SFSA Cast In Steel 2025-
George Washington's Sword Technical Report
California State Polytechnic University, Pomona- Team 2, Molten Metal Marauders

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Table of Contents

Abstract ... 3

Introduction ... 5

Background ... 5

- Anatomy of a Sword ... 5
- Significance of George Washington's Sword ... 6
- Key Swords in George Washington's Collection ... 6
- Why a Spadroon? ... 8

Constraints & Initial Design Considerations ... 8

- Sword Design & Development ... 8
  - SolidWorks 3D Modeling ... 10

Process Development ... 10

- Material Availability Considerations ... 10
- Casting Process ... 12
  - Mold Preparation & Pouring Execution ... 18

Post Process and Assembly ... 20

- Heat Treatment ... 20
- Surface Finishing ... 20

Testing and Inspection ... 23

Results & Discussion ... 23

- Did the Sword Meet Expectations? ... 23
- Strengths and Weaknesses of the Final Design ... 24
- Lessons Learned ... 24

Conclusion & Recommendations ... 25

References ... 26

Abstract

We would like to thank our advisor, Dr. Viktor Ohkuysen, for his guidance and support throughout this competition.

Additionally, we would like to thank Sheldon Kilpack from Kilpack Kustoms, for allowing our team to use their shop space and equipment to complete the post processing of the sword; and Zeke van Rooyen for lending his sword sharpening expertise.

Lastly, thank you to our foundry sponsor, SoundCast. Jason Guitierrez and his team of professionals for providing us with technical knowledge, resources, and assistance with the mold creation and carrying out the pour, which was critical to successfully casting the sword.

Figure. Portrait of George Washington Taking the Salute at Trenton

We, the Molten Metal Marauders, developed a spadroon-style sword for the 2025 Cast in Steel competition, drawing inspiration from George Washington's distinguished weapons collection.

, depicts him with a sword at his side, reinforcing the symbolic and functional significance of his weaponry. Guided by this historical reference, we sought to create a blade that embodies both the legacy of Washington's leadership and the craftsmanship of 18th-century swordsmiths.

With the support of our foundry sponsor, SoundCast, we utilized sand casting to produce our spadroon in 4130 Alloy Steel. Throughout production, we prioritized historical authenticity, selecting design elements reflective of 17th and 18th-century swords, while ensuring the functionality and durability necessary for practical use. By adhering to modern casting and manufacturing practices, we have crafted a lightweight yet durable sword that meets competition standards and accurately replicates the style of Washington's weaponry.

This report details the design process, metallurgical decisions, casting methodology, testing protocols, and final results, illustrating how this project successfully integrates historical context with modern engineering techniques.

Introduction

Casting is no simple task. Already a technically challenging process, it becomes even more industrious when asked to create a historically significant weapon using modern manufacturing techniques. Additionally, the cultural importance of the specific weapon we are recreating must be considered to fully understand the extent of the competition. Not only are we making a sword inspired by the ones used by the first leader of our country, but we must also comprehend the subject was the nation's first symbol of freedom, strength and determination. This project challenges us to recreate a sword from George Washington's collection- an important piece of history- by applying current casting techniques.

SFSA has created this competition to encourage students to learn about making steel products using the casting process and applying the latest technology available. Our team, the Molten Metal Marauders, will be one of four teams proudly representing Cal Poly Pomona upon completing this project. With assistance from our foundry sponsor, this competition has given us the opportunity to apply lessons from the classroom in an industry setting. With the goal of accurately manufacturing a sword using techniques and industry standard methods, we believe we have produced a spadroon-style sword worthy of being compared to the weapons in George Washington's collection. Following extensive research regarding George Washington's preferences, historical references that depict the style and design aspects of swords from the period, and metallurgical analysis for material selection, we have sand-casted 4130 Alloy Steel to create a historically authentic and structurally sound replica.

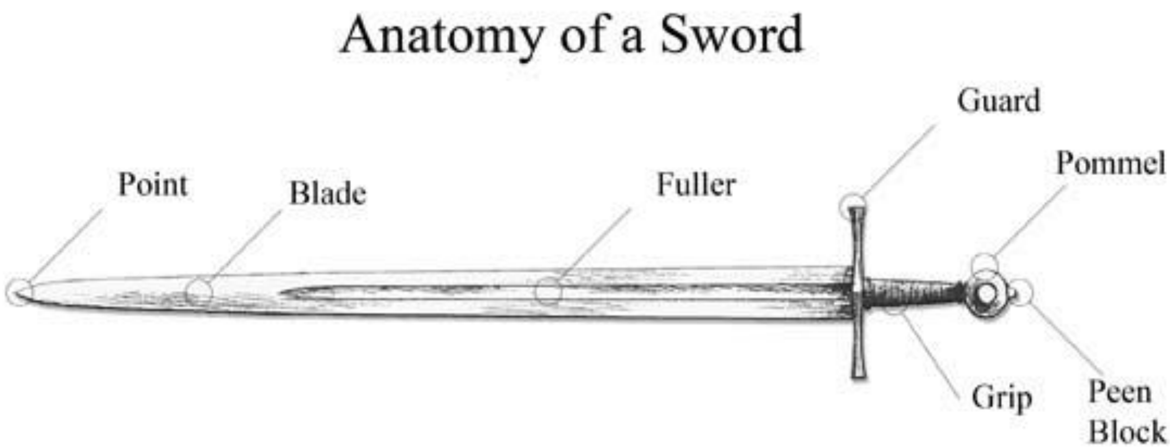
This report contains our research regarding George Washington's collection, our design process, material selection, and the casting method used. It will also briefly touch upon the post processing and testing procedures, final inspection and assembly, the economic analysis of casting the sword, and lastly, how modern manufacturing techniques can be applied to capture historical craftsmanship.

Background

- ### Anatomy of a Sword

Error! Reference source not found. illustrates the key components of a spadroon, a sword designed for both cutting and thrusting. The **point** and **blade** facilitate precise strikes, while the

fuller reduces weight without compromising strength. The **guard** protects the wielder's hand, and the **grip** ensures secure handling. The **pommel** balances the sword, and the **peen block** secures the blade to the handle. While not shown in the diagram, spadroons often feature a **D-shaped knuckle guard** for added protection. These elements are essential in accurately replicating George Washington's sword.



Anatomy of a Sword

- Significance of George Washington's Sword

George Washingtons sword is more than a weapon, it is a symbol of freedom, determination, leadership, and strength which were all important to the founding of the United States of America. As the commander in chief of the continental army, Washington carried a sword through key battles of the American revolution. He also carried a sword during lots of formal occasions, such as his inauguration as the first President of the United States in 1789.

