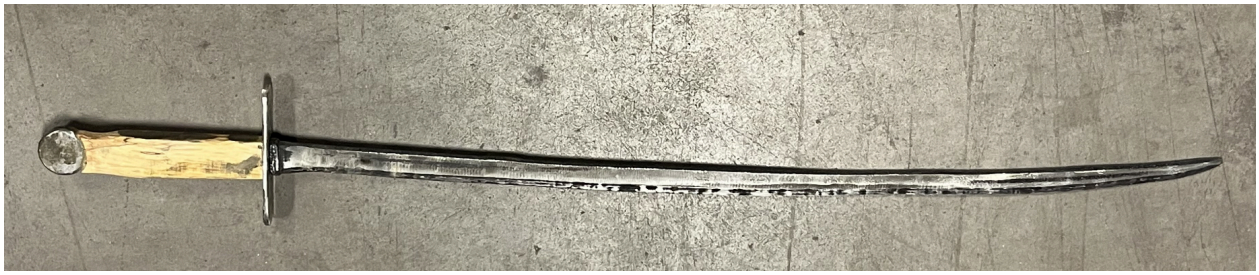
# SFSA Cast In Steel 2025 - George Washington's Sword Technical Report

Michigan Technological University - The Founding Founders

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## Introduction

The purpose of this report is to communicate the process used by MTU's The Founding Founders team to design, cast, and process a replica of one of George Washington's swords for the SFSA Cast in Steel 2025 competition. 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 report discusses the reasons the team selected the sword it replicated, the alloy selection process for the replica casting, the process of designing the casting geometry of the sword, the physical casting, heat treatment, casting cleaning, making the sword's handle, and the final sword replica.

## Background

*Sword selection:* The sword The Founding Founders team chose to replicate was The Silver Lion-Headed Cuttoe owned by George Washington beginning in 1770 (Figure 1) [1]. The Silver Lion-Headed Cuttoe had a silver lion head pommel and guard, a bone handle, and a 30-inch long curved single-edged blade, which likely had an increased length due to George Washington's height (Figure 1) [1]. The team chose this sword due to the design of the lion head pommel and that the blade was curved.

*Figure 1.* Image of George Washington's Silver Lion-Headed Cuttoe [1].

*Alloy selection:* To select the steel alloy to be used to cast the replica of The Silver Lion-Headed Cuttoe, The Founding Founders used the GRANTA materials database as a tool for material selection by comparing all the steel alloys included in the database. Sequential material selection design constraints were selected based on graphs of yield strength vs. density (Figure 2), toughness vs. density (figure 3), and fracture toughness vs. density (Figure 4) [2]. These graphs

were used for alloy selection to prioritize having a lightweight alloy with good mechanical properties, while also being able to withstand processing such as grinding and forging. After the steel alloys were narrowed down, discussions with Temperform led The Founding Founders to choose a quench and tempered AISI 4135 alloy because Temperform had experience casting the alloy and the team was able to do post processing (heat treatments, casting cleaning, etc.) of the alloy at MTU. The AISI 4135 alloy was also selected because it had the best castability rating of the alloys that passed the material selection criteria [2].

