Design of a Self-Correcting Projectile Launching System

An Analysis of the Successes and Failures of the Strategic Defense Initiative

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By
Jake Coughlin

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Technical Team Members: Kai Barzdukas, Angus Chang, and David Chen

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.

ADVISORS

Benjamin Laugelli, Department of Engineering and Society

Gang Tao, Department of Electrical and Computer Engineering

Introduction

From the conditions that cause a baseball to sail over an outfield wall (Adair, 1995), to the long-term evolution of the development of ballistics for combat (Denny, 2011), the study of projectile motion is extensive and important. With respect to the latter, projectile weapon systems are today more advanced than ever before, and adequate defense technology is imperative. Missiles such as the American LGM-30G Minuteman III intercontinental ballistic missiles (ICBMs) can travel up to 700 miles at 15,000 miles per hour (U.S. Department of Defense, 2022). The Russian corollary has been labeled "Satan II" by NATO and has thermonuclear capabilities (Beachum, Ilyushina, Demirjian, 2022). Such advanced devices could deliver catastrophic damage to their targets especially with nuclear payloads. Although nuclear arsenals are being reduced, author Max Roser states in his 2022 article about the current status of nuclear weapons in the world that the risk of nuclear war is still high. He lists numerous "close calls" with nuclear weapons including 1983 and 1995 incidents where Russian systems falsely detected nuclear missile attacks toward Russia and could have retaliated but did not. There have also been several testing accidents including the 2007 U.S. incident in North Dakota wherein 6 live nuclear missiles were accidentally loaded onto a B-52 bomber and went unnoticed for 36 hours. These accidents in addition to any potential for war make nuclear weapons as dangerous as ever.

If this threat still exists and countries refuse to de-nuclearize, having a sufficient defense system is critical. The core challenge is building something that could target a missile attack and eliminate it before it can cause destruction. Having a system that defends the U.S from this threat is far more complicated than just physically constructing one. With the complexity of the technology, relationships between world governments, and relationships with the public, there are many actors with their own power, interests, and consequences. Thus, if both these technical and social elements of the issue of nuclear defense are not described together, achieving and retaining an effective strategy could be impossible. Therefore, in my technical project, I will go through the technical process of designing a small representation of a projectile-launching and targeting technology. This system will also contain self-correction in the event of a failed launch. It will launch ping-pong balls controlled by a User Interface (UI) on a laptop and launch at a target grid of sixteen targets. This design process of creating a device that can adequately strike targets in a safe manner is the core idea of the technical design for such a system. Looking at both the design and the sociotechnical challenges regarding the design are both critical in this case. Thus, I will then use Actor-Network theory to analyze a real case of the complex sociotechnical issue of a nuclear defense system. This will entail the technological shortcomings but also political successes of Ronald Reagan's Strategic Defense Initiative, which was the late Cold War attempt at U.S. nuclear defense technology (Atomic Heritage Foundation, 2018).

Technical Project Proposal

To continue the study of projectile motion and targeting systems in the context of a simple projectile launching device, we are designing an electronic control, launching, and feedback system that is self-targeting and self-correcting. Given the constraints on time, resources, space, and with safety considerations in mind, the system will launch standard ping pong balls at a specified target. For a complete design, four major subsystems are necessary: a UI to command a launch, a launcher frame and target frame, the launcher aiming/launching mechanism, and the feedback/self-correction system. Altogether, the intended overall functionality is for the user to select one of sixteen target boxes in a grid on the UI and command a launch. The aiming mechanism will direct the launcher towards the target and launch. The self-correction system will programmatically determine the success of the launch and indicate such or make an adjustment accordingly. The instructions and connections between these major systems are all controlled by a central Texas Instruments MSP432 microcontroller.

To begin the design process, we reviewed a similar project that launched racquet balls into targets developed by Hujae Choi, Woohyun Jung, and Nakwan Kim in 2017. In this ball launching system, image processing is used to assess targets. For our project, we are using image processing to determine the success or failure of the launch. Another similar project was detailed in Robotics and Automation in 2010 titled "Movement templates for learning of hitting and batting." This design did not have any error-correction methods, as it was used in a competition-style environment with only one chance to hit targets. Our version will allow the launcher to incorporate small adjustments to the aiming trajectory if a ball misses its target the first time. There will also be multiple target options at a time (a 16-section grid), so we have the added feature of user input selecting which space to land. The idea is to have data for the variance of the ball drop and measure changes within that dataset. Our system will use a Kalman filter to change the ball's trajectory if it does miss. This is a common prediction algorithm (Becker, 2022) that will be housed on the microcontroller and perform the adjustments in the event of a failed launch.

In 1997, Yamada et al. researched using electromagnets as a method of propulsion and published a paper detailing the use of an electromagnetic solenoid coil to launch a steel ball. Our launching mechanism will similarly use a solenoid coil with an internal pushing rod to strike the ball and propel it forward. When current is driven into the solenoid, a magnetic field is created, and the internal rod is thrusted outward. Figure 1 contains an overall diagram of the system.