- Key Swords in George Washington's Collection

George Washington's collection of swords not only reflected his personal style and preference but also reflected his role in the establishment of the United States. Two of his swords stand out for their historical significance and craftsmanship, *Figure: Silver Lion Headed Cuttoe* and *Figure: Alte Presentation Broadsword.* These swords each having a unique design and purpose provide valuable insight on Washingtons leadership and identity.

Figure: Silver Lion Headed Cuttoe

The Silver Lion Headed Cuttoe was one of Washingtons personal swords that he had acquired around the 1770. It features a lion headed pommel, a fine spiraled bone grip, and an elegant yet functional design that reflected the style of swords used in the 18th century. The lions head symbolizes strength, determination, and leadership.

Washington carried this sword during the early stages of the American Revolution and had used it during the famous crossing of the Delaware River.

This sword is a symbol of his leadership during the American Revolution as well as a reflection of his personal style as well as the military culture in the 18th century.

Figure: Alte Presentation Broadsword

This Broadsword that was presented to him during his second presidential term was deemed a reflection of the peoples appetition for him. Some of its key features include the blades inscription and the luxurious materials which showcase exquisite craftsmanship.

Studying George Washingtons sword collection provided us valuable context and insight on the symbolism, and craftmanship during the 18th century. Our team was inspired by the elements in the swords researched and set out to design and manufacture an accurate representation that captures the functionality and symbolism of Washingtons swords. The following section details approach the design, production, and the post processing of our sword.

- ### Why a Spadroon?

Among Washington's collection of swords, the spadroon stood out as a lightweight, versatile weapon favored by military officers during the late 18th century. Unlike the heavier broadsword, which was primarily used for slashing, or the cuttoe, which was a civilian dress sword, the spadroon provided a balance between cutting and thrusting techniques, making it highly practical for both ceremonial and combat purposes. This adaptability made it an ideal choice for our project, ensuring historical accuracy while maintaining functional design elements that align with modern casting and testing requirements.

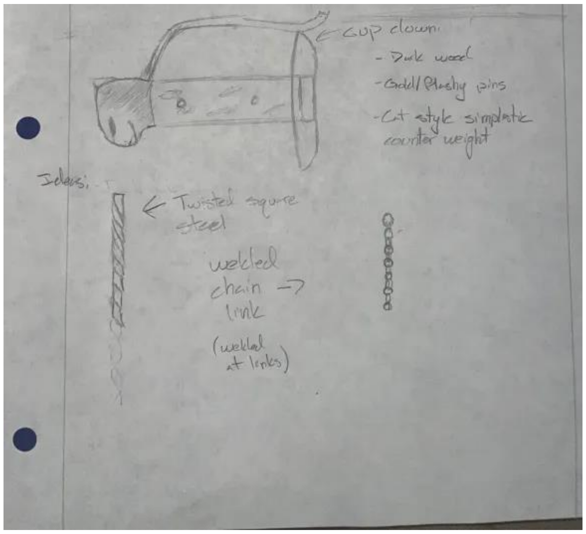
Constraints & Initial Design Considerations

The design and manufacturing of our spadroon had to comply with both historical accuracy and the technical constraints set by the SFSA Cast in Steel competition. According to competition guidelines, the sword must remain under 2 kg in weight and not exceed 1 meter in length, imposing restrictions on material selection and overall geometry. Additionally, the sand casting process introduced limitations related to size, material shrinkage, and dimensional precision, requiring careful gating system design and pattern allowances to ensure an accurate final product. Strength and durability were also key concerns, as the selected material needed to withstand heat treatment and mechanical testing while maintaining historical authenticity. Another major consideration was whether to cast the sword as a single piece or in multiple parts. A one-piece cast would ensure structural integrity but present greater challenges in achieving precise detail and minimizing defects, while a two-piece cast would allow for better control over final dimensions but require additional machining and post-processing. These constraints shaped our approach to design, material selection, and manufacturing strategy, ensuring our final product met both competition and functional requirements.

- ### Sword Design & Development

After extensive research our team began the brainstorming phase. We explored various design elements including blade shape, hilt detailing, material selection and other significant features that would capture the historical significance of Washingtons sword to ensure we manufacture a sword that reflects historical accuracy, functionality, and structural Integrity.

Our early designs evolved as we considered different aesthetic and structural choices. Figure: Early Design 1 introduced the concept of incorporating an animal head pommel, inspired by historical swords with symbolic carvings. In Figure Early Design 2, we explored a two-piece rounded guard, which would provide additional protection to the wielder's hand while allowing for a more intricate casting process. Finally, Figure 1-1: Early Design 3 solidified our vision, featuring an eagle head pommel, a defining element that aligned with Washington's legacy and American symbolism. This final design brought together the best aspects of our earlier iterations, ensuring the sword met both historical and functional criteria.



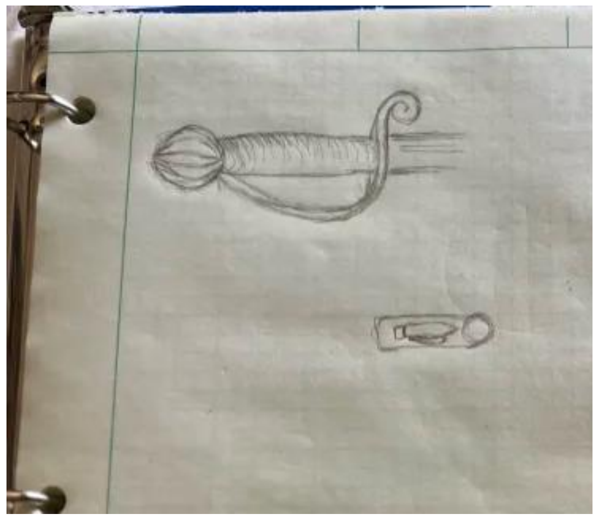


Figure: Early Design 1

Figure Early Design 2

Figure 1-1: Early Design 3

While these early concepts provided a strong foundation, modern manufacturing requires careful feasibility analysis before finalizing a design. The next phase involved evaluating material selection, casting complexity, mechanical properties, and manufacturability to ensure the chosen design could be successfully produced while maintaining competition constraints.

- SolidWorks 3D Modeling

Our spadroon design was developed in SolidWorks, allowing us to refine blade geometry, hilt structure, and overall balance while ensuring manufacturability. The initial model was a rough, unrefined version, primarily used to establish basic proportions and adherence to SFSA constraints for size, weight, and structural integrity. As our design progressed, we made incremental adjustments, improving edge definition, pommel detailing, and center of mass distribution to enhance historical accuracy and casting feasibility.

