Legal Considerations for the usage of Lasers implemented in the Laser Scarecrow

The following is a listing of laser laws relevant to this project with a non-comprehensive summary of each.

**FEDERAL RULINGS**

It is illegal to knowingly point a laser at an aircraft. The punishment is a fine no more than 5 years or fines of no more than 250,000$, or both [U.S.C Title 18, chapter 2]. In addition, the FAA has the ability to fine up to 25,000$. To help ensure that these laws are not violated, the laser scarecrow is equipped with a tilt sensor and cannot be pointed above the horizon. This prevents accidental or intentional pointing at aircraft and will turn off the device if tipped over, ensuring it is never pointed above the horizon. However, this is not a perfect solution: pointing lasers at airplanes on the ground, or other vehicles, is still illegal and so the final responsibility is on the user.

**STATE RULINGS**

According to [this document](https://assets.lia.org/s3fs-public/pdf/Govt_Regulations.pdf) produced by the LIA which summarizes laser laws by state, the “Massachusetts Radiation Control Program rules are contained in 105 CMR 121.000, Regulations for the Control of Lasers”, which can be found [here](https://www.mass.gov/regulations/105-CMR-12000-the-control-of-radiation). It states that the standards set in ANSI Z136.1 are to be used as the state law regarding the safe use of lasers, and that class 3B lasers and above (which is what we are using) must be registered with the state. The form with which to register these lasers can be found [here](http://www.mass.gov/eohhs/docs/dph/environmental/radiationcontrol/laser-registration-form.doc). When filling out this form, there is some technical specifications to be aware of:

* The manufacturer of our lasers is laserland
* The maximum wavelength is 532nm (from manufacturer)
* They are not tunable (from manufacturer)
* The beam diameter is 50mm (from manufacturer)
* The beam divergence is “” (measured and calculated) (TODO)
* The Max Pulse Repetition Frequency is 0.625 PRF (?) (calculated)
* The Min Pulse Duration is 16s (by our design)
* The Max Joules Per Pulse is 0.8 Joules (calculated) (?)
* The Average Pulsed Power is “” (calculated) (TODO)
* The continuous wave max power is “” (calculated) (TODO)
* They are pulsed (by our design)
* The medium is air. (?) (by our design)

The registration requires that there be a “Laser Safety Officer” (LSO). This is defined by ANSIZ136.1 as someone on staff who is knowledgeable about the safe use of lasers, is the point of contact for safety and regulation issues, and handles safety with lasers. It does not need to be a full time occupation, and is named by the employer. The responsibilities of the LSO are described appendix A of ANSIZ136.1.

**ANSI Z136.1**

This document is a standard produces by ANSI which lists requirements, recommendations, and definitions for the safe use of lasers. It is used as law by several states including Massachusetts, and can be obtained from ANSI [here](https://www.lia.org/store/product/ansi-z1361-2014-safe-use-lasers-electronic-version). The document is broken into sections, and the section of each regulation is specified in [brackets].

Some terms to be aware of used in ANSIZ136.1 and therefore used in this summary:
LSO: Laser Safety Officer, a role defined in ANSIZ136.1

MPE: Maximum Permissible Exposure, which is how long a person can be subjected to the lasers without injury. In our case, assume not at all if shone in the eyes, and N/A if shone on the skin.

NHZ: Nominal Hazard Zone, the area where an individual may get subjected to over the MPE. Because of our use case, assume this is the entire field.

Section 1 of the standard contains an overview of the entire document.

Section 2 of the standard establishes terms and acronyms.

Section 3 of the standard covers Hazard Evaluation and Classification.

Section 4 covers "Control Measures"- it specifies what things must and must not be done when using certain lasers. We are using a class 3B laser, meaning that it "may be hazardous under direct and specular reflection viewing conditions, but is normally not a fire hazard, diffuse reflection hazard, nor a laser generated air contaminant production hazard".