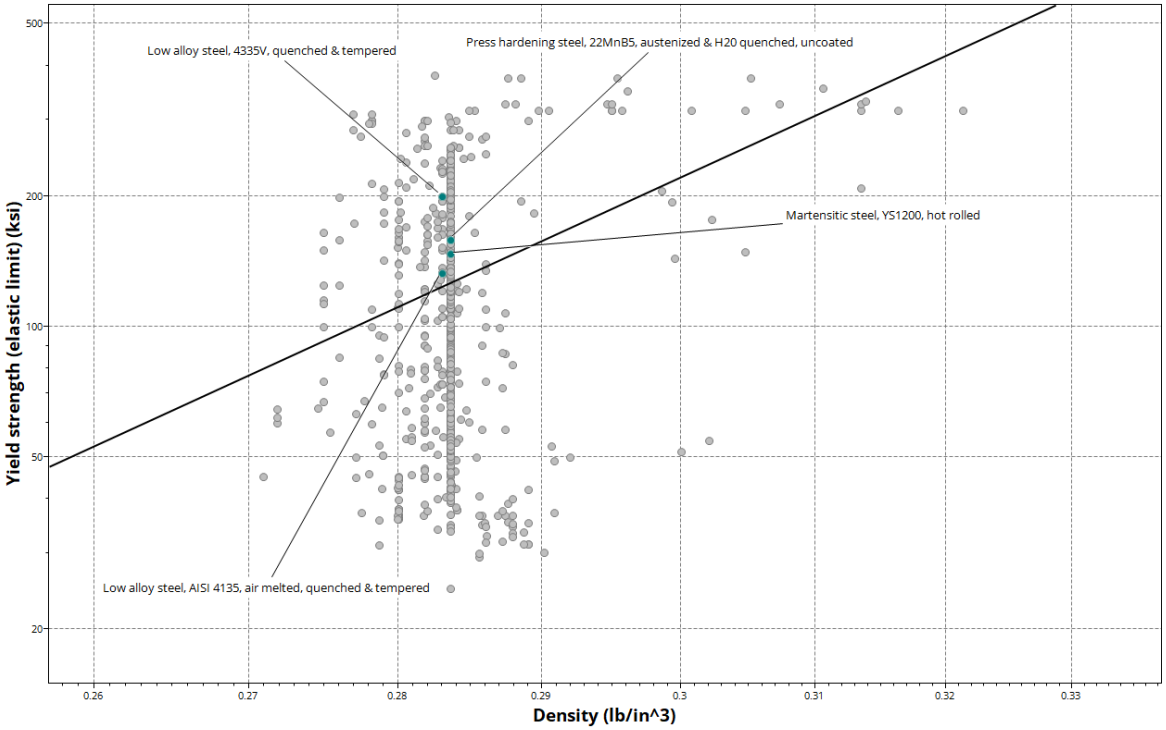


*Figure 2.* Yield strength vs. density graph of steel alloys used to determine which steel alloys were lightweight and strong [2].