The Following image illustrate this progression, from our early blunt model to the final refined version used for casting simulations and pattern production. These iterative improvements ensured that the final design was optimized for both competition performance and manufacturing efficiency.

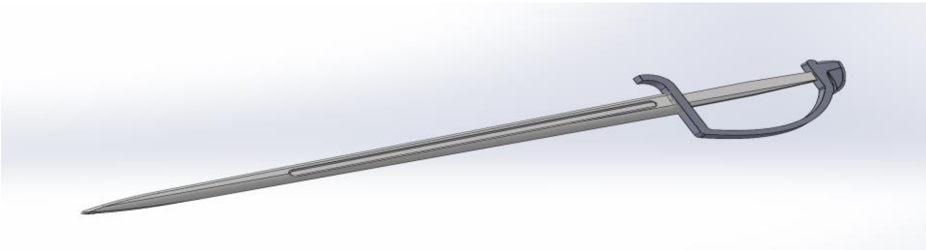


FIgure A-2: Final Design

Process Development

The design and casting process for our spadroon presented multiple challenges that required engineering adjustments and optimizations to ensure structural integrity, functional balance, and defect minimization. Addressing these challenges early in the design phase allowed us to refine both manufacturing feasibility and performance characteristics of the final sword.

- *Material Availability Considerations*

Our two available choices for material were 4130 or 4140 Alloy Steel. The team performed extensive research into the many characteristics we had to consider when determining which alloy would be better suited to manufacture our sword out of. We considered both alloy's chemical composition, *Figure 10* serves as a reference chart for the standard composition of both alloy steels, and *Figure 11* focuses on mechanical properties that were initially considered during the material selection process.

Chemical Composition Comparison of 4130 and 4140 Alloy Steel	
4130	4140

Carbon: 0.28-0.33%	Carbon: 0.38-0.43%
Chromium: 0.8-1.1%	Chromium: 0.8-1.1%
Manganese: 0.40-0.60%	Manganese: 0.75-1.0%
Phosphorus: 0.035%	Phosphorus: 0.035%
Sulfur: 0.040%	Sulfur: 0.040%
Silicon: 0.15-0.35%	Silicon: 0.15-0.35%
Molybdenum: 0.15-0.25%	Molybdenum: 0.15-0.25%

Figure 1: Chemical Composition of Available Material

	AISI/SAE 4130 Steel	AISI/SAE 4140 Steel
Tensile Strength	97000 psi	148000 psi
Yield Strength	63000 psi	95000 psi
Elongation (2")	25.5%	17.7%
Brinell Hardness	197	302

Figure 2: Mechanical Properties of 4130 and 4140 Steel (Harrison)

When selecting the material for our sword, we carefully evaluated key characteristics such as tensile strength, toughness, wear resistance, fatigue resistance, and post processing behavior, to ensure the final product met both functional and historical standards. Both 4140 and 4130 steel exhibit high tensile strength, making them well-suited for high-stress applications. While 4130 offers a superior strength-to-weight ratio—ideal for weight-sensitive designs—4140 surpasses it in overall strength, ranking among the strongest low-alloy steels available.

Post processing was another crucial factor, as 4130 is easily welded using conventional methods, whereas 4140 requires additional heat treatment to prevent cracking and achieve the desired mechanical properties. Balancing these considerations, we determined that 4130's post cast workability and lighter weight made it the optimal choice for our sword.

