

EYE SAFETY CONCERNS IN AIRBORNE LIDAR MAPPING

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ABSTRACT

An increasing number of airborne lidar sensors are being deployed as operational tools by surveying and mapping firms. The majority of these sensors are based on Class 4 lasers that require appropriate laser safety controls be implemented to ensure safe operation of the sensors in the field, including standard engineering controls which must be incorporated in the instrument designs as per laser safety regulations. It is critical that lidar operators implement proper laser safety procedures at the operational level to ensure safety in the field. Since the majority of firms deploying these sensors are from the survey and mapping sector, the knowledge base and laser safety expertise within each firm and within the industry as a whole is not as deep as that within the laser/lidar sector. It is critical that operators of lidar instruments and their clients have an understanding and appreciation of the eye safety issues related to operating these systems. This paper provides an overview of the laser safety standards and regulations applicable to airborne lidar sensors, the common terms and definitions that are used, the general laser safety features that are incorporated in today's designs, general operational guidelines for maintaining eye safety in the field and specific guidelines to use when subcontracting for lidar data collection services to ensure laser safety concerns are addressed by service providers.

INTRODUCTION

Safety must be a primary concern during any field survey operation. Proper safety procedures and practices must be observed by everybody involved in the survey to ensure the safety of field crews, flight crews, airborne operators and any non-survey personnel in the survey area. While the general body of knowledge of survey practitioners contains a baseline of standard safety practices for normal aerial or ground surveys, the increasing deployment of airborne lidar instruments, which are based on active laser sensors, introduces a new set of hazards that need to be addressed by appropriate safety procedures. Given that the majority of surveyors are not experts in laser safety issues, best practices or regulatory standards related to the operation of lasers in an outdoor environment, it is important to educate both the operators and the end users about the relevant laser safety standards and practices that need to be incorporated when deploying airborne lidar. Since airborne lidar system designs can vary significantly and each organization's operational scenarios are different, the material presented in this paper is intended as an introduction to the subject and should not be taken as a rigorous analysis of specific laser safety issues related to airborne lidar. Every organization should determine its own laser safety issues and requirements independently or consult with a qualified laser safety expert if in doubt about laser safety for its operations.

LASER SAFETY

In the US laser safety standards for the manufacture and operation of laser equipment are covered by two separate sets of guidelines. Manufacturers of products that incorporate a laser use the FDA/CDRH standard issued by the US Department of Health and Human Services to classify and certify their laser products. The standard's full title is **Title 21 CFR, Subchapter J (Radiological Health) Part 1040.10, Performance Standard for Laser Products** but it is generally referred to as CDRH 1040. It is designed specifically to assist laser system manufacturers in certifying new and existing laser products. While the CDRH 1040 standard is primarily aimed at laser equipment manufacturers, equipment operators should still be familiar with some of the concepts in the

standard, specifically the ideas of laser classification and regulatory compliance. Safe operation of laser equipment in the field is the responsibility of the company operating the equipment and is covered in the US by the **American National Standard for the Safe Use of Lasers** specifically **ANSI Z136.1**. In Europe and other regions the **International Electrotechnical Commission - Safety of Laser Products (IEC 825-1)** standard applies but the majority of the concepts in the two standards are the same so this paper will reference the ANSI standards for safe operation.

Laser System Classification

Laser is an acronym standing for **L**ight **A**mplification thru **S**timulated **E**mission of **R**adiation. Lasers are generally referred to by the name of the active optical medium, for example ND:YAG for lasers based on crystals of neodymium (Nd), yttrium (Y), aluminum (A), and garnet (G) or by the particular laser type used, for example the diode lasers found in CD players. Laser performance is characterized by the system's output wavelength, output power, and in the case of pulsed lasers, the system's pulse duration, pulse energy, and pulse repetition rate. For the layperson, a laser can be considered a source of very bright, intense light operating either as a continuous beam, similar to a flashlight, or as a series of short pulses, similar to rapidly turning a flashlight on and off. A lidar, another acronym standing for **L**ight **D**etection **A**nd **R**anging, can be thought of as optical radar using a laser as the active source of radiation. Essentially it measures the time it takes a laser pulse to travel from the source to a target and back again and uses this time to calculate the distance to the object. The majority of laser systems employed in airborne lidar mapping today are based on pulsed lasers operating in the near infrared around 1.0 μm with pulse durations on the order of 10 ns, pulse energies of 100s μJ and with pulse repetition rates of 10,000+ Hz. There are several variations on these general characteristics in use today, including some systems that operate at different wavelengths.