* Our laser is unsupervised when operating, so the laser must be clearly labeled with the laser warning symbol and the area in which it is being used must be labeled and not be dangerous to unprotected spectators [4.4.1.2.1]. For this reason, we’ve used stickers on each laser. Warning signs like the one [here](https://www.mysafetysign.com/laser-in-use-do-not-enter-stop-warning-sign/sku-s2-0573) should be also used. The signs to be hung should be hung around the perimeter of the field that is fenced off in some way so that people can’t just wander into the path of the laser.
* The LSO must review the area and ensure that it's safe (because we don't have a protective housing surrounding the beam) [4.4.2.1]. The definition and responsibilities of the LSO are described in ANSIZ136.1’s appendix.
* The laser must not be able to be turned on when the lid is opened [4.4.2.1.3]. This is satisfied by placing the tilt switches on the cover, so that when it is opened the lasers will not turn on.
* It must be possible to lock out the switch [4.4.2.2] and must be clearly labeled [4.4.2.10.2]. This is satisfied by placing a clearly labeled switch inside a lockable box with the batteries.
* We have a fully open beam path [4.4.2.7.1], so the LSO needs to perform a laser hazard evaluation to make sure the beam terminates and does not point at anything that may become a safety issue.
* We need a warning device that is viewable when wearing protective eye-wear. This is typically a light that is green when safe, yellow when energized, and red when transmitting. Because of the nature of our design it is yellow when the device is powered on and red when shining a laser beam, and this is an acceptable solution. [4.4.2.8.1]
* Safety procedures must be established by the LSO [4.4.3]
* Education and training must be provided to employees working with these lasers [4.4.3.3]
* The LSO must declare certain individuals 'authorized' to used the lasers, and these individuals are the only people allowed to operate, maintain, or service the laser equipment [4.4.3.4]
* There may be other things to keep in mind found in ANSI Z136.6, which specifies things for the outdoors in particular [4.4.2.12]. Section 4.4.3.6 gives an overview:
	+ LSO must do a laser hazard analysis
	+ If visible at night, the LSO must make sure it won't interfere with any other systems. Also make sure it doesn't fly into an airplane, esp. if near airport [FAA Order JO 7400.2]
	+ The NHZ must be labeled clearly as a laser hazard area
	+ All personnel who will enter the NHZ must be appropriately trained (see [5.2])
	+ Only authorized personnel may operate the laser machinery
	+ PPE for lasers must be provided by the employer to individuals who may come in contact with the lasers
	+ No pointing them at cars and planes and stuff
	+ No pointing the lasers at eye level unless allowed by the LSO
	+ The beam must end somewhere instead of being allowed to point out of the field, so it must either be pointed at the ground within the user’s designated area, or pointed at a termination block.
	+ When not in use, disable in a way that prevents it from being used. This is satisfied by keeping the switch in a locked box.
* No spectators allowed where the system is being used while it is being used unless appropriate approval has been obtained, degree of hazard and avoidance procedure explained, and appropriate protective measures taken. [4.4.3.7]
* "Laser alignment shall be performed in such a manner that the primary beam [...] does not expose the eye to" an unsafe level. Written SOP's outlining alignment procedure must be established, and using lower power lasers for alignment is recommended. Exclude unnecessary and non-authorized individuals when aligning, use lower power lasers to align whenever possible, wear laser eye protection, use a beam block except when actually needed, use beam blocks to terminate the beam downrange, locate and block stray reflections, make sure all beams are terminated before high-power operation, post warnings when aligning [4.4.3.8]. An alignment laser tool has been provided that helps meet these requirements along with the termination block design.
* Because we don't have certain control measures, eye protection is needed. [4.4.4.2]

Section 5 discusses the training that must be given to those interacting with the lasers.

* Training must be provided to employees interacting with this laser system [5.1]

Section 6 discusses how to handle medical examinations involving potential laser injuries.

Section 7 covers non-beam hazards. I don't believe they are relevant to use due to the low voltage we're dealing with (they talk about arcing, electrocution, ionizing radiation, etc).