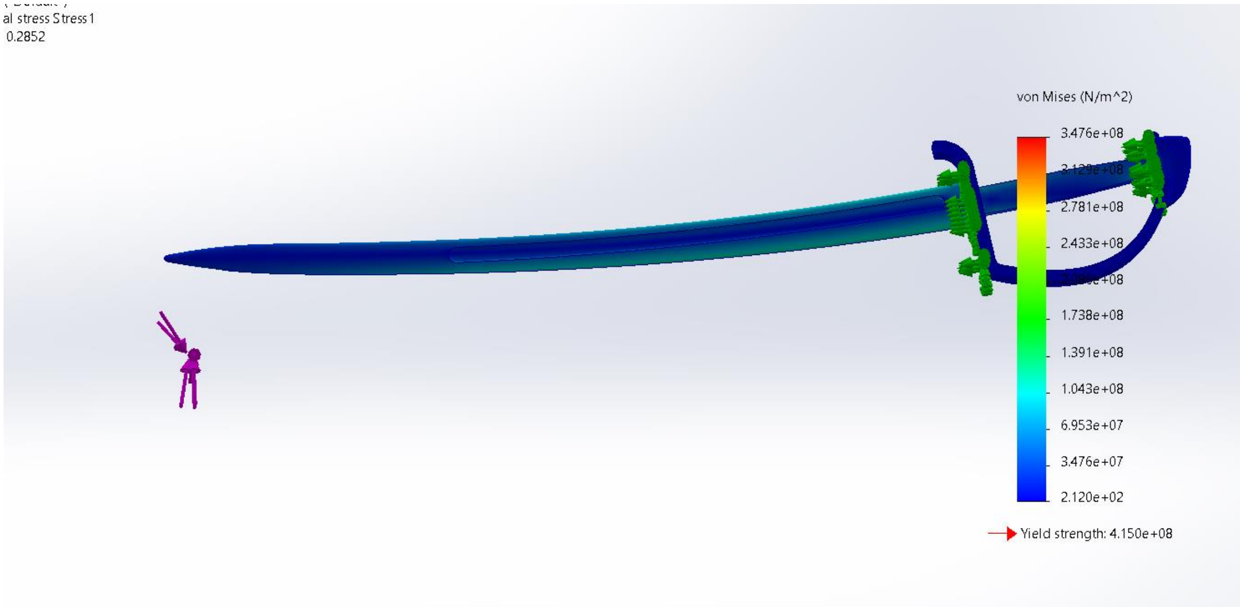


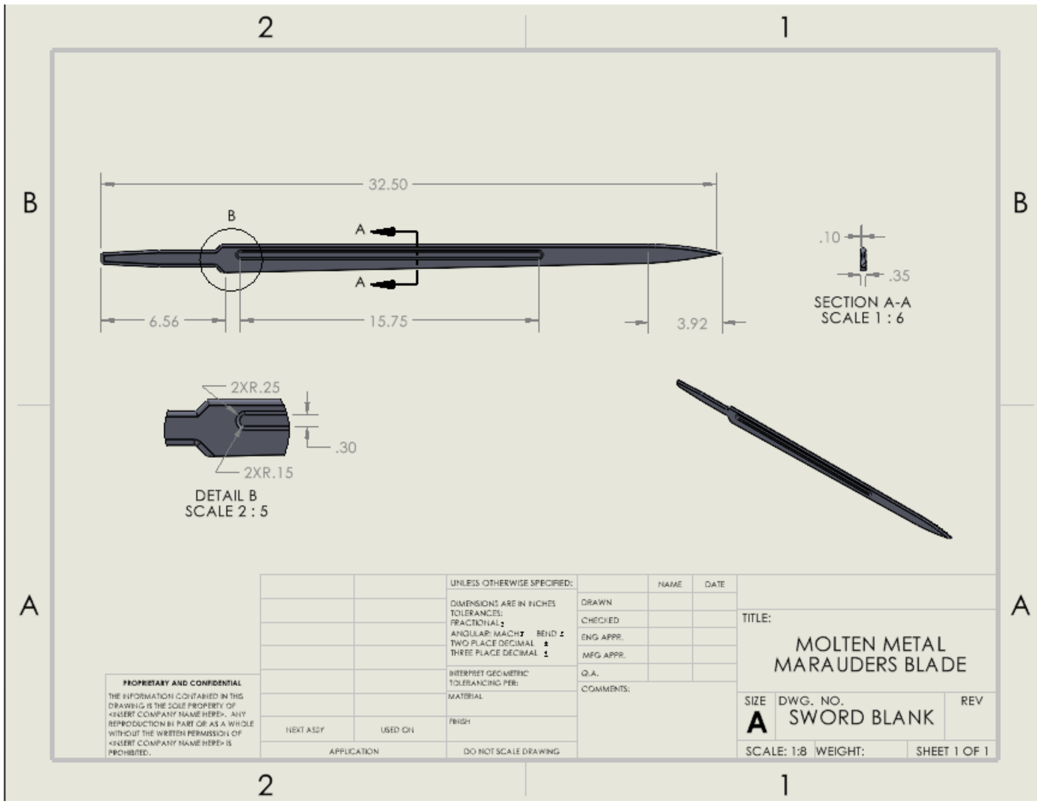
Figure 3 Engineering Drawings and 3D renders

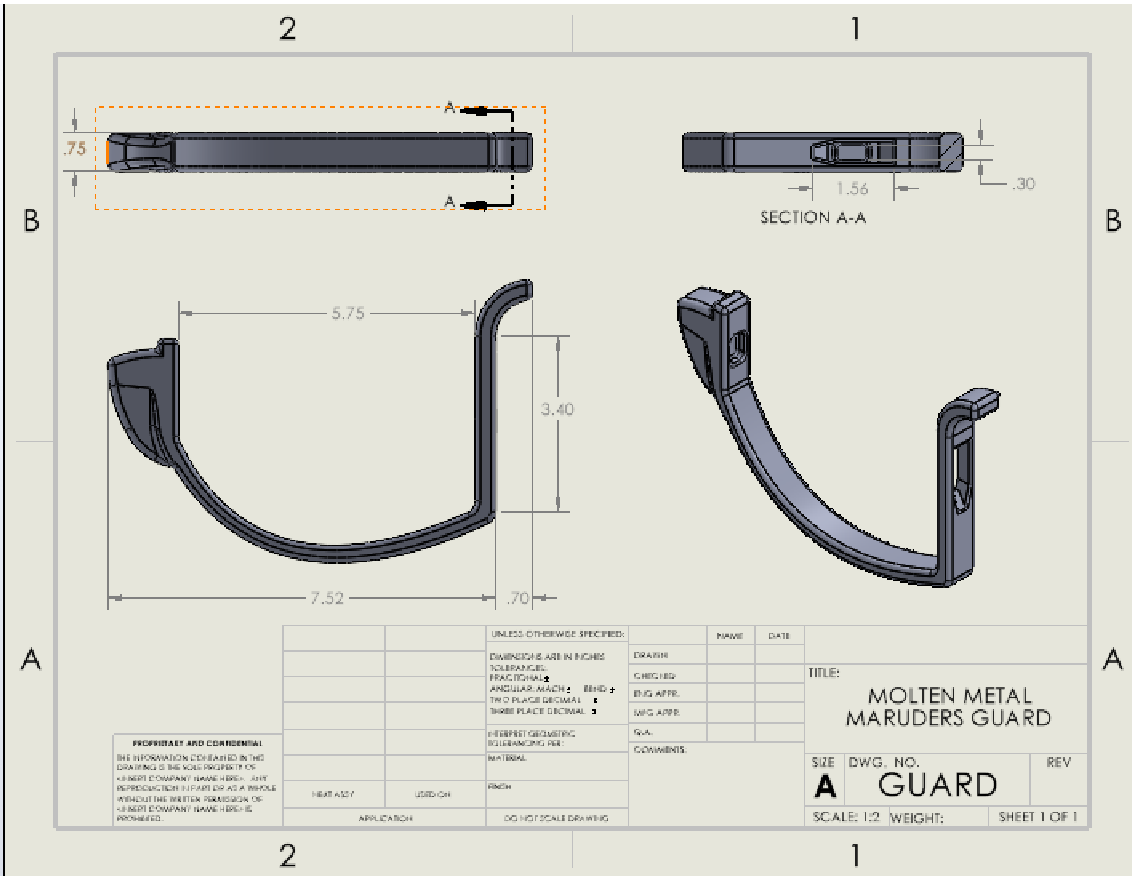
Once we had selected our allow, balancing the center of mass and handling characteristics was another key factor in our design. The spadroon is intended to be a lightweight yet durable sword, so weight distribution needed to be carefully adjusted to maintain usability while adhering to competition constraints. SolidWorks simulations like the one above were used to analyze how changes in pommel and guard weight impacted balance, ensuring that the final design reflected historical functionality while remaining structurally sound for testing.

- *Casting Process*

One of the primary design challenges we faced was optimizing the casting process, as improper gating could lead to shrinkage defects, turbulence, or incomplete fills. Our team carefully designed the gating system to ensure even metal distribution, minimizing air entrapment and porosity. We decided to cast the sword in two separate components- **The blade and the guard-** We also intentionally designed the blade component as a “blank” to help with mold geometry, fill, and defect prevention. This two-component casting approach not only improved overall cast quality but also allowed for greater control during post processing such as surface finish, alignment, and final assembly.

