EXAMINING MONTHLY AND ANNUAL LASER STRIKE REPORTS FROM 2010-2021

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Abstract: Laser strikes are becoming an increasing problem for the aviation industry, where the lives of both crews and passengers are at risk. The aim of this research was twofold: a) determine if there was a statistically significant difference in laser strike frequency by month and b) identify the trend in annual laser strike reports. This study examined the number of laser strikes reported to the FAA from January 2010 to September 2021. The data showed no statistically significant difference in frequency of laser strike reports between calendar months. The linear regression indicated an increasing annual trend of laser strike reports. The risk of a potential laser strike is approximately the same throughout the year regardless of the calendar month. There is a positive trend in laser strike reports from 2010 to 2021, which indicates that we need further research to help mitigate this risk.

Key Words: *Laser strikes, FAA laser reports, aviation safety*

1. INTRODUCTION

Lasers of all strengths and colors pose the threat of temporary blindness and permanent damage to the eye. Pilots, along with crewmembers or civilians, are at risk for a laser strike incident whether the strike is intentional or accidental. The Federal Aviation Administration (FAA) has established a voluntary laser incident database that collects laser strike reports and publishes the data publicly. The FAA has published advisory circulars regarding laser strike encounters and regulations that establish critical flight zones around airports where lasers are prohibited. Lasers create a safety hazard to the aviation industry as it can result in pilot blindness, and aircraft aborting landings (Nakagawara & Montgomery, 2004). Due to the safety risk associated with laser strikes, a better understanding of their frequency is necessary.

The purpose of this study was to a) examine if there is a difference between the frequency of reported laser strikes on aircraft from 2010 to 2021 based on the month of the year, and b) analyze the annual trend of laser strike reports. The laser strikes that are reported by crewmembers, air traffic control, and the public are collected by the Federal Aviation Administration (FAA) in the Laser Incidents Database (FAA, 2021); this study utilized all data from January 1, 2010 to September 30, 2021 to calculate the monthly frequency of laser incidents and the annual laser strike report frequency.

The importance of this study was to determine the calendar months that laser strikes occur most frequently in the United States of America, and the annual trend in laser strike reports. Laser strikes can cause significant injury to crewmembers and anyone onboard the aircraft (Cole, 2011). The results from this study may allow for further safety practices and crewmember awareness to be implemented for the given month, or for the future years.

2. LITERATURE REVIEW

2.1 Definition of Laser Strike Problem

The L.A.S.E.R. or "Light Amplification by Stimulated Emission of Radiation" (Harrington & Wigle, 2004) was first used approximately 60 years ago. As the name suggests, the light is amplified into a narrow beam. This became an important tool for many industries because of its wide range of uses "from photocopiers to antimissile defense systems" (Harrington & Wigle, 2004, para. 2). However, this is not always the case. Laser strikes are becoming a large problem for the aviation industry with an increasing number of laser strikes being reported to the FAA (Schmid & Stanton, 2018). Hawaii observed an increased number of laser strikes reported around Christmas of 2010 (Cole, 2011). Additionally, the FAA (2021) has reported an increase in laser strikes every calendar year. In fact, even with fewer airborne aircraft in 2020 due to the pandemic, the FAA (2021) noted an increase in laser strikes from the previous year. This does not only affect commercial aviation. It also affects general aviation, military aviation, and all other aviation types (Harrington & Wigle, 2004). There are records of laser strikes occurring for over three decades (Carroll & Richards, 2018). However, only in the previous two decades was it noted as an increasing problem (Carroll & Richards, 2018). Therefore, data is limited, and this study will utilize the results from January 2010 to September 2021.

According to Nontapot and Rujirat (2018), this increasing trend of laser strikes occurs because of the availability and accessibility of lasers, which have a wide range of uses for both work and recreation. One common usage includes inside of the classroom (Nontapot & Rujirat, 2018). Educators and lecturers may find this tool important to keep their audience focused on their current topic or a focal area on a PowerPoint slide. However, it is not uncommon to see these devices being used by the younger, untrained population (Nontapot & Rujirat, 2018). In this scenario, it may be used as a toy or for entertainment purposes such as party laser devices or pet entertainment.

