a replica of George Washington's sword) and its significance. In addition, the report explains the process used by the Brotherhood of Steel to draft and create the team's completed piece.

2 Historical Background and Significance

For the 2025 Cast in Steel competition, the challenge was to replicate one of George Washington's many swords. George Washington was undoubtedly one of the most important figures in U.S. American history, with his legacy cemented by his unwavering leadership in the Revolutionary War and his role as the first president of the United States. But beyond being a military commander and statesman, he also had an impressive collection of swords, ranging from practical weapons to highly decorative ceremonial pieces. With so many options to choose from, the Brotherhood of Steel had to think carefully about which sword to recreate. The Mount Vernon website had a variety of choices, each with its own unique design and history. After some discussion, the team decided on the Alte Presentation Broadsword, shown in Figure 1.

Fig. 1 – Alte Presentation Broadsword

The Alte Presentation Broadsword was crafted by Theophilus Alte, a swordsmith from Solingen, Prussia—a town renowned since the Middle Ages for its blade-making prowess (Lange, 1993). Solingen's reputation grew from its skilled smiths who produced durable, sharp steel swords, prized across Europe for their quality (Schulze, 2007). This broadsword reflects that tradition, blending function with all the ornateness fit for royalty.

The sword's story begins around 1795 when Alte made it, and it reached Washington in 1796, a year before his death (Mount Vernon Ladies' Association, n.d.). Unlike other swords which Washington earned through service or bought himself, this one arrived mysteriously. Alte meant for his son, Daniel, to deliver it personally, hoping Washington would offer the young man support. In a letter, Alte called Washington "the only man I know…who acted in an uninterested manner for the happiness of his country," framing the sword as both a tribute to the victor of the American revolution and a favor owed back in the future (Washington, 1796, as cited in Fitzpatrick, 1939). But Daniel never arrived at Washington's door. The sword turned up at a tavern, pawned for $30, and was later sent to Mount Vernon by a stranger via Alexandria, Virginia, nine miles away (Mount Vernon Ladies' Association, n.d.).

Washington wrote about the strange event to John Quincy Adams on September 12, 1796, noting he'd read in a gazette about one "celebrated artist" planning to gift him a fine sword (Washington, 1796, as cited in Fitzpatrick, 1939). He did not pay the rumor much attention until the beautiful sword arrived without explanation, calling it "a perfect enigma" and wondering how it ended up "in such loose hands" and what happened to its bearer (Washington, 1796, as cited in Fitzpatrick, 1939). How the sword got there and what happened to Daniel remains unknown.

As for its make, the Alte Presentation Broadsword is a horseman's sword with a straight, double-edged steel blade measuring about 33.5 inches, making the total length around 39.5 inches (Mount Vernon Ladies' Association, n.d.). The blade is flattened and lenticular—wider in the middle, tapering to a point (see Figure 1) designed for cutting and slashing, common for cavalry broadswords (Oakeshott, 1991).

Symbology on the Alte Presentation Sword

Alte carefully adorned the sword with engravings, etchings, and gilding, showcasing Solingen's craft. Gilding is a process where a thin layer of gold is applied to metal, often by heating gold leaf or a gold-mercury mix and brushing it on, adding a shiny, lasting finish (Untracht, 1982). One side of the blade shows a staff officer trampling a lion and unicorn, a symbology of triumph with "GEORGE WASHINGTON" on a banner above (Mount Vernon Ladies' Association, n.d.). The lion and unicorn come from the British coat of arms, representing strength and purity, here crushed to signal defiance (Fox-Davies, 1909). The other side has a German inscription: "Destroyer of Despotism, Protector of Freedom, Steadfast Man, Take from My Son's Hands This Sword, I Pray Thee, Theophilus Alte at Solingen" (Mount Vernon Ladies' Association, n.d.). This is in High German, the standard written form of the late 18th century, not a regional dialect (Waterman, 1991). The hilt is brass with copper and gold accents, the grip leather wrapped with metallic wire, and a gilt ferrule reinforces it (Mount Vernon Ladies' Association, n.d.).

Solingen swords from this era typically featured high-carbon steel blades, forged for strength and flexibility, with a balance of hardness and toughness (Schulze, 2007). One would typically see a smooth, polished finish, often with decorative etchings or inlays, and hilts made from brass or iron, sometimes gilded for prestige (Lange, 1993). Theophilus Alte's work fits the stereotype, via a solid, durable blade with added flair. Other notable users of Solingen blades were Frederick the Great of Prussia and his army (Duffy, 1985), as well as Napoleon Bonaparte's cavalry swords, his dragoons (mounted infantry) using them as heavy sabers (Elting, 1988).

