RESEARCH ARTICLE

Laser Illumination of Flight Crewmembers by Altitude and Chronology of Occurrence

Van B. Nakagawara, Ronald W. Montgomery, and Kathryn J. Wood

Nakagawara VB, Montgomery RW, Wood KJ. ***Laser illumination of flight crewmembers by altitude and chronology of occurrence.*** **Aviat Space Environ Med 2011; 82:1055–60.**

Introduction: The illumination of flight crew personnel by lasers while they perform landing and departure maneuvers has concerned the aviation community for the past two decades. This study examines the frequency of illumination events in the United States by altitude and chronology of occurrence to determine where and when aviators and the flying public may be at greatest risk. ***Methods:*** Reports of aircraft illuminated by high-intensity light sources are maintained in a database at the Federal Aviation Administration's Civil Aerospace Medical Institute. Reports of flight crewmembers exposed to lasers from January 1, 2004, to December 31, 2008, were collected and analyzed. ***Results:*** Cockpit illuminations at or below 2000 ft (~610 m) increased from 12.5 to 26.7% over the 5-yr period, while the percentage of illuminations between 2000 and 10,000 ft (~610–3048 m) decreased from 87.5 to 58.4%. The months of November and December had the highest frequency of laser events (23%), while May and June had the least (12%). Sunday was the most likely day for an aircraft to be illuminated (18.3%), while Wednesday was the least likely day for such an incident (15.4%). More than 91% of all aircraft illumination events occurred between 1800 and midnight. ***Conclusion:*** The continuing increase in the number of laser illuminations reported at or below 2000 ft (~610 m) represents an escalating threat to aviation safety. Information provided in this study may allow law enforcement to deploy their resources more efficiently to apprehend those responsible for these crimes.

Keywords: visible radiation, exposure, visual impairment, time, hazard zone, height.

THE AVIATION COMMUNITY has been concerned about the risk from the illumination of civilian and military aircraft by laser beams in the National Airspace System for nearly two decades. The principal concern is the effect laser exposure may have on flight crew personnel during landing and departure maneuvers when operational requirements are most critical. Federal Aviation Regulations require a sterile cockpit (i.e., only operationally relevant communication) below 10,000 ft (3048 m) to minimize distractions and reduce the potential for procedural errors (17). 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 (13,14).

Prior to 1995, laser operators were allowed to project laser beams into navigable airspace as long as irradiance levels 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" (15). This standard is based on the maximum permissible exposure of 2.54 $mW \cdot cm^{-2}$, above which ocular tissue damage may occur from exposure durations longer than 0.25 s for continuous-wave lasers. The recommended maximum permissible exposure 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, mode of operation (continuous or pulsed), exposure duration, and beam divergence (4).

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 (11) such as the following:

- 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 may persist for several minutes.

The zones of protected airspace around airports are known as flight hazard zones (**Fig. 1**). These zones are intended to mitigate the hazardous effect of 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 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:

From the Civil Aerospace Medical Institute, Federal Aviation Administration, Oklahoma City, OK.

This manuscript was received for review in June 2011. It was accepted for publication in August 2011.

Address correspondence and reprint requests to: Van B. Nakagawara, O.D., FAA-CAMI, Vision Research Team, AAM-610, P.O. Box 25082, Oklahoma City, OK 73125; van.nakagawara@faa.gov.

