Federal Aviation Administration

DOT/FAA/AM-10/21
Office of Aerospace Medicine
Washington, DC 20591

The Illumination of Aircraft at Altitude by Laser Beams: A 5-Year Study Period (2004–2008)

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

Civil Aerospace Medical Institute
Federal Aviation Administration
Oklahoma City, OK 73125

December 2010

Final Report

OK-11-0024-JAH

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents thereof.

This publication and all Office of Aerospace Medicine technical reports are available in full-text from the Civil Aerospace Medical Institute's publications Web site:
www.faa.gov/library/reports/medical/oamtechreports

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AM-10/21		

4. Title and Subtitle	5. Report Date
The Illumination of Aircraft at Altitude by Laser Beams: A 5-Year Study Period (2004-2008)	December 2010
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Nakagawara VB, Montgomery RW, Wood KJ	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
FAA Civil Aerospace Medical Institute P.O. Box 25082 Oklahoma City, OK 73125	11. Contract or Grant No.
12. Sponsoring Agency name and Address	13. Type of Report and Period Covered
Office of Aerospace Medicine Federal Aviation Administration 800 Independence Ave, S.W. Washington, DC 20591	14. Sponsoring Agency Code

15. Supplemental Notes

This work was accomplished under the approved task PSR Lab.AV9100.

16. Abstract

INTRODUCTION: Laser illuminations of aircraft in navigable airspace have concerned the aviation community for over a decade. The principal apprehension is the effect laser illumination may have on flight crew personnel performing landing and departure maneuvers, where procedural requirements are critical. This study examines the frequency of aviation-related laser incidents by altitude of occurrence. METHODS: Event reports of aircraft illuminated by high-intensity light sources have been collected from various sources and entered into a database maintained by the Federal Aviation Administration's Civil Aerospace Medical Institute. Reported events of laser exposure of civilian aircraft for a 5-year period (January 1, 2004 to December 31, 2008) were collated and analyzed. RESULTS: A total of 2,492 laser events occurred in the U.S. during the study period. The cockpit environment was illuminated by laser beam in 1,676 (67.3%) events, and altitude information was provided in 1,361 (81.2%) of these reports. At altitude levels associated with the FAA's Laser-Free Zone (0–2,000 feet), cockpit illuminations increased from 12.5% to 26.7% for the period, while the percentage for Critical Flight Zone equivalent altitudes (>2,000–10,000 feet) decreased from 87.5% to 58.4%. For the period, green laser light was reported in 92% of the events where color was identified. CONCLUSION: The increasing percentage of aircraft laser illuminations reported at or below 2,000 feet that involve green laser light may represent an escalating threat to aviation safety. Low-flying aircraft, which may not be within currently established flight hazard zones around airports, need protection due to their increased vulnerability to laser illumination and their close proximity to obstacles and terrain.

17. Key Words	18. Distribution Statement
Aviation, Laser, Laser Events, Safety	Document is available to the public through the Defense Technical Information Service Center, Ft. Belvoir, VA 22060; National Technical Information Service, Alexandria, VA 22312

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	12	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

CONTENTS

The Illumination of Aircraft at Altitude by Laser Beams: A 5-Year Study Period (2004–2008)

INTRODUCTION

Laser illuminations of civilian and military aircraft in navigable airspace have concerned the aviation community for over a decade. The principal concern is the affect laser illumination may have on flight crew personnel during landing and departure maneuvers when procedural requirements are critical. Federal Aviation Regulations (FAR) require a “sterile cockpit” (i.e., only operationally relevant communication) below 10,000 feet to minimize distractions and reduce the potential for procedural errors (1). Laser illumination during these critical operations can create unsafe conditions by distracting or visually impairing flight crewmembers, thus disrupting cockpit procedures and crew coordination.

