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

Wentworth Inst. Of Technology: Foundry Fathers


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CPP-Boston (Wollaston Alloys)

# Abstract

**Washington's Silver & Nail-Hilted Cut-Toes** is a reimagining of General George Washington's Bailey Silver and Ivory-Hilted Cuttoe, engineered with precision and determination by the student team at Wentworth Institute of Technology in Boston. As competitors in the 2025 Cast in Steel Competition, hosted by the Steel Founders' Society of America (SFSA), the objective was clear: recreate a historic blade, cast it in steel, and incorporate modern advancements while preserving its historical authenticity. The result is a sword that balances traditional craftsmanship with contemporary casting techniques, honoring the past while meeting the demands of modern performance standards.

This year's challenge required a departure from traditional forging methods in favor of modern casting techniques. Advanced 3D-printed pattern technology was used to design each component before committing it to the sand casting process. The blade, ornate guard, and handle were shaped manually, melted in a furnace, and poured into precision molds. The hand guard was cast in a homemade furnace, while the remaining components were produced at CPP Boston, where the methodology was refined in collaboration with industry professionals. The handle, traditionally made from ivory, was given a unique adaptation by embedding actual fingernail fragments in a resin-cast oak core. This detail serves as a symbolic tribute to the dedication and labor invested in the project, replacing ivory with a material that represents the team's hard work and perseverance.

Beyond its distinctive aesthetic and historical symbolism, the sword was designed for durability and performance. From the initial concept, impact resistance was a priority. Blade geometry was optimized using computer-aided simulations, and stress tests were conducted to ensure structural integrity under rigorous conditions. Each aspect of the cuttoe's function, including cutting ability, durability, and impact absorption—was carefully evaluated to create a weapon capable of withstanding demanding trials.

For the Boston-based team, this project extends beyond an academic exercise. It represents a connection between past and present, an opportunity to follow in the footsteps of history while advancing modern metallurgy. George Washington once walked these streets with a cuttoe at his side, and today, this recreation pays tribute to his legacy. The creation of this sword embodies American ingenuity, innovation, and the relentless pursuit of excellence.

To ensure the highest quality standards, finite element analysis (FEA) was conducted to simulate real-world stress conditions. These simulations provided critical insights into potential weak points, allowing for refinements in material thickness and impact resistance. Additional physical testing, including repeated strike durability trials, validated the final blade's robustness.

# Introduction

The Cuttoe sword, carried by George Washington during pivotal moments in American history, embodies resilience, leadership, and revolutionary ideals. For the 2025 SFSA Cast In Steel Competition, our team has embraced the challenge of crafting a historically inspired iteration using modern casting technology.

The Foundry Fathers have christened our creation "Washington's Silver & Nail-Hilted Cut-Toes," a playful yet respectful homage to Washington's original ivory-hilted cuttoe. By integrating innovative 3D-printed pattern technology with traditional sand casting methods, our sword seeks to revitalize historical authenticity while delving into new metallurgical frontiers. Collaborating with CPP Boston, we have gained invaluable practical insights into casting and fabrication processes, melding hands-on experience with cutting-edge technology.

**Project Goals**

- **Historical Accuracy**: Faithfully replicate the design and characteristics of the original cuttoe sword while employing modern casting techniques.
- **Symbolic Integration**: Incorporate meaningful elements, such as embedding fingernails in the resin handle, to symbolize dedication and craftsmanship.
- **Metallurgical Innovation**: Utilize advanced simulation and testing methods to enhance the sword's performance and structural integrity.

## SFSA Cast In Steel Competition Overview

The Steel Founders' Society of America annually sponsors the Cast In Steel Competition, challenging university students to recreate historical weapons using contemporary casting methods. This competition fosters collaboration between engineering students and industry professionals, showcasing the versatility and strength of cast metals.

# Historical Review

**The Original Cuttoe Sword**

The original Silver and Ivory-Hilted Cuttoe, crafted by English-born American cutler John Bailey around 1771, stands as a significant artifact in American military and cultural history. Bailey, who emigrated from Sheffield, England, established his craftsmanship in New York City before relocating to Fishkill, New York, during the Revolutionary War. His meticulous designs, renowned for their elegance and functional utility, garnered popularity among military officers of the period, including General George Washington.

However, there is a contrast between the mythicized rendition of Washington's crossing of the Delaware and the actual crossing. While the 1851 painting depicts Washington wielding his Bailey silver & ivory-hilted cuttoe, he didn't possess the sword at the point of the war. Instead, it's more likely that he utilized his silver lion-headed cuttoe instead which he received in 1770 by Jacob Gooding. It's interesting to note that this blade had a length of 30" which was greater than the standard, possibly requested by Washington to match his 6'2" frame which was very uncommon at that time..

Combat of the time was organized with focus on gunpowder warfare, melee combat still had its place in 18th century battles. Officers carried swords to direct soldiers and cavalry often used sabres to engage in hand to hand combat but the average soldier would rely on bayonets and knives when combat devolved from line formations to melee brawls. That being said, there were some proponents who advocated the common soldier be given pikes. Ben Franklin wrote to General Charles Lee that soldiers should be equipped with bows and pikes since they're effective weapons and more importantly easy to manufacture in a time where the colonies had very little production capabilities..

Fig 1. Silver Lion Cuttoe

Fig 2. Bailey Silver & Ivory-Hilted Cuttoe

# Design Methodology

## Cast in Steel Guidelines

The Steel Founders' Society of America  Cast in Steel Competition is a prestigious annual event that challenges university students to recreate historical weapons using modern casting techniques. The 2025 competition focuses on replicating George Washington's Bailey Silver and Ivory-Hilted Cuttoe, merging historical accuracy with modern engineering advancements.

To ensure consistency across all entries, the competition establishes key requirements that all participants must follow:

- Weight Restriction – The final sword must not exceed 2 kg (4.4 lbs.).
- Length Requirements – The total length must be between 25 inches and 43 inches, with a blade length between 20 inches and 35 inches.
- Manufacturing Process – The blade and key components must be cast rather than forged or machined from stock material.
- Historical Inspiration – The design must either be a close replica of an existing historical sword or an inspired reinterpretation that aligns with Washington-era styles.