DOI: 10.3357/ASEM.3124.2011

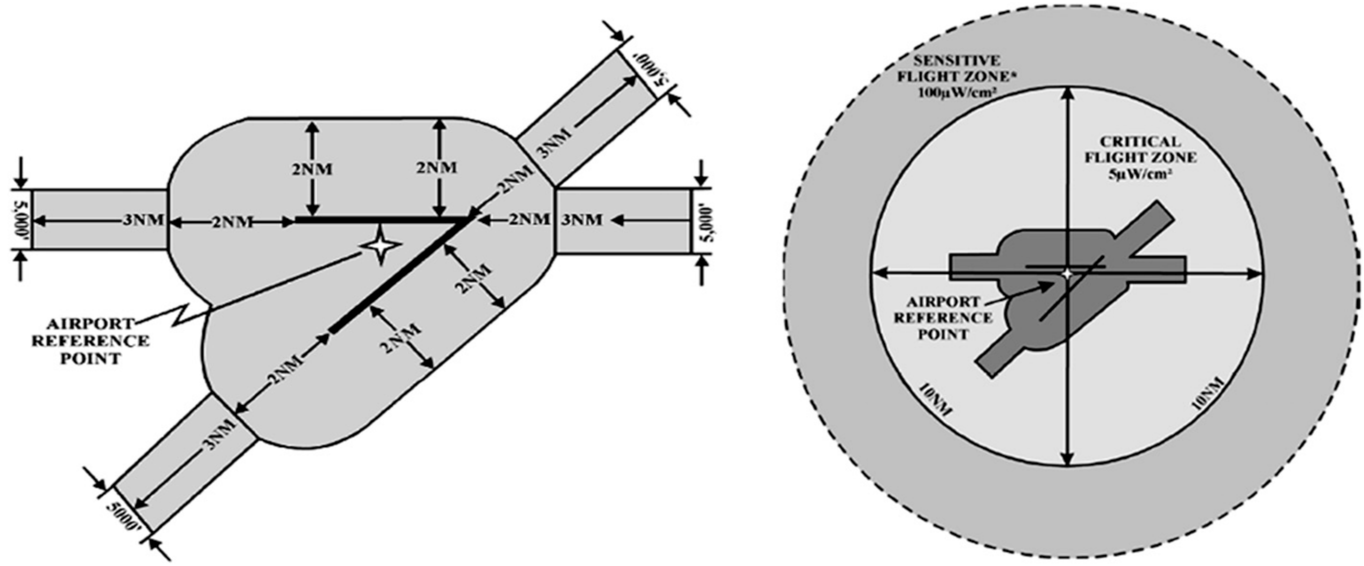


Fig. 1. Aerial view of the flight hazard zones for a two-runway airport. LFZ (left) extends 2 NM in all directions from the runway centerline, 5 NM beyond the runway ends, and up to 2000 ft (~610 m) above ground level (AGL). The CFZ (right) includes all airspace surrounding the LFZ within a 10-NM radius of the airport reference point and up to 10,000 ft (3048 m) AGL.

- LFZ = 50 nW · cm^{-2};
- CFZ = 5 μW · cm^{-2};
- SFZ = 100 μW · cm^{-2};
- NFZ = 2.54 mW · cm^{-2}.

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 (10,11). Unfortunately, during the fall/winter of 2004 and January of 2005, there was a marked increase in reported laser incidents. The majority of these appeared to be random acts by individuals using handheld laser devices (10). In response to this increase in laser events, then-Secretary of Transportation Norman Mineta announced the publication of an FAA Advisory Circular (AC 70-2), entitled "Reporting of Laser Illumination of Aircraft," in a press conference at the FAA's Civil Aerospace Medical Institute (CAMI) in Oklahoma City, OK (16). This Advisory Circular (AC) has become the official reporting mechanism for laser events in the National Airspace System. The AC includes a "Laser Beam Exposure Questionnaire" that exposed aircrew members can fill out to describe the event and its effect on individuals and aviation operations. These event reports also provide a means to identify patterns or similarities that could aid in prevention and mitigation of any adverse effects on flight crew personnel and aviation safety. In addition, the AC directed the local air traffic authority to improve coordination with local and federal law enforcement agencies to aid in the apprehension and prosecution of individuals responsible for these acts.