A Napoleonic Calvary Sword

Solingen smiths would have forged the blade from high-carbon steel in coal forges, hammering it into shape on anvils (Schulze, 2007) possibly utilizing crude auto hammers. The double edges were then ground and sharpened by hand, while engravings were cut with chisels or etched with acid, then gilded for effect (Untracht, 1982). The hilt parts were cast or forged separately and fitted to the blade (Lange, 1993). Each sword was custom made, but Alte likely created this particular sword extra care and time, all to fulfill his aim to impress Washington. The sword is now in the inventory of the Mount Vernon Ladies' Association, donated in 1924 by Alice L. Riggs's descendants (Mount Vernon Ladies' Association, n.d.).

3 Process

3.1 Choosing the Design

Our team began this project by looking through George Washington's collection online through the Mount Vernon website. We looked through the catalog with our priorities being ease of recreation using modern technique we were familiar with. Of the options provided: the 1753 Silver-Hilted Smallsword, the 1767 Silver-Hilted Smallsword, the Silver Lion-Headed Cuttoe, the Green and Ivory Cuttoe, the Alte Presentation Broadsword, the Steel-Hilted Smallsword, and the Officer's Epee. The team was impressed by the meticulous craftmanship and ornate designs of these weapons, but eventually it was decided to go with the Alte Presentation Broadsword due to its thick castable blade, simple handle, and the easily replicable designs on its blade. The Lion-Headed Cuttoe as the second place contender.

Before settling on the Alte Presentation Broadsword, we thoroughly considered the Silver Lion-Headed Cuttoe (pronounced KUT-oh), a sword with a distinctive lion-headed pommel and beautiful spiral grip. This sword's place as one carried during the Revolutionary War by Washington immediately put it towards the top of our internal rankings, but the sword also offered several features for a casting exercise. The lion-headed pommel, with its solid geometry and minimal intricate details, appeared straight forward to replicate with a 3d printed pattern. The color of the lion and handguard also was suited for a steel casting. The grip's matte color was suited for a 3d printed solution, and with a steel under-handle the blade could possibly be made by methods other than casting. However the complexity of the curved blade, seemingly undersized tang, and chain between the pommel and cross guard did not make it an immediate winner.

Lion's head pommels were quite popular on British cuttoes in the early 1760s. Connected to the center of the lion's teeth is a silver ring intended to secure the upper end of the knuckle chain, which is made up of twisted links.

Fig. 2: The Silver Lion-Headed Cuttoe

Our next choice was the Alte Presentation Broadsword. Its design was one of the simplest with its distinctive features being somewhat straightforward to replicate with today's technology. The handle, although detailed, avoids the fragility of the more slender or overly ornate handguards found in swords like the 1753 or 1767 Silver-Hilted Smallswords. Its color, resolution of detail, and features outside of the grip were suited for casting as one piece in bronze, further simplifying manufacture.

Additionally, the blade of the broadsword was seemingly the widest and thickest increasing the chance of our sword surviving unknown testing regimes with a sharp edge. As it became apparent that we were going to end up casting the blade and handle of whatever sword we went with, the thicker blade was also recognized for reducing the risks of porosity and uneven cooling. The very simple and geometric blade also allowed for a "near net shape" outcome meaning the cast blade would be an evenly oversized blade with the same amount of material on all sides, greatly simplifying post processing. After getting farther along in the blade design process further affirmation of our broadsword choice was made in the large tang that we could extend very far back into the handle after we integrated the grip into the handle casing, making the sword even more durable.

The final, although minor, consideration between swords was the ease of replicating the decorative features on the blades. The Alte Presentation Broadsword bears intricate etchings of symbolism on one side and a worded inscription in Prussian on the other, a feature that elevates its suitability for modern replication. These inscriptions, originally hand done, were captured in high resolution 2d images against a silvery background seemingly making for easy digital replication. Of all the swords, the Broadsword was the best for this sort of replication due to its boxy nature.

3.2 Planning

The team created a rough plan based on ideal conditions and known constraints. Initial designs consisted of breaking the sword into 5 different parts: the blade and 4 distinct handle pieces. Through discussions with our advisor, it was determined that the optimal choice would be to combine these pieces into two different castings. The first one being the blade, and the second being a one-piece handle. The handle would include two undersized holes to guide a drill press bit through the tang in the intended places. The handle would be investment cast to shape, with any grainy details finished up by a Dremel tool, then the whole handle would be ground down with a flapper wheel on a angle grinder then polished up afterword. The blade would come cast slightly oversized and heat treated at the foundry. Then each side of the blade would be face-milled down to the width of the tang with a CNC mill, then finished with a angle grinder. Next the blade would be engraved by a ornate laser engraving on both of its flat sides. Finally, the sword blade would then be coated in a oil spray to prevent rusting.