Lasers can be categorized in different ways. First, there are several different colors of lasers. Each color may have a different power output and may pose more or less threat to pilots and the flying public. Generally, red, green, blue, and violet lasers are predominantly seen in use and reported today (Reddix et al., 2019). Reddix et al. (2019) reported different power output for different colors of laser. They concluded that the output varies by more than just its color, evaluating red, blue, and three different wavelengths of green. The blue laser recorded the highest output and veiling glare, and it produced the shortest wavelength. However, after interpreting the chart, no direct relationship between the wavelengths and power output or veiling glare was observed.

Lasers are also classified from one to four with a risk of incapacitation for any class above one (Schmid & Stanton, 2018). Therefore, many lasers that exist can be harmful to pilots. According to Harrington and Wigle (2004), wavelength, energy, aperture size, divergence, continuous or pulsed emission all contribute to the strength and class of a laser. Thus, even the lower strength or class lasers, which are more readily available, can be harmful to flight crews.

2.2 Threats of Lasers

Each type of laser produces a different level of threat for a pilot or anyone that may be impacted by laser usage in the United States. A high-intensity laser incident that shines upon a human eye can cause temporary blindness and possibly permanent damage to the eye. These two different impacts on the human eye are categorized into dazzle and damage (Freeman & Williamson, 2020). Murphy (2009) categorized laser incidents into three levels of effect on the human eye: distraction, glare, and temporary flash blindness. The high-intensity light from a laser can damage the retina, causing temporary or permanent blindness. Murphy (2009) found that the glare and flash blindness levels of lasers resulted in an aborted landing rate of 20-25%, with an impact level of more than 50% during the approach. Lasers are a significant threat to human eyes as they can cause permanent damage to the retina or temporary blindness that restricts the eye's ability to focus on the outside light.

The threat of a laser strike to a pilot or an occupant onboard an aircraft depends on different light factors. Murphy (2009) specified strength of the laser, beam divergence, laser wavelength, color, and whether the laser is pulsed or continuous as important factors. Bright, low divergence, green-yellowish colored lasers were found to create the greatest threat to pilots (Murphy, 2009, p. 5-6). Another factor that impacts the threat of a laser incident is whether it occurs during nighttime or daytime (Murphy, 2009, p. 6, Nakagawara et al., 2004). During nighttime or low light conditions, the rods and cones in the eye are adjusted to the low-light conditions, which causes a greater impact to the eyes from a laser strike (Murphy, 2009, p. 6, Nakagawara et al., 2004). Laser incidents have been proven to be distracting to pilots at low altitudes, including critical phases of flight such as takeoff and landing (Nakagawara et al., 2004). In 2004, Nakagawara et al. found that a laser strike with strengths between 0.5 uW/cm2 and 50 uW/cm2 resulted in 75% of the pilots suffering from glare, flash blindness, and afterimages (Nakagawara et al., 2004). Of the 75% that were impacted by the laser strike in the simulator, eight executed missed approaches, and one handed over the controls to the co-pilot. The simulator was accepted to replicate the cockpit environment in the aircraft, although it is important to take into account that the simulator may have had different humidity, temperature, clouds impact on laser, and the laser electronically created and displayed through the simulator visual system (there was no actual laser being used in the simulator), meaning that actual lasers may have different impacts. These studies indicate that laser strikes result in missed approaches and aborted landings, all due to the temporary blindness of lasers.

Causes of laser incidents vary from personal lasers that can be bought online to lasers that are used for entertainment at outdoor venues (Murphy, 2009). Public-used lasers are available for purchase with different intensities (brightness) and colors. Common lasers have approximately 1 W of power, which is within the danger range for impacting the human eye (Nontapot & Rujirat, 2018). Laser incidents with aircraft can be executed on purpose by an individual with an underlying goal or accidentally by a source (Murphy, 2009). The trend of the increasing number of lasers being accessible to the public poses a threat to pilots in the cockpit whether the strikes are purposeful or not (Murphy, 2009, Nakagawara et al., 2004). Lasers that have dangerous levels of power are readily available to the public for purchase, which poses a threat to pilots.