Under CDRH 1040, manufacturers are required to classify any product that incorporates a laser based on the accessible emission level - the magnitude of accessible laser light (radiation) the product emits - using well-defined measurement and calibration criteria. For operational safety purposes all lasers or instruments incorporating lasers as a source of radiation, such as an airborne lidar instrument, are classified according to the amount of radiation accessible during operation. There are different criteria for maintenance situations. Only personnel trained in laser safety, optical engineering or physics are considered suited to perform the detailed hazard evaluation calculations or laser system classifications outlined in CDRH 1040. Since the classification calculations have to take in to account a range of laser types covering a wide spread of wavelengths, pulse durations, repetition rates and levels of radiant exposure, the calculations can be complex and will not be discussed in detail here. In general terms the classification of a particular laser system depends on parameters such as the wavelength of the laser, the laser power, the duration of the laser emission, the spatial divergence or spread of the laser emission and other related factors. While the required calculations are explained in detail in the standard, it is not necessary for an equipment operator or end user to be familiar with these. It is more critical for them to know the final classification of the sensor.

As a result of the manufacturer's classification, every laser system will be assigned a class from Class 1 to Class 4, with Class 4 lasers being the most hazardous. The class of a laser essentially determines the laser or laser system's capability of injuring people and is based on the highest accessible emission level of radiation to which any access is possible during operation of the system. Class 1 lasers are not considered hazardous while Class 4 lasers are considered to be an acute hazard to both the eyes and skin of a person exposed to either a direct or indirect, scattered beam. Class 4 lasers can cause permanent - and painful - damage to a person who gets a beam in the eye or on their skin. The majority of airborne lidar systems in use today are classified as Class 4 systems due to their high pulse energies, narrow beam divergences and repetition rates. As such they represent a serious hazard if not operated properly and in accordance with laser safety guidelines, in particular equipment operators must pay close attention to minimum operating altitudes for survey aircraft to prevent harmful exposure to people on the ground. An automatic interlock that disables the laser if the aircraft is too low to allow safe operation must be incorporated in to all system designs. It should be noted however that different system designs might have different classifications, especially those systems operating at wavelengths different from 1.0 μm . For example, systems operating at 1.5 μm are safer than 1.0 μm systems when considering eye safety, while those operating in the visible portion of the spectrum can be more hazardous.

Laser Safety Considerations During System Design

The classification of the laser subsystem incorporated in an airborne lidar sensor dictates important engineering controls that must be incorporated in the instrument design by the equipment manufacturer as outlined

in CDRH 1040. Since the majority of airborne lidar systems in use today incorporate a Class 4 laser, some of the required engineering controls specified in CDRH 1040 for this class of laser are summarized in Table 1.

Control	Notes
Protective Housing	To prevent access to hazardous radiation during operation.
Safety Interlocks	To prevent laser from operating if protective housing is removed; in certain cases may be designed to be defeated if visible or audio signal of interlock over-ride is included.
Remote Interlock	Readily accessible interlock that can be used to shutoff laser if externally triggered, for example if aircraft drops below eye safe operating altitude.
Key Control	A key-actuated master control with removable key. System must not be operable when key is removed.
Laser Radiation Emission Indicator	A visible or audible indicator signal during emission of accessible laser radiation in excess of Class 1 limits; must activate sufficiently prior to actual emission to allow appropriate action by personnel to avoid exposure.
Beam Attenuator	One or more permanently attached means of blocking access to hazardous levels of emission. Generally mechanical or electro-mechanical shutters to physically block the laser emission.
Location Of Controls	Ergonomically designed to ensure operator is not exposed to laser emission while operating the instrument.
Scanning Safeguard	To prevent a potentially hazardous emission of radiation if a scanner fails or locks in position.
Labeling	Clear and prominent labels conforming to approved label designs and layouts providing details on the laser system, emission points and safety information.

Table 1 – Required Engineering Controls For Class 4 Lasers

Manufacturers of airborne lidar instruments also incorporate an additional engineering control in their designs that monitors the altitude of the aircraft and the operating parameters of the laser and automatically shuts the laser off if the aircraft altitude drops below the manufacturer's listed safe altitude for the particular system. Some airborne lidar systems, especially earlier designs from before 1998, allow the airborne operator to override this feature. Extreme caution must be exercised when overriding this safeguard and the manufacturers do not recommend it.