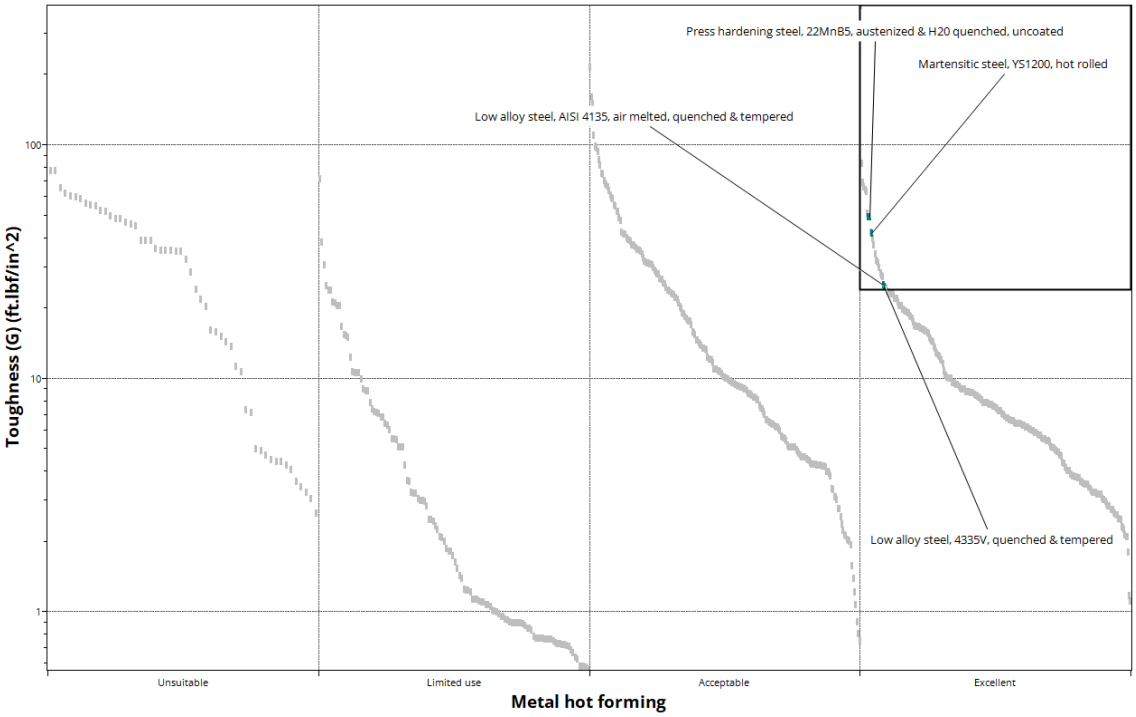


*Figure 3.* Toughness vs. metal hot forming graph of steel alloys used to select alloys with high toughness that would be able to withstand metal hot forming [2].

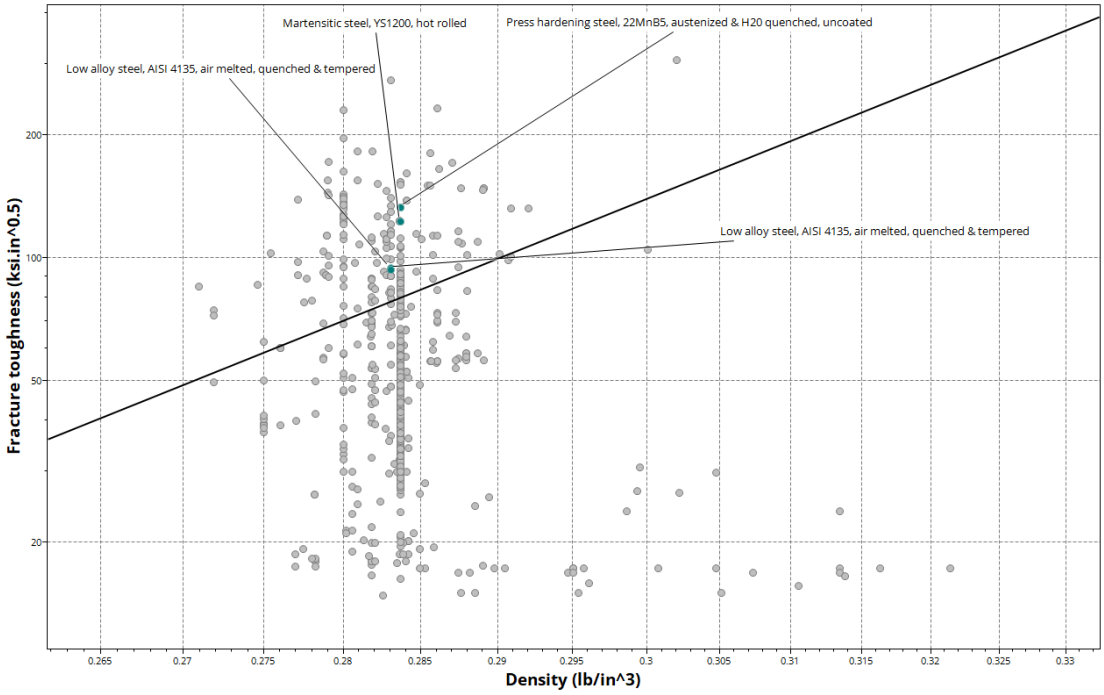


*Figure 4.* Fracture toughness vs. density graph used during alloy selection to select a lightweight alloy with high fracture toughness [2].