To assemble the sword the oversized tang would be brought down slowly by a angle grinder, with a focus on the corners, until the slides on all the way. Then a brass rod will be cut into pins slightly greater than the width of the handle with one of their ends rounded down with a belt sander. Next, a drill press would be used to extend the holes in the handle through the tang, then expanded until slightly smaller then the pin, then expanded by reamers until the brass pin's rounded end can be hammered though and ground down with a Dremel tool to be flush to the handle.

3.2.1 Hilt Planning

Initially, our team planned on using brass for the hilt of the blade. Basing our design off of the Alte Presentation Broadsword's hilt, which utilizes a brass guard with a copper grip. However, due to wanting to maximize our partner's abilities and expertise, we opted to use bronze as the primary handle material. Despite using different material, bronze can still offer sufficient mechanical properties. Accompanied with its attractive appearance, bronze is a desirable replacement for Brass. Compared to brass, bronze features low metal-to-metal friction, an ideal characteristic for a melee weapon such as a sword. Additionally, bronze is naturally highly corrosion resistant, making it especially desirable for a weapon expected to be in severe conditions.

Upon initial investigation of the Alte Broadsword, it was believed that the handle was made of four components. The under-handle with its slash guard, a ring press fit on below that which the pommel cover extends into, brass pommel cover to conceal the ends of the leather wrap as well as the tang end, and a leather wrap for the handguard. We believed that the handguard was assembled by first sliding the upper handle onto the tang, then the bottom of the tang was either screwed or hammered into the bottom of the handle, next the handle was wrapped in the copper inlayed leather strip, after that the pommel cover was slid on which may have had a slot in the under handle handguard for extra stability, and finally the brass ring was press fit onto the extension of the pommel cover underneath the handguard.

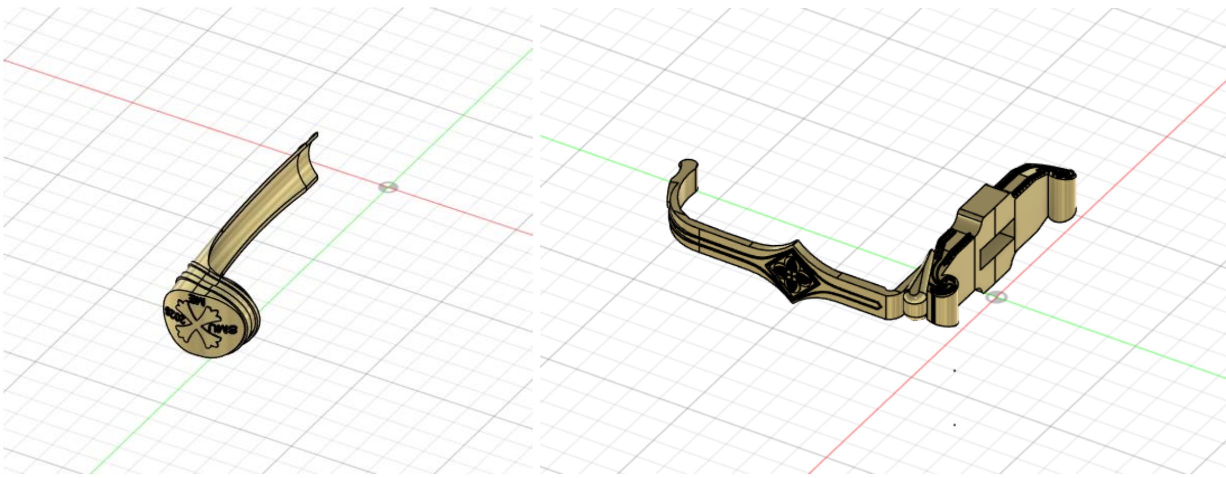

Figure 3: Components of modeled hilt: backplate & handguard

To recreate the handguard, we first thought of replicating the hilt piece-by-piece, as described prior. After some discussion, we concluded that if the hilt were to be made with so many pieces, major fitment issues and accumulated error between component tolerances, would eventually prevent the handle being assembled properly. Attempting to pour each individual component would require such considerations that would be very difficult to make without any experience with the manufacturing pipeline. To simplify the design and reduce the likelihood issues with the fit, we opted to design the handle to be one piece of cast brass, with two brass pins to serve as mechanical fasteners. Additionally, the design of the copper inlay was replicated and raised directly off of the brass handle to add grip to the design. Once manufactured the team plans to use some sort of stain to replicate the leather color on the lower grip.