The responsibility for conformance to CDRH 1040 resides with the system manufacturer in the case of commercial off-the-shelf instruments such as the Optech ALTM or Azimuth AeroScan, or with the final system integrator in the case of laser subsystems provided as OEM components of custom-designed lidar sensors. All of these engineering control requirements have to be met by the manufacturer, along with well-specified laser safety labeling requirements for both the product and the product literature, in order for the manufacturer to certify that the product is in compliance with the standard. Manufacturers have to provide proof of such certification in the form of a label or tag that they must permanently attach to or inscribe on the product in an area readily accessible to view. Certification is essentially completed by the manufacturer or final system integrator and is self-determined. However, manufacturers are required to submit product reports and annual reports to the CDRH. They also have to keep a record of distribution of their laser products and to report all occurrences of accidental radiation exposure reported to or otherwise known to them arising from the manufacturing, testing, or use of any of their laser products.

The standard is essentially self-enforcing but there are penalties for non-compliance. If a product, through a defect in manufacturing, a misclassification of the laser system or simply by poor design, is determined by the owner, the distributor, the manufacturer or an outside party, to be non-compliant with the standard - for example a Class 4 product with no or inadequate interlocks - the manufacturer must immediately notify the CDRH and all purchasers of the product that the product is non-compliant. The manufacturer must then make arrangements to either (a) bring the product into conformity or remedy the defect without charge to the product owners for any expenses including parts, labor, transportation and shipping; (b) replace the product with a functionally equivalent product which complies with the standards; or (c) refund the cost of the product to the purchaser. The situation is

similar to a safety recall in the automobile industry. It can have significant financial implications for the manufacturer; consequently they tend to be very careful with classification and certification issues.

Laser Safety Considerations During Operation

While classification and certification of laser equipment are the manufacturers responsibility, safe operation of a product is the responsibility of the company operating the instrument. Safe operation of laser equipment is covered in the U.S. by the **American National Standard for the Safe Use of Lasers** specifically **ANSI Z136.1**. In the case of airborne lidar instruments the responsible party is generally the system owner/operator, or in the case of rented or leased equipment, the actual field crew and airborne operators of the instrument.

Under Z136.1 the management (the employer) of an organization that routinely employs lasers in its operations is required to establish and maintain an adequate program for the control of any laser hazards associated with its operations. Proper safety and training programs for the organizations employees are required under these regulations for all instances where laser systems classified as Class 3(b) or higher are used, while training is recommended but not required for systems of lower classes. Operators of Class 1 lasers are generally not required to offer training. In general practice the authority and responsibility for the monitoring and enforcement of laser hazard evaluation and control resides with an organization's designated Laser Safety Officer (LSO). It is strongly recommended by ANSI that any organization operating a laser product, especially a Class 4 laser system, have a clearly designated LSO who is trained in laser safety issues and can implement a laser safety plan for the organization based on its unique operating environment. The regulations require that there be a clearly designated LSO with responsible charge for all circumstances of operation of a laser or laser system above Class 2. Management is responsible for providing proper education and training to the designated LSO in all aspects of laser safety including laser classification, potential hazard assessment, control measures, applicable standards and other pertinent information. This is generally accomplished through outside training offered by groups such as the Laser Institute of America (LIA). LSOs are also responsible for a variety of other laser safety issues, such as training of staff or annual eye examinations; Appendix D of Z136.1 has more details. Depending on the extent of the laser operations within an organization, the role of LSO may be a full or part-time position and in larger organization may be supplemented by a formal Laser Safety Committee or Review Board. It is the responsibility of the management of the organization operating the airborne lidar equipment, not the system's manufacturer or final integrator, to ensure that a suitable LSO and appropriate laser safety training are in place before commencing operations.

Within an organization it is the responsibility of the LSO to complete a hazard assessment of all the organization's laser operations and compile, implement and monitor a laser safety plan to address those hazards. Revisions of the laser safety plan, incident reporting and medical surveillance of personnel, if applicable, are also the responsibility of the LSO. When assessing laser safety hazards, the LSO needs to consider three main aspects of the organization's laser operations:

- (1) The laser system's capability of injuring people.
- (2) The environment in which the laser will be used.
- (3) The people who may be exposed to laser radiation.