**Methods**

The sword design was created using NX Series 2412, with an image from George Washington's Mount Vernon website imported to trace the general shape of the blade. The tang, hilt, and crossguard were initially crafted based on general knowledge of swords, forming the basis of our first design (Figure 6, 7, and 8). To refine the design, the sponsor provided reference materials to help us better understand the tang thickness, crossguard/ricasso length, and the tang shoulder. In the team's first design, we didn't realize that certain parameters were required for easier casting of the blade. As a result, the team made adjustments to the fuller, forte, middle, and foible to improve the casting process. These modifications led to our second and final design for casting (Figure 9, 10, and 11). The figures below illustrate these design modifications, particularly the increased thickness of the fuller and tang, along with the overall reduction of sharp edges to improve casting ease (Figure 6 and 9).

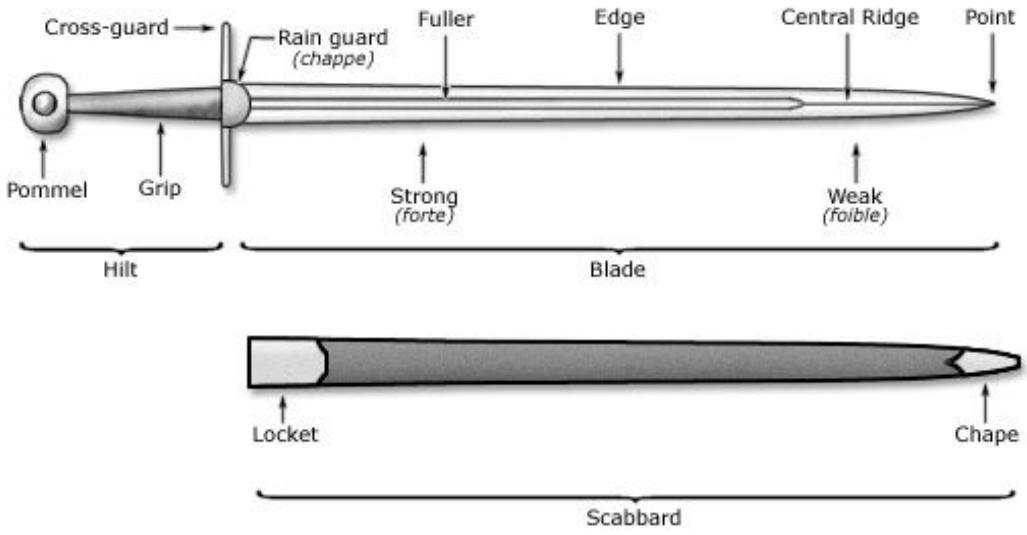


*Figure 5*. Showcases the different naming conventions for the sword

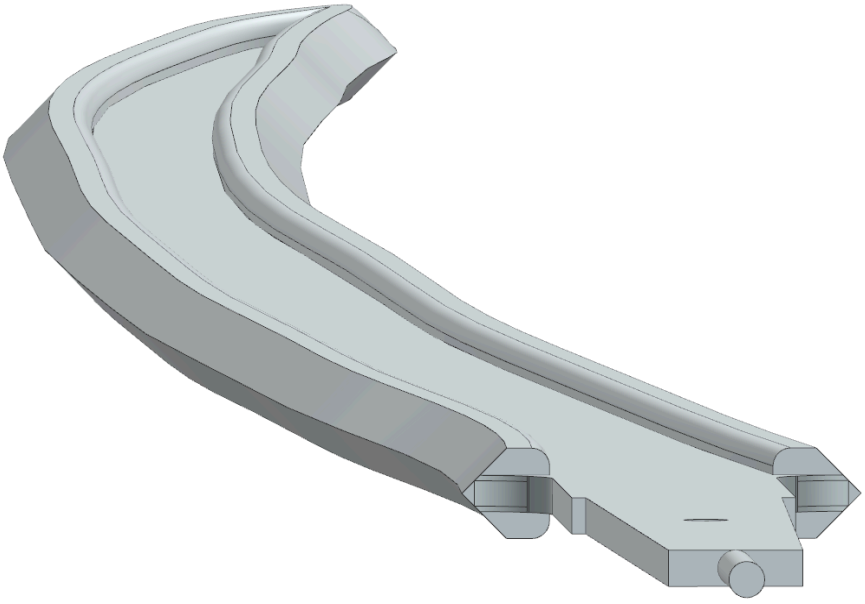

*Figure 6.* First design iteration showcasing the amount of space from the fuller to the edge of the blade.