To ensure compliance, weight distribution analyses, finite element analysis (FEA), and casting simulations were conducted. These evaluations guided the mold design, structural reinforcement, and overall casting integrity to produce a high-quality final product.

## Sword Dimensions and Final Specifications

The following table provides the dimensions and specifications of the final Washington's Silver & Nail-Hilted Cut-Toes sword:

| Component | Length (in.) | Width/Diameter (in.) | Thickness (in.) |
|---|---|---|---|
| Blade | 37 ¼" | 1 ⅛ " | ¼ " |
| Handle | 6.25" | 1 ¾" | 1" |
| Handguard | 2" | 4 ½ " | 1" |
| Overall Length | 38" | N/A | N/A |
| Total Weight | 3.4lbs (must not exceed 2 kg) | N/A | N/A |

All measurements were taken to ensure compliance with competition guidelines while maintaining historical accuracy and structural integrity.

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## Modern Adaptation and Scaling

To enhance the structural reliability of the final sword, the design was scaled to approximately three-quarters of the historical size. This modification was necessary to accommodate material limitations that affect edge retention and overall durability.

The selected cast material, comparable to surgical steel, does not maintain prolonged sharpness like high-carbon steel. To compensate, the blade geometry was optimized through iterative CAD modeling and material testing, ensuring a balance between historical authenticity and modern performance.

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# Symbolic Elements: Oak and Fingernails

## Inspiration and Symbolism

The development of Washington's Silver & Nail-Hilted Cut-Toes was not only an engineering challenge but also an opportunity to incorporate meaningful historical symbolism. Several design choices reflect Washington's legacy, reinforcing the historical and cultural significance of the weapon.

- Oak Handle – The oak tree has long been a symbol of strength, endurance, and resilience. Historical records associate Washington with oak trees, most notably the Washington Oak in Princeton, New Jersey, where he is believed to have rested during the Revolutionary War. Integrating oak into the handle pays tribute to his leadership and perseverance.

- Embedded Fingernails – Due to ivory's unavailability, an alternative design was implemented, embedding fingernail fragments into a resin-cast oak core. Historically, fingernails have been seen as personal relics, symbolizing dedication and craftsmanship. This detail serves as a representation of the labor and effort behind the project, aligning with Washington's writings on national strength and perseverance.

- Silver Wire Wrapping – Silver wire was commonly used on high-ranking officers' weapons in the 18th century. This feature enhances both the aesthetic authenticity and functional grip of the handle while reflecting Washington's personal armory.

## Design of Washington’s Silver & Nail-Hilted Cut-Toes

The development of Washington’s Silver & Nail-Hilted Cut-Toes required an intensive CAD-driven design process, merging historical accuracy, structural integrity, and manufacturability into a single, cohesive weapon. Every element of the blade, handguard, and handle was designed with casting-based manufacturing in mind, allowing for an integration of modern industrial foundry techniques alongside handcrafted refinements. The resulting sword is a product of precision engineering, material science, and a deep respect for historical craftsmanship.

# Key Design Considerations

- **Blade Geometry –** The blade design follows **the profile of Washington’s original cuttoe**, tapering into a **fine slicing section in the final few inches**. This tapering enhances **cutting efficiency** while maintaining **structural robustness**. To ensure **historical proportional accuracy**, the **original sword image was traced in Onshape**, establishing an **accurate CAD model** for later refinements.

- **Handguard Casting –** The **handguard was cast in a homemade foundry**, composed of a **custom alloy of copper, aluminum, and silver** to replicate **historical electrum-like materials**. This composition not only improves **durability and corrosion resistance** but also enhances the **aesthetic authenticity** of the final product.

- **Handle Construction** – The **handle was modeled as a solid structure** in CAD to serve as a **pattern for a silicone mold**. In the final fabrication, the **handle was cast in epoxy resin**, embedding a **real oak core** for added **strength and historical significance**. To further emphasize **craftsmanship and dedication**, **fingernail fragments** were embedded within the resin, encased in a **clear epoxy layer** alongside **silver wire wrapping** to reinforce the structural integrity of the grip.

- **Pommel Substitution –** A **cast pommel attempt was unsuccessful**, requiring an alternative approach. A **salvaged emergency glass breaker knub from a switchblade** was used instead, ensuring **functional durability while adding an unconventional but practical design solution**.

- **Material Selection** – The blade material was **CA6 stainless steel**, a choice dictated by **foundry production limitations** but optimized for **castability, durability, and corrosion resistance**. While not traditionally used in edged weapons due to its lower carbon content, the **blade geometry and post-processing methods were adjusted** to compensate for any material-related drawbacks.

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## Iterative Design Process

The design underwent a **series of modifications and optimizations**, focusing on **structural, casting, and functional performance improvements**:

1. **Version 1** – The **initial CAD model** was developed using **historical reference images**, ensuring **accurate proportions and period-appropriate features**.

2. **Version 2** – Simulations of **weight distribution and balance adjustments** were performed, leading to modifications in **blade thickness, center of gravity placement, and structural reinforcement**.

3. **Version 3** – Final **casting test results** dictated refinements in **gating configurations, mold design, and solidification control**, ensuring **successful metal flow and defect-free casting**.

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## Casting and Manufacturing Processes

The manufacturing of Washington's Silver & Nail-Hilted Cut-Toes deviated from traditional sword-making techniques, opting for a double-impression mold setup rather than the conventional vertical sword mold. This choice was made to simulate real-world industrial casting conditions and gain hands-on experience in customer-driven manufacturing methodologies. While the handguard could have been cast alongside the blade at CPP Boston, it was intentionally fabricated in a homemade foundry, providing additional insight into small-scale casting techniques. Every decision made throughout the casting and fabrication process was guided by a commitment to practicality, experimentation, and engineering excellence.