Prior to 1995, laser operators were allowed to project laser beams into the navigable airspace as long as they did not exceed the exposure limit imposed by Federal Aviation Administration (FAA) Order 7400.2. Guidance material used to establish this FAA Order included the Food & Drug Administration’s (FDA’s) “Performance Standards for Light-Emitting Products” (2). The FDA 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 (NOHD), which varies depending on the laser’s output power, wavelength, pulse duration, and beam divergence (3).

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 transient visual effects (4) that consist of:

- 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 automobile 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 (see Figures 1 and 2). These

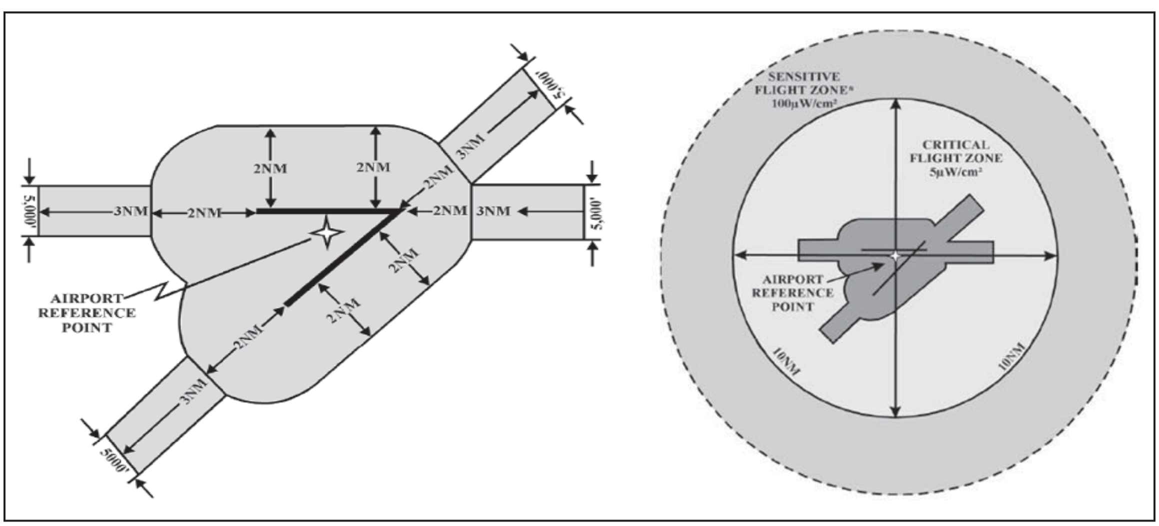

Figure 1: Aerial view of the flight hazard zones for a two-runway airport. LFZ (left) extends 2 nautical miles (NM) in all directions from the runway centerline. It includes an additional 3-NM extension along the runway centerline. CFZ (right) includes all airspace surrounding the LFZ within a 10-NM radius of the airport reference point.

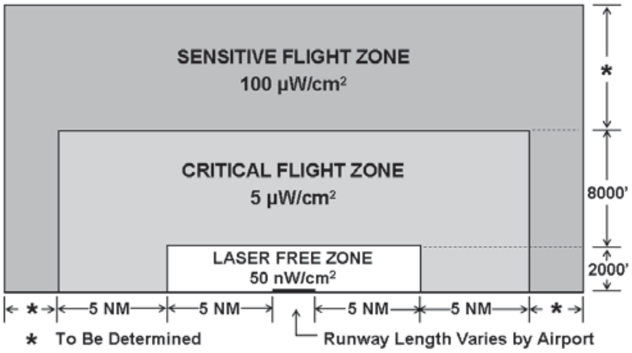

Figure 2: A profile view of protected flight zones around a single-runway airport. The LFZ extends 5 NM beyond the runway ends and up to 2,000 feet above ground level (AGL). The CFZ includes airspace surrounding the LFZ, out to 10 NM and up to 10,000 feet AGL.