*Figure 7.* First design iteration showing the full blade with tang.

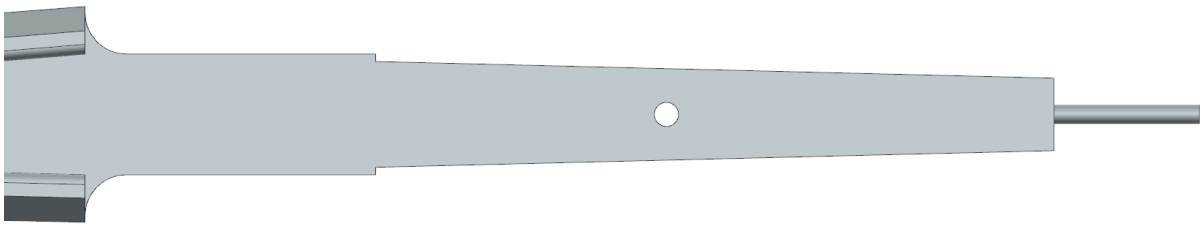

*Figure 8.* First design with tang and end shaft for pommel.

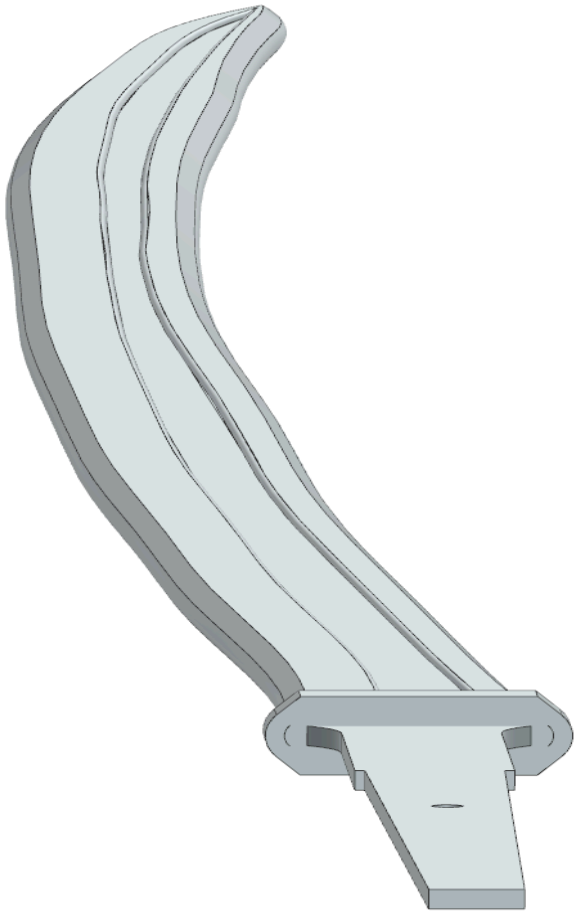

*Figure 9.* Final design iteration with ricasso.

*Figure 10.* Final design full length blade with tang changes and ricasso.

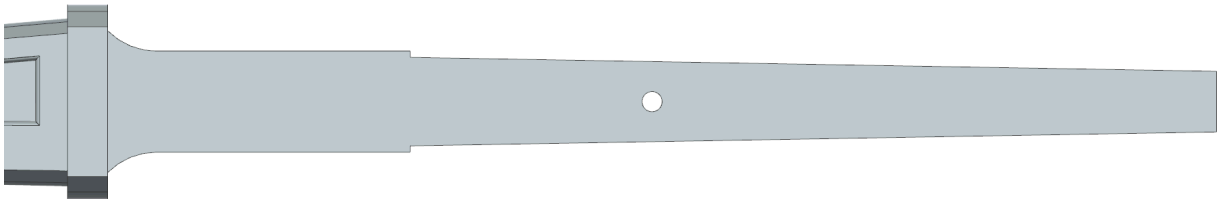

*Figure 11.* Final design with tang and tang shoulder.