2.3 Measures Already in Place to Prevent Laser Strikes

The number of laser incidents have increased for a variety of reasons, one being how inexpensive it is to purchase lasers online. The FAA established airspace zones protected around airports and other sensitive areas that protected aircraft from exposure to a laser. Nakagawara et al. (2004) evaluated pilot's performance while they encountered laser illuminations during final approach above the laser free zone (Nakagawara et al., 2004). This study included definitions for Critical Flight Zone, Sensitive Flight Zone, Laser Free Zone, and Normal Flight Zone. The Critical Flight Zone covers 10NM and has an emission power limit of 5μW/cm² established. The Sensitive Flight Zone covers everything outside the critical zone and has an emission power limit of 100 μW/cm² established. The Laser Free zone covers everything in the vicinity of the airport and has an emission power limit of 50μW/cm² established. The Normal Flight Zone covers all navigable airspace and has an emission power limit of 2.5 mW/ cm² (Nakagawara et al., 2004). Nakagawara et al. (2010) mentioned that because of the frequency of laser strikes, the Advisory Circular 70-2 was published in 2005 (Nakagawara et al., 2010). After its issuance in 2005, the reports for incidents were more reliable at the time of their submission, and they were more detailed (Nakagawara et al., 2010, p.4). This document was later updated to Advisory Circular 70-2A, which was published in 2013 and provided information on the FAA's measures taken for laser strikes. AC 70-2A also provided counter-tactics for aircrew, such as avoiding direct eye contact and shielding eyes during the presence of a laser strike (Burress Jr., 2017). The AC 70-1A provided sufficient information regarding laser strikes, including why is it important to notify the FAA about incidents, who should file the incidents, where to submit the reports, what information should be included, and what the FAA will do with the information (FAA, 2018). After any unauthorized laser illumination events, pilots are required to report by radio to ATC and fill out the "FAA Laser Beam Exposure Questionnaire" upon arrival at their destination. The FAA Laser Beam Exposure Questionnaire is an instrument for collecting data regarding laser incidents (FAA, 2018). ATC should report any incidents to the Domestic Events Network. The public should email the FAA to report an incident, including name, contact information, date, time, and location (FAA, 2018, Nakagawara et al., 2010). The FAA Modernization and Reform Act enacted on February 14th, 2012 makes laser strikes a crime:

Section 311 amended Title 18 of the United States Code (18 USC), Chapter 2, § 39, by adding § 39A, which makes it a Federal crime to aim a laser pointer at an aircraft. The crime is punishable by a fine up to $250,000 and five years' imprisonment. (FAA, 2016, para. 2)

The FAA has taken steps necessary to attempt to reduce the number of laser incidents, as they know the danger these impose to safety.

Previous research suggested there was an increasing trend in laser strikes, and one claimed more strikes closer to winter holidays. The threat for pilots has also increased as lasers are capable of causing permanent and temporary damage based on the different light factors (FAA, 2021, Murphy, 2009, Nakagawara et al., 2010, Reddix et al., 2019). As the accessibility of lasers is increasing to the public (Nakagawara et al., 2004), the resultant laser incident occurrences are likely to increase. The FAA states that "pointing a laser is a federal crime" (FAA, 2021, para. 2), and although this may not end laser strikes completely, the FAA has taken this step to reduce the number of laser strikes. However, it is necessary to continue to research the relationship between the number of laser incidents reported and trends in laser strikes over time so that aviation professionals have current information on the hazards.