### Molding and Creating the Blade

The blade fabrication process followed an industrial casting methodology, leveraging the advanced capabilities of CPP Boston, formerly Wollaston Alloys. A 3D-printed split-pattern blade was developed with built-in shrinkage allowances, accounting for dimensional changes during solidification. The double-impression molding technique allowed for increased production efficiency while maintaining high levels of accuracy. The rigging system, including runners, risers, and gating structures, was developed through SolidWorks CAD modeling and further validated using MAGMASOFT casting simulations.

Frank, a NAVY-trained wooden pattern maker, worked alongside CPP Boston's engineering team, utilizing traditional pattern-making techniques to refine the rigged pattern. Epoxy and bondo were strategically applied to optimize flow characteristics and metal distribution within the mold cavity. Once finalized, the pattern was placed into a sand-binder flask, where a non-stick coating was applied to prevent sand adhesion and ensure a clean release. Gas vents were drilled into the mold to facilitate proper air evacuation, preventing porosity and improving metal flow.

With the mold fully assembled and sealed, the pouring process commenced at CPP Boston's high-capacity foundry. A four-man crew, clad in heat-resistant aluminum suits, operated the 3,000-pound induction furnace, ensuring precise temperature control and alloy consistency. Molten CA6 stainless steel was checked using thermocouples and spectrometry analysis before being ladled onto a specialized pouring track. The team carefully regulated metal flow, monitored risers to prevent premature freezing, and applied hot-top material to optimize solidification rates. After cooling overnight, the casting was extracted, cut from its gating system, shot-blasted, and prepared for post-processing.

### Molding and Creating the Handguard

The handguard was also 3D printed before undergoing a series of modifications to improve castability and ensure historical accuracy. Achieving precise raised lettering and surface details required multiple design iterations before finalizing the pattern. A traditional flask system, measuring 8x10x6 inches, was used for mold preparation, ensuring stability and proper alignment throughout the process. The pattern was placed flat, and sand was packed tightly around it to achieve a high-fidelity mold impression. Once the cope section was added and aligned using precision-machined pins, the pattern was carefully removed, leaving behind a clean cavity for casting.

To create the final metal handguard, a custom bronze alloy composed of copper, aluminum, and silver was melted and poured into the mold. This alloy was chosen for its historical resemblance to electrum, a material commonly used in the 18th century for decorative metalwork. The casting was refined using Dremel tools and high-grit sandpaper, enhancing the engraved details and achieving the desired surface texture. A controlled heat-induced oxidation process was also applied to produce a patina that closely matched historical weapon fittings from Washington's era.

## Handle Construction

The handle presented one of the most intricate challenges in the fabrication process, requiring a multi-step approach that incorporated 3D printing, silicone mold making, epoxy resin casting, and hand-finishing techniques. The initial handle was 3D modeled and printed as a solid structure, serving as the master pattern for a silicone mold. This pattern was placed inside a custom-built wooden mold box, where it was suspended using paper clips to ensure proper alignment before the silicone was poured. Once cured, the mold was carefully cut along a seamline, allowing for precise pattern removal and future resin casting.

For the final handle, a pre-shaped oak core was positioned within the mold's center to add structural integrity and historical authenticity. A high-strength tabletop epoxy resin, dyed green for aesthetic contrast, was then poured into the mold, fully encapsulating the oak core. Embedded within the resin were fingernail fragments, symbolizing the craftsmanship and dedication that went into the project. Once the resin cured, the handle was removed and subjected to additional refinements, including hand-ground grooves for silver wire wrapping. The silver wire was meticulously wrapped around the handle to reinforce the grip and enhance visual appeal. To replicate the texture of an ivory handle, black accent lines were painted onto the surface before a final clear epoxy coating was applied, permanently sealing the silver wire and painted details beneath a durable, protective layer.

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## Post-Processing & Finishing

### Surface Refinement & Polishing

Following casting, the blade underwent extensive grinding and polishing, gradually refining the surface finish to meet both functional and aesthetic standards. Initial material removal was performed using a belt sander and bench grinder, shaping the blade to its final profile while removing excess casting material. Precision detailing was completed with a Dremel, followed by progressive high-grit sanding, ranging up to 3000 grit to achieve a smooth and uniform surface texture. The final finish was hand-buffed, producing a matte sheen that retained a historically accurate aesthetic while enhancing corrosion resistance.

### Edge Testing & Sharpening

Sharpening a cast stainless-steel blade presented unique challenges, as the material properties differ from traditional high-carbon steel commonly used in edged weapons. The sharpening process was approached systematically, testing various bevel angles to determine an optimal cutting edge that balanced sharpness and durability. Initial edge shaping was carried out with a belt sander, followed by progressive refinements using whetstones ranging from 300 to 8000 grit. High-grit sandpaper was then used to hone the final edge, producing a sharp and clean finish.

To evaluate the blade's cutting performance, a series of controlled test cuts were conducted on pineapples at various locations around historic Boston. These tests provided qualitative data on edge retention, slicing efficiency, and impact resistance, simulating real-world cutting conditions while adding a symbolic connection to the historical presence of Washington's original sword in the region.

# Final Assembly & Balancing

## Handguard & Handle Installation

The handguard was designed with a core, allowing it to slide over the tang and slightly overlap the base of the blade, mirroring the structural configuration of the original cuttoe. This ensured a secure mechanical fit while maintaining historical authenticity. With the 4-inch tang exposed, a hole was drilled into the oak core of the handle, allowing the entire assembly to be hammered into place for a tight friction fit.

To further reinforce the structural integrity of the assembly, epoxy was applied at key contact points, permanently securing the handguard and handle in position. This method eliminated any potential movement, ensuring that the weapon remained rigid and reliable under stress.

## Weight Distribution & Balancing

Balancing played a critical role in ensuring that the final sword was both historically accurate and functional in practice. The center of gravity was carefully adjusted, with excess material selectively removed from the blade until the balance point was positioned five inches above the handguard. This precise adjustment allowed the weapon to achieve optimal handling characteristics, ensuring it could be comfortably wielded while maintaining an effective cutting force.