Figure 3: Issuance of AC No. 70-2 announced by then-Secretary of Transportation Norman Mineta on January 12, 2005, at a press conference held at the FAA Civil Aerospace Medical Institute.

zones are intended to mitigate the hazardous affect 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 Laser Free Flight Zone (LFZ) and Critical Flight Zone (CFZ) 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/cm^2);
- CFZ = 5 microwatt per square centimeter ($\mu W/cm^2$);
- SFZ = 100 $\mu W/cm^2$;
- 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 revision of FAA Order 7400.2. During the fall/winter of 2004 and January of 2005, however, there was a marked increase in reported laser events that were attributed to random acts by individuals using handheld lasers (5). In response to this rapid increase in laser events, then-Secretary of Transportation Norman Mineta held a press conference at the FAA's Civil Aerospace Medical Institute (CAMI) in Oklahoma City, OK, to announce the publication of an Advisory Circular (AC No. 70-2), entitled "Reporting of Laser Illumination of Aircraft" (6) (see Figure 3). 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 (see Appendix A). 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 aircraft laser illumination event reports has been maintained by CAMI's Vision Research Team since these were first recognized as a problem. Analysis of laser events provides the means to determine if current FAA safety policies are adequate to protect aviators and the flying public. In addition, continued monitoring of laser events can help determine whether advances in laser technology and new outdoor laser applications may adversely affect aviation safety. The present study examines the frequency of laser illuminations of aircraft by altitude at the time of the event.

METHODS

Reports of high-intensity light illumination of civilian aircraft were collected from numerous sources including: Washington Operations Control Center, FAA regional offices, Transportation Security Administration, Department of Homeland Security/Federal Bureau Investigation information bulletin, the FAA's Office of Accident Investigation, newspaper articles and Internet sites, and interviews with illuminated personnel. Details from these reports were entered into a computer database and maintained by the Vision Research Team.

Data from reports of laser illumination events involving civilian aircraft in the United States for a 5-year period (January 1, 2004, to December 31, 2008) were analyzed. Frequency and altitude at the time of exposure were used

Table 1. Frequency and (Percentage) of Cockpit Illuminations by Altitude and Year						
Altitude (ft.)	**2004**	**2005**	**2006**	**2007**	**2008**	**TOTAL**
0 – 1,000	1 (6.3)	7 (4.7)	12 (5.4)	40 (11.2)	66 (10.7)	**126 (9.3)**
1001 - 2,000	1 (6.3)	13 (8.8)	36 (16.1)	51 (14.2)	98 (15.9)	**199 (14.6)**
LFZ	**2 (12.5)**	**20 (13.5)**	**48 (21.4)**	**91 (25.4)**	**164 (26.7)**	**325 (23.9)**
2,001 - 3,000	5 (31.3)	18 (12.2)	31 (13.8)	72 (20.1)	91 (14.8)	**217 (15.9)**
3,001 - 4,000	2 (12.5)	18 (12.2)	24 (10.7)	35 (9.8)	53 (8.6)	**132 (9.7)**
4,001 - 5,000	1 (6.3)	12 (8.1)	27 (12.1)	30 (8.4)	43 (7.0)	**113 (8.3)**
5,001 - 6,000	1 (6.3)	20 (13.5)	24 (10.7)	29 (8.1)	53 (8.6)	**127 (9.3)**
6,001 - 7,000	0 (0)	8 (5.4)	19 (8.5)	22 (6.1)	35 (5.7)	**84 (6.2)**
7,001 - 8,000	2 (12.5)	8 (5.4)	13 (5.8)	15 (4.2)	33 (5.4)	**71 (5.2)**
8,001 - 9,000	1 (6.3)	7 (4.7)	7 (3.1)	11 (3.1)	17 (2.8)	**43 (3.2)**
9,001 - 10,000	2 (12.5)	5 (3.4)	11 (4.9)	9 (2.5)	34 (5.5)	**61 (4.5)**
CFZ	**14 (87.5)**	**96 (64.9)**	**156 (69.6)**	**223 (62.3)**	**359 (58.4)**	**848 (62.3)**
NFZ (>10,000)	0 (0)	32 (21.6)	20 (8.9)	44 (12.3)	92 (15.0)	**188 (13.8)**
Total Cockpit Illuminations	**16 (1.2)**	**148 (10.9)**	**224 (16.5)**	**358 (26.3)**	**615 (45.2)**	**1361 (100)**