The laser's capability to injure people is covered by its classification as discussed above. The other two factors vary with each laser application and operational scenario and usually cannot be readily standardized. Consequently, the total laser hazard has to be evaluated for each organization and each particular operational scenario to determine what control measures are needed. For airborne lidar systems item (1), classification, is normally covered by the system manufacturer in the case of commercial off-the-shelf instruments, or the system integrator in the case of custom-designed sensors. If such a classification is not provided, the LSO is required to complete the calculations and assign a classification to the equipment prior to any deployment of the instrument.

In addressing (2), the environment in which the airborne lidar system will be used, the LSO needs to carefully consider the operational deployment of the system. Essentially, once the LSO knows the classification of the product they have to consider the environmental factors that will be in place during operation and determine any appropriate laser safety control measures that must be implemented. They have to consider such things as the probability of personnel exposure to hazardous radiation - which can be influenced by operation indoors, or outdoors - or the potential exposure of unprotected or unaware personnel to the laser beam. A more detailed explanation of hazard evaluation and classification can be found in Section 3 of Z136.1. In evaluating any potential hazard the LSO needs to determine several key parameters based on the specific laser system being used. These parameters are

the Maximum Permissible Exposure (MPE), the Nominal Hazard Zone (NHZ) and the Nominal Ocular Hazard Distance (NOHD).

In brief, the NHZ describes the space around the equipment within which the level of the direct, reflected or scattered laser radiation during operation exceeds the MPE. The LSO can calculate the MPE knowing the wavelength, power, duration and divergence of the laser source or the manufacturer can be asked to provide it. The MPE is the level of laser radiation that a person can be exposed to without hazardous effects or adverse changes in the eye or skin. Inside the NHZ a person is at risk; outside the NHZ the exposure levels are below the MPE and are not considered dangerous. Referring to most of the literature and specification sheets that are available on airborne lidar instruments, the terms NHZ, NOHD and MPE are usually not referenced but rather a quantity called an eye safe range is listed. This is not an officially approved term according to the ANSI standard. When listing an eye safe range the manufacturers or equipment operators are generally referring to the NOHD for a specific set of defined operating parameters. Hence this is the distance beyond which direct exposure of the eye to the laser radiation - direct viewing - is not expected to exceed the MPE for the eye for the defined operating conditions. This nominal ocular hazard distance would be the safe distance from the instrument in the case of a person on the ground looking up at the airplane or helicopter while the system was surveying, essentially, the safe operating altitude. Since the specific operating conditions under which the quoted eye safe range has been calculated are usually not listed by the system manufacturers or operators, any LSO dealing with an airborne lidar system should clarify these parameters with the manufacturer or operator to ensure mutual understanding of the validity of the specified eye safe range. The MPE for the eye is different from the MPE for the skin and usually lower, so eye safety is the primary concern during survey operations, however the LSO should be aware that Class 4 lasers also have the potential to cause skin damage.

While the most obvious hazardous situation during an airborne lidar survey would be inadvertent exposure of people on the ground to a direct beam from the lidar system at a distance less than the NOHD, that is direct exposure to a person within the NHZ, the LSO also needs to consider reflected beams and specular reflections as well. A person on the ground doesn't necessarily have to be looking directly at the aircraft. There are also factors other than the manufacturer's stated NOHD or eye safe range that the LSO needs to consider. The type of exposure that might occur, whether a person would be exposed to a single pulse or multiple pulses, is an important factor. Given the airspeeds, scan angles and scan speeds that are common for the current generation of airborne lidar instruments, the single-shot case can generally be considered adequate for most operational scenarios. However, the LSO must be very careful to consider possibilities such as a scanner failure that locks the scanner in one position or intentional operation in a near-profiling mode or at a fixed view angle. Both these cases could result in multiple pulse exposure to somebody on the ground and would increase the NOHD or eye safe distance. As well, slow moving platforms, such as helicopters, need to be considered very carefully, especially if the system will be operating while the platform is hovering. This has the potential to be a very dangerous situation. Both because a person on the ground could be exposed to a high number of laser pulses from a slow, low-flying platform, but also because a hovering helicopter attracts more attention and hence is more likely to be looked up at by somebody on the ground. An LSO has to consider all these types of factors and the probability of them occurring in determining a suitable laser safety plan and implementing the correct controls to avoid hazardous exposures to people on the ground.

