



**Federal Aviation
Administration**

DOT/FAA/AM-11/7
Office of Aerospace Medicine
Washington, DC 20591

Laser Illumination of Flight Crew Personnel by Month, Day of Week, and Time of Day for a 5-Year Study Period: 2004-2008

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April 2011

Final Report

OK-11-0024-JAH

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Technical Report Documentation Page

1. Report No. DOT/FAA/AM-11/7		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Laser Illumination of Flight Crew Personnel by Month, Day of Week, and Time of Day for a 5-Year Study Period: 2004-2008				5. Report Date April 2011	
				6. Performing Organization Code	
7. Author(s) Nakagawara VB, Montgomery RW, Wood KJ				8. Performing Organization Report No.	
9. Performing Organization Name and Address FAA Civil Aerospace Medical Institute P.O. Box 25082 Oklahoma City, OK 73125				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No.	
12. Sponsoring Agency name and Address Office of Aerospace Medicine Federal Aviation Administration 800 Independence Ave, S.W. Washington, DC 20591				13. Type of Report and Period Covered	
				14. Sponsoring Agency Code	
15. Supplemental Notes					
16. Abstract <p>INTRODUCTION: Illumination of civilian and military aircraft by laser beams in the National Airspace System (NAS) has concerned the aviation community for nearly two decades. The principal concern is the affect laser exposure may have on flight crew personnel during landing and departure maneuvers when operational requirements are critical. This study examines the frequency of aviation-related laser event reports by month, day of the week, and time of day.</p> <p>METHODS: Reports of aircraft illuminated by high-intensity light sources have been consolidated from multiple information sources into a database maintained by the Civil Aerospace Medical Institute's Vision Research Team. Laser illumination event data involving civilian aircraft in the United States for a 5-year period (January 1, 2004 to December 31, 2008) were examined for this study.</p> <p>RESULTS: There were a total of 2,492 laser events in the U.S. during the study period. In 1,676 (67.3%) of these, the cockpit environment was illuminated by a laser light. August through December were the most active months with 51% of all reports, while May through July were the least active with only 19% of all reported incidents. Sunday was the most likely day of the week for an aircraft to be illuminated by a laser (15.4%), with a relatively high number of aircraft illuminations occurring on Friday and Saturday. Weekdays exhibited the fewest laser illumination events. Time of day was provided in 2,429 (97.5%) aircraft laser illumination reports. Approximately 69.8% (1,696) of the aircraft illuminations occurred between 7 p.m. (1900 hours) and 11 p.m. (2300 hours) during the study period.</p> <p>CONCLUSIONS: Laser illumination events are most likely to occur from late summer to early winter months and on weekends between 7:00 p.m. and 11:00 p.m. Both weather conditions and daylight savings time may play important roles in determining an opportune time frame for laser activity in a particular locale. Knowledge of these findings may assist the aviation community and law enforcement officials in allocating their limited resources to increase the likelihood of apprehending those responsible for these criminal acts.</p>					
17. Key Words Aviation, Laser, Incidents, Safety			18. Distribution Statement Document is available to the public through the Defense Technical Information Service Center, Ft. Belvoir, VA 22060; and National Technical Information Services, Springfield, VA 22161		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 12	22. Price

CONTENTS

INTRODUCTION	1
METHODS	3
RESULTS	3
DISCUSSION	5
REFERENCES	7

LASER ILLUMINATION OF FLIGHT CREW PERSONNEL BY MONTH, DAY OF WEEK, AND TIME OF DAY FOR A 5-YEAR STUDY PERIOD: 2004-2008

INTRODUCTION

Illumination of civilian and military aircraft by laser beams in the National Airspace System (NAS) has concerned the aviation community for nearly two decades. The principal concern is the affect laser exposure may have on flight crew personnel during landing and departure maneuvers when operational requirements are critical. Federal Aviation Regulations require a sterile cockpit (i.e., only operationally relevant communication) below 10,000 feet to minimize distractions and reduce the potential for flight procedure errors (1). During the final approach phase, the pilot should be able to visually identify the runway threshold or a go-around (missed approach) must be performed (2,3).