## Final Handling & Performance Validation

To verify the final assembly, a series of handling and grip comfort tests were conducted. The completed sword was assessed for structural integrity, grip security, and maneuverability, ensuring that Washington's Silver & Nail-Hilted Cut-Toes was not just a historical recreation but a fully functional, well-balanced weapon.

# Technical Specifications

*Fig 3 -Exploded Assembly of the Sword*

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**Simulations & FEA**

This section evaluates the team's rendition of Washington's Sword against through computer simulation and analysis. Utilizing  Magmasoft to determine potential niyama, soundness, and hotspots and solidworks to perform stress analysis.

**Simulation Scenarios**

- Why it matters: Virtual testing allows refinement before physical prototypes are produced
- Key considerations: MAGMASOFT casting and simulations analyzing sword stress under use
- Data location: MAGMASOFT Result & Case 1-3

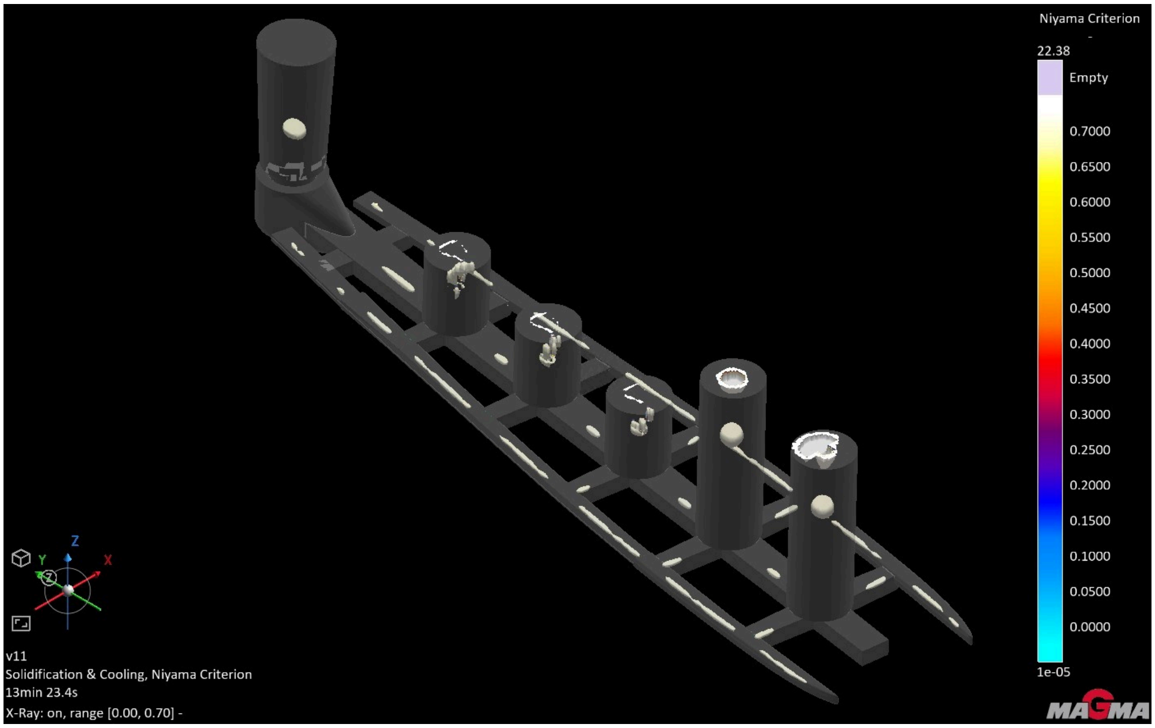


*Fig. 4 Sword Niyama Plot*

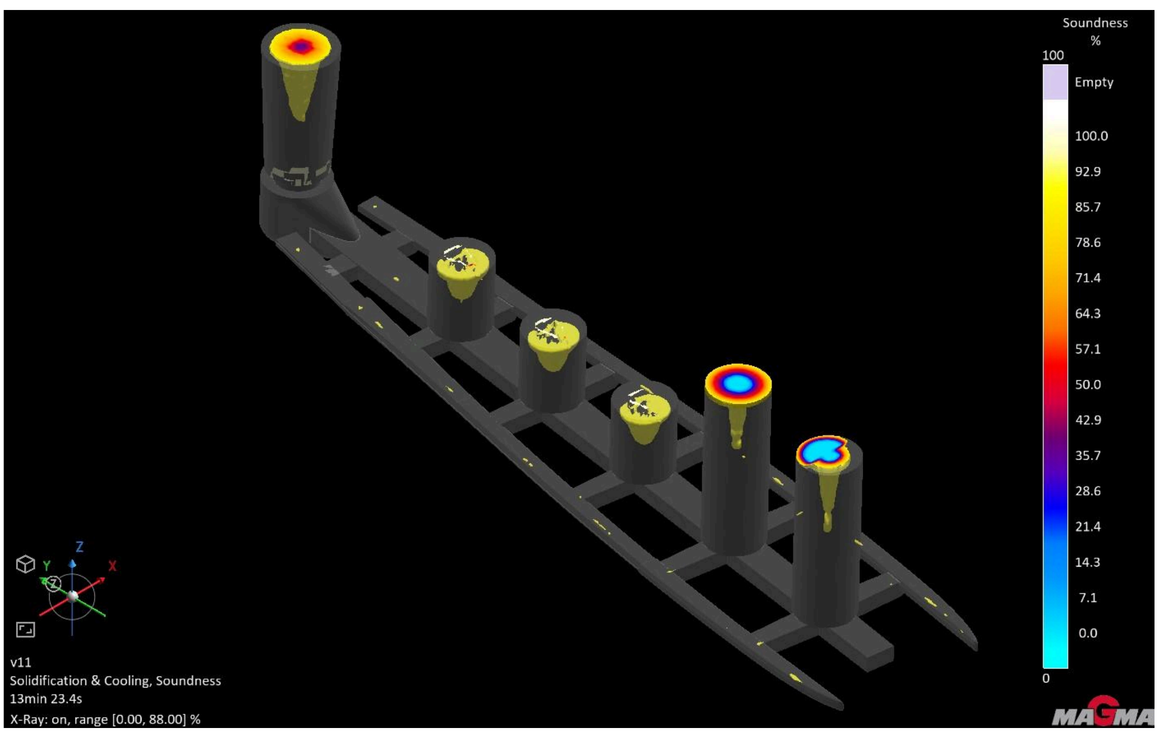


*Fig. 5 Sword Soundness Plot*

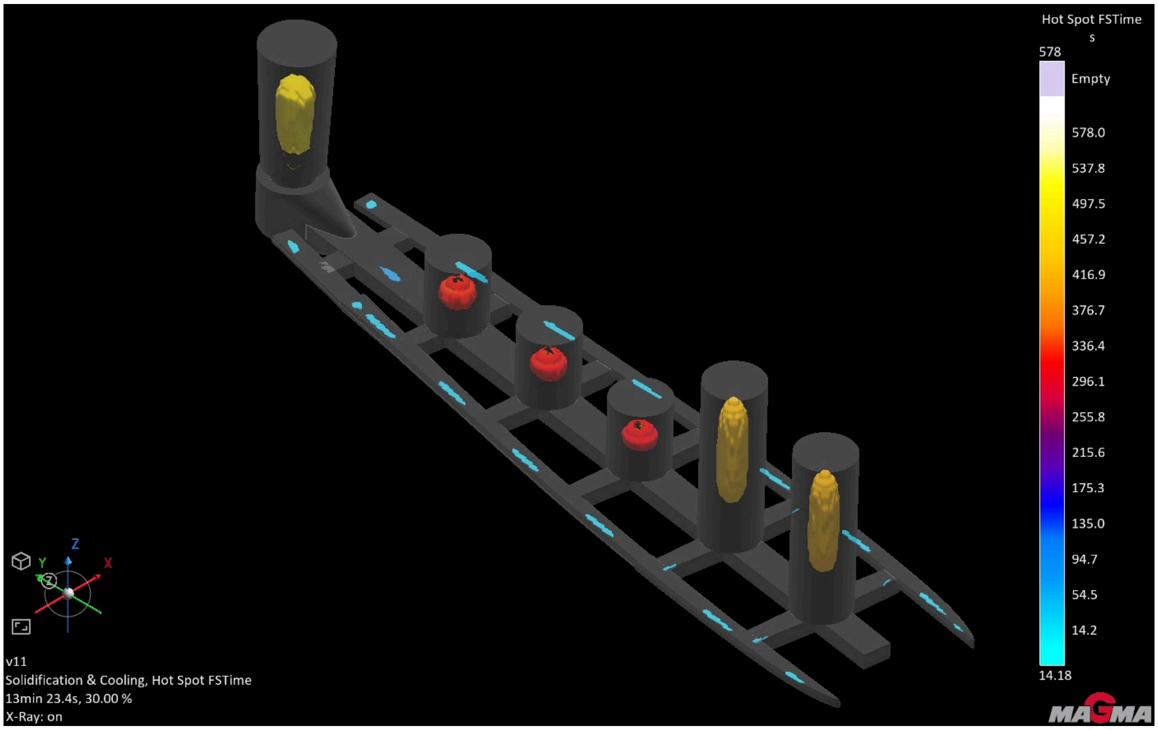


*Fig. 6 Sword Hotspot Plot*

**Balance & Weight Distribution**

- Why it matters: Ensuring proper weight distribution improves usability and endurance
- Key considerations: Center of gravity location
- Data location: SolidWorks Sword Assembly

**Structural Integrity Validation**

- Why it matters: Confirming the sword maintains strength under combat-like stress (a defensive parry specifically)
- Key considerations: Comparison of displacement and stress between the original and new design
- Data location: Simulation Summary and Discussion