A database of laser event reports has been maintained by CAMI's Vision Research Team that includes information collected from AC 70-2 reports and other sources. Analysis of laser events provides a means to determine if current FAA safety policies are adequate to protect aviators and the flying public. Additionally, the study of these events will help identify how the application of advanced laser technologies may adversely affect aviation safety. Furthermore, examination of trends in aircraft illumination events may help determine how the resources of local police, airport security, and federal law enforcement can be judiciously applied to maximize their effectiveness. The present study examines the frequency of laser illumination events by altitude and chronology of occurrence (month, day of week, and time of day) for a 5-yr period.

METHODS

The Vision Research Team has gathered reports of high-intensity light illuminations of civilian and military aircraft from various sources for more than a decade. These sources include: 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 crewmember interviews. Data from these reports are entered into a computer database. Data from reports of illumination events involving civilian aircraft in the United States for the 5-yr period from January 1, 2004, to December 31, 2008, were collected for this study. These data were collated and analyzed to determine the frequency by altitude and the chronology (month, day of the week, and time of day) of laser events during the study period.

RESULTS

Of the 2492 illumination events that took place within the United States (i.e., 49 states plus the District of Columbia) from January 1, 2004, to December 31, 2008, the cockpit environment was illuminated by a laser beam on 1676 (67.3%) occasions. Altitude information was provided in 1361 (81.2%) of the 1676 event reports in which the cockpit was illuminated during the 5-yr period (**Table I**). Reports included 325 (23.9%) cockpit illuminations that occurred within the LFZ (≤2000 ft/~610 m), while the majority of these events, 848 (62.3%), occurred within the altitude limits defined by the CFZ (>2000 ft/~610 m to ≤10,000 ft/3048 m). Relatively few laser exposures (188 reports, or 13.8%) were reported above 10,000 ft (3048 m).

Adverse effects included reports of annoyance/distraction, visual effects, operational problems, and pain/injury (**Table II**). One or more adverse effects were noted in 145 (11%) of the 1361 reported cockpit illuminations when altitude was known, while another 39 reports provided no altitude data. Of the 145 laser exposures, the majority (126 or 87%) occurred at 10,000 ft (3048 m) AGL or less (within the equivalent LFZ and CFZ). Few adverse effects occurred above 10,000 ft (3048 m) (19 reports or 13%).

Aircraft and cockpit illumination events are categorized by the month in which the events occurred, as shown in **Fig. 2**. August through December were the most active months during the 5-yr study period with 51% (1271) of all reports, while May through July were the least active with only 19% (473) of the reported incidents. Analysis of variance (ANOVA) found statistically significant variation in the frequency of aircraft illuminations reported by month (df = 11, F = 6.59, $P < 0.001$).

Laser events are summarized by day of the week in **Fig. 3**. 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 slightly fewer laser illumination events. ANOVA found no significant variation in frequency of reports by day of the week (df = 6, F = 0.514, $P > 0.05$).

All laser events for the study period arranged by time of day are presented in **Fig. 4**. Time of day was provided in 2429 (97.5%) aircraft laser illumination reports. Approximately 79.4% (1929) of the aircraft illuminations occurred between 1900 and 2300 during the study period.

TABLE I. FREQUENCY OF COCKPIT ILLUMINATIONS BY ALTITUDE AND YEAR.

Altitude (ft)	2004	2005	2006	2007	2008	Total
0–1000	1	7	12	40	66	126
1001–2000	1	13	36	51	98	199
LFZ	2	20	48	91	164	325
2001–3000	5	18	31	72	91	217
3001–4000	2	18	24	35	53	132
4001–5000	1	12	27	30	43	113
5001–6000	1	20	24	29	53	127
6001–7000	0	8	19	22	35	84
7001–8000	2	8	13	15	33	71
8001–9000	1	7	7	11	17	43
9001–10,000	2	5	11	9	34	61
CFZ	14	96	156	223	359	848
NFZ (>10,000)	0	32	20	44	92	188
Total Cockpit Illuminations	16	148	224	358	615	1361

LFZ = laser-free flight zone; CFZ = critical flight zone; NFZ = normal flight zone.