Prior to 1995, laser operators were allowed to project laser beams into navigable airspace as long as they did not exceed the limit imposed by Federal Aviation Administration (FAA) Order 7400.2. Guidance material used to establish this FAA Order included the Food & Drug Administration's "Performance Standards for Light-Emitting Products" (4). This standard is based on the Maximum Permissible Exposure (MPE) of 2.54 milliwatts per centimeter square (mW/cm^2), above which ocular tissue damage may occur from exposure

durations longer than 0.25 second. The recommended MPE limit, originally developed by the American National Standards Institute, is used to calculate the nominal ocular hazard distance, which varies depending on the laser's output power, wavelength, pulse duration, and beam divergence (5).

In 1995, FAA Order 7400.2 was revised to establish lower laser exposure limits to protect flight crewmembers from adverse effects in specific zones of airspace around airports. These adverse effects include annoyance, momentary distraction, and visual effects (6) such as:

- Glare – Obscuration of an object in a person's field of vision due to a bright light source located near the same line of sight (e.g., as experienced with oncoming headlights).
- Flashblindness – A temporary visual interference effect that persists after the source of illumination has ceased.
- Afterimage – A reverse contrast shadow image left in the visual field after an exposure to a bright light that may be distracting and disruptive, and it may persist for several minutes.

The zones of protected airspace around airports are known as flight hazard zones (see Figures 1 and 2). These zones are intended to mitigate the hazardous affect of

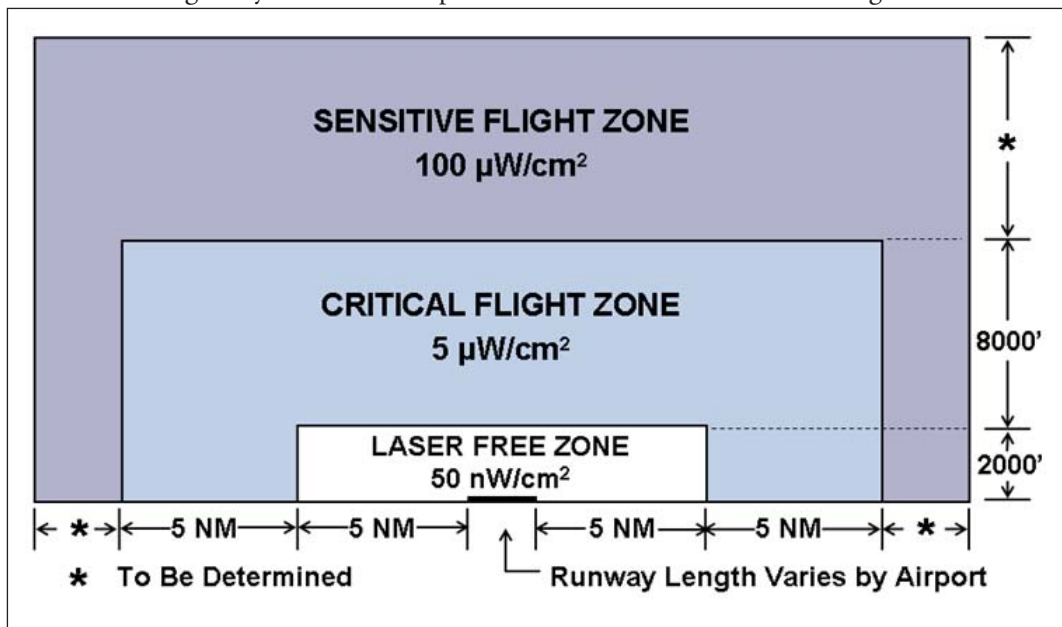


Figure 1: A profile view of the flight hazard zones around a single-runway airport. The LFZ extends 5 nautical miles (NM) beyond the runway ends and up to 2,000 feet above ground level (AGL). The CFZ includes airspace surrounding the LFZ, out to 10 NM and up to 10,000 feet AGL.