to stratify events into 1,000-foot increments and grouped into zones of airspace "equivalent in altitude" to those established around airports (i.e., flight hazard zones[1]). Additionally, data from the laser illumination reports were used to evaluate the adverse visual and operational effects experienced by pilots within the range of altitude corresponding to the flight hazard zones around airports.

RESULTS

A total of 2,587 aircraft illumination events were reported during the study period. Of these, 2,492 (96.3%) events took place within the United States (i.e., 49 states plus the District of Columbia). The cockpit environment was illuminated by a laser beam in 1,676 (67.3%) events (see Figure 4). From 2004 to 2008, the total number of aircraft illuminations increased from 46 to 988, which included an increase from 27 to 767 in cockpit illuminations.

Altitude information was provided in 1,361 (81.2%) of the 1,676 laser illumination reports in which the cockpit was illuminated (see Table 1). Reports for the 5-year study period included 325 (23.9%) cockpit illuminations that occurred within the LFZ (at or below 2,000 feet), while the majority of these events, 848 (62.3%), occurred within the altitude limits defined by the CFZ (> 2,000 to 10,000 feet). Relatively few laser exposures (13.8%) were reported above 10,000 feet.

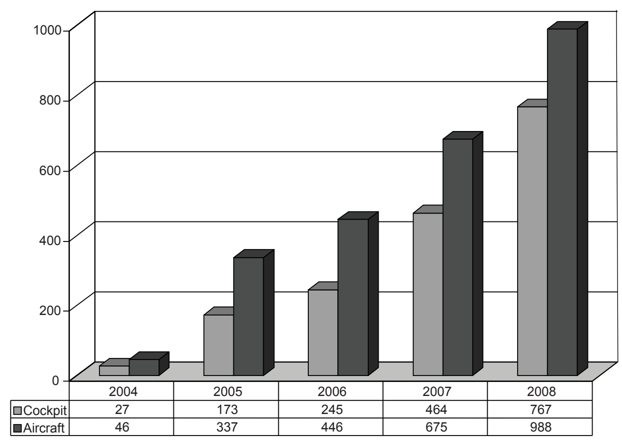

Figure 4: Frequency of aircraft and cockpit illuminations by year.

Of the 1,361 cockpit illumination events reported for the study period, only 1.2% occurred in 2004, while almost half occurred in 2008. The percentage of cockpit illuminations show an overall increase at altitudes equivalent to that of the LFZ (≤ 2,000 feet), from 12.5% (2004) to 26.7% (2008). At altitudes equivalent to that of the NFZ (>10,000 feet), cockpit illuminations increased from 0% (2004) to 15% (2008). The percentage of cockpit

[1] Note: The proximity to the nearest airport of a laser illumination was often not included in the information provided in the event report. For this study, laser events that occurred within the range of altitudes defined by a zone of protected airspace (i.e., flight hazard zone) were analyzed and referred to as having occurred within that zone. The Sensitive Fight Zone was not used in this analysis as it may be assigned to any zone of airspace at the discretion of the local air traffic authority.