Figure 4 Engineering Drawings and 3D renders

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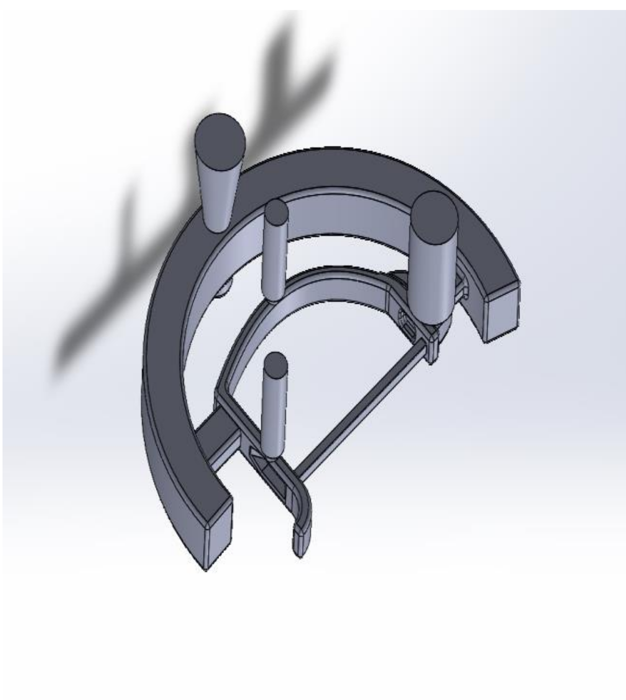
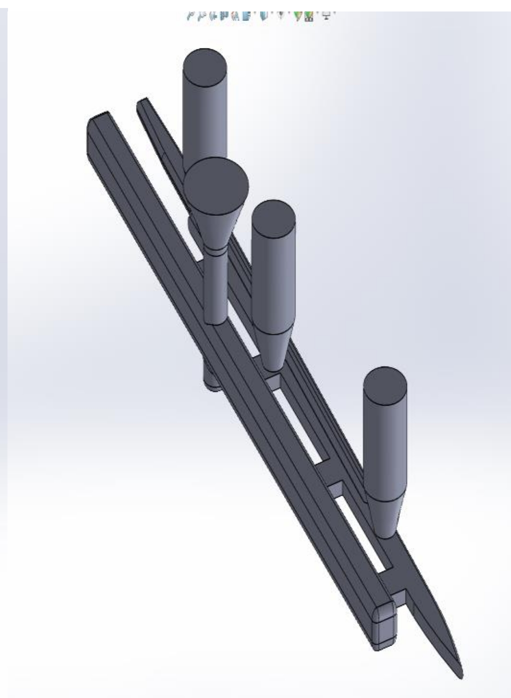
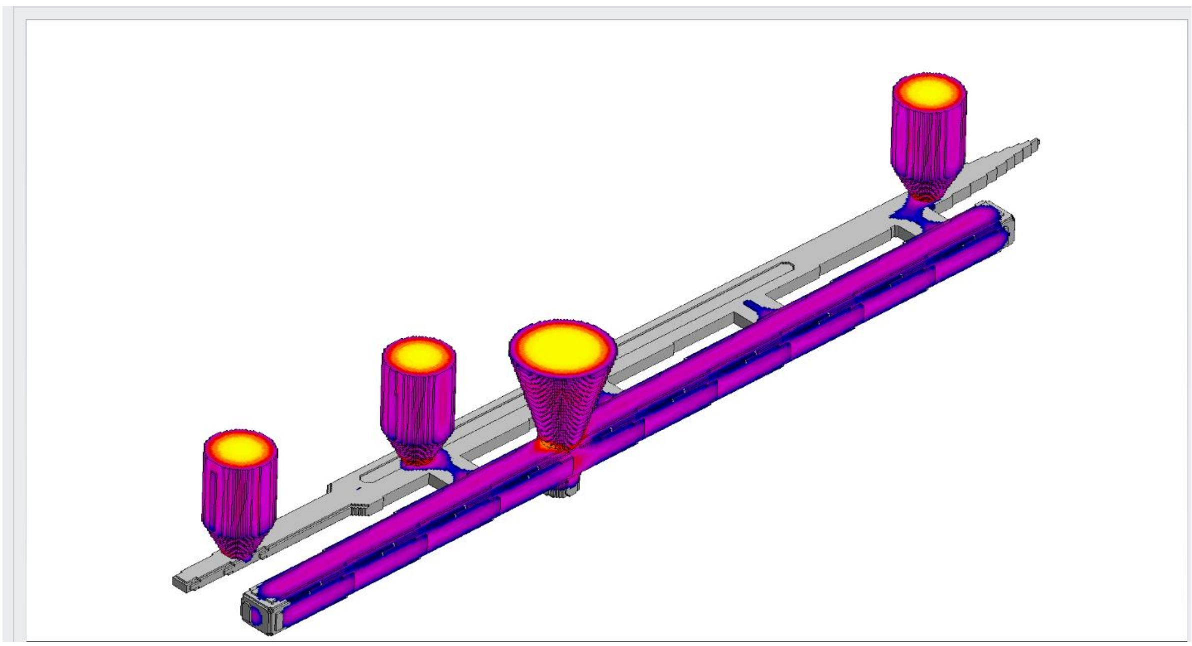
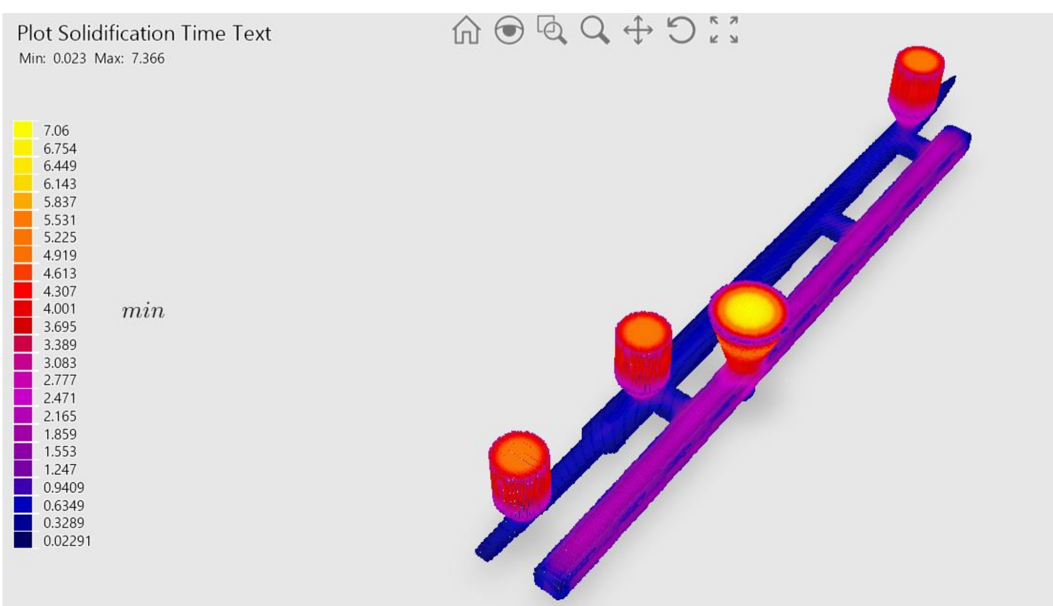