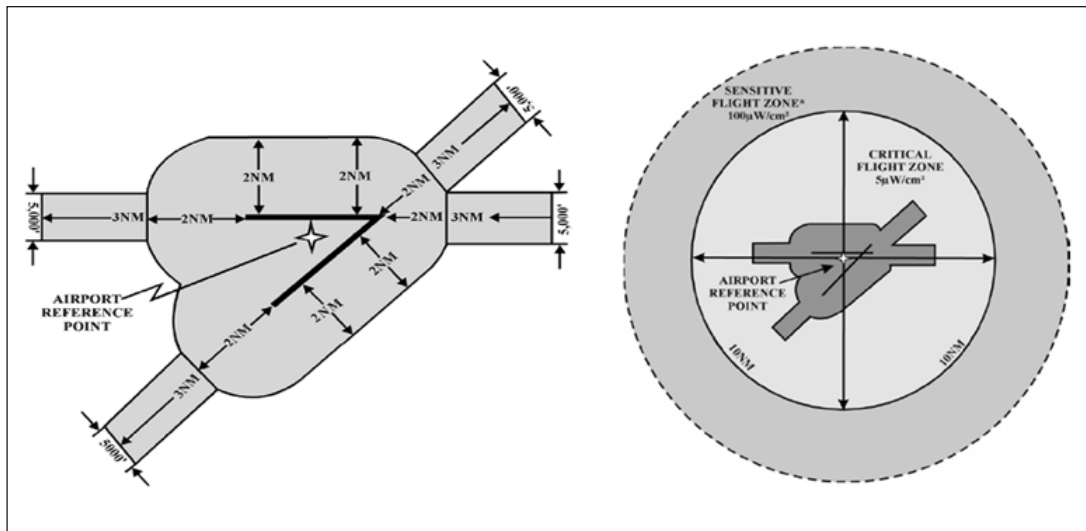


Figure 2: Aerial view of the flight hazard zones for a two-runway airport. LFZ (left) extends 2 NM in all directions from the runway centerline. It includes an additional 3-NM extension along the runway centerline. CFZ (right) includes all airspace surrounding the LFZ within a 10-NM radius of the airport reference point.

visible laser radiation by limiting the allowable laser irradiance permitted in that airspace. The Normal Flight Zone (NFZ) encompasses all navigable airspace not included within the newly established zones. The Sensitive Flight Zone (SFZ) may be assigned to any airspace outside the Critical Flight Zone (CFZ) and Laser Free Flight Zone (LFZ) at the discretion of the local air traffic authorities. Exposure levels are not to exceed the following effective irradiance levels within the corresponding flight hazard zones:

- LFZ = 50 nanowatt per square centimeter (nW/cm²);
- CFZ = 5 microwatt per square centimeter (μW/cm²);
- SFZ = 100 μW/cm²;
- NFZ = 2.54 mW/cm².

A substantial decrease in the number of reported laser illumination events originating from authorized outdoor laser demonstrations was observed in the years following this revision of FAA Order 7400.2 (7).

During the fall/winter of 2004 and January of 2005, there was a marked increase in reported laser incidents (7), the majority of which appeared to be random acts by individuals using handheld laser devices. In response to this increase in laser events, the Secretary of Transportation, Norman Mineta, held a press conference at the FAA's Civil Aerospace Medical Institute (CAMI) in Oklahoma City, Oklahoma (see Figure 3) to announce the publication of an FAA Advisory Circular (AC 70-2), entitled "Reporting of Laser Illumination of Aircraft" (8). The AC includes a "Laser Beam Exposure Questionnaire" to be filled out by the exposed aircrew member(s) to provide additional data to better define the nature of the threat and its affect on civil aviation operations. These laser

event reports provide a means to monitor and recognize patterns or similarities that could aid in the prevention or mitigation of this threat to aviation safety. It was also intended to improve coordination with local and federal law enforcement agencies to aid in the apprehension and prosecution of responsible individuals.

A database of laser exposure event reports has been maintained by CAMI's Vision Research Team, including information collected from AC 70-2 reports. Analysis of laser events provides a means to determine if current FAA safety policies are adequate to protect aviators and the flying public. In addition, continued monitoring of such events can help determine whether advances in laser technology and their outdoor applications may adversely affect aviation safety.

Since local police, airport security, and regulatory safety resources are limited, this study examines the trends in aircraft illumination events to determine if



Figure 3: Issuance of AC No. 70-2 announced by the Secretary of Transportation, Norman Mineta, at CAMI on January 12, 2005.

