Mountain Directed Energy Wayfinder (D.E.W.)

(Technical Paper)

An Examination of Laser-Based Guidance Systems and Relevant Applications

(STS Paper)

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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

According to physicist and Nobel Prize winner Charles H. Townes, upon the introduction of the first working laser (light amplification by stimulated emission of radiation) device by Theodore Maiman in 1960, the technology constituted “a solution looking for a problem” (Townes, 2003, p.107). In the decades since, the laser has captivated the public conscience as an invention torn out of science-fiction serials: indeed, even upon initial publication, Townes describes the sensationalism surrounding the laser, such as “front-page discussions of possible death rays, but also some skepticism among scientists” (ibid, p.108) arising from a lack of familiarity and a cursory understanding of the foundation of Maiman’s experiment that resulted in the first successful operational firing of a laser. As of the time of writing, no such “death ray” has been developed to a degree of refinement for practical utilization, directed-energy weaponry purposed for military usage is actively researched and developed. While non-martial applications of laser technology do exist, it is the defense or security applications that are most likely to encounter matters of ethical concern.

My technical project, Mountain Directed Energy Wayfinder (D.E.W.), is a star locator, comprised of a gimbal-mounted laser that can be programmed to identify and point to a user-desired celestial body, purposed as an aid or assistive tool for amateur or educational astronomy. In the course of developing this project, I will ask questions in regards to laser safety and air safety regulatory compliance, in addition to questions in regards to the commercial viability and environmental impact. I will consider the environmental strain introduced by new technologies, such as those that arise through trends in modernization and increased urbanization of rural regions. Increasing educational accessibility of astronomy with such a method and the concern that arises from increased light pollution are perhaps an ouroboros: with increased laser light

fired through the atmosphere into space, we must consider how the visibility of stars with the naked eye may then made even more difficult.

I will attempt to examine the ethical implications of laser-based guidance system technologies and their applications, primarily asking how the technology can be abused by bad actors with the intent of discrimination against targeted individuals or demographics, and to establish a framework from which potential pathways can be developed for solutions or safeguards against such actors. In a digital age, we must consider the development of frameworks that safeguard against violations of privacy and of basic human rights, and as policing becomes increasingly invasive in quotidian civilian life, the question of the balance between public security and individual privacy is strikingly topical and relevant.

Systematically, Mountain D.E.W., as a device that points to identified stars, is abstractly a targeting system in and of itself. From this abstract perspective, the invention may perhaps be extended to use as a targeting system, thus making a consideration of the misuse or abuse of such a technology crucially relevant to the iterative design process for Mountain D.E.W.

Mountain Directed Energy Wayfinder (D.E.W.)

Mountain Directed Energy Wayfinder (D.E.W.) is a laser-based automatic star locator, designed to automatically locate various celestial objects and utilizing a laser pointer as a visual aid for amateur astronomy enthusiasts and educational groups (e.g., scouting groups), for the purpose of assisted stargazing through a rugged, cost-effective, outdoor-environment-compatible apparatus. The primary concern arising from this project is in threading the line between robust operation and cost-effectiveness of the overall system: similar commercially-available products are typically incorporated attachments to computerized telescopes that utilize sky imaging and image analysis methods to align and calibrate to recognize objects in a stored database, with the tradeoff of an expensive product often in the range of several thousands of dollars. The question of aviation safety is crucially necessary to consider, given the moderate air traffic for the city of Charlottesville, Virginia: furthermore, while the goal of the design is to generate a minimum-viable product, field testing is still necessary, and therefore, preventing injury or incident to users, bystanders, and aircraft is to be carefully considered throughout the design process.

Mountain D.E.W is comprised of a laser mounted on a two-axis gimbal with both yaw (horizontal or azimuthal rotation) and pitch (vertical or elevational rotation) degrees of motion. User calibration and rotation of the device is controlled by the STM32 microcontroller, which is used to control an LCD display showing star coordinates, available targets, and options for movement; the yaw and pitch motor movement; and switching the laser itself on or off. A green laser is used for Mountain D.E.W. on account of its more optimal visibility in dark areas, and its conventional use for amateur astronomy. The majority of the technical work involved in developing Mountain D.E.W. comes from establishing four core elements: the turning on-and-off of the laser, the rotation of the yaw and pitch motors, independently powering the device, and

accurate targeting. The team I am part of will develop these elements over the course of a semester, and assemble them into a prototypal product for presentation.

While Mountain D.E.W. is ultimately intended for educational use and recreational utility, the software implementation, in the form of GNSS (global navigation satellite system) for geo-positioning and time data, as well as its primary functionality of pointing towards desired targets, make the device translatable to defense and military applications. Design and research endeavors must recognize the unintentional yet potential utility of the technology, thereby necessitating ethical considerations in the design process. Furthermore, inquiries into the device's impact on the commercial market and amateur astronomy should be raised. What are the immediate and long-term effects of introducing a more accessible and cost-effective astronomical tool? While accessibility increases, what is the consequential trade-off in terms of heightened light pollution and the elevated risk of laser-related incidents with aircraft? Such questions are imperative to address during technology development.

