Project Overview

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Zen and the Art of a Craftsman's Journey: Lessons Learned While Designing and Prototyping a Period-Inspired Roman Trigger Mechanism for a Euthytone Catapulta Ballista in SCA Siege Combat

By Joshua Berry (Montgomery Josh the Hilariously Awesome)

This entry into Yule Revel's competition on growth as a craftsman chronicles my journey from a technical, tooling, and emotional point of view through the engineering archaeology of designing a Roman-style trigger mechanism for a Sige engine used in Rattan Combat. At the start of this project, I had technical skills from numerous household and robotics projects but lacked the mindset and experience to do precision fabrication of parts. Through many mis-steps trying to use a wooden trigger claw and lessons learned on basic wood and metal crafting I refined the design into something reliable and safe I can share with the Siege community. During this process, I re-claimed myself as a builder by finally acquiring the tools and skills to make parts the right way. I am not yet a master craftsman, but the growth over this project enabled me to continue that journey.

Ballista Overview

A ballista is an ancient and medieval siege engine used to throw bolts over long distances at opposing armies or structures. The Greek and Roman versions were powered by two twisted rope bundles which acted like torsion springs. These rope bundles were connected to a set of swing arms which were connected to a bow string. As the soldier cocked the ballista, the trigger mechanism would slide back, twisting the rope further and adding tension into the system. When the trigger was released, the swing arms could rotate forward thus launching the bolt. In various forms, ballistas were used for centuries and evolved considerably with the reported ability to launch projectiles well in excess of 600 yards. Since them groups have reconstructed them and they have found their way into active events such as the "Pumpkin Chunkin" and SCA combat. From ancient sources, we only have one description of the trigger mechanism for the last version of a ballista.

Purpose of the Project

This project was my version of "engineering archaeology" to design and build a working Ballista trigger using the Roman design. The trigger project was part of a larger prototype and design effort for a Roman Euthytone Catapulta Ballista based off 20 year old plans. These plans included a non-period trigger mechanism based on later period crossbows. The anticipated output of this project was a set of plans and methods to manufacture them so I could update the ballista plans accordingly. Since the designs were to be built and tested in multiple rounds, also have a functioning trigger mechanism that could be used for SCA Combat and Target Siege.

It also had a number of other objectives:

1. Teach me about Roman designs and how they approached siege engine building.
2. Gain practical experience in building the components and furthering my skills as a wood and metal craftsman.
3. Identify deficiencies in my home workshop and tooling so I can either acquire tools or identify others whose tools I could use or outsource part construction.
4. Gain experience documenting projects for A&S entries.

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Constraints and Deviations from Period

As a functional component of a siege engine and not a museum piece, this trigger design needed to take certain considerations into account:

1. It must be rugged enough to withstand the rigors of combat and being used or stored in inclement weather.
2. It must meet all SCA guidelines.
3. It should be simple enough for a siege engineer to build in a home workshop without placing undue limits on using period correct methods or materials as long as the finished trigger *looked* period.
4. Working with raw iron is not practical. Instead, I chose to use commonly available steel and aluminum as choices, since they would likely be painted.

Therefore,

1. The final trigger design included three designs / manufacturing corresponding to the tools and skills of:
    a. A DIY-level home workshop
    b. A professional workshop or outsourced manufacturing facility
    c. A workshop with a metal forge and tools to make it as it could have been in period
2. For the home workshop, I designed the trigger to be built using either 3/16 steel plate or 1/8 inch aluminum, which can be sourced at a local home improvement store.
3. For the professional workshop or forge, I designed it to be made from a billet of steel or aluminum which a siege engineer can quickly source online.

Stages of Build / Design

The physical exhibits show the progress of the trigger design, which matured with the overall ballista design over the course of the Summer and Fall of 2002. This progress can be seen through the physical exhibits.

- Exhibit 1: Initial wooden hinge and trigger shim to verify the geometry and have a feature complete ballista prototype for a static display at River Wars.
- Exhibit 2: Repaired wooden trigger claw following failure of wooden claw fingers prior to River Wars, and Updated hinge and trigger shim design for the wood claw.
- Exhibit 3: Aluminum-based trigger mechanism PoC following fracture of wooden claw.
- Exhibit 4: Wooden trigger showing abilities since Exhibit 2
- Exhibit 5: Updated Trigger claw for a simple home workshop capable of cutting only metal strips made out of aluminum.
- Exhibit 6: Updated Trigger claw for a professional workshop capable of cutting metal billet blocks made out of aluminum.