Table 2. Summary of Visual Effects, Operational and Physiological Problems by Altitude											
Altitude (ft.)	Annoy/ Distract	Visual Effects			Op Prob	Pain/ Injury	LFZ	CFZ	NFZ	Total Effects	Arrests
		Glare	Flash-Blindness	After-image							
0 - 1,000	5	1	8	4	7	1	24	-	-	24	15
1,001 - 2,000	15	5	9	6	10	4	29	-	-	29	7
2,001 - 3,000	7	3	9	3	10	3	-	22	-	22	4
3,001 - 4,000	10	3	4	1	6	0	-	17	-	17	2
4,001 - 5,000	3	1	0	0	0	1	-	3	-	3	0
5,001 - 6,000	4	2	0	0	2	1	-	7	-	7	1
6,001 - 7,000	2	0	1	1	0	2	-	5	-	5	0
7,001 - 8,000	3	2	2	1	2	3	-	10	-	10	1
8,001 - 9,000	2	2	0	1	2	2	-	6	-	6	1
9,001 - 10,000	2	1	0	0	1	0	-	3	-	3	1
> 10,000	11	6	5	3	4	3	-	-	19	19	1
No Alt Data	4	0	10	2	8	10	-	-	-	39	25
TOTAL	68	26	48	22	52	30	53	73	19	184	58

illuminations, however, deceased from 87.5% (2004) to 58.4% (2008) within altitudes equivalent to that of the CFZ (≥ 2,000 to 10,000 feet).

Adverse effects included reports of annoyance/distraction, visual effects, operational problems, and pain/injury (see Table 2). One or more adverse effects were noted in 145 of the 1,361 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 feet AGL or less (within the equivalent LFZ and CFZ). Few adverse effects occurred above 10,000 feet (19 reports, or 13%).

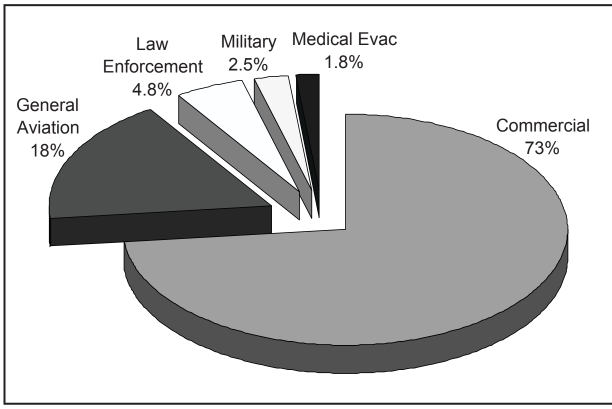

Figure 5: Percentage of aircraft illuminations by type of flight for the study period.

DISCUSSION

Prior to the issuance of AC 70-2, laser event reports were often not forwarded to the proper authorities in a timely manner, and the information on some events was often incomplete. Since issuance of the AC in January 2005, laser reports have become more reliable in the timeliness of delivery and provide more detailed and useful information. In the first year following introduction of the AC, the number of event reports increased 633%, and the review performed by this study confirms the quality of data being provided has improved substantially. The continued increase in the number of aircraft illumination reports over the last years of the study, however, suggests that more remains to be done to curb the continuing escalation of inappropriate outdoor laser activity.

The study data revealed that commercial air carriers were at greatest risk of laser illumination. When the type of flight was provided in the event reports, more than 73% (1,693) of all aircraft illumination events were identified as commercial carriers (see Figure 5). General aviation (GA) accounted for less than 18% (411) of all event reports. Although few in number, GA pilots may be more at risk for an aviation accident from a laser illumination, as they rarely fly with a co-pilot and would have fewer options — including relinquishing control of the aircraft — should temporary disorientation or visual impairment to the pilot occur. Law enforcement (5%) and medical evacuation (2%) flights involved mostly rotary-wing aircraft that are easy targets for individuals with handheld laser devices, since such flights are normally flown at low altitude and at relatively slow speed. Pilots flying military aircraft reported only 3% of the events.

Information was provided regarding the phase of flight for 1,218 (73%) of the 1,676 cockpit illumination events (see Figure 6). The majority of these reports (69%) involved laser beams entering the cockpit when the aircraft was performing approach maneuvers.[2] This statistic is a concern because the

[2] Note: If approach or final approach were documented in the event report, the event was assigned that phase of flight. However, if there was no mention of the phase of flight, "approach" was assigned to those events that stated the flight was in/or at their destination airport, and "final approach" was assigned to those events that stated the aircraft was cleared for a specific runway.