3. METHODS

The research used an ex post facto design to examine the relationship between the number of laser strikes reported to the FAA from 2010 to 2021 and the frequency for each calendar month and the annual trend in reports. The reports in the FAA database are reported by crewmembers, air traffic control, and the public (FAA, 2021). The names of reporting individuals have been de-identified. Laser incident data between January 1, 2010, and September 30, 2021, in the United States was exported from the FAA (2021) Laser Incident Database to an Excel file.

The dataset retrieved from the FAA (2021) Laser Incident Database was limited to the laser incident and the date it occurred. When downloaded, the data was separated by year; we combined the data into one sheet for 2010 to 2021. The monthly laser strike report frequency was calculated for each month from the first day to the last day. The annual laser strike reports were calculated by summing reports for all 12 months from the first day of the year to the last day of the year that data was available for each year from January 1, 2010 to September 30, 2021. For 2021, the total reports were multiplied by 1.33 because reports for October through December were not yet released. This result was used as the annual laser strike total for the purpose of determining the yearly trend.

The descriptive and inferential statistics were calculated on the entire dataset for each month. Excel was used to calculate the descriptive statistics; inferential statistics were calculated by exporting the dataset to R studio v 1.4. A one-way analysis of variance (ANOVA) was used to determine the difference in laser strikes by month.

4. RESULTS

The data utilized contained 64,558 individual laser strike reports. This included all reports submitted to the FAA in the period ranging from January 1, 2010, to September 30, 2021 (FAA, 2021). Data from the last three months of 2021 did not exist or had not yet been released. These laser strikes were reported by pilots who had been flying a variety of aircraft ranging from piston aircraft as small as a Cessna C-150, to much larger jets such as an Airbus A380. The data also showed the strikes reported at different altitudes and all states in the U.S.

Descriptive statistics for laser strike reports by month are shown in Table 1 and Figure 1. The overall monthly mean was 458 laser strikes. However, there were as few as 117 laser strikes reported in March of 2010, and as many as 946 in December of 2015, resulting in a total range of 829 laser strikes per month and a standard deviation of 185. There were no modes observed for any month. The ANOVA found no significant effect of month on laser strike reports, $F(11, 129) = 1.45$, $p = .16$. Eta squared was 0.11, which indicated a medium effect size.

The trend in laser strike reports over time was also examined. Figure 2 shows a positive trend over time with increasing numbers of laser strikes reported. The linear regression had a slope of 466.02 and an intercept of negative 933,706 ($R^2 = 0.72$), illustrating the increasing trend in laser strikes.

Table 1 Descriptive statistics for monthly Laser strike reports for 2010 - 2021

Statistics	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Mean	437	371	436	396	380	399	477	496	518	515	550	538	458
Median	463	374	480	356	357	407	466	486	495	519	468	608	424
Max	673	617	775	743	796	758	817	768	893	775	892	946	117
Min	148	117	159	217	191	194	288	361	328	321	238	214	946
Range	525	500	616	526	605	564	529	427	565	454	654	732	829
Std. Dev.	173	156	177	161	160	151	159	142	192	178	252	257	185