*Casting:* Once the design of the sword replica was finalized, a gating system was designed and simulated by Temperform using MAGMASOFT (Figure 12). The simulations ran by Temperform showed that there were a few spots that could have porosity when cast, shown in Figure 13 below. After designing and running casting simulations on the gating system, Temperform cast the swords using AISI 4135 steel at 3042℉ (Figure 14). Due to a casting defect and the thickness of the casting, part of the sword's tang broke off during shakeout after the swords solidified. To fix the tang that broke off, Temperform welded a piece of metal to the sword to act as the tang. Temperform sectioned the gating system off of the raw casting.

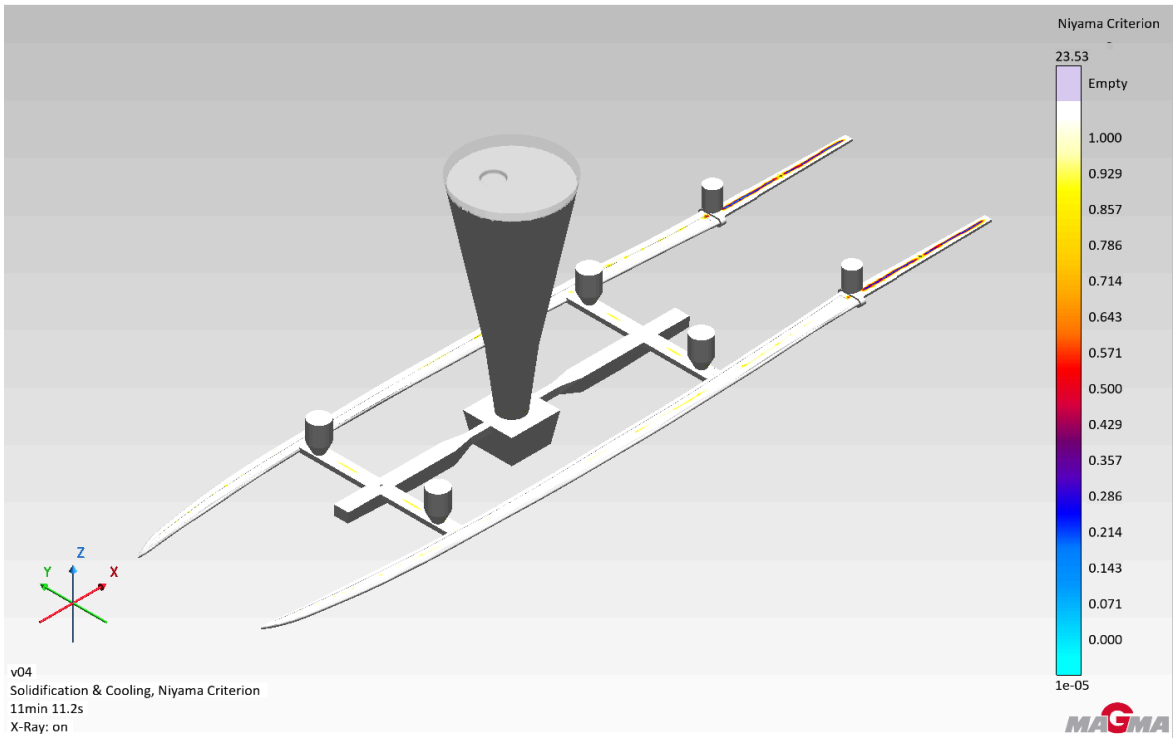


*Figure 12*. Solidification results of the sword replica casting simulation using MAGMASOFT (run by Temperform).

