

**Design and Manufacture of Novel Pinball Machine Mechanisms**

**Analysis of the Efficacy of Classical Just War Theory in the Modern Environment**

A Thesis Prospectus

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By

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On my Honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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## Introduction

The game of pinball is an iconic element of the cultural landscape of the 1980's. Countless games were designed drawing thematic inspiration from contemporary movies, television shows, musical artists, and other cultural icons. The developers of these machines made use of clever electrical and mechanical mechanisms in the construction of the playfield and various elements of the machines (such as flippers, slingshots, drop targets). Popular interest in pinball waned significantly in the mid-1990's until innovations in the mid-2010's led to a resurgence of popularity (Joseph Henry Project, 2023). The creation of these mechanisms and the task of integrating them into a comprehensive game is a fruitful exercise in the elements of the mechanical engineering design process resulting in a tangible product which can be utilized to facilitate positive social interaction in a community. In 2016 a team of UVA students attempted to build a pinball machine, but this attempt was unsuccessful. Drawing inspiration from this attempt, a new iteration of the project is being initiated, with the twofold goals of (1) developing the competency of the team in mechanical engineering design and (2) creating a product which will contribute to the life of the University community.

It is incumbent upon an engineer – or any worker, for that matter – to understand the moral and ethical implications of their work, lest they find themselves contributing to an end which they themselves would not support. A significant number of engineers work in the military or defense industries. In fact, nearly half of all federally employed engineers work for the Department of Defense or its subsidiaries (Falkenheim, 2020). The author himself will be working in this industry as a federal employee upon graduation. It is therefore prudent for an engineer – and this engineer, in particular – to consider the ethics of war and how it relates to his future work. One of the most well-known ethical frameworks for evaluating military conflicts is

Just War Theory. This framework has been in existence for centuries, drawing its origins from Augustine of Hippo in his 5<sup>th</sup> century book *The City of God* and being formalized in the 13<sup>th</sup> century by Thomas Aquinas in the *Summa Theologiae* (Aquinas, 1274). This framework is widely regarded as a comprehensive tool for examining and making judgements on the moral and ethical quality of a conflict. Because of its medieval origins, some have asked whether Just War Theory remains relevant in the modern era, claiming it to be outdated or irrelevant. It is therefore a worthwhile endeavor to examine the contemporary applications of Just War Theory and determine whether it can effectively be used to make judgments in an environment where rapid technological advances have dramatically changed the manner in which wars are fought.

In this proposal, I outline the technical framework through which the pinball machine will be developed. I also propose the use of Aristotelian Virtue Ethics to evaluate the suitability of Just War Theory in the modern environment.

### **Technical Topic**

The field of mechanical engineering has historically involved the creation of mechanical mechanisms which translate a simple motion, such as a continuous rotational input, into a more complicated output motion, such as linear motion, intermittent motion, or oscillating motion. In the past several decades, the field has evolved to where these purely mechanical mechanisms are replaced by mechanisms which blend mechanical components with computer control and sensors. This interdisciplinary concept is called “mechatronics” as a portmanteau of the words “mechanical” and “electronics.” Yet, mechanism design continues to be a fundamental aspect of the field of mechanical engineering.

As an exercise in mechanical engineering design with emphasis on mechanism design, mechatronics, and modular collaboration (because engineers rarely work alone), a novel design for a pinball machine was selected as a project.

The work of this project is constituted primarily by thematic game design, mechanical mechanism design and fabrication, and electrical design.

For thematic inspiration, the design team drew from various elements of the culture and architecture of the University of Virginia in order to provide a sense of relevancy and sentimentality to the target audience of the finished product. In the playfield design, the team primarily took inspiration from the Black Knight, a 1980 Williams machine designed by Steve Ritchie, a pinball designer noted for creating machines with excellent gameplay flow, as well as from a few machines produced by Stern Pinball and Jersey Jack Pinball, which are the two major modern manufacturers of pinball machines.

For design of mechanical mechanisms, the computer-aided-design software SOLIDWORKS was utilized. Designs were made so that they could be fabricated using easily accessible materials and methods of manufacture. Designs were prototyped using 3-D printed ABS plastic and laser cut acrylic and refined based on preliminary tests. Finished designs were manufactured primarily using waterjet-cut aluminum sheets due to the need for durability inside the machine. The mechanisms were digitally rendered in a playfield assembly in SOLIDWORKS throughout the process to ensure that they would not interfere with one another in the final product. The mechanisms were designed so that most of the manufacturing can be done by computer-controlled machinery to provide repeatability, minimize reliance on human skill, and eliminate as many discrepancies and opportunities for error as reasonably possible. Nevertheless, several manual methods were used, including the vertical mill, lathe, drill press,

hand drills, pop rivets, manually tapped threads, and polishing wheel. Possible discrepancies from these manual methods were mitigated by common training in methods as well as use of digital methods to ensure accuracy, such as a digital read-out for the vertical mill.