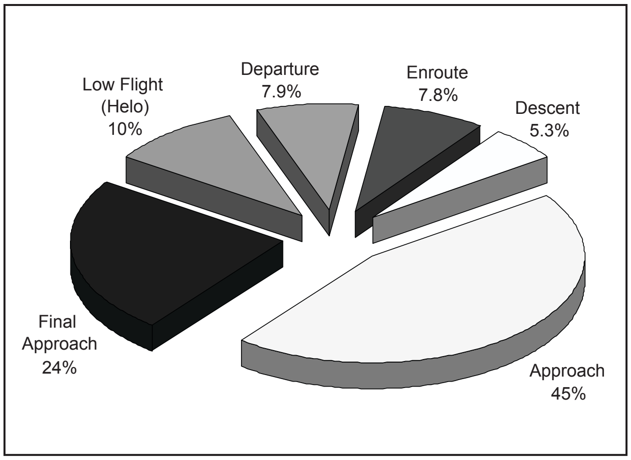

Figure 6: Percentage of cockpit illuminations by phase of flight for the study period.

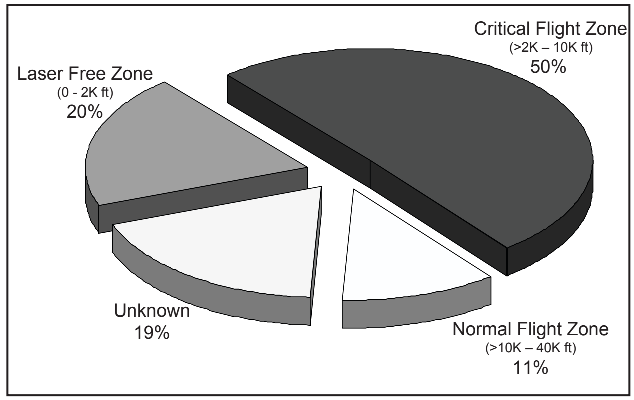

Figure 7: Percentage of cockpit illumination by flight zone for the study period.

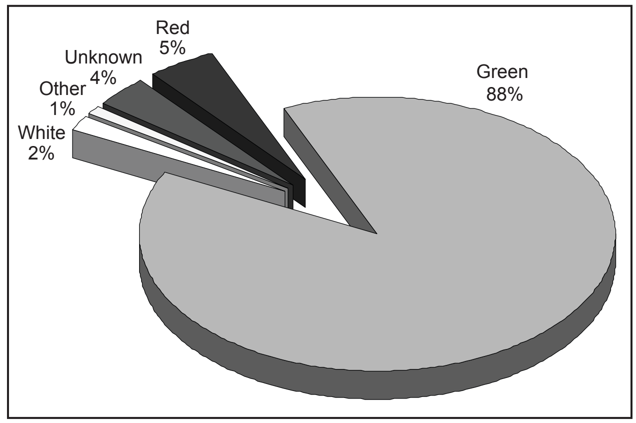

Figure 8: Percentage of cockpit illuminations by color.

distraction and/or disruption occur when the flight crew is busy performing critical flight operations at low altitude and is most vulnerable. Low-flying helicopters accounted for about 10% of laser exposure reports and may be as vulnerable as aircraft on approach maneuvers due to their close proximity to obstacles and terrain. Laser illuminations during the departure and enroute phases of flight were reported about 8% each, followed by the descent phase, with about 5% reported. These events may be less problematic since they generally occur at higher altitude, which allows more time for the pilot to recover from the debilitating effects of laser exposure.