3.2.2 Blade Planning

When choosing the material for the blade, we had to acknowledge a common challenge: cast components typically have weaker mechanical properties compared to forged ones. This is especially relevant for sword blades since forging has historically been the preferred method due to its ability to enhance strength and toughness. While we'll get into the pros and cons of casting later in the report, our first focus will be on how we decided on the material for this project.

Looking back at history, different alloys have been used for melee weapons depending on their performance in battle. In the 18th century, Wootz steel, high-alloy carbon steel, and manganese steel were some of the most commonly used materials. These alloys were chosen because they offered the right mix of hardness and flexibility—hard enough to cut through armor but tough enough to withstand repeated impacts without breaking. Wootz steel, for example, was famous for its sharpness and durability, often seen in Damascus blades. High-alloy carbon steels had added elements like chromium and vanadium to boost strength, while manganese steel was particularly valued for its extreme toughness and ability to resist wear over time.

For this year's competition, we initially considered two main options: spring steel and manganese steel. Spring steel is great because it has high yield strength, meaning it can bend and flex significantly before returning to its original shape. This makes it an excellent choice for applications where durability and resistance to deformation are key. It can also be made from a range of compositions, including low-alloy manganese, medium-carbon, or high-carbon steel. Manganese steel, on the other hand, is known for being extremely tough and impact-resistant, which is why it has been historically used in weapons and armor. While both materials had a lot of potential, we had to take more than just performance into account.

Instead of selecting the best material from a mechanical standpoint, we had to choose something that would not only get the job done but also be feasible given the constraints of the competition and our timeframe. Since we relied on donated materials and machining time from industry partners, we didn't have the luxury of picking whatever material we wanted. Instead, we had to work within the pouring schedules of our sponsors, meaning we needed to find an option that was both available and practical. Ideally, we could have gone with a high-end, wear- and impact-resistant alloy, but because we were working with leftover or "waste" material from other casting jobs, we had to be flexible with our selection.

After adjusting our expectations and working with our industry partner to line up our pour with another project, we landed on 8630 alloy steel. It turned out to be the best all-around choice since it offers a solid mix of machinability, castability, and heat-treatment potential. It's one of those materials that isn't necessarily the best in any single category but performs well across the board. Plus, the ability to heat-treat it gave us more control over its final properties, allowing us to fine-tune its strength and toughness to better suit our needs.

Ultimately, while historical materials like Wootz steel and high-carbon steels were impressive in their time, we had to consider practical factors like availability and ease of processing. Choosing 8630 alloy steel allowed us to strike a balance between performance and manufacturability, making it the most realistic and effective option for our project. In the end, the best material wasn't necessarily the one with the most impressive mechanical properties

3.3 Tentative Timeline

Source partners + establish roles	**November**
Spec Sheet/Sword Design selection	November
CAD modeling + Simulation	December-January
Casting Period	February
Finishing period	March

The above table gives a rough idea of the schedule that was initially proposed and the one that our team had hope to have followed. Although our team was hoping to have the sword completed by the beginning of March, we weren't able to pick up our parts until the very last minute. This prompted our team to rush through finishing.

Some improvements that could be made for next year include having a preliminary model, or "rough sketch" model of whatever project for that year, would've speed up our CAD modeling period. On top of this, delivering a pattern to our industry partner at an earlier date would've given us more time for finishing, but also more time for the partner to ensure an optimal pour.

3.4 Manufacturing Processes

When it came to creating the blade, the actual process varied compared to the planning stages. The following describes the steps that were taken to achieve our final result.

3.4.1 Hilt Manufacturing

Dealing with nonferrous materials such as Bronze, and in conjunction with our industry partner's expertise, we opted to use investment casting as a means to acquire the intricate details of our design. Investment casting is a process which utilizes a pattern, typically made of foam or wax, which gets covered in a ceramic-slurry coating. After the coating is evenly applied across the entire external surface in multiple layers, the shell is then heated. During this heating, the wax or foam that gets coated with the ceramic-slurry will melt out of the internal cavity of the "shell". After this shell is hardened and the internal cavity is cleared, molten metal will then be poured into the shell, cooled, and the shell is then removed. After sufficient cooling, we're left with a cast version of whatever was initially foam or wax. This process is called the "lost wax" or "lost foam" method.