An Examination of Laser-Based Guidance Systems and Relevant Applications

Perhaps one of the most prominent depictions of the laser comes from the *Star Wars* multimedia franchise, popularizing the idea of the laser as a fantastical weapon. Several characters of contrasting moralities wield laser-based firearms, and the most notable example in the public conscience is the Death Star (and its derivatives), with its planet-destroying laser array. By nature of being perceived as a technology with significant potential for weaponization, public perception often characterizes the laser as a martial tool, an implement for imposing authority, perhaps analogous to Winner's example of the atomic bomb, wherein "its lethal properties demand that it be controlled by a centralized, rigidly hierarchical chain of command closed to all influences that might make its workings unpredictable" (Winner, 1980, p.131). However, this interpretation, of course, only considers the popular perception of lasers. Arguably, the laser itself is not inherently political: referring back to Townes' thoughts on the laser as a "solution looking for a problem", it is easy to see why: with the limited operation of its technological predecessor, proponents of the laser needed to prove that it had useful applications.

In contemporary times, beyond scientific applications like spectroscopy or laser microscopy, lasers serve as solutions to problems that also bear political or sociopolitical implications. In scenarios reminiscent of science fiction, lasers are employed in defense contexts as directed-energy weapons to neutralize unmanned aerial vehicles (UAVs), exposed vehicle engines, and even active projectiles such as rocket-propelled grenades and artillery shells. Consequently, the scientific utility of lasers is overshadowed by their military applications, perpetuated by science fiction and popular media.

Throughout this project, I aim to explore laser-based guidance systems and their integration with image recognition technologies in both commercial and defense sectors. I will investigate how such systems may be exploited by malicious actors to perpetuate discriminatory hierarchies rooted in prejudice, and how engineering design can incorporate safeguards against such misuse. Given the growing surveillance practices of both governments and private entities, it is imperative to address these issues within the realm of scientific development.

My ultimate goal is to examine the ethical implications of technical systems designed for targeting, and the ensuing ramifications. By reviewing literature on existing systems and comparing various implementation approaches of targeting and image recognition, I intend to establish a foundational framework, drawing upon actor-network theory (ANT), to analyze the interplay between technology and its users. This analysis will inform the exploration of potential solutions, whether reactive responses to current systems or proactive measures to prevent discrimination in future contexts.

Key Texts

I have used, and will use, several key examples in order to both evaluate current public policy in regards to government surveillance of constituents and to form a policy basis to which technical bases will be compared.

One such example is the United States Foreign Intelligence Surveillance Act (FISA), in particular Section 702. The American Civil Liberties Union (ACLU) reports that the National Security Agency engages in two kinds of surveillance under Section 702: PRISM and upstream. Through these systems, the NSA can demand full disclosure of "all communications and data to and from" non-U.S. persons from technology and social media companies, and can create copies of international internet communications for American citizens; those communications with foreign persons of interest can be "retained in NSA databases for further use and analysis" (Taitz, 2023).

Additionally, an example of defensive laser use may be found in, as previously mentioned, President Ronald Reagan's SDI, a technology policy initiative designed to safeguard against the potential threat of nuclear missile attacks from the Soviet Union: SDI research and development constituted directed energy weapons including "space-based lasers, ground-based lasers, space-based particle beams, and X-ray lasers powered by nuclear explosives" (Yonas, 1985, p.82).

To gain a stronger understanding of scientific applications of laser technology, I will require additional references: for example, Wolfgang Demtroder writes that "laser spectroscopy…by far [surpasses] the capabilities of former methods with regard to sensitivity and spectral or time resolution" (Demtroder, 1999). Understanding non-martial applications of lasers allows for a

more comprehensive comparison to martial applications, such that I can establish a foundation for a better understanding of the technical details behind laser science.

Fourthly, I will use a reference on the use of lasers for optical guidance, in comparison to the technology used for the Mountain D.E.W. project, to evaluate more "civilian" applications as well: the example reference discusses the use of a laser pointer for guidance of a robot's movement, in which "the guidance system indicates target positions for the robot by means of a laser light projected onto the ground" (Paromtchik, 2004, p.463).

I, of course, intend to further develop the portfolio of useful references relevant to both the technology at hand and the ethical implications of that technology, pursuant to the thesis developed with this topic in mind.

Conclusion

The social contract between a government and its constituents, according to Hobbes, stipulates that order be imposed upon the natural state of chaos. We as citizens give up a certain level of freedom, of individual rights, such that a state of order may be achieved. In an ideal world, this balance of order and individual freedoms is perfected, where a government serves its people as much as the people provide for the government. However, in the modern reality we live in, the delicate, imperfect balance achieved between a government provision of security and its people's individual freedom and privacy continues to sway. Both governments and private entities continue to encroach further and further into individuals' private lives around the world.

As we continue to develop technology that advances beyond the paradigm, we must take care to consider this delicate balance, for it is in science and technology that the course of history is shifted. In the hands of engineers is the power to shape society, and as the Spider-Man adage goes, "with great power there must also come great responsibility". The design process is the most critical time to make ethical considerations about the technology we create: the ramifications -- large and small, short-term and far-flung in the future -- make ripples.

In the course of my research projects, I hope that I can convey even the semblance of this message: that to design for good, we must also define good. To dream of a better world, we must envision the steps along the way, to not only hope for a brighter future, but to create it.

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