Sword Assembly

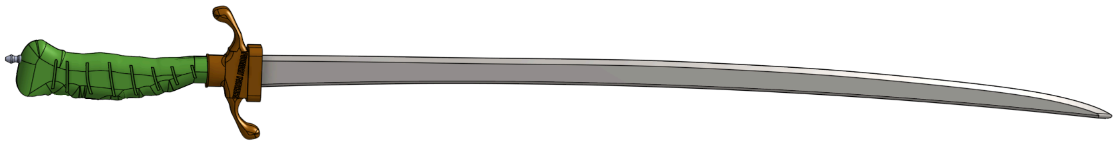

*Fig 7 - OnShape Sword Assembly Blade Up*

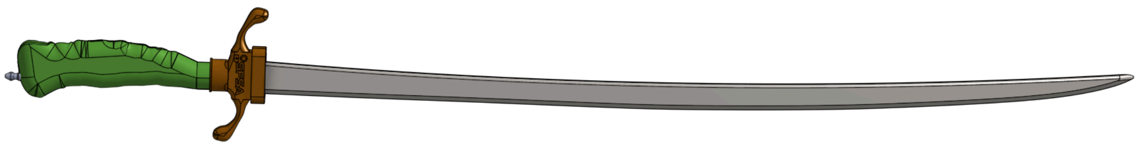

*Fig 8 - OnShape Sword Assembly Blade Down*

Center of Gravity Feature

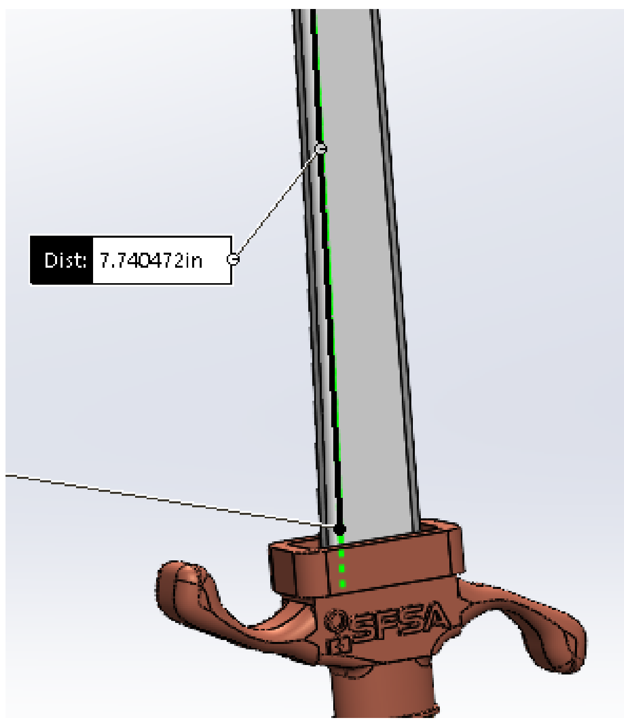


*Fig 9- Rough Center of Gravity Simulation Solidworks*

Taking OnShape models into solidworks, the team applied respective materials to ascertain an approximate center of gravity of the sword. Ideally, the center of gravity for the sword would have been located closer to 6" off the hilt, closer than where it is now. This result is not inherently displeasing to the team, as assumptions made dictated that the result would be further away than in actuality. The actual sword blade is thinner and has more material removed from the tang. All of which would push the center of gravity closer to the hilt. Most importantly, actual handling of the sword agrees with the conclusion of this section as the sword handles with balance.

## Simulation Setup and Research

To evaluate the feasibility of the team's design, static simulations in solidworks were undertaken. The aim was to conduct a literature review to ascertain a model of similar sword behavior in a typical combat movement. In their journal entry, Konyukhov, A., & Yeniavci, H, analyze the mechanics of the defending sword in a traditional Japanese Kendo parry. They specifically analyze the forces acting upon the center of gravity of the sword through the parrying motion [11].

Selecting the initial parry collision as the target simulation for the team's sword model, three simulation cases were developed. The first case simulates the parry force, the second: 1.5x the parry force, and the third: 2x the parry force.

| Case | X 'Slicing' Force [11] | Y 'Cutting' Force [11] | Z 'Scraping' Force [11] |
|---|---|---|---|
| 1 | -90 N | -100 N | -12 N |
| 2 | -135 N | -150 N | -18 N |
| 3 | -180 N | -200 N | -24 N |

*Table 1 - Simulation Cases*

With the cases generated, a SolidWorks static FEM simulation study was developed by the team. The blade is modeled itself, with fixed geometry at the tang to represent the connection to the handle and handguard. Forces are applied in their respective directions at the sword center of gravity on the parrying face of the blade. The model was meshed with standard curvature, with a maximum element size of 0.15 inches. The solver was configured to run the simulation utilizing the H-adaptive method at 95% convergence. For all three cases convergence was reached within 5 iterations.