Our workflow varied from this in the sense that one of our partners, Form3D labs based in Portland, Oregon, utilizes an in-house, proprietary processing method which allows them to produce parts with incredible detail, straight from an .STL file. This allowed us to create a model in Fusion 360, send it to our friends at Form3D, and they could directly print out our file using their innovative "pseudo-3D printing machines". Unlike normal Fused Deposition Modeling, or FDM printers used for common 3D printing tasks, this proprietary system utilizes 2 separate gantry arms that lay down alternating layers of extremely fine acrylic powder, and a specialized concoction of glue and adhesive. By using this advanced workflow, Form3D was able to produce parts that closely resembled powdered metal instead of FDM, prior to being dipped in foundry wax.

3.4.2 Blade Manufacturing

When it came to designing and manufacturing the blade, one of the biggest challenges we faced was the fact that we were limited to using steel that had to be cast rather than forged. This immediately raised concerns because cast parts are typically weaker than forged parts. There are several reasons for this, including the higher carbon content needed for casting ferrous metals, the grain structure that forms during the cooling process, and the specific alloys we had to work with. On top of that, we were restricted to a casting process that aligned with our industry partner McKenzie's experience in working with cast steels. While there were more advanced or exotic casting methods available, we had to stick with what was realistic given our resources and timeline.

Casting can be a difficult process, especially for something as long and slender as a sword blade. One of the biggest issues is that metal cools at different rates across the part, which can cause defects like shrinkage and inconsistent mechanical properties. Because of this, we had to pour a much larger amount of steel than the final blade would actually need just to ensure we had enough solid, defect-free material to machine down to the final shape. Ideally, casting a part to "net shape" would mean pouring the metal as close to its final form as possible, with only minor finishing needed. However, given the inherent defects and challenges of casting a sword blade, our version of "net shape" looked more like a chunky steel 2x4 rather than anything resembling an 18th-century broadsword.

Despite these hurdles, working with McKenzie allowed us to navigate the casting process in a way that balanced practicality with performance. While casting wasn't the ideal method for producing a sword blade, it was the most viable option within the constraints of the competition, and it pushed us to rethink how we approached both the design and manufacturing stages of the project.

4 Constraints and Discussion

The team encountered several challenges while preparing for the Cast in Steel competition. At their school, a new policy now requires supervision in the machine shop, unlike in previous years. This reduced the amount of time they could spend working there. Additionally, the team had limited experience communicating with suppliers, leading to some misunderstandings. These issues caused delays and resulted in multiple versions of the blade and handle at different stages of production.

Within the group, task delegation and scheduling could have been more effective, leaving Taylour to handle most of the work. Securing funding for the Atlanta trip also proved difficult. The team was organized as a schoolwide club to access more school resources, but was unable to secure adequate funding due to the heavy engineering focus. For the competition, they provided only 25% of the requested funds with two months left, expecting the team to raise the rest in only two months. This led the team to rely on the engineering department for additional funding, as they had in past competitions. Meanwhile, meeting the student body's requirements of regular club meetings and larger assemblies took up time that could have been used on the project.

The sword was received a few weeks in advance, while the handle was received only a week in advance of the shipping due date. The handle received was of an earlier pattern missing some decoration and holes for the pins. Therefore, the milling step of the submitted sword was lack of time to make soft jaws to safely hold the sword during milling. Instead, the sword was ground down slowly by angle grinders. During the blade grind process, a few impurities were found on the blade. Most were rusted out surface pits that were ground out, but a few were small bubbles in the blade that failed to fill with steel or bits of sand from the casting that broke loose then solidified. No internal defects exceeded 1mm in any dimension.

The team's suppliers were another challenge. Since the work was requested for free as a charity, our team's parts weren't a priority, slowing down manufacturing. While coordinating with these suppliers, the team also sought advice on materials, casting methods, and design, relying on their goodwill for both production and input. The casting outlet used last year, Spokane Foundry, was unavailable to assist this year. Additionally, their previous advisor, Professor Shelbie Wickett, is unavailable this year due to her PhD commitments.

5 Concluding Statements

Despite our setbacks, the team was still able to create a full sword that serves as a wonderful reminder of the many great accomplishments of George Washington. We would like to thank the Steel Founders Society of America, Saint Martin's University, our Dean of Engineering; Dr. David Olwell, Professor Shelbie Wickett, faculty advisor Dr. Frank Washko, McKenzie Castings, 2Raven Studios, the Mount Vernon Museum, the Lacey MakerSpace, and Form3d Foundry for the opportunity and means to participate in this competition. In addition, this sword wouldn't have been possible without the help of team at Central Welding Supply of Lacey, Washington.

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