Autonomous Obstacle Avoidance for Unmanned Aerial Vehicles (UAV)
(Technical topic)

Lack of International Consensus Regarding Usability of Lethal Autonomous Weapons Systems (LAWS)
(STS topic)

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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

Humans have used weapons throughout all of history for everything from prehistoric hunting to modern day warfare. Weapons have changed from simple wooden spears to modern day nuclear bombs capable of mass destruction as new technologies are developed and adopted. One thing left primarily untouched, however, is the requirement of a human agent to utilize such weaponry. Guns must be pointed and have a trigger that must be pulled and nuclear bombs are launched by pressing a button – humans are required to make real-time decisions and oversee the majority of the operation. However, new advances in artificial intelligence and autonomous technologies are paving the way for a new series of weaponry less reliant on human agents. What was once seen as science fiction is now being developed and deployed by governments around the world and capable of targeting enemies and applying deadly force without human oversight.

Commonly known as "killer robots" or more formally lethal autonomous weapons systems (LAWS), the use of fully autonomous machines capable of killing humans on the battlefield has been the topic of serious debate (ICRC, 2020, p. 1). Ethical, logistical, political, safety, and operational concerns surround this developing weapon, and experts have yet to come to a conclusive decision on the best path forward. Some argue robots offer supreme military advantages and are ethically preferable to human soldiers (Sassoli, 2014; Sukman, 2015; Kahn, 2022), while others believe people's moral and human conscience can't be replaced and lethal robots will instead cause an increase in civilian casualties and decreased accountability (Zielinkski, 2018; Rosert, 2019; Russel, 2022). Challenges also exist surrounding the definition of LAWS (Sayler, 2022; Taddeo, 2022), such as arguments about whether a landmine sensing a person (and exploding) is that much different from a fully autonomous robot sensing an enemy combatant (and responding with similar lethal force).

My theis portfolio aims to address the issues surrounding such autonomous technologies through both a technical and STS topic. The technical project will focus on a particular application of autonomy, known as shared autonomy or semi-autonomy, with an aerial platform developed using a system of printed circuit boards, motors and sensors to enable shared autonomy and obstacle avoidance for unmanned aerial vehicles (UAV), or “a class of aircrafts that can fly without the onboard presence of pilots” (FAA, 2022). The STS topic will focus on examining the connection between the human, social and technical elements of LAWS through the Social Construction of Technology (SCOT) framework (Pinch & Bijker, 1984), in order to better understand how human action and social factors have shaped this technology’s development and meaning. The goal of this research is to answer the following question: what factors have historically been the impediments of a strong international consensus regarding the usability of lethal autonomous weapons systems (LAWS), and what efforts (and their success) have been made to resolve those conflicts? Given what I learn from my research, I aim to suggest possible courses of action that I anticipate may be successful in creating a stronger international consensus surrounding the use of LAWS.

Technical Topic: Autonomous Obstacle Avoidance for Unmanned Aerial Vehicles (UAV)

Flying is the dream of many but only a few can truly experience it freely. What was once seen as science fiction, however, is now becoming a reality as new advances in computation and sensing lead to the development of advanced robotic systems. Autonomous mobile robots are entering our society and finding many applications like aerial photography, infrastructure inspection, surveillance, hobby application, and even search and rescue operations. In particular, unmanned aerial vehicles (UAV), defined as "a class of aircraft that can fly without the onboard presence of pilots" (FAA, 2022), have led to a common debate among experts regarding if fully autonomous unmanned aerial vehicles provide greater benefits than human controlled aerial vehicles. Drone crashes, safety challenges, security issues and privacy concerns have led many to believe that fully autonomous UAVs are not worth the risk nor cost.

This technical project was chosen to address the common types of issues with fully autonomous UAVs. Our team's goal is to investigate and enable a form of shared autonomy (or semi-autonomy) that incorporates both capabilities – human-controlled input and onboard autonomy. This compromise allows for desired human input (e.g., fly a drone to an area of interest), while keeping the system safe (or perform other tasks) through onboard autonomy and obstacle avoidance. This will allow for a much safer and efficient drone that is less likely to crash due to operator error, which our team believes is a necessary development in the advancement of autonomous UAVs.