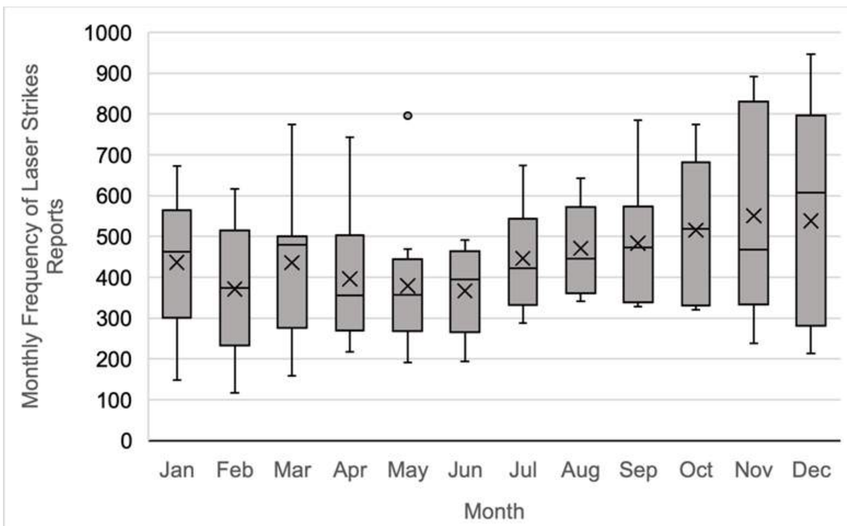

Figure 1 Laser strike reports by month for 2010 to 2021

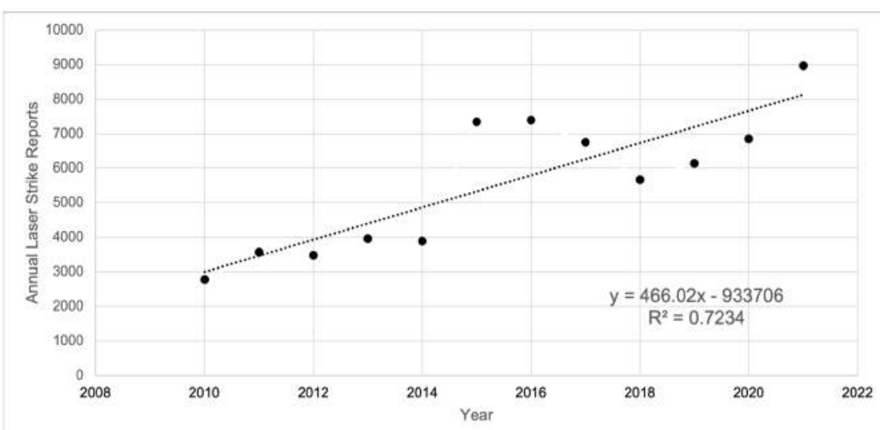

Figure 2 Annual laser strike reports by year

5. DISCUSSION

The goal of this study was to a) investigate if the monthly frequency of laser strikes varies between calendar months from 2010 to 2021, and b) to identify if there is a trend in annual laser strike reports from 2010 to 2021. The first aim examined whether the monthly frequency of reported laser strikes varies between calendar months from 2010 to 2021. The ANOVA found that the number of reported laser strikes in the United States on aircraft from 2010 to 2021 did not differ between calendar months; thus, the data did not support the hypothesis.

The aim of this study was to identify if there is an annual trend in laser strike reports from 2010 to 2021. The hypothesis was that there would be an increasing trend from 2010 to 2021, which was supported by the linear regression calculated (Figure 2). The linear regression has a positive slope indicating that there are approximately 466 more laser strikes each year. The goodness of fit ($R^2 = 0.72$) indicated that 72% of the variance in strikes is explained by the year.

One limitation of our study was the non-existence of results from October 2021 to December 2021. Therefore, to accommodate for this, the total count for 2021 reported until the end of September was multiplied by 1.33. This estimation was used to represent the total count for 2021. Laser strike reports to the FAA do not include all laser strikes that may be encountered by aircraft because the reporting is voluntary. Some airlines require laser strikes to be reported, while other carriers or general aviation aircraft are not required to submit a report. Those who are not required to report the laser strike may not report a laser incident, which limits the number of reports in the database and variety of report sources. That said, the FAA (2021) database is government maintained and the best available data.

This study examined the difference between the frequency of reported laser strikes on aircraft from 2010 to 2021 based on the month of the year, and the annual trend in total laser strike reports from 2010 to 2021. The data indicated that there is no difference in the frequency of laser strike reports and the calendar month. The linear regression showed an increasing trend for number of laser strike reports from 2010 to 2021. The aviation industry can use the data collected in this study to reinforce that pilots and crew members need to be aware of laser strikes during every flight, regardless of the month the flight is taking place. In addition, the aviation industry should be aware of the increasing trend in annual laser strike reports. Other research may be conducted on protective measures/technology that can be installed in aircraft to mitigate the possible damage by a laser on the crew. From the data analyzed in this study, the aviation industry can conduct future research by collecting and analyzing laser strike report data to identify possible trends in laser strikes' geographical positions or type of source the reports are coming from. Further research is required on laser strikes because lasers pose a significant threat to pilots and passengers, and with the laser strike reports annual trend increasing, proactive measures are a necessity for the aviation industry regarding laser strikes.