*Fig 10 - Sword Simulation Setup*

**Case 1 (1x Parry Force)**

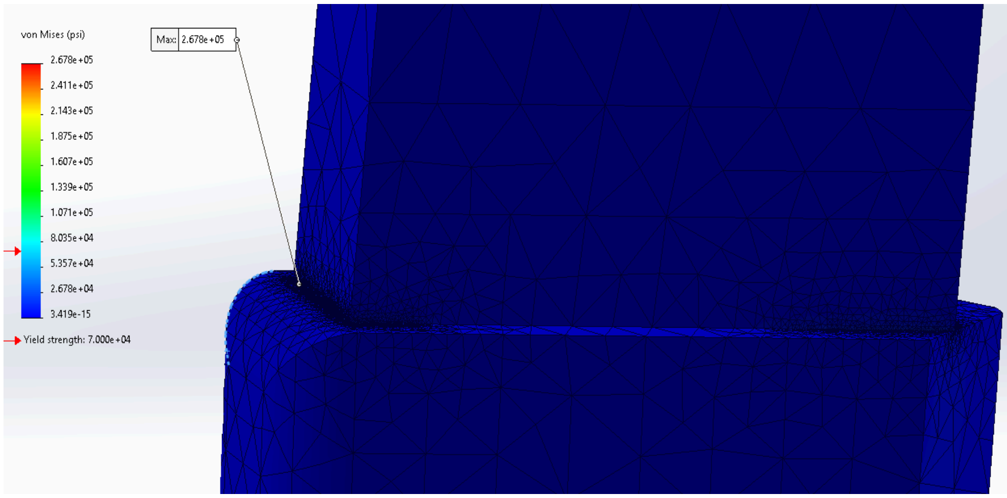


*Fig 11 - Case 1 Stress Plot*

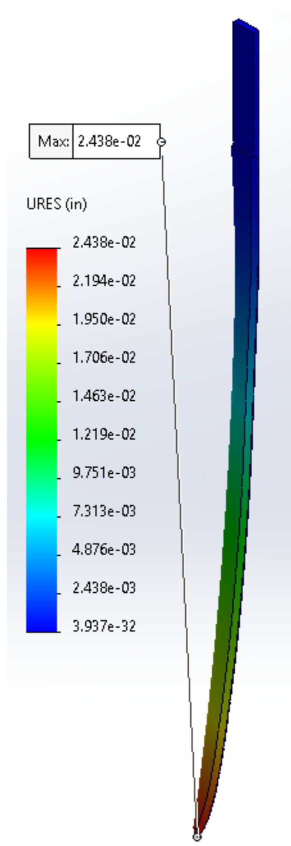


*Fig 12- Case 1 Displacement Plot*

**Case 2 (1.5x Parry Force)**

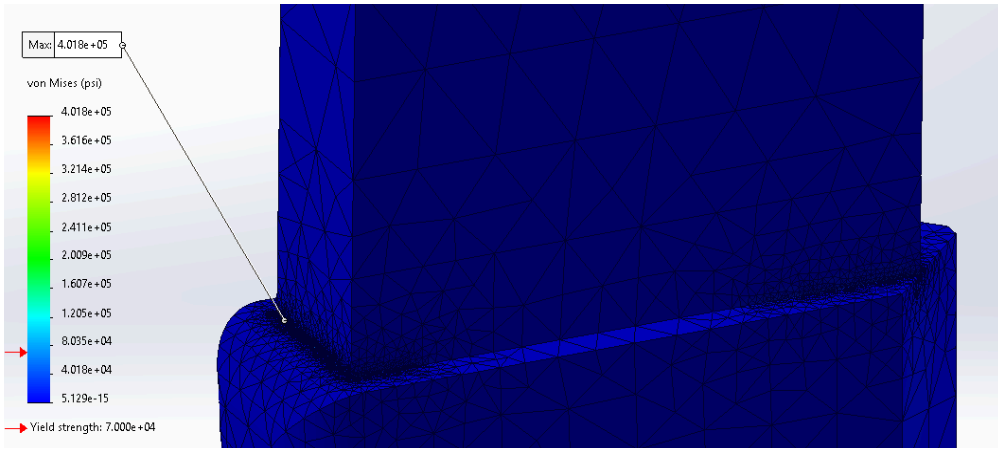


*Fig 13- Case 2 Stress Plot*

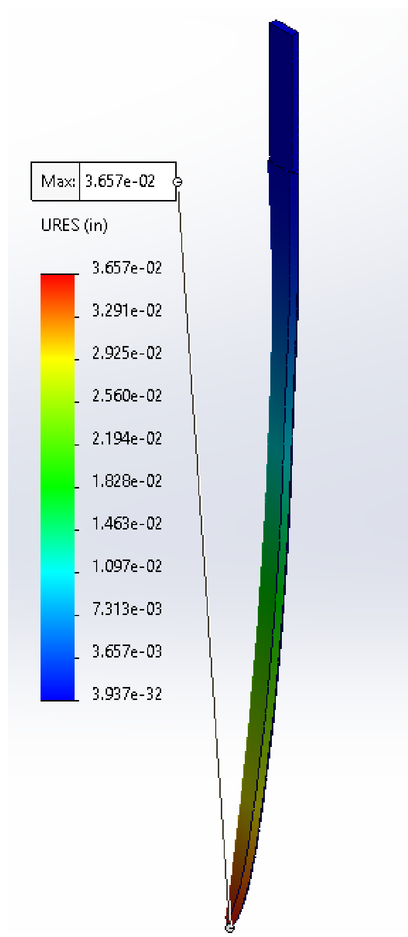


*Fig 14 - Case 2 Displacement Plot*

## Case 3 (2x Parry Force)

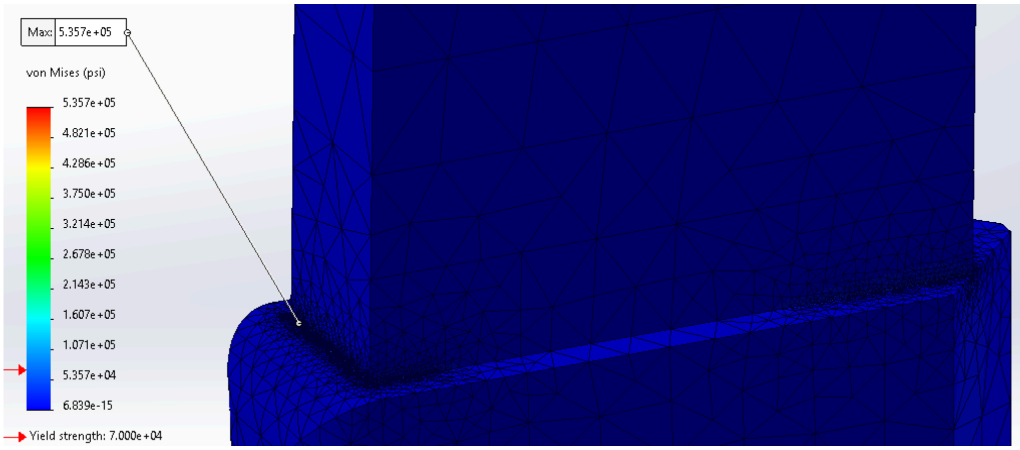


*Fig 15- Case 3 Stress Plot*

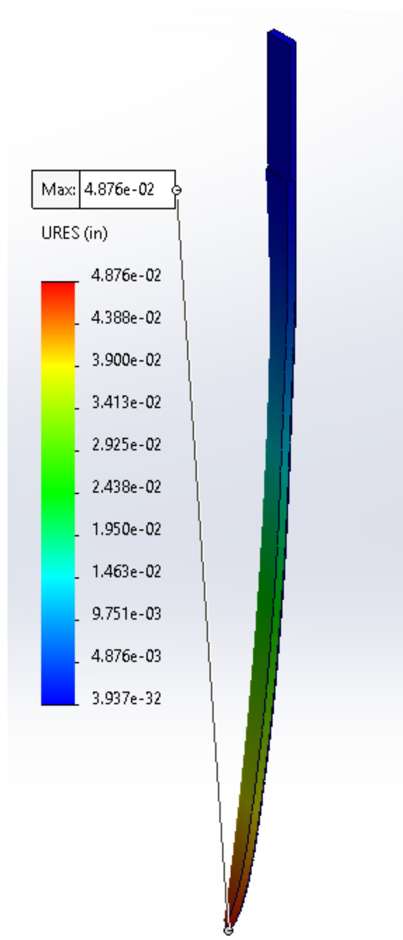


*Fig 16 - Case 3 Displacement Plot*

**Simulation Summary and Discussion**

| Case | Max. Von-Mises Stress (psi) | Max. Resultant Displacement (in) |
|---|---|---|
| 1 | *2.678E5* | *2.438E-2* |
| 2 | *4.018E5* | *3.657E-2* |
| 3 | *5.357E5* | *4.876E-2* |

*Table 2 - Simulation Results*

All three cases ran with stresses below the yield strength of the blade material and without excessive displacement. The peak stress values approach within 50% of the yield strength for cases 2 and 3 which is a cause for concern. This concern is mitigated by understanding the discrepancy between the real sword and the model in simulation.

The simulation models the tang and blade connection as if it were two rectangles face to face creating a perfect edge, an incredible stress raiser. In reality, the interface between the tang and blade has a filleted radius, lowering the actual stresses in the max stress region. This is, however, where one would expect the most stress and a potential failure point, and actual assembly must take into account the structural importance of this region.