Aided viewing, which is exposure to the laser radiation through collecting optics such as binoculars, implies a much greater radiant exposure or irradiance at the retina and can be a particularly challenging operational scenario for an LSO to address. Simply put binoculars used by a person on the ground do what they are designed to do, they collect and collimate light in to a much tighter area for improved viewing by the retina. Very useful if a person is trying to read the registration numbers on the tail of an aircraft; extremely dangerous if that aircraft happens to be directing a laser beam in their direction. Z136.1 addresses the situation of aided viewing by requiring the use of a larger measurement aperture for classification of the laser, 50 mm as opposed to 7 mm for unaided viewing, effectively increasing the classification of the laser system. More importantly for airborne lidar operational scenarios, the NOHD or eye safe distance increases significantly for aided viewing since the MPE remains the same but the actual exposure will increase by a well-defined ratio (see Z136.1 Appendix B4.5 for details). For example, a pair of 10 x 50 binoculars will increase the exposure for direct viewing by a factor of 25, assuming the beam is larger than the input lens. This situation could very well increase the NOHD or eye safe distance to well beyond the maximum operating altitude of the particular instrument. As a result, the LSO needs to consider this increase in the NOHD carefully if there is a reasonable chance somebody will be looking at the aircraft with binoculars. Given the operating altitudes that are normal for these survey flights, 5,000' – 10,000', the laser wavelengths, the beam divergences, the likely pulse energy densities on the ground and the pulse durations that are involved, combined with the fact surveys over urban areas are becoming much more common, every LSO responsible for airborne lidar

instrument should be verifying the NOHD for both aided and unaided viewing before they start to operate the system. If they don't know what the NOHD is for typical aided viewing, they should calculate it or ask the instrument manufacturer for it. Not knowing the NOHD for aided viewing, even if it is later determined that aided viewing is not a hazard, is a sign of poor laser safety planning that can reflect badly on the organization if there is an incident.

A section of Z136.1 (Sec. 4.3.11) explicitly covers control measures for outdoor use of Class 4 lasers. The LSO for an airborne lidar operator should be thoroughly familiar with this section of the regulations. A specific requirement under this section states that directing a Class 4 laser beam toward automobile, aircraft or other manned structures or vehicles is prohibited within the NHZ unless adequate training and protective equipment is provided and used by all personnel within these targets (4.3.11(7)). There are also FAA restrictions on the use of Class 4 lasers in navigable airspace, although these restrictions are aimed more at the laser entertainment display sector and it is not clear if these apply to airborne lidar survey operations. The FAA is mainly concerned with laser beams directed upwards from the ground that may blind or distract pilots but technically, under Z136.1 all laser experiments or operations that will involve the use of laser or laser systems (other than Class 1 or 2) in navigable airspace should be coordinated with the FAA.

The ANSI standards for operational safety of laser equipment are self-enforcing, similar to the laser classification and certification required by CDRH 1040 for the equipment manufacturers. The responsibility for safe operation of airborne lidar systems lies with the operators of the instruments. Unless there is an incident or complaint, no independent certification or external review of an organization's laser safety procedures is required. It can be assumed that, aside from the ethical implications, the financial liabilities to a company that operates any laser instrument in an unsafe manner are potentially huge. This liability far outweighs the time and effort to complete a proper laser hazard analysis and put in place a proper laser safety plan, both of which can be completed in a matter of days by a trained laser safety expert. It may not seem a significant risk to people who are not educated about the hazards associated with lasers, given the altitudes and speeds of the platforms involved, but a single incident could be devastating, both for the unfortunate individuals involved and the company responsible, hence laser safety must be an integral part of the operations of any airborne lidar operator.

It is strongly recommended that every company operating an airborne lidar instrument designate a Laser Safety Officer and make sure that he or she is fully trained in these issues. As well, the LSO must be given the necessary authority to implement any changes needed related to laser safety issues, even to the point of grounding an instrument if unsafe practices are discovered. A qualified, trained LSO goes a long way towards creating a safe operating environment and minimizes any risk of a possible incident. In the unfortunate case an incident does occur, a competent LSO will have the proper documentation and records in place to help protect the company from any financial liability. And more importantly, they will be able to properly analyze the incident and improve the laser safety plan and controls to insure it does not happen again.