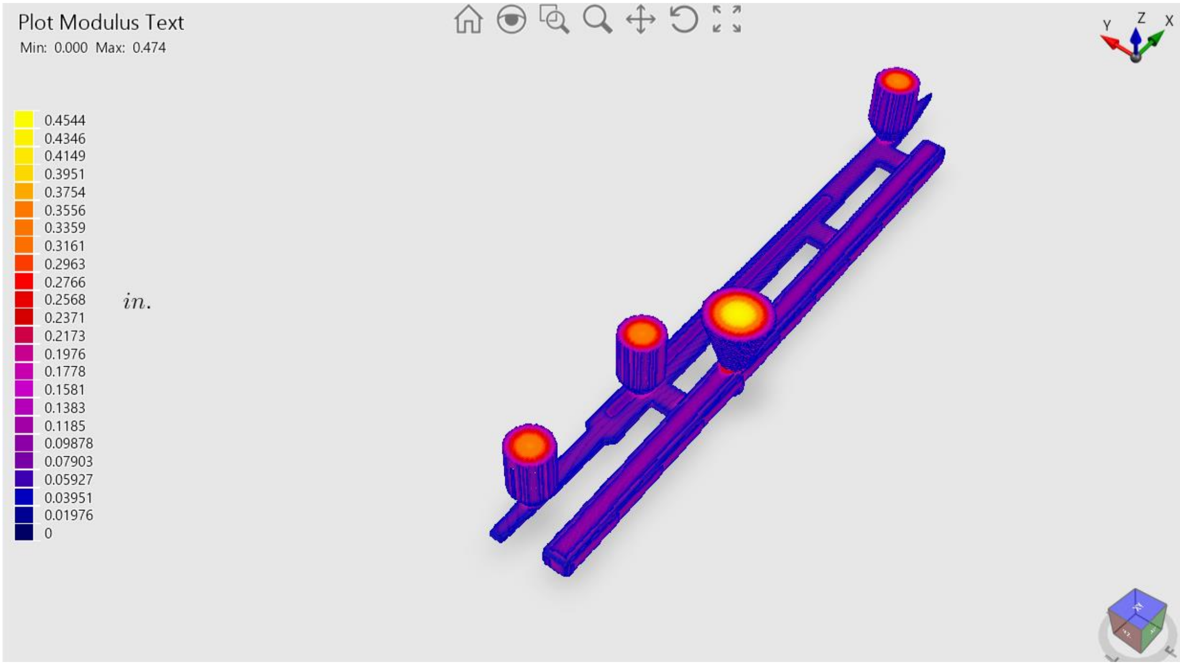


To further improve casting quality, we used Solid cast to help us identify potential hot spots and porosity risks. These simulations allowed us to make preemptive adjustments to our mold design, ensuring proper cooling rates and solidification time minimizing defects before physical casting.

Figure 5 Solid cast Sims



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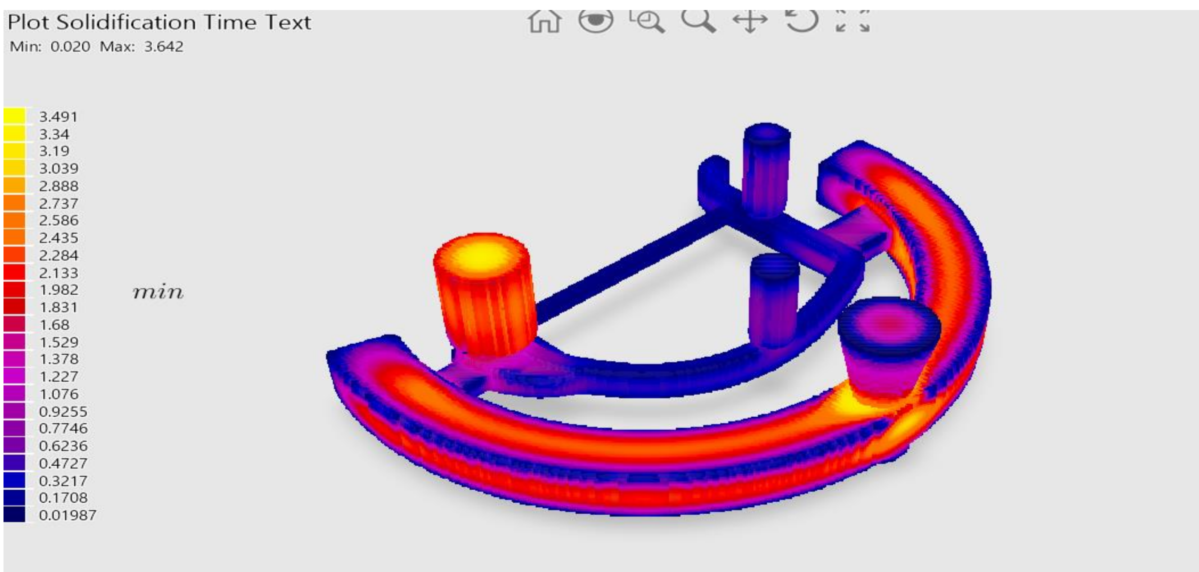
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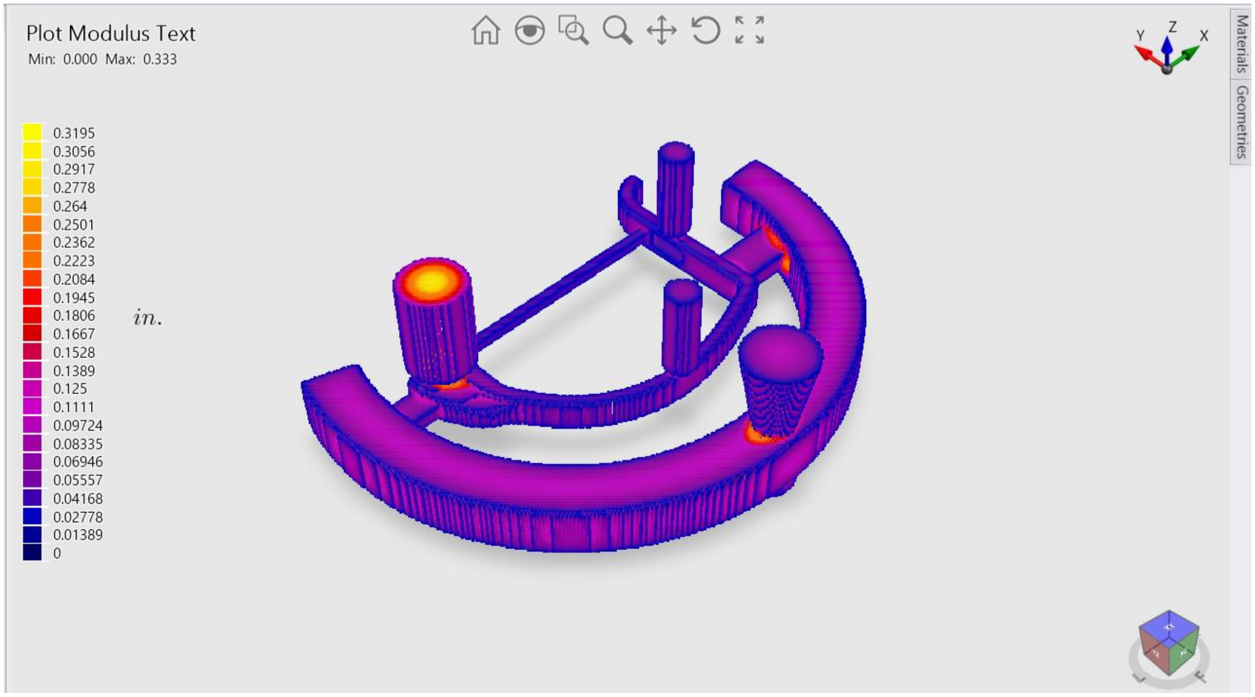
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- *Mold Preparation & Pouring Execution*