Section 8 discusses the maximum levels of exposure to lasers before injury. The lasers we are using can be safely shined into the eye for only a tiny fraction of a second, so assume that they cannot be shined at a person at all for our use case.

Section 9 discusses measurements and how to perform them, and do not appear relevant to our use case because we already know the classifications of the lasers being used.

Section 10 is a description of the revisions to the standards.

The remainder of the document is a collection of tables and appendices.

Appendix A defines responsibilities of certain staff members.

The Laser Safety officer is an individual required to be on staff because of the power level of these lasers. The Laser Safety Officer is "an individual designated by the employer with the authority and responsibility to effect the knowledgeable evaluation and control of laser hazards, and to monitor and enforce the control of such hazards". The LSO does not need to be a full-time occupation when "the workload for an LSO does not require a full time effort".

The responsibilities of the LSO that are relevant to this project are as follows:

* Creating safety policies and procedures that are in line with relevant legal requirements, and keeping this policies up-to-date.
* Verifying the classifications of lasers being used
* Performing hazard evaluation
* Making sure the control measures are being followed
* Approving the use of lasers
* Approving the procedures involving lasers
* Recommending, approving, and supplying protective equipment
* Making sure warning labels and signs are clear and set up
* Inspecting facilities and installations before being used
* Ensuring that personnel are appropriately trained and aware of safety procedures if they will encounter these lasers
* Performing medical examinations when necessary
* Recording injuries as a result of lasers to be provided to medical staff or governments when relevant
* Performing audits, surveys, and inspections
* Have a plan in place to respond to accidents involving lasers
* Approving usage of laser systems

**LOCKOUT/TAGOUT OSHA REGULATION 29 CFR 1910.147**

This regulation is an OSHA standard that applies to equipment that could cause injury if powered on unexpectedly and can be read [here](https://www.osha-safety-training.net/lockout-tagout-osha-regulation-29-cfr-1910-147/). Because of the nature of this device, and because it is specified in ANSIZ136.1, the laser scarecrow must conform to OSHA’s lockout/tagout procedures.

According to that standard, “An energy isolating device is capable of being locked out if it has a hasp or other means of attachment to which, or through which, a lock can be affixed, or it has a locking mechanism built into it” [1910.147(b)]. For this reason, the battery and switch are held inside a case that can be locked. Because ANSIZ136.1 requires that unauthorized usage be prevented, this box should be kept locked at all times.

Similar to ANSIZ136.1, the employer is required to train employees on logout/tagout procedures, and to inform them that they are not to operate equipment that has been locked or tagged out [1910.147(c)(1)].

In the case of the laser scarecrow, locking out procedures must be used and tagging out procedures cannot be used in its place [1910.147(c)(2)(ii)] [1910.147(c)(2)(iii)].

Typically, the employer must create and use a procedure to ensure the safety of employees when employees are performing tasks found in 1910.147(c)(4). However, the laser scarecrow project meets all the criteria to be excepted, so this is only necessary if the employer has “had no accidents involving the unexpected activation or reenergization of the machine or equipment during servicing or maintenance”.

The employer must provide lockout equipment. Locks that meet the standard can be found [here](https://www.uline.com/BL_4558/Lockout-Padlocks). This meets the lockout requirement and prevents unauthorized usage (meeting requirements in ANSIZ136.1). To make it clear that the box is not to be opened, and to meet the requirement that “Lockout devices and tagout devices shall indicate the identity of the employee applying the device” [1910.147(c)(5)(ii)(D)], a lockout tag reading “Do Not Open” may need to be purchased. Acceptable tags can be found [here](https://www.amazon.com/NMC-LOTAG9-25-DANGER-Lockout-Unrippable/dp/B00700MZG0/ref%3Dsr_1_4?s=industrial&ie=UTF8&qid=1528817073&sr=1-4). Note that a laminated tag and not a cardstock one because the laser scarecrow will be used outdoors [1910.147(c)(5)(ii)(A)(1)] [1910.147(c)(5)(ii)(A)(2)]