## Testing & Performance Analysis

Every weapon, no matter how meticulously crafted, must be put to the test, and Washington's Silver & Nail-Hilted Cut-Toes was no exception. While the engineering data from CPP Boston's metallurgy and chemistry reports provided a detailed understanding of the sword's material composition and structural integrity, real-world validation was necessary to evaluate its handling, durability, and cutting efficiency.

Although the final product was treated with careful handling after its last round of polishing, performance trials were conducted to assess edge retention, balance, and impact resilience. The sword was not confined to laboratory analysis—it was taken to the streets of historic Boston, a location where Washington himself may have once carried a similar blade. The final test involved a series of controlled strikes against pineapples, chosen for their fibrous resistance and layered structure, providing qualitative feedback on sharpness and slicing capability.

## Testing Environment and Collaborators

To ensure **accurate and meaningful results**, testing was conducted in collaboration with **metallurgical experts, blacksmiths, and historical weapon enthusiasts**. The sword was first analyzed in **controlled lab conditions at CPP Boston**, where **spectrometers and hardness testers** verified its **alloy composition, mechanical properties, and edge wear characteristics**. These assessments provided **quantifiable data** on the sword's **structural soundness and durability**.

Beyond the lab, the sword underwent a more **theatrical but equally valuable test** in the **streets of Boston**, where it was wielded before an **unexpected audience**. The historical significance of the setting added weight to the demonstration, as **Washington's own sword may have once passed through these same streets**. The true casualties of this test were **a cluster of British pineapples**, which fell swiftly to the blade in a **dramatic display of slicing precision**

## Results and Performance Evaluation

The final round of testing confirmed that Washington's Silver & Nail-Hilted Cut-Toes was not only structurally sound but also fully capable of performing as intended. The sword exhibited minimal signs of wear or deformation, even under moderate force, demonstrating the durability of the CA6 stainless steel blade. Some minor edge rolling was noted in the mechanical data, though real-world testing was limited to controlled cuts. Despite this, the sharpening process and edge geometry allowed for clean and precise slicing, as demonstrated in the pineapple tests conducted in historic Boston.

Further examination of the structural integrity revealed that the blade maintained stable elasticity, returning to its original shape after flex testing without any permanent set. The handguard remained securely in place, properly aligned and structurally stable during test swings, validating the effectiveness of the assembly method and epoxy reinforcement. Additionally, no visible casting defects or weld failures were detected, ensuring that the manufacturing process successfully produced a defect-free component.

Overall, the testing phase confirmed that the design, material selection, and fabrication techniques resulted in a well-balanced and historically inspired sword, capable of withstanding use while maintaining structural integrity and visual authenticity.

## Conclusion

The creation of Washington's Silver & Nail-Hilted Cut-Toes was more than just an exercise in casting. It was a test of engineering ingenuity, historical reverence, and hands-on craftsmanship. From the initial CAD modeling to the final sharpening, every stage of the process was guided by precision, problem-solving, and an unwavering commitment to mastering the art of metalcasting. The final product stands as a fusion of tradition and modern innovation, embodying the spirit of the Foundry Fathers and the relentless pursuit of excellence in manufacturing.

Through rigorous design iterations, experimental casting techniques, and performance validation, this sword was refined into a functional, battle-ready weapon, capable of meeting the demands of both history and competition. While the blade was never truly tested in battle, its strength, balance, and cutting ability were proven through meticulous analysis and controlled demonstrations.

At its core, this project was a tribute to craftsmanship and innovation, a testament to what can be achieved when engineering meets artistry, and when history is not just studied, but recreated. Washington's Silver & Nail-Hilted Cut-Toes is not merely an artifact—it is a legacy cast in steel.

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## Acknowledgements:

All the Foundry Fathers, would like to collectively thank and acknowledge everyone involved in the development of this project. "Silver & Nail Hilted Cut-Toes" would not have been possible without the great support of our magnificent educational institution, Wentworth Institute of Technology, additionally we would like to give special thanks to the faculty involved here at Wentworth Tech, To the man who taught us the ins and outs of engineering graphics, got us involved with the competition, and our sponsor foundry to our beloved faculty advisor and Professor Serdar Tumkor, Ph.D.

Next we would like to bring attention to our sponsor foundry known as CPP Boston and everyone involved there. Seeing the operations at CPP Boston has inspired us to push our engineering education to the next level and deepen our appreciation for metal casting. They offered us their facilities and expertise without hesitation and we truly admire the work they do there. Shout out to the entire engineering team for guiding us through every step of the casting process and generously sharing their knowledge. A special thanks to the melt crew for letting us witness the real heat of production up close. Lastly we want to acknowledge everyone on the floor who helped us prepare and refine our molds ensuring we ended up with the best possible cast for Washington's Sword.

We would like to thank the New England Chapter of American Foundry Society for getting us involved with the steel casting community and helping us network within the field.

A special acknowledgement to the Steel Founders' Society of America (SFSA) for orchestrating such an engaging and educational event. The competition was not only a platform for innovation but also an opportunity to showcase our dedication and skills, made even more memorable by the presence of esteemed judges like Ben Abbot, Dave Baker, John Cory, Phillip Harrison, and Pat Nowak. Their expertise and insights are eagerly anticipated during the testing phase. A heartfelt thank you to Renee Mueller for her meticulous organization and

communication, ensuring we remained well-informed and on track with every deadline and detail of the event.

Lastly, if you have read this far, thank you. Your support means everything to us, and this project would not have been possible without the dedication, perseverance, and unwavering commitment of everyone involved. This blade is more than just steel—it carries a piece of us, forged with our own hands, embedded with our own fingernails, and shaped through relentless hard work. It stands as a testament to the grit, determination, and craftsmanship poured into every stage of its creation.

Above all, glory be to God, for He has given us the strength, wisdom, and resilience to see this project through. As Proverbs 27:17 says, "Iron sharpens iron, and one man sharpens another." Through this journey, we have been refined, tested, and strengthened—not just in skill, but in character. This sword, much like its creators, has been shaped through fire, challenge, and perseverance, standing as proof that through hard work, faith, and brotherhood, anything can be forged into something greater.

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