DISCUSSION

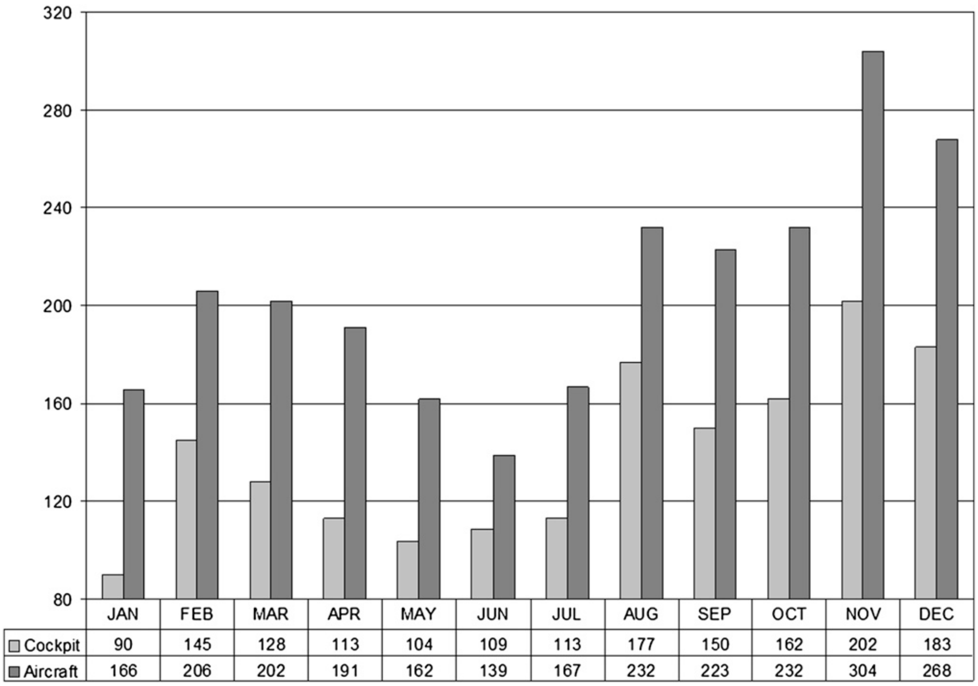
Reported illuminations of aircraft by laser light have increased substantially. This study found a 37-fold increase in the number of cockpit illuminations reported (16 to 615 events) during the 5-yr study period. Understandably, in the years prior to issuance of AC 70-2, reporting of laser events was sporadic. Pilots and air traffic controllers were uncertain how or what to report and where the data should be sent. The implementation of a formal reporting procedure has heightened awareness of these acts and increased the probability that aircraft illuminations are reported. The continuing increase in the number of reports may suggest that the process is still gaining acceptance and that inappropriate outdoor laser activity remains a serious threat.

The growing popularity and availability of high-powered, handheld laser devices has likely contributed to the increasing frequency of aircraft illumination reports. Lasers with output powers between 1 and 5 mW were once only marketed to the public as "laser pointers." Handheld laser devices are now available from internet retailers with power output as high as 1000 mW (1 W) for only a few hundred dollars (5,12). Laser devices

TABLE II. SUMMARY OF VISUAL EFFECTS, OPERATIONAL AND PHYSIOLOGICAL PROBLEMS BY ALTITUDE.

		Visual Effects								
Altitude (ft)	Annoy/ Distract	Glare	Flash Blindness	Afterimage	Oper. Prob.	Pain/ Injury	LFZ	CFZ	NFZ	Total Effects
0–1000	5	1	8	4	7	1	24	-	-	24
1001–2000	15	5	9	6	10	4	29	-	-	29
2001–3000	7	3	9	3	10	3	-	22	-	22
3001–4000	10	3	4	1	6	0	-	17	-	17
4001–5000	3	1	0	0	0	1	-	3	-	3
5001–6000	4	2	0	0	2	1	-	7	-	7
6001–7000	2	0	1	1	0	2	-	5	-	5
7001–8000	3	2	2	1	2	3	-	10	-	10
8001–9000	2	2	0	1	2	2	-	6	-	6
9001–10,000	2	1	0	0	1	0	-	3	-	3
>10,000	11	6	5	3	4	3	-	-	19	19
No Alt. Data	4	0	10	2	8	10	-	-	-	39
Total	68	26	48	22	52	30	53	73	19	184