More detailed definitions and descriptions of the laser safety terms referred to along with detailed explanations of how to implement safe operating procedures for laser equipment can be found in the **American National Standard for the Safe Use of Lasers ANSI Z136.1**.

Incorporating Laser Safety Considerations in RFPs

With the increasing number of projects that are deploying airborne lidar as an integral part of their field data collection campaigns, it is important that end users, contracting agencies and prime contractors be aware and incorporate laser safety issues into their normal safety concerns when releasing RFPs or making contract awards for lidar surveys. However, in general this group of stakeholders is not familiar with laser safety issues and usually not educated or knowledgeable about how to address these concerns beyond general safety terms and conditions. The following guidelines are suggested for such groups who wish to address these issues in their dealings with airborne lidar subcontractors or service providers but do not necessarily have laser safety expertise in-house:

1. Explicitly require any lidar instrument deployed on a project to be certified to CDRH 1040 standards by referencing FDA/CDRH Title 21 CFR, Subchapter J (Radiological Health) Part 1040.10, Performance Standard for Laser Products. Verify this by inspecting any lidar instrument and making note of the appropriate labeling and certification plate or tag.
2. Explicitly require any contractor or subcontractor to adhere to the guidelines and requirements for safe operation of laser equipment contained in the American National Standard for the Safe Use of Lasers specifically ANSI Z136.1. Verify this by requesting a written laser safety plan be submitted prior to the commencement of any fieldwork.

3. Require any contractor or subcontractor to provide relevant laser safety information on their instrument including laser classification, Nominal Hazard Zone (NHZ), Nominal Ocular Hazard Distance and Maximum Permissible Exposure (MPE) for their instrument under its normal operating conditions.
4. Require any contractor or subcontractor to identify their designated Laser Safety Officer by name and confirm that the LSO has responsible charge over all operational issues related to laser safety. If necessary, request a copy of the designated LSO's qualifications for the position, including details of any relevant training.
5. Require a Laser Safety Review, to be attended by all stakeholders and the contractor's or subcontractor's LSO or their appointed delegate, be conducted prior to starting any fieldwork. On large field projects requiring crews to be in the field for extended periods, incorporate laser safety reminders in to daily safety reviews and/or request a written laser safety plan specifically for the project be submitted by the contractor or subcontractor's LSO and disseminate this information to all people involved in the project.
6. For projects which include lidar surveys of densely populated areas such as urban centers require a written analysis of the probability of unique situations, such as aided viewing, and a written hazard assessment and safety plan to cover these situations.
7. For organizations that are or anticipate using airborne lidar on a routine basis, either through their own system or through subcontractors, designate an individual in-house to be trained as a Laser Safety Operator and give the LSO responsible charge over all laser safety issues.
8. For organizations which do not have the volume of work to justify having an internal LSO but who are contracting out a major project that incorporates airborne lidar, such as statewide mapping programs, retain the services of an outside laser safety expert to audit all laser safety issues and plans prior to commencing field operations.

CONCLUSIONS

The growing number of airborne lidar instruments that are being deployed in routine survey operations is increasing the need for awareness and education on laser safety regulations and procedures. Since many stakeholders do not have a background in lasers or laser safety, it is important that system manufacturers, system operators and end users stress safe operation of lidar instruments at every opportunity. This paper has provided an overview of the laser safety standards and regulations applicable to airborne lidar sensors, some of the common terms and definitions that are used, the general laser safety features that are incorporated in today's designs, some general operational guidelines for maintaining eye safety in the field and specific guidelines to use when subcontracting for lidar data collection services to ensure laser safety concerns are addressed by service providers. The availability of a properly trained and clearly designated Laser Safety Officer within any organization involved in airborne lidar operations is highly recommended. Guidelines for incorporating laser safety in RFPs and contract awards have been included above. Since airborne lidar system designs can vary significantly and each organization's operational scenarios are different, the material presented in this paper is intended as an introduction to the subject and should not be taken as a rigorous analysis of specific laser safety issues related to airborne lidar. Every organization should determine its own laser safety issues and requirements independently. Take laser safety seriously! The risks may seem minor and financial drivers may put pressure on organizations not to look too closely at the issues, but the consequences of unsafe operation can be devastating to everybody involved.

References

- [1] FDA/CDRH Title 21 CFR, Subchapter J (Radiological Health) Part 1040.10 - Performance Standard for Laser Products
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