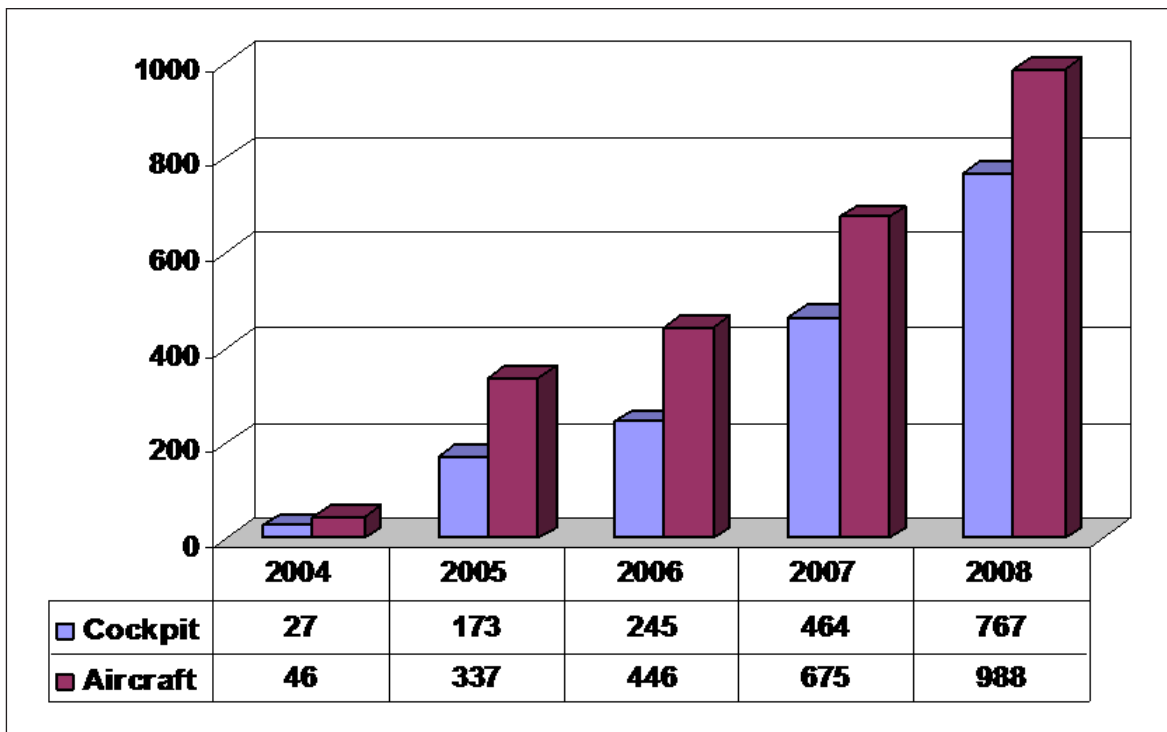


Figure 4: Frequency of aircraft and cockpit illumination events by year.

these finite resources can be more judiciously applied to maximize their effectiveness. The present study examines the frequency of laser illumination events by month, day of the week, and time of day for a 5-year period (2004 - 2008).

METHODS

Reports of high-intensity light illuminations of civilian and military aircraft are gathered from various sources including: Washington Operations Control Center, FAA regional offices, Transportation Security Administration, joint Department of Homeland Security/Federal Bureau Investigation information bulletins, the FAA's Office of Accident Investigation, newspaper and internet-based articles, and illuminated crewmember interviews. Details from these reports are entered into a computer database maintained by the Vision Research Team.

Laser event data from reports of illuminations involving civilian aircraft in the United States for a 5-year period (January 1, 2004 to December 31, 2008) were examined for this study. These data were collated and analyzed to determine the event frequency by the time of day, day of week, and month in which they occurred during the study period.

RESULTS

A total of 2,492 reported laser illumination events were identified for the 5-year study period. Of these, 1,676 (67.3%) involved cockpit illuminations (see Figure 4).

All aircraft and cockpit illuminations by the month in which the events occurred are summarized in Figure 5. August through December were the most active months during the 5-year study period with 51% of all reports, while the months of May through July were the least active with only 19% of all reported incidents.