LFZ = laser free zone; CFZ = critical flight zone; NFZ = normal flight zone.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Cockpit	90	145	128	113	104	109	113	177	150	162	202	183
Aircraft	166	206	202	191	162	139	167	232	223	232	304	268

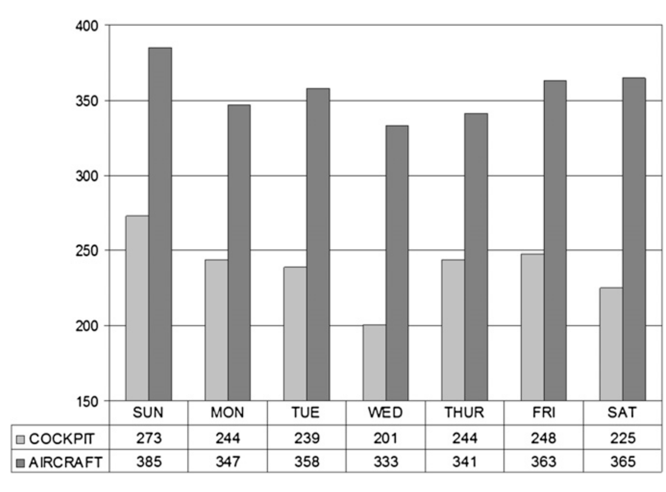
Fig. 2. Frequency of aircraft and cockpit illumination events by month.

that produce radiation levels of a few hundred milliwatts are even more inexpensive (e.g., \$50–100) and those that emit radiation levels from 5 mW to 100 mW are affordable to even the most pedestrian of laser enthusiasts (e.g., \$50 or less) (18). The Food & Drug Administration considers handheld laser devices with output that exceeds 5 mW to be legal when they are not marketed to the public as "laser pointers." These lasers must also be properly classified and equipped with appropriate warning labels, key switches, and/or safety interlocks (4).

Reports indicate that aircraft illuminations are primarily from green lasers (88%) as opposed to red lasers (5%), which were more common a few years ago (9). A green laser beam can appear as much as 28 times brighter than an equivalently powered 670-nm red laser beam due to the inherent sensitivity of photoreceptors in the eye to green light (19,20). The wavelength of most green lasers (532 nm) is near to the peak sensitivity of a pilot's eyes at night, especially when partially dark-adapted in a cockpit environment. The heightened visibility of green lasers even at great distances and the increased probability of adverse visual effects is undoubtedly responsible for many incident reports by flight crewmembers. This and their increased popularity explains why green laser beams were reported 8.8 times more often than other colors in airspace equivalent to that of the LFZ, 12.7 times more in the CFZ, and 19.4 times more in the NFZ above 10,000 ft (3048 m) (9).

Approximately 86.2% (1173) of the laser events were reportedly at or below the 10,000-ft (3048-m) limit of the CFZ during the study period and only 13.8% (188) reached altitudes above 10,000 ft (3048 m). About 23.9% (325) of the events reported were within the altitude limit designated for the LFZ ($\leq$2000 ft/$\sim$610 m). In this altitude range, the percentage of cockpit illuminations per year more than doubled (from 12.5 to 26.7%) during the study period. Laser illuminations that occur at lower altitudes are of great concern since they have been shown to be significantly more disruptive to visual and operational performance than exposures of equal intensity that occur at higher altitudes (6,7). Low-flying helicopters and aircraft on approach maneuvers are also vulnerable due to their close proximity to obstacles and terrain.