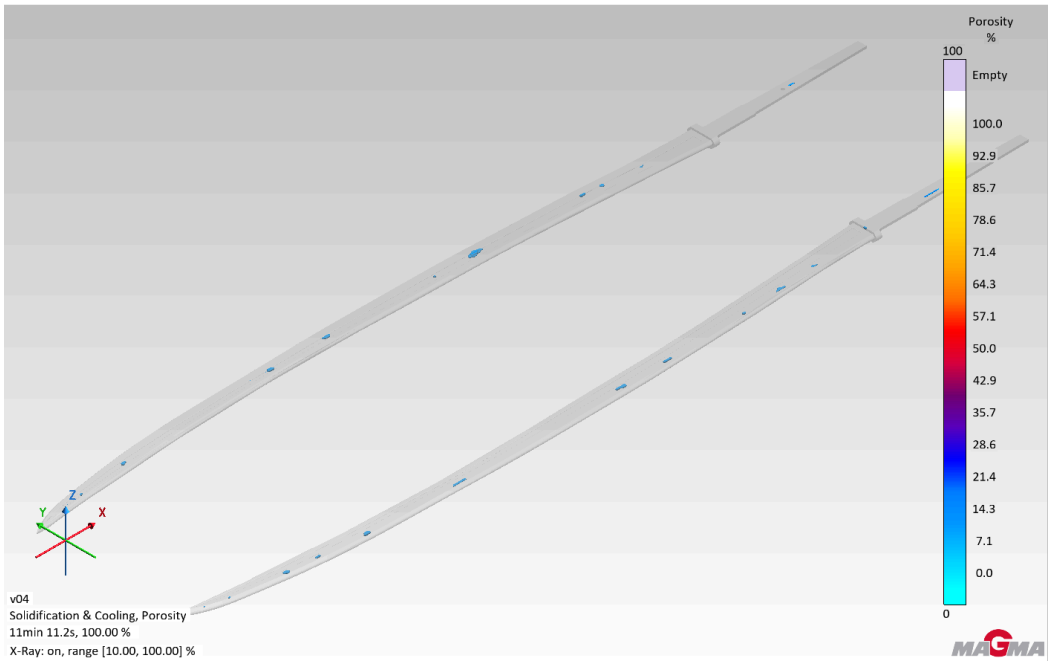


*Figure 13.* Porosity results of the sword replica casting simulation using MAGMASOFT (run by Temperform).

*Figure 14*. Sword replica raw casting (cast and photographed by Temperform).

*Heat treatment:* The sword replica underwent a homogenization heat treatment at Temperform after being cast and having the gating system removed from the castings. After the sword was shipped to MTU, The Founding Founders used a Lucifer Furnaces brand furnace at MTU to perform a quench and temper heat treatment on the sword replica (Figure 15). Initially, the sword was held at 1616℉ for 0.5 hours, then quenched in an oil quench bath until the sword hit room temperature. During heat treatment, the welded piece of the sword's tang bent during handling at high temperature, which needed to be fixed during casting cleaning. After the sword was quenched, it was put back into the furnace for the tempering heat treatment and was held at 932℉ for 0.5 hours. The sword replica was aircooled after the tempering heat treatment.

*Figure 15*. MTU's Lucifer Furnaces brand furnace and the oil quench used for the quench and temper heat treatment.

*Casting cleaning:* After the sword replica was quenched and tempered at MTU, the sword blade was cleaned using an edge grinder, a dremel, and a grinding wheel in order to create and sharpen the blade's edge. The bent tang discussed above was then fixed by hammering the metal back into place and cleaning the tang with a dremel. Unfortunately, while grinding the sword replica's edge, a spot of porosity was exposed as shown in Figure 16 below. After the sword's edge was sharpened, the team made a handle for the sword out of wood to avoid needing to work with or acquire bone for the handle, like George Washington's Silver Lion-Headed Cuttoe had.

*Figure 16*. Porosity defect exposed while grinding the sword replica's edge.

**Results**

The finished replica of George Washington's Silver Lion-Headed Cuttoe made by The Founding Founders for the SFSA Cast in Steel 2025 competition is shown below in Figure 17. The total length of the sword replica was 36.4 inches, and the length of the sword's blade was 29.5 inches (Table 1). The final weight of the sword replica including the handle and pommel was 1.75 lbs (Table 1). The tang, guard, and blade of the sword were all made of one cast piece of quenched and tempered AISI 4135 steel, along with a wooden handle that was bolted to the sword replica (Table 1).