Laser events by day of the week are summarized in Figure 6. For the study period, more laser illumination events occurred on Sunday than on any other day of the week. A relatively high number of aircraft illuminations occurred on Friday and Saturday, while the weekdays (Monday through Thursday) exhibited fewer laser illumination events.

All laser events by time of day are summarized in Figure 7. Time of day was provided in 2,429 (97.5%) aircraft laser illumination reports. Approximately 69.8% (1,696) of the aircraft illuminations occurred between 7 p.m. (1900 hours) and 11 p.m. (2300 hours) during the study period.

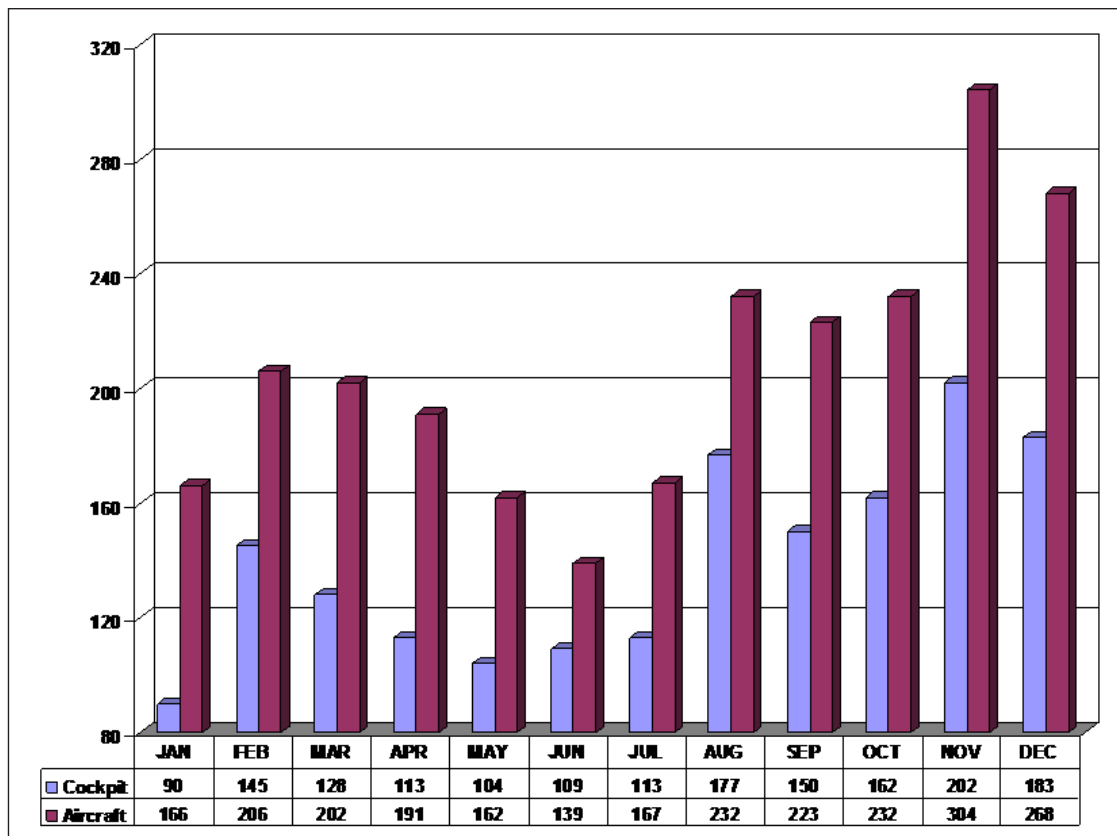


Figure 5: Frequency of aircraft and cockpit illumination events by month.