Although the data in this study were categorized into equivalent flight hazard zones for analysis purposes, numerous aircraft illuminations occurred when the aircraft were outside one of these zones. These incidents



	SUN	MON	TUE	WED	THUR	FRI	SAT
COCKPIT	273	244	239	201	244	248	225
AIRCRAFT	385	347	358	333	341	363	365

Fig. 3. Frequency of aircraft and cockpit illumination events by day of the week.

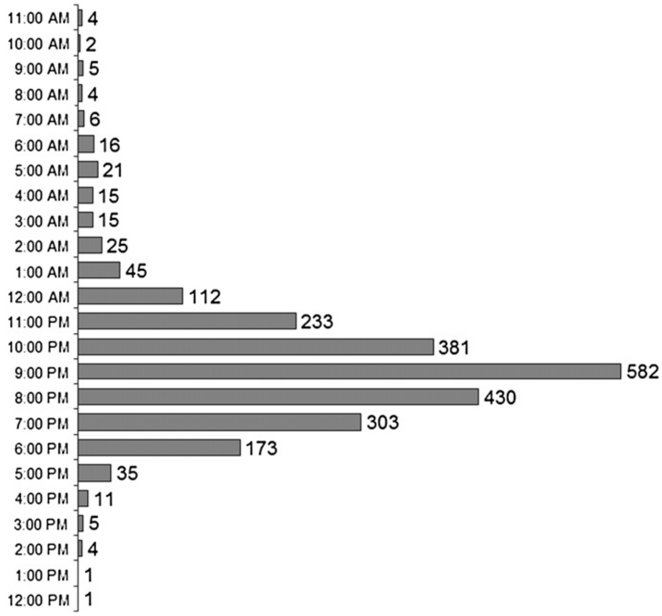


Fig. 4. Frequency of aircraft laser illumination events by time of day for the period.

primarily involved law enforcement and medical evacuation helicopters that were often enroute to (or from) crime scenes or medical facilities at the time of the incident and accounted for approximately 7% (152) of all aircraft illuminations (9). The flight crews in these aircraft are susceptible to visual impairment from laser illuminations due to their low-altitude flight profile and the large, wrap-around bubble canopies on helicopters that can allow more light to enter and scatter throughout the cockpit. Furthermore, these aircraft frequently have a single pilot, which adds to the danger of sudden incapacitation from a laser strike. Based on these findings, specific safety guidelines should be considered to protect all aircraft that fly at or below 2000 ft (~610 m) AGL regardless of their proximity to the nearest airport.

Commercial carriers were involved in more than 73% (1693) of all aircraft illumination events. General aviation accounted for less than 18% (411) (9). However, general aviation pilots may be at greater risk since they rarely fly with a copilot and would have fewer options—including relinquishing control of the aircraft—should temporary disorientation or visual impairment result from the illumination. Surprisingly, the adverse effects reported by flight crewmembers (184) in 145 events represented only 11% of the cockpit illuminations (1361) for the study period. This seems low based on the results of a previous simulator study where adverse visual effects were reported in 60% of all exposure trials (6,7). The disparity may be due to the alignment of the simulator's exposure stimulus near the pilot's axis of vision through the windscreen. Reports indicate that the beam's incident angle is more often from one side rather than aligned with the direction of flight. Additionally, the irradiance level in one-third of the simulator trials was at the upper limit of what might be experienced in most real-world scenario (50 $\mu W \cdot cm^{-2}$). It seems unlikely, however, that all details concerning visual and operational effects are being reported accurately.

This study found that laser illumination events occur more frequently in 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 evening temperatures. During the long, hot days and short nights of summer, the number of laser illuminations declines to its lowest level. The extended hours of daylight prevent accurate targeting of aircraft until much later at night. The number of laser events also diminishes as the cold, wet weather of late winter and early spring advances, making conditions less comfortable for outdoor activities.