For mold preparation and pour execution, several critical steps were taken to ensure the casting process was as controlled as possible. The mold was prepared using a sand-casting method, though inconsistencies in compaction and venting contributed to notable surface defects. Proper venting channels were included to mitigate gas entrapment, but some areas may not have been adequately addressed, leading to porosity and pitting in the final casting. Given the high stakes of a single-pour opportunity, we adjusted the gating system to optimize metal flow and reduce turbulence, yet execution still relied heavily on manual techniques.

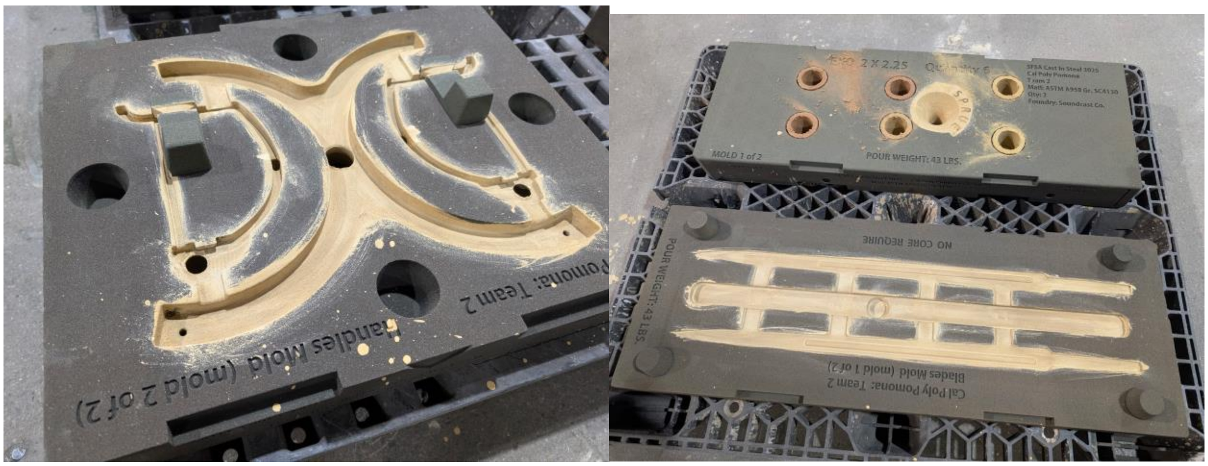

Figure 6 Mold Prep

The pour was completed in one attempt, ensuring that the cast formed as intended.

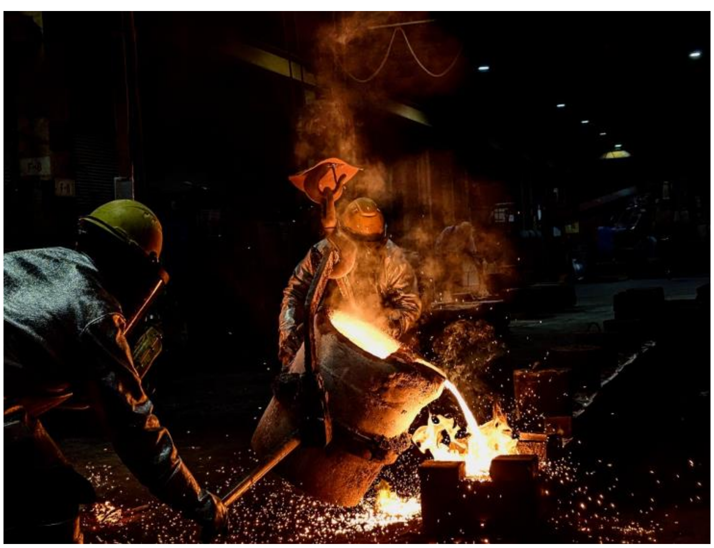

Figure 7 Gating after Pour: Sword and Guard

Following the pour, we documented the mold immediately after the casting process, capturing key visuals of metal solidification within the sand mold as seen in **Error! Reference source not found.** and **Error! Reference source not found.**. A video of the pour was also recorded, providing further insight into flow characteristics and pouring technique. These visual references serve as a record of our casting execution, allowing for post-analysis of gating performance and potential areas of improvement for future iterations.