This project is different from past work by others because of the simultaneous use of both human-controlled inputs and onboard autonomy, instead of switching between one mode or the other. Previous projects with shared autonomy usually have two operating modes, either manual (human) or autonomous. This method, however, analyzes both manual inputs from a human operator and onboard sensors/autonomy to avoid obstacles while completing the desired flight plan or performance tasks. For example, if the human is manually flying the drone forward, the robot can override the manual input and stop the UAVs movement (or change the movement) in order to avoid an obstacle.

To design and develop an aerial platform to enable shared autonomy and obstacle avoidance for unmanned aerial vehicles (UAV), a printed circuit board (PCB) will be designed and manufactured to aid in UAV obstacle avoidance using a series of 1-D time of flight "light detection and ranging (LIDAR)" sensors (NOAA, 2012). A servo motor will be utilized in order to increase the range and visibility of the front sensor. This will allow obstacle detection within the range of the UAVs movements and simultaneously deliver real-time data through "inter-integrated circuit (I2C)" communication protocols (Techopedia, 2022). A 3-D printed tower will be manufactured to physically mount the PCB, LIDAR sensors and motor to the aerial platform. The final deliverable will utilize an embedded "Robotic Operating System (ROS)" to visualize real time LIDAR data and simulate obstacle avoidance for UAV systems (Open Robotics, 2022). All components will be powered by an external battery supply designed to meet power requirements and weight constraints. The proposed technical deliverables are shown in Figure 1.