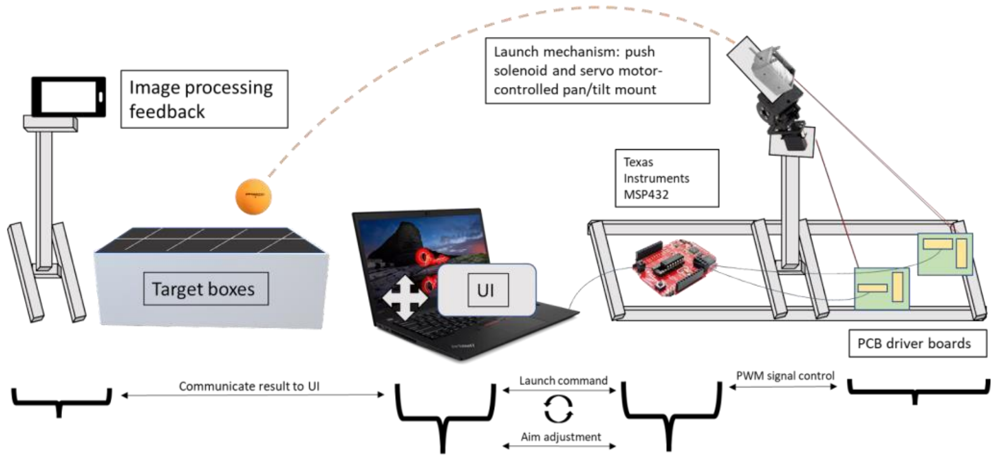

Figure 1: Launching System Diagram

The proposed flow of the system is as follows. The user begins by selecting the desired target on the UI. A command will be sent to the microcontroller via a USB connection adaptor. The microcontroller will send a signal to two motors that are housed in a “pan/tilt” mount. Depending on the signal, these motors will rotate the mount and effectively aim the launcher. Once the aiming is done, the microcontroller will send another signal to the solenoid that is housed on top of the mount. The solenoid rod will propel forward and strike the ping-pong ball. The ball will be launched toward the target grid. If the ball lands in the desired square, an image processing feed will notify the user of a successful shot on the UI. If not, the code of the correction filter will make the adjustments depending on the location of the failed shot and try again. The goal is to have a system with up to 90% accuracy.

STS Project Proposal

The major nuclear powers throughout the Cold War, the U.S. and the U.S.S.R., held a policy of Mutually Assured Destruction, or MAD. Once the two powers had developed sufficiently capable nuclear weapons, they acknowledged that any attack from the other would result in the elimination of both (Atomic Heritage Foundation, 2018). In the 1980s, President

Ronald Reagan initiated a significant deviation from MAD called the Strategic Defense Initiative (SDI). President Reagan began a program that "sought to create a space-based shield that would render nuclear missiles obsolete," (Atomic Heritage Foundation, 2018). There was much speculation throughout the scientific community regarding the actual technological specifics of such a defense system. Ideas included ground lasers, space lasers, or additional missile systems that are for defense instead of offense. However, none of these systems ever came to fruition as they were envisioned by President Reagan. After his administration, funding for the program was significantly reduced, effectively killing its original purpose (Atomic Heritage Foundation, 2018).

The reasons for the program's collapse are primarily attributed to the technological limitations of the system. The Atomic Heritage Foundation article on the program continues asserts that, "Strategic Defense Initiative was ultimately Reagan's personal vision because it was based on technology that had not yet been invented." In addition to this, they state that there had been no scientific discoveries to date significant enough in missile defense technology that could prove SDI as President Reagan saw it was even possible. However, the technical challenges of the project do not account for the entirety of its eventual end. Political pressure against the program was present from multiple different directions. Many of President Reagan's own advisors were "blindsided" by the announcement of SDI. They had not been given any warning that it was going to become a policy (Atomic Heritage Foundation, 2018). Additionally, the governments of the Soviet Union and American allies in the West shared similar oppositions to the program. They felt that partially abandoning the existing assurance of MAD could create a new arms race and potentially destabilize the Cold War. American Allies also feared that if the United States was able to successfully develop SDI, they would have no incentive to defend their allies anymore (Atomic Heritage Foundation, 2018). This combination of the potentially revolutionary new defense technology but internal and external political strife threatened a new destabilization of the Cold War.

I will argue that the eventual effective abandonment of the Strategic Defense Initiative was not solely a result of lack of technological capability, but a result of this along with pressure from the United States' enemies and allies. Also, the political conditions of the time eventually reached a state where this project's utility was much diminished and, by pressuring Russia to continue to overspend in an attempt to stay competitive with the United States, the program served its purpose in a different way than was intended initially. Actor-Network theory (ANT) can be applied to this complicated relationship of destructive technology, defensive technology, and the dynamics between and within the governments of the two world superpowers during the final years of the Cold War. Using ANT, this network of nuclear technology along with political and social forces is applied to ANT's emphasis on human and non-human actors that accomplish a goal. To do this, I will analyze sources from the time period within the United States government such as George P. Shultz's memoir "Turmoil and Triumph" accounting his time in the Reagan Administration, sources in the Soviet Union government such as Mikhail Gorbachev's "Memiors", opinion polls of the United States public, and also descriptions of what such a technology may actually look like, such as missile interceptors (CSIS Missile Defense Project).

Conclusion

The technical deliverable for this project will be the design of system that is a self-targeting, self-correcting, ball launching robot. The intent of this technical deliverable is to effectively mimic and understand at a small-scale some of the fundamentals of designing a projectile launching system. The STS research paper will analyze a project of a similar nature at the largest scale with very tangible consequences and numerous actors affecting its eventual outcome. To do so, I will apply Actor-Network theory to relate the advanced technology to the political and social forces surrounding the project of Ronald Reagan's Strategic Defense Initiative. The value of this analysis is that its implications are still relevant in similar ways to the late 1980s with the advanced military technology of the day. Thus, there is a continued necessity for effective technologies and political decisions regarding nuclear defense.

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