Figure 2 and 9: Gating after Pour: Sword and Guard

After Solidification the molds were opened and proceeded with the shake out process revealing our Casted Product

Figure 10: Shakeout

Post Process and Assembly

- ### Heat Treatment

Heat treatment plays a crucial role in refining the mechanical properties of 4130 steel. Common methods include annealing, normalizing, quenching, and tempering, each serving a distinct purpose in enhancing material characteristics. Annealing is often applied before machining or after welding to reduce hardness and strength while increasing ductility and toughness. This process also helps eliminate internal stress and improve machinability. Normalizing, on the other hand, refines the grain structure and improves microstructural uniformity, typically serving as a preliminary treatment for 4130 steel before quenching and tempering or as a final heat treatment in certain applications. Quenching significantly increases hardness and strength, making it a key process for 4130 steels when high wear resistance is required. However, quenching must be followed by tempering to reduce brittleness and relieve internal stress. Tempering further enhances ductility and toughness while improving the steel's overall stability. In practical applications, 4130 steel is typically normalized and tempered to balance durability with machinability. Given these properties, 4130 steel provides superior results for applications requiring high strength, wear resistance, and durability. Its refined microstructure and increased hardness allow it to withstand greater impact forces, reducing the risk of fractures and deformation under stress.

For this project, the sword was cast at a 2900°F pour temperature and, after cooling and removal from the mold, was reheated to 1650°F before undergoing a water quench. To further refine its mechanical properties, the blade was then tempered at 1050°F and air-cooled. Each heat treatment stage maintained a consistent soak time of 2–3 hours, ensuring uniform material properties and structural integrity.

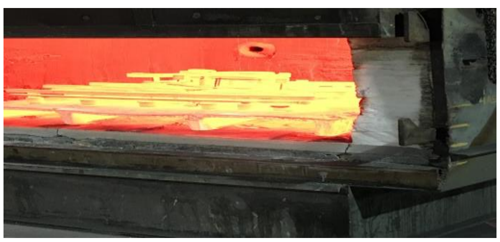

Figure 10: Partial View of Heat Treatment

- ### Surface Finishing

Our group completed a majority of the post processing at Kilpack Kustoms *(Figure 12)*. We would like to take the time to thank Sheldon Kilpack for allowing our team to complete this portion of the process at his shop. We received the sword following its first heat treatment and began to grind down blade using a belt sander. As more of the material was removed, issues with the cast began to appear. *Figure 13* shows the entire sword partially grinded down with dents and pitting in the blade. A closer look at the pitting that was most prevalent at the end of the sword is pictured in *Figure 14*.

Figure 11: Full view of partially grinded sword alongside handle, unassembled

Figure 12: Full view of partially grinded sword alongside handle, unassembled

Figure 13: Pitting exhibited on blade tip during post process

After the pitting was discovered, we returned the sword to our foundry pattern to complete spot welding and a second round of heat treatment. Upon being returned to us, the sword was partially ground down and the edge of the blade was not fully centered due to the amount of material that was removed. There were also waves that appeared in the material after the second heat treatment. A full view of the sword can be seen in Figure 14, with a more detailed view of the end of the blade in Figure 15.

Figure 14: Full view of the blade post second heat treatment

Figure 15: End of the blade, view of material distortion

The blade was once again grinded with a belt sander, and the two-piece guard- made of ebony wood- was attached with epoxy and two pins, one at each end. Final touches to the sword included sharpening it using a whetstone, coating the blade in mineral oil to maintain its condition, and adding beeswax to polish the wooden guard.

Testing and Inspection

Figure 16: Finished Sword

In compliance with the SFSA's Cast in Steel competition guidelines, we have produced a sword inspired by George Washington's collection, meeting the specified weight limit of 4.4 pounds and length tolerance of 43 inches. The final dimensions are as follows: 32 inches in total length and 3 pounds, 2.3 ounces in weight. The blade measures 26 inches, while the handle extends 6 inches.

Testing of the sword will be completed in person at the Cast in Steel competition on April 9-11th, 2025.

Results & Discussion

- ### Did the Sword Meet Expectations?

The final product met our expectations, though modifications were necessary due to time constraints. One of the key challenges we faced was an issue with the gating system prior to pouring, which required us to adjust our approach. Instead of pouring on the face of the mold as originally planned, we had to pour from the blade edge. This adjustment led to the formation of air bubbles within the metal, causing pitting along the top edge of the blade. To address these imperfections, additional heat treatment and spot welding were required to strengthen the affected areas. Despite these last-minute changes, our team successfully produced a spadroon-style sword that aligns with the design principles found in George Washington's collection.

- ## Strengths and Weaknesses of the Final Design

While the final design was structurally sound and historically accurate, certain areas could have been improved. Greater emphasis should have been placed on refining the gating system to enhance the pour quality and minimize the potential for pitting. Additionally, the casting method we selected limited the amount of intricate detail that could be incorporated into the blade. Seeking external resources for guidance on optimizing the design for casting could have helped mitigate these limitations.

However, the overall design was one of the project's strongest aspects. Extensive research went into ensuring durability and minimizing potential points of fracture or weakness. The design team prioritized structural integrity, selecting elements that reinforced the blade's strength while remaining true to historical accuracy. Unlike many decorative swords, Washington's spadroons did not feature elaborate etchings on the blade. Instead, much of the stylistic expression was conveyed through the pommel and hilt—an approach we carefully mirrored in our final product

- ## Lessons Learned

One of the key takeaways from this project was the importance of consistent communication. While we maintained contact throughout the process, more structured and frequent check-ins—such as weekly updates—could have improved coordination and minimized last-minute adjustments. Additionally, seeking insight from external experts earlier in the design phase could have provided valuable recommendations on material selection, gating strategies, and overall casting efficiency.

Moving forward, these lessons will serve as a foundation for refining our approach to future projects. By improving communication strategies and leveraging additional resources,

we could've enhanced both the design and manufacturing process, ensuring even greater accuracy and craftsmanship in our work.

Conclusion & Recommendations

The Cast in Steel 2025 competition provided our team with a unique opportunity to blend historical craftsmanship with modern engineering. Through extensive research, design iterations, and manufacturing trials, we successfully developed a spadroon-style sword that adheres to both historical accuracy and SFSA competition constraints. Our final product reflects a balance between structural integrity, functional design, and manufacturability, showcasing our ability to apply casting principles, metallurgical knowledge, and mechanical testing to a real-world fabrication challenge.

Beyond the physical creation of the sword, this project reinforced the importance of design feasibility, simulation analysis, and adaptive problem-solving. The challenges faced during casting and post-processing highlighted key areas for improvement in gating design, solidification control, and surface finishing techniques.

Looking ahead, future work could focus on further refining the casting process to reduce defects and machining time, as well as exploring alternative materials or heat treatment methods to enhance durability and performance. The knowledge gained from this project will be invaluable in future manufacturing and engineering applications, making this experience a critical step in our growth as engineers and problem-solvers.

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