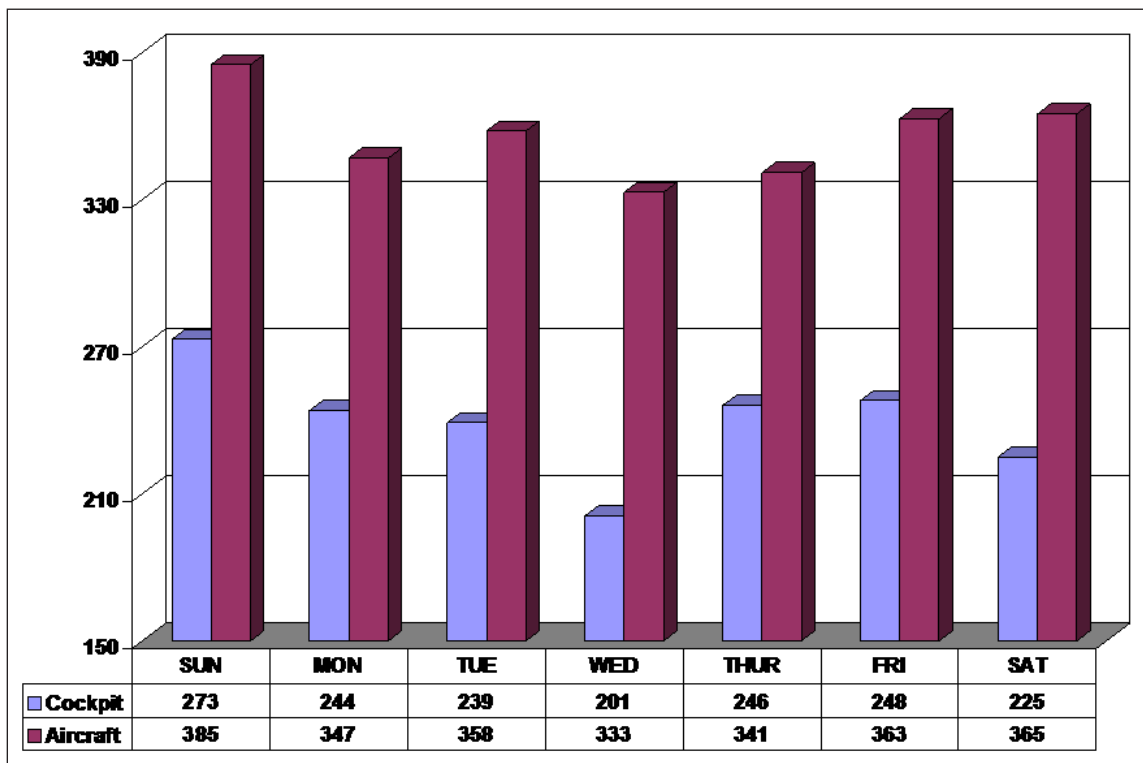


Figure 6: Frequency of aircraft and cockpit illumination events by day of the week.