Personal Growth and Learning

I spent most of this project learning and growing as a craftsman. I was used to home improvements, and building precision robotics using pre-made components but not making precision parts. Over the course of this project I grew not only in my technical skillset, but in my mindset and approach to being a craftsman. At the

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start of this project I used simple hand tools and workarounds when I lacked skills or tooling. By the end of the project I learned to invest in myself as a craftsman through investing in tools and learning better technique. My complete learning and growth was the bulk of the formal Yule entry, but was summarized here:

Basic Wood and Metal Working Techniques

As embarrassing as this may be to admit in writing, many of the problems I encountered in the overall project (including the trigger misfiring) were because of improper basic metal and wood working techniques. For example, one of the reasons for the early misfires was because I did not mill the top of the slider flat for the trigger claw to press against. That gap led to the bow string slipping underneath one of the claw's fingers and misfiring, firing the ballista without me pulling the trigger shim. Other misfires were due to misaligned holes from using a hand drill without guides or using a punch / small pilot hole. I obviously learned how to make straight holes and properly align components.

I created the initial trigger out of wood because I did not have enough experience in metal working. Over the course of this project, I became familiar with tools and techniques such as bending thicker pieces of steel and better ways of cutting metal. As I became comfortable working with steel and the appropriate tools, my techniques in the tools grew with each component I created.

While pausing at the end of the test and calibrate phase, I researched other basic techniques such as allowing wood to acclimate to the environment and milling the wood in stages to minimize effects of warping as the wood ages. At this point I also researched Roman wood and metal working techniques, including making curved laminated wood for the swing arms. I incorporated those into the final design and in my next steps of making a trigger mechanism in a modern and period forge. Specifically, I took the approach of using thin strips of material to make the trigger claw due to my lack of tooling to make one from a solid piece of steel.

Home Workshop Tooling

At the start of this project, my home workshop was completely inadequate to make a ballista, including the detailed metal work for a functional trigger. Early in the project I had to go to multiple friends' homes to use their tools. Over the course of this project and the trigger, I acquired appropriate tools and knowledge on how to use them: wood planer, a bandsaw, drill press, hand drill guide, belt sander, metal bender, Dremel cutoff wheel and others. In some cases, I did not know some of the tools existed such as a jig for a hand drill. In other cases, I did not know home-scaled versions of a metal bender existed.

While writing this document and designing / building the final design shown in the Exhibits, I taught myself how to use each of the tools and added them to my home workshop. The learning process was not limited to using each tool but using them in conjunction with each other and other considerations for a home workshop such as dust collection and workspace to mount or use a tool.

Also, I learned a painful lesson in trueing up tools. My chop saw and other tools have variability in their settings for different cut angles. Sometimes "zero" on the gauge is not 90 degrees from the cutting surface, leading to slightly out of square cuts. I spent a lot of time diagnosing fitment issues that were due to not adjusting various tools to be square. I also learned about upgrading DIY-grade bandsaws so they function with aluminum and steel.

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Design Methodology

As I learned a new tool and technique, my design methodology changed to adapt to it. By the time I arrived at my final design, I approached the design in a completely different way than when I started thinking of terms of bending flat metal stock into parts required. For me, this was the biggest growth because it fundamentally changed how I viewed component design.

Next Steps

1. Make the trigger claw out of steel using both the laminated and solid billet designs to the extent my tools permit. Update the manufacturing steps as necessary.
2. Fully document the trigger components and assembly instructions for future siege engineers.
3. Put the trigger mechanism into a CAD program for future siege engineers to use to either build manually, edit, outsource manufacturing, or manufacture in a CNC mill.
4. Tear down and rebuild the overall ballista prototype so it fully meets SCA requirements and to incorporate design changes based on my build.
5. Thorough testing of the trigger mechanism once ballista is at full power.
6. Update the trigger mechanism (for example, widen claw fingers) based on testing.
7. Make the modern and coal forge versions of the claw for experience and for future A&S entries of the completed ballista so they have a trigger mechanism made with period tools and techniques.

Significant Sources

1. Legion XXIV, a Roman re-enactment group who created Siege Engines for Pennsic and other uses. Their main web page is: https://www.legionxxiv.org/Default.htm There are two pages I referenced:
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    b. https://www.legionxxiv.org/ballista.htm dated 27 December 2009
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3. Alan Wilkins and Len Morgan, 2018: ‘A suggested reconstruction of Vitruvius’ Stone-thrower: de Architectura X, 11, 4-9’, Journal of Roman Military Equipment Studies 18. A version is available at: http://www.romanarmy.net/pdf/Reconstruction%20of%20Vitruvius%27%20Ballista%20Ver%201-05.pdf
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    c. “CATAPULTA INCREASING POWER PT 2” - https://www.youtube.com/watch?v=AYe3GmlZi5M