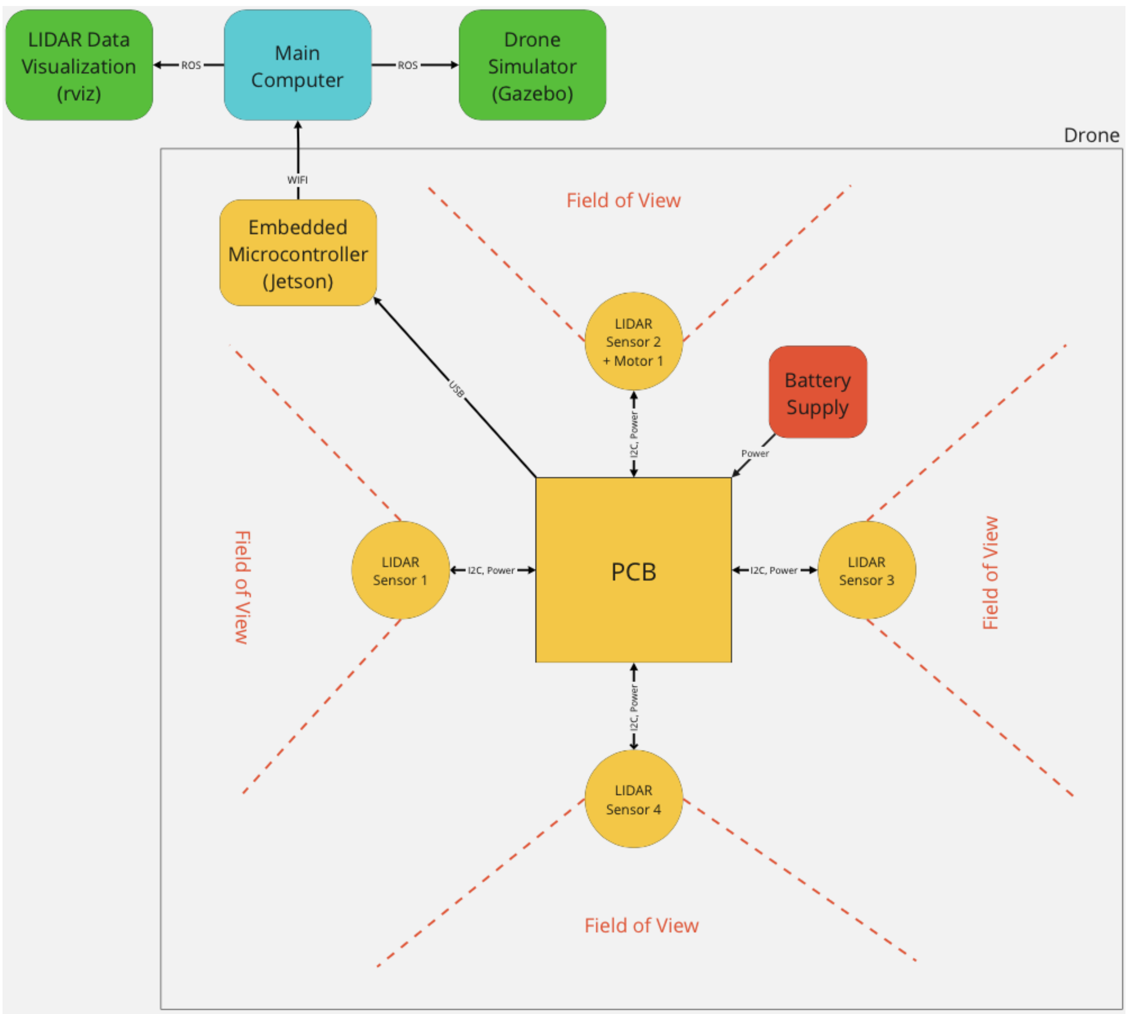

Figure 1. *Note:* Block Diagram of Technical Topic: Autonomous Obstacle Avoidance for Unmanned Aerial Vehicles (UAV). (Created by author).

STS Topic: Limited International Consensus Regarding Usability of Lethal Autonomous Weapons Systems (LAWS)

Lethal autonomous weapons systems (LAWS), commonly known as “killer robots”, are defined as “any weapon system with autonomy that can select (i.e., search for or detect, identify, track, select) and attack (i.e., use force against, neutralize, damage or destroy) targets without human intervention” (ICRC, 2020, p. 1). Ethical, logistical, political, safety, and operational concerns surround this developing weapon as it begins to be implemented throughout modern day warfare, with examples like “Libyan armed forces (HAF), hunted down and remotely engaged by Turkey’s STM Kargu-2, a lethal autonomous weapons system programmed to attack targets without requiring data connectivity between the operator and the munition” (UN Libya Panel, 2021, p. 17). Nonetheless, the technology remains in an international “regulatory grey zone” (Stercke, 20, p. 1) as countries have yet to come to an agreed upon definition of LAWS (Sayler, 2022; Taddeo, 2022) and international debates have not led to a conclusive decision concerning the use of LAWS (Heyns, 2014; Geiss, 2015; Daisuke, 2019; Congress, 2021).

To understand how human action and social factors have shaped the development and meaning of LAWS, the Social Construction of Technology (SCOT) framework will be utilized to examine the connection between the human, social and technical elements of this technology. According to Pinch and Bijker (1984), the Social Construction of Technology (SCOT) framework is a theory and research methodology based on the influence of social factors on the definition, development, and implementation of a technology. A form of social constructivism, SCOT emphasizes that the success of a technology is determined by its social context. The ideas of relevant social group, interpretative flexibility, closure (and rhetorical closure), and stabilization are foundational to the SCOT framework (Pinch & Bijker, 1984).

Relevant social group refers to the “social groups concerned with the technological artefact, and by the meanings which those groups give to the artefact” (Pinch & Bijker, 1984, p. 414). In other words, relevant social group describes the individuals and organizations (such as users and consumers) that interact (or are affected by) a technology, and subsequently give meaning to that technology. Relevant social groups related to LAWS may include: engineers and companies designing and building the autonomous weapon systems, countries and their respective governments, members of armed forces in charge of implementing the systems, and the individuals who may be a victim of lethal force applied by LAWS. Furthermore, “a detailed description of the relevant social groups, to better define the function of the artefact with respect to each group,” will help give a more specific meaning to LAWS (Pinch & Bijker, 1984, p. 415).