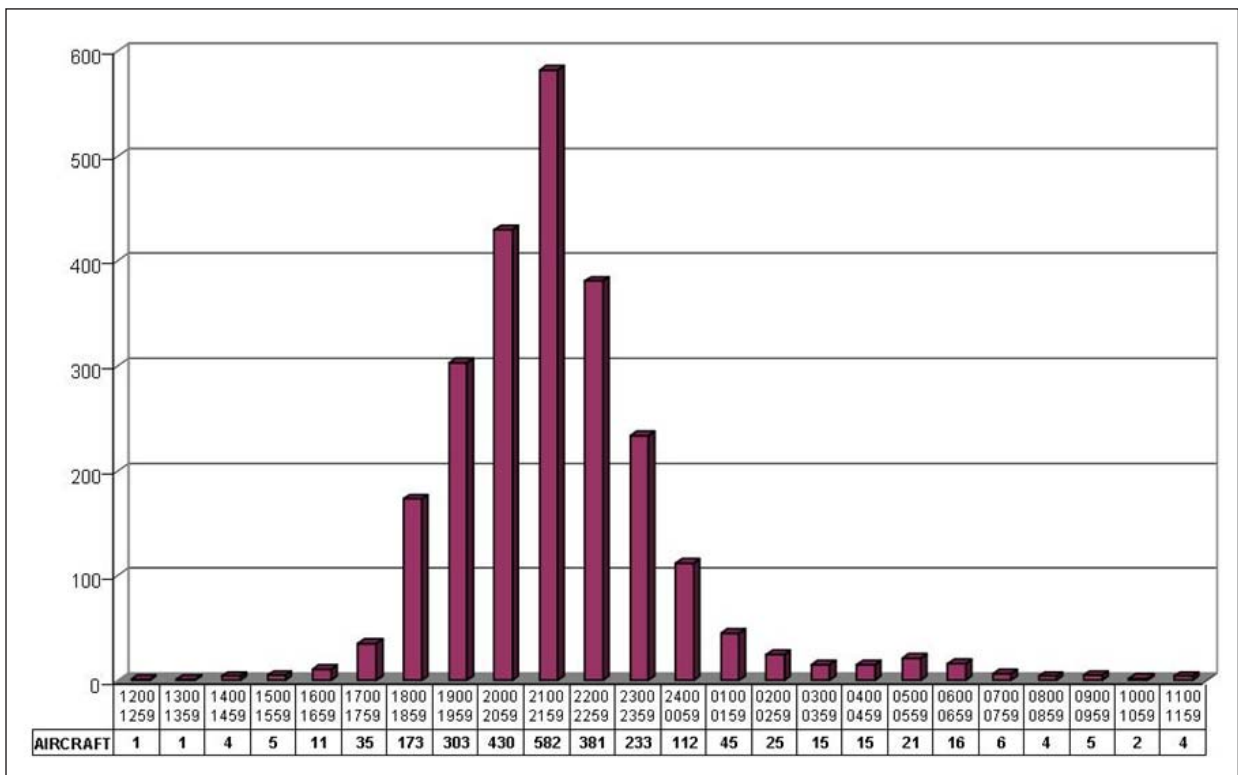


Figure 7: Frequency of aircraft laser illumination events by time of day for the period.

DISCUSSION

Reported illuminations of aircraft by laser light have increased substantially during the study period, with an overall 21.5-fold increase (46 to 988) from 2004 to 2008. The implementation of a formal reporting process (AC 70-2) has heightened awareness of these acts and increased the probability that laser events are reported. Understandably, reporting was less common before a standardized method was established to provide details regarding such events. Prior to issuance of AC 70-2, pilots and air traffic controllers were unclear on how or what to report and where the data should be sent for collection and review.

The popularity and availability of high-powered, handheld laser devices may also be responsible, in part, for the increasing frequency of aircraft illumination reports. Once only marketed as “laser pointers,” with power output of less than 5 mW, handheld laser devices can now be purchased from internet retailers with power output as high as 500 mW (9). Laser devices that produce radiation levels of 100 mW or more are still relatively expensive (e.g., \$100 – \$3,000); however, those that emit radiation levels from 5 mW to 100 mW are affordable for most laser enthusiasts (e.g., \$10 – \$100) (10). FDA regulations prohibit the sale of handheld laser devices promoted as “laser pointers” that exceed 5 mW in power output (11).

Handheld laser devices exceeding 5 mW are considered legal when properly classified, equipped with appropriate warning labels, key switches and/or safety interlocks, and are not advertised as “laser pointers” (see Figure 8) (5).

A recent report indicates that aircraft illuminations are primarily from green lasers (88%), as opposed to red lasers (5%), which were more common in the years preceding the study period (12). A green laser beam can appear as much as 28 times brighter than an equivalently powered 670-nanometer (nm) red laser beam (13). The inherent sensitivity of photoreceptors in the eye (i.e., peak sensitivity of 555 nm) is responsible for this disproportionate brightness (see Figure 9) (14). The wavelength of most green lasers (532 nm) is near to the peak sensitivity of a pilot’s eyes at night when partially dark-adapted in a cockpit environment. Due to this heightened visibility and the increased likelihood of adverse visual effects, illumination by green lasers may result in more events being reported by flight crews. Additionally, green laser beams may be more visible to the perpetrator, making it easier to focus on the targeted aircraft. Continued monitoring of laser illumination events will help to validate these assumptions.

The physical environment where these illumination events occurred, along with human behavioral tendencies, should be considered when interpreting the results of this study. Low-light levels are necessary to determine whether a laser beam hits its target or not. This study found that



Figure 8: Examples of high-powered, handheld laser devices available via Internet retailers.