The data suggest that laser illumination events may be more likely to occur on weekends. Many of those perpetrating these acts may have school or work schedules that make them less likely to engage in this reckless behavior during the week. Aircraft are most often illuminated between 1900 and 2300. 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 (8) suggest that both weather conditions and daylight saving time may play an important role in determining an opportune time frame for laser activity in a particular locale.

Recommendations to minimize the effects of laser illumination were developed based on the analysis of reports by flight crewmembers that have experienced laser exposures and in collaboration with international regulatory agencies (1–3). These include the following:

- Anticipate: when operating in a known or suspected laser environment (the non-flying pilot should be prepared to take control of the aircraft);
- Aviate: engage the autopilot, check the aircraft's configuration, and reestablish a normal flight profile, if necessary;
- Navigate: use the body of the aircraft to block the light by climbing or turning 90° to the beam, if practical;
- Communicate: inform local air traffic control of the situation, including location/direction of beam, present location, altitude, etc. Once on the ground, complete a "Laser Beam Exposure Questionnaire" (AC 70-2);
- Illuminate: turn up the cockpit lights to constrict the pupils and minimize further illumination effects;
- Delegate: if one crewmember has avoided exposure, consider handing over control to the unexposed crewmember;
- Attenuate: shield your eyes when possible (e.g., hand, clipboard, glare shield). Do not look directly at the laser beam and avoid drawing the attention of other crewmembers to the beam;
- Do not exacerbate: avoid rubbing the eyes as this may result in irritation to the cornea and conjunctiva of the eye; and
- Evaluate: if visual symptoms persist, consult an eye doctor.

In summary, results of this study show that reporting of laser events has improved dramatically since issuance of AC 70-2. During the 5-yr study period there has been a 37-fold increase in cockpit laser illumination reports. The frequency of laser events reported in the LFZ more than doubled (12.5 to 26.7%), while those in the

CFZ decreased by 29% (87.5 to 58.4%). Chronologically, the study found that laser illumination events are most likely to occur from late summer to early winter months and on weekends between 1900 and 2300. Timely reporting of laser illumination events by flight crews and optimal coordination between local air traffic and law enforcement authorities are essential. 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.

ACKNOWLEDGMENTS

The opinions expressed in this article are the views of the authors and do not necessarily represent the official position of the Department of Transportation or the Federal Aviation Administration.

Authors and affiliation: Van B. Nakagawara, O.D., Ronald W. Montgomery, B.S., and Kathryn J. Wood, CPOT, Civil Aerospace Medical Institute, Federal Aviation Administration, Oklahoma City, OK.