Interpretative flexibility refers to the idea that “different social groups have radically different interpretations of one technological artefact”, and reflects how “there is flexibility in how people think of, or interpret, artefacts, and there is flexibility in how artefacts are designed” (Pinch & Bijker, 1984, p. 421). For example, software engineers may have a drastically different idea on the purpose and use of LAWS compared to an army general who lacks a technical background. These differing interpretations create different problems to be solved and tradeoffs to consider. A tech company may prefer to design a system that prioritizes efficiency, robustness, and accuracy to maximize profit, where a government agency may require bulky, slow and energy consuming components that meet international guidelines for human rights and ethical concerns.

The SCOT theory defines closure mechanisms of a technology as “rhetorical closure” and “closure by redefinition of problem”, both involving “the stabilization of an artefact (technology) and the disappearance of problems” (Pinch & Bijker, 1984, p. 425-426). Rhetorical closure is when “relevant social groups see the problem as being solved”, and closure by redefinition of problem is when a technology surrounded by conflict is stabilized by utilizing it to solve a different problem (Pinch & Bijker, 1984, p. 427). For LAWS, rhetorical closure and stabilization may occur if an international treaty is signed regarding the definition and uses of the technology, and closure by redefinition of problem may occur if LAWS is used for another purpose besides human warfare, such as protecting humans from animal attacks or invasive species. Research on international treaty efforts and prominent applications of LAWS (e.g., human warfare) from relevant social groups will be useful in applying the SCOT framework to this STS topic.

Research Question and Methods

This paper will seek to answer the research question: what factors have historically been the impediments of a strong international consensus regarding the usability of lethal autonomous weapons systems (LAWS), and what efforts (and their success) have been made to resolve those conflicts? This research question is important because the process of answering it may lead to possible courses of action that may be successful in creating a stronger international consensus surrounding the definition and uses of LAWS. The research methods utilized will include discourse analysis and literature review/synthesis.

Discourse analysis refers to the close reading of texts produced by the relevant social groups (user, producers and other agents who interact with the technology), and analyzes what is being said, who is saying it, and to whom it is being said (Tenorio, 2011). The texts will be gathered from scholarly websites and journals, and will include texts produced by major global players regarding statements on LAWS, as well during international debates and conventions. Examples include the U.S. Department of Defense statement on LAWS, the International Committee of the Red Cross’s statement on humanitarian law and LAWS, as well as the international gathering at the UN Convention of Certain Conventional Weapons (Carter, 2017; ICRC, 2020; Heyns, 2014).

Literature review and synthesis refers to gathering existing research on individual arguments/subtopics to examine intersections and gaps to better understand the state of knowledge of a topic, in this case LAWS (Li & Wang, 2018). The threads of research compiled will include current technology that is being developed and deployed, as well as the efforts (and their success) made by relevant agents as to the definition and usability of LAWS (UN Libya Panel, 2021; Geiss, 2015; Sassoli, 2014). To scope the breadth of the literature search, major global players, such as countries like United States, Russia, and China or influential global organizations like the International Committee of the Red Cross, will be the focus of the research to determine the most significant impediments of a strong international consensus regarding the usability of LAWS (Sayler, 2022; Congress, 2021; Daisuke, 2019).

Conclusion

Lethal autonomous weapons systems (LAWS) are beginning to be developed and deployed throughout modern day warfare, representing an increasing advancement in autonomous technologies. This paper aims to address the rising concerns and issues with autonomous technologies through a technical and STS topic. The technical topic, focused on creating an aerial platform that enables shared autonomy and obstacle avoidance for unmanned aerial vehicles (UAV), addresses the safety and operational benefits of autonomous technologies while maintaining human oversight for ethical concerns. The STS topic focuses on applying the Social Construction of Technology (SCOT) framework to understand how human action and social factors have shaped the development and meaning of LAWS. The goal of this research is to determine the factors that historically have been the impediments of a strong international consensus regarding the usability of LAWS, as well as the efforts (and their success) to resolve those conflicts. The results of this research may suggest possible courses of action that may be successful in creating a stronger international consensus surrounding the use of LAWS. The specific actors that might use and apply this research to create a stronger international consensus include the government bodies of the United States, Russia, and China, because these leading military powers are likely to be “particularly influential in determining the trajectory of international discussions of LAWS” (Congress, 2021).

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