6. REFERENCES

[1] Burress Jr., E. W. (2017). Finding the Balance Between Price and Protection: Establishing a Surface-to-Air Fire Risk-Reduction Training Policy for Air-Carrier Pilots. Journal of Aviation / Aerospace Education & Research, 26(2), 81–109. https://doi.org/10.15394/jaaer.2017.1719

[2] Carroll, J., & Richards, D. (2018, June). Shining the light on public attitudes toward laser attacks on aircraft. AIAA AVIATION Forum. https://doi.org/10.2514/6.2018-3512

[3] Cole, W. (2011, Jan 06). Lasers a danger to pilots. Honolulu Star – Advertiser. Retreived from https://www-proquest-com.portal.lib.fit.edu/newspapers/lasers-danger-pilots/docview/822699701/se-2?accountid=27313

[4] Federal Aviation Administration. (2016). Law enforcement guidance for identifying and reporting unauthorized laser illumination incidents against aircraft. U.S. Dept. of Transportation, Federal Aviation Administration.

[5] Federal Aviation Administration. (2021). Laser incidents. Washington, DC: Federal Aviation Administration. Retrieved from https://www.faa.gov/about/initiatives/lasers/laws/

[6] Federal Aviation Administration. (2018). Report a Laser Incident. Washington, DC: Federal Aviation Administration. Retrieved from https://www.faa.gov/aircraft/safety/report/laserinfo/.

[7] Freeman, O. J., & Williamson, C. A. (2020). Visualizing the trade-offs between laser eye protection and laser eye dazzle. Journal of Laser Applications, 32(1), 012008. https://doi.org/10.2351/1.5132601

[8] Harrington, L. K., & Wigle, J. C. (2004). Ocular laser exposure incident reporting. Military Medicine, 169(4), 277-81. https://doi.org/10.7205/MILMED.169.4.277

[9] Murphy, P. (2009, March). Lasers and aviation safety. International Laser Safety Conference. Laser Institute of America. 2009(1), 41-50. doi:10.2351/1.5056720

[10] Nakagawara, V., & Montgomery, R., Dillard, A.E., McLin, L.N., & Connor, C.W. (2004). The effects of laser illumination on operational and visual performance of pilots during final approach. Springfield, VA: Federal Aviation Administration.

[11] Nakagawara, V. B., Montgomery, R. W., & Wood, K. J. (2010). The Illumination of Aircraft at Altitude by Laser Beams: A 5-Year Study Period (2004-2008). Federal Aviation Administration, Office of Aerospace Medicine. DOT/FAA/AM-10/21.

[12] Nontapot K., Rujirat N. (2018) High Accuracy Laser Power Measurement for Laser Pointers Safety Assessment. Springer Series in Optical Sciences, 218. https://doi.org/10.1007/978-3-319-98548-0_4

[13] Reddix, M. D., Funke, M. E., Kinney, M. J., Bradley, J. L., Irvin, G., Rea, E. J., Kunkle, C. K., McCann, M. B., & Gomez, J. (2019). Evaluation of Aircrew Low-Intensity Threat Laser Eye Protection. Military Medicine, 184, 593–603. https://doi.org/10.1093/milmed/usy335

[14] Schmid, D., & Stanton, N. A. (2018). How are laser attacks encountered in commercial aviation? A hazard analysis based on systems theory. Safety Science, 110 (Part A), 178–191.

[15] United States, Federal Aviation Administration, AJV-P. (2019). Advisory Circular 70-1A: Outdoor Laser Operations. U.S Dept. of Transportation, Federal Aviation Administration.