REFERENCES

1. CAP 736. Operation of directed light, fireworks, toy balloons and sky lanterns within UK airspace. London, UK: Directorate of Airspace Policy, Civil Aviation Authority; 2011. Retrieved 20 April 2011 from http://www.caa.co.uk/docs/33/CAP736.PDF.
2. EUROCONTROL Safety Regulation Commission (SRC). Outdoor laser operations in the navigable airspace. Safety Regulation Commission Document - SRC DOC 7. Retrieved 20 April 2011 from http://www.eurocontrol.int/src/gallery/content/public/documents/deliverables/srcdoc7ri.pdf.
3. ICAO manual on laser emitters and flight safety. DOC 9815, Ed 1, 2003. Retrieved 20 April 2011 from http://store1.icao.int/documentItemView.ch2?ID=9425.
4. Laser Institute of America. American national standard for safe use of lasers. Washington, DC: American National Standards Institute; 2007. Report No. ANSI Z136.1-2007.
5. Laserglow Technologies. LaserGlow handheld lasers. Retrieved 15 April 2011 from http://www.laserglow.com/int-handheld.htm.
6. Nakagawara VB, Montgomery RW, Dillard A, McLin L, Connor CW. The effects of laser illumination on operational and visual performance of pilots during final approach. Washington, DC: Department of Transportation/Federal Aviation Administration, Office of Aerospace Medicine; 2004. Report No. DOT/FAA/AM-04/9. Retrieved 8 August 2011 from http://www.faa.gov/library/reports/medical/oamtechreports/.
7. Nakagawara VB, Montgomery RW, Dillard A, McLin L, Connor CW. The effects of laser illumination on operational and visual performance of pilots conducting terminal operations. Washington, DC: Department of Transportation/Federal Aviation Administration, Office of Aerospace Medicine; 2003. Report No. DOT/FAA/AM-03/12. Retrieved 8 August 2011 from http://www.faa.gov/library/reports/medical/oamtechreports/.
8. Nakagawara VB, Montgomery RW, Wood KJ. Laser illumination of aircraft by geographic location for a 3-year period. Washington, DC: Department of Transportation/Federal Aviation Administration, Office of Aerospace Medicine; 2008. Report No. DOT/FAA/AM-08/14. Retrieved 8 August 2011 from http://www.faa.gov/library/reports/medical/oamtechreports/.
9. Nakagawara VB, Montgomery RW, Wood KJ. The Illumination of aircraft at altitude by laser beams: a 5-year study period (2004–2008). Washington, DC: Department of Transportation/Federal Aviation Administration, Office of Aerospace Medicine; 2010. Report No. DOT/FAA/AM-10/21. Retrieved 8 August 2011 from http://www.faa.gov/library/reports/medical/oamtechreports/.
10. Nakagawara VB, Wood KJ, Montgomery RW. A review of recent laser illumination events in the aviation environment. Washington, DC: Department of Transportation/Federal Aviation Administration, Office of Aerospace Medicine; 2006. Report No. DOT/FAA/AM-06/23. Retrieved 8 August 2011 from http://www.faa.gov/library/reports/medical/oamtechreports/.
11. Order JO. 7400.2H: procedures for handling airspace matters, part 6. Miscellaneous procedures, chapter 29. Outdoor laser operations. U.S. Department of Transportation, Federal Aviation Administration; 10 March 2011. Retrieved 15 April 2011 from http://www.faa.gov/air_traffic/publications/atpubs/AIR/air2901.html#air2901.html.
12. Texas Laser Systems. Cool blue 1000 mW variable focus laser. Retrieved 15 April 2011 from http://www.texaslasersystems.com/ProductDetails.asp?ProductCode=CB1WB.
13. U.S. Code of Federal Regulations. Title 14, part 121. Washington, DC: U.S. Government Printing Office; January 2011. Retrieved 8 August 2011 from http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title14/14cfr121_main_02.tpl.
14. U.S. Code of Federal Regulations. Title 14, part 135. Washington, DC: U.S. Government Printing Office; January 2011. Retrieved 8 August 2011 from http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title14/14cfr135_main_02.tpl.
15. U.S. Code of Federal Regulations. Title 21, part 1040. Washington, DC: U.S. Government Printing Office; April 2010. Retrieved 8 August 2011 from http://cfr.vlex.com/vid/1040-11-specific-purpose-laser-products-19716373.
16. U.S. Department of Transportation. Reporting of laser illumination of aircraft. AC No. 70-2. January 11, 2005. Retrieved 8 August 2011 from http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/list/AC%2070-2/$FILE/AC%2070-2.pdf.
17. U.S. Department of Transportation. Standard operating procedures for flight deck crewmembers. AC No. 120-71. August 10, 2000. Retrieved 8 August 2011 from http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/8ce3f88c034ae31a85256981007848e7/d1ee41d2fdf4d6ea862569ed00509de3/$FILE/AC120-71.pdf.
18. Wicked Lasers. S3 Arctic series. Retrieved 15 April 2011 from http://www.wickedlasers.com/lasers/Spyder_III_Pro_Arctic_Series-96-37.html.
19. Williamson SJ, Cummins HZ. Light and color in nature and art. New York: John Wiley and Sons, Inc; 1983:173.
20. Wyszecki G, Stiles WS. Color science: Concepts and methods, quantitative data and formulae, 2nd ed. New York: John Wiley and Sons, Inc; 1982:392–94.