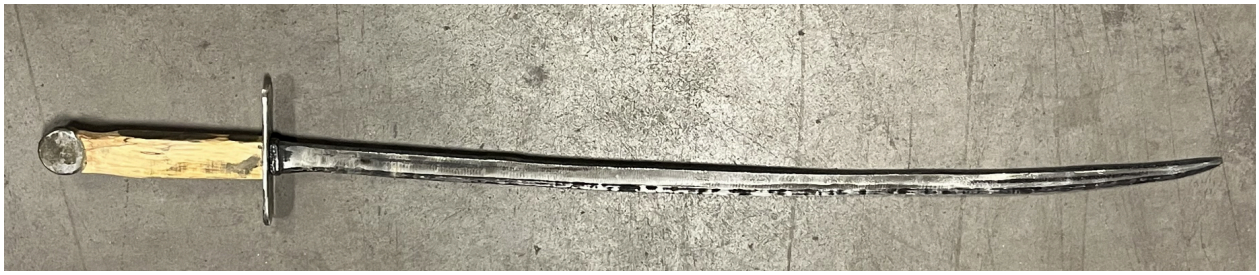

*Figure 17.* Final replica of George Washington's Silver Lion-Headed Cuttoe.

*Table 1.* Sword Replica Results

| Result Type | Value/Material |
|---|---|
| Total length | 36.4 in |
| Blade length | 29.5 in |
| Total weight | 1.75 lbs |
| Tang, guard, blade, and pommel | AISI 4135 Steel |
| Handle | Wood |

**Discussion**

Although the dimensions of the replica of George Washington's Silver Lion-Headed Cuttoe were similar to the original sword, the lion-head pommel was unfortunately omitted from the team's replica due to time and budget constraints. Another difference between the sword replica and George Washington's sword was that the handle of George Washington's sword was made of bone, while the team's replica was made of wood to avoid using bone as a material. Also, casting the sword replica was a different production method than the multiple piece forged assembly, some of which were made of silver, that George Washington's The Silver Lion-Headed Cuttoe was originally produced with, although the single piece casting was a more efficient way of producing the sword. Overall, The Founding Founders sword replicate was similar in some ways to George Washington's sword, including blade dimensions and overall length of the sword and sword blade, but different in others, including the design of the pommel, the technique used to make the sword, and the materials used to make the sword.

**Conclusion**

The process to design, cast, and fabricate a replica of one of George Washinton's swords was a challenging and rewarding task. Team members applied what they had learned in their classes and learned new skills to select an alloy while utilizing Granta Edupack, designing the blade in NX, heat treating the sword in the school's own foundry, and fabricating the final pieces. Overall, this experience was not only a chance to be able to make something students would not get to otherwise, but also to learn a lot about and participate in many different facets of manufacturing.

**Acknowledgements**

The Founding Founders would like to thank SFSA for running the Cast in Steel competition and for all the help we've had from SFSA during and before the competition. The team would also like to thank Temperform, Nick Knotts, Lauren Innis, Jacob Grimm, and Gloria Webber for being our foundry partner and contacts and for all the work they've done to get our sword cast, including giving us advice during the sword's design phase, designing the sword's gating system, casting the sword, and saving any castings that had failed. Lastly, The Founding Founders would

like to thank everyone at MTU who helped the team throughout the competition including our advisor, Dr. David Labyak, Dr. Dale Dewald, and MSE undergraduate students Josh Worral and Veronica North.

**References**

[1] “George Washington’s Silver Lion-Headed Cuttoe,” George Washington’s Mount Vernon, 2025.https://www.mountvernon.org/preservation/collections-holdings/washingtons-swords/the-silver-lion-headed-cuttoe.

[2] Granta Edupack 2024, “Ferrous Alloys - Steel,” Ansys Granta, (last accessed March 21, 2025)