Electrical components of the machine include solenoid actuation of some mechanical mechanisms described above, motor control of other mechanisms, an LED scoreboard display, game control using a Propeller 2 microcontroller chip, and various arrays of lights and sensors throughout the playfield. The solenoid actuator functions by coiling a wire on a spool several hundred times while having an iron core run through the spool. When a current is run through the wire, the core will be pulled into the spool by the resulting electromagnetic field to actuate the mechanism. When the current is removed, a spring will return the core to its original position. Other mechanisms will be detailed in the technical report.

Even though the entirety of the game will likely not be completed this semester, it is the goal of the team to have the overall design plan as well as several key mechanisms perfected so that a future team can easily pick up the task where the current team left off and bring to life a fully functional product. Design and process choices were made to reflect this goal and plan.

### **STS Topic**

The major research question to be investigated in the forthcoming thesis is whether the classical Just War Theory is still a relevant and tenable framework for evaluating armed conflicts in the modern environment. Secondly, the thesis will investigate either (1) if the theory is still relevant, how it accounts for the modern technological and geopolitical developments which have caused the nature of armed conflict to drastically evolve over the modern period, or (2) if the theory is found to be lacking in relevance, how the theory can be adjusted to enable it to be

used to effectively judge conflicts in the modern environment while still retaining its essential nature. Various cases which lend a unique character to the modern environment will be judged, including drone strikes, autonomous weapons systems, conflicts involving non-state actors, and asymmetric warfare.

This is an important question to put under investigation. Armed conflicts are present in nearly every time and place in history, and the modern era is no exception to this. Given that armed conflicts are in many ways full of moral quandaries and ethical dilemmas, it is a significant task to try to wage war in a just and ethically sound manner. Since every person of sound mind desires to live and act in such a manner, it is necessary to establish a framework through which to determine how a war can be waged justly. The Thomistic just war theory is one of the oldest and most well-respected set of principles outlining ethical cause for and conduct in war, but the nature of armed conflict is rapidly evolving, so it seems prudent to test whether the principles of the just war theory are universally applicable or only applicable in relevant times and places.

Just war theory has two main components: *jus ad bellum* (just cause for recourse to war) and *jus in bello* (just conduct in war). Typical criteria for *jus ad bellum* include sovereign authority, right cause (e.g. self-defense, retribution for evils, support of allied nation), right intention, and reasonable probability of success. Additional criteria have been proposed which are considered by some to be part of the canon of *jus ad bellum* criteria. Most notable among these is the “last resort” criterion, which, for the purposes of this paper, is not considered a criterion based on the reasoning of Aloyo (2015). The traditional two criteria for *jus in bello* are proportionality and discrimination (between combatants and civilians to make particular effort toward the protection of the latter) (Johnson, 2005). Some thinkers propose a third component

called *jus post bellum* (just ending of war) which focuses on reaching a just peace, while others consider that to be a part of the right intention criterion of *jus ad bellum* since a just peace is the *telos*, or natural purpose, of a just war (Evans, 2005).

The problem will be analyzed utilizing a combination of the principles of Aristotelian virtue ethics, Kantian deontological duty ethics, and, since a theory should be considered in the context of its original worldview, Thomistic moral theology. The case studies of drone strikes/targeted killings, autonomous weapons systems, asymmetric wars, and conflicts of which one or more parties are non-state entities without sovereign authority will be examined individually to determine if the classical just war theory is able to adequately render judgements on these cases which elucidate a coherent and consistent set of principles for application.

## **Conclusion**

Once again, the major focus of the research portion of the proposed thesis is an investigation into whether the classical just war theory is a suitable tool for judging the moral and ethical qualities of conflicts in the modern environment. Since the nature and manner of armed conflict has changed significantly over the past century or so, it is reasonable to reevaluate whether classical frameworks are still as effective as they have been in the past. This topic of investigation is one of considerable societal impact. Armed conflict has been a consistent presence throughout nearly all human civilization. Moral and ethical codes and standards are the key characteristics which distinguish civilization from savagery and barbarism. Thus, to ensure that wars are conducted in a civilized manner, there must be an effective moral and ethical framework through which they can be judged. Without a framework such as just war theory, mankind faces a great risk of losing the core of its unique characteristics, its conscience.

The forthcoming thesis is expected to demonstrate whether the current scholarship of just war theory provides a sufficient framework to effectively judge the moral and ethical qualities of modern conflicts in terms of both *jus ad bellum* and *jus in bello*. To achieve this, various case studies will be examined. Should current scholarship be found lacking, the thesis will propose additional principles which would enable the theory to be more fittingly applied to the modern environment.

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