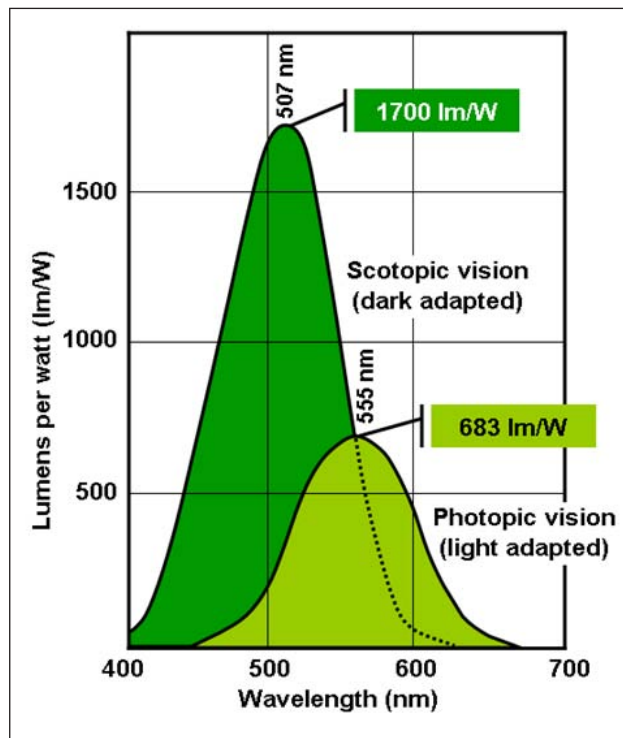


Figure 9: The relative sensitivity of the eye to visible wavelengths.

laser illumination events occur most frequently from late summer through early winter, as the days grow shorter and the sun sets earlier in the evening. This time of year often provides comfortable temperatures for people to be outdoors during the evening hours. During the long, hot days and short nights of summer, the number of laser illuminations decline to their lowest level when the extended hours of daylight prevent accurate targeting of aircraft in-flight until much later at night. The number of laser events also diminishes as the cold, wet weather of late winter and spring advances, making conditions less comfortable for outdoor activities. Laser illumination events are also more likely to occur during the weekends. Many of those responsible for these acts may have school or work schedules that make them less likely to engage in such reckless behavior during the week. Aircraft are most often illuminated between 7 and 11 p.m. in the evening. Early-morning illuminations are inconvenient for laser perpetrators due to sleep schedules and because most major commercial air carriers reduce the number of scheduled flights around midnight, which limits the number of available targets for illumination. These results, and the fact that the Western Pacific Region experiences a disproportionate number of laser illumination events compared to other FAA Regions (15), suggest that both weather conditions and daylight saving time may play important roles in determining an opportune time frame for laser activity in a particular locale.

During the study period, there were more than 60 arrests made of individuals illuminating aircraft in the U.S. documented in CAMI's laser event database. Of the laser events that provided altitude information ($n = 33$), arrests were more likely ($n = 22$, or 67%) when the incident occurred at lower altitudes, i.e., below 5,000 ft (12). This finding is logical since the location of the laser source would be more easily pinpointed by flight crewmembers when the illumination occurs at lower altitudes. Additionally, some events included multiple illuminations of different aircraft over a period of days or even months before the source location could be identified and an arrest made. In other instances, the suspect's location was revealed when a single aircraft was tracked and struck repeatedly, leading to an arrest.

In summary, this study found that laser illumination events are most likely to occur from late summer to early winter months and on weekends between 7:00 p.m. and 11:00 p.m. Timely reporting of laser illumination events by flight crews and optimal coordination between local air traffic and law enforcement authorities are essential to ensure apprehension of those responsible for these acts. Since a laser perpetrator often repeatedly illuminates multiple aircraft during the course of an evening or over several evenings from the same location, a coordinated response

by local authorities to initial reports should increase the probability of an arrest. These study findings may assist the aviation community and law enforcement officials in allocating their limited resources to increase the likelihood of apprehending those responsible for these crimes. Continued monitoring of laser events is recommended to identify patterns of misuse and the implementation of new outdoor laser technologies that may warrant changes in safety policy or mitigation procedures that could reduce the hazards associated with laser illumination of aircraft in navigable airspace.

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