Approximately 70% (1,175) of the laser events were reported to be at or below the 10,000-foot limit of the CFZ during the study period, and only 11% (188) reached altitudes above 10,000 feet (see Figure 7). However, as Table 1 illustrates, cockpit illumination above 10,000 feet increased from 0% to 15% from 2004 to 2008. This substantial increase may be due to several factors, including: increased laser activity, improved reporting, greater public access to more powerful laser devices, and better visibility of green versus red lasers. About 20% of the events (327) reported were within the altitude limit designated for the LFZ (≤ 2,000 feet). 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 a concern as they have been shown to be significantly more disruptive to visual and operational performance than exposures of equal intensity that occur at higher altitudes (7). Although the data in this study were categorized into equivalent flight zones for analysis purposes, approximately 18% of aircraft illuminations occurred when the aircraft were not in the protected flight zones of an airport. These were primarily law enforcement and medical evacuation helicopters that were likely enroute to or from crime scenes or medical facilities at the time of the incident. 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, safety guidelines should be considered for all aircraft that fly at or below 2,000 feet AGL, even when not in the vicinity of an airport.

Inexpensive red and red-orange lasers, with wavelengths ranging from 630 to 680 nanometers (nm), have been in use by the general public for more than a decade. Green handheld lasers, however, have gained popularity in recent years, as the technology to produce them has made them more affordable. This may explain why green lasers were identified in 88% of the all cockpit illuminations (see Figure 8). Another reason for the increased number of reports is that a green (532 nm) laser beam may appear as much as 28 times brighter than an equivalently powered 670-nm red laser beam (8). The inherent sensitivity of photoreceptors in the eye (i.e., peak sensitivity of 555

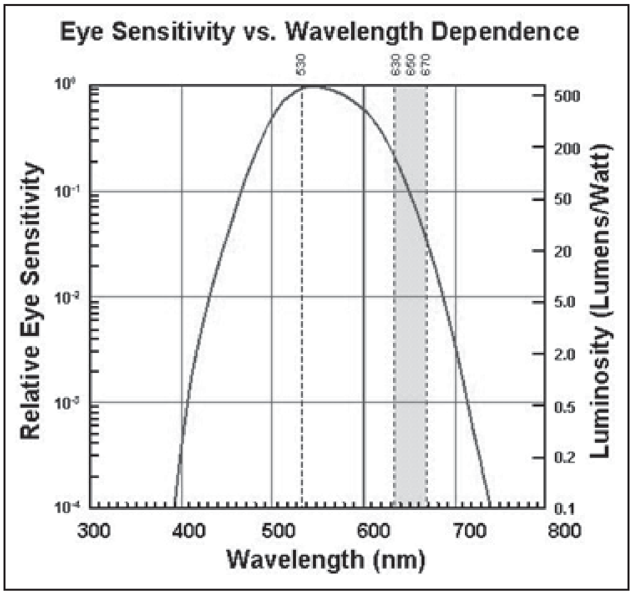

Figure 9: The human eye's relative sensitively to light

nm) is responsible for this disproportionate brightness (see Figure 9). The extended visual range of these devices may explain 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.

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 (9,10,11). These include:

- 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 90º 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 of eyes as this may result in irritation to the cornea and conjunctiva of the eye.
- Evaluate—If visual symptoms persist, consult an eye doctor.

The small number of the adverse effects reported (184) for the study period was only 11% of the cockpit illuminations reported (1,676). This number seems surprisingly low, based on the results of a previous simulator study in which adverse visual effects were reported in 60% of all exposure trials (12). The disparity may be due to the simulator's exposure stimulus being aligned near to the pilot's axis of vision through the windscreen. Additionally, the irradiance level in one-third of the simulator trials was at the upper limit of what might be experienced in a real-world scenario (50 $\mu W/cm^2$). It seems likely that event details concerning adverse visual and operational effects, however, are not being reported properly. The hesitance of a pilot to report visual or operational effects from a laser exposure might be motivated by fear of reprisal or loss of flying privileges from regulatory agencies (13). Only through the analysis of accurate and comprehensive data can regulatory policies be tailored to deal with continuing changes in laser technology and limit the misuse that threatens aviation safety.

In summary, results of this study show that reporting of laser events has improved dramatically since issuance of AC 70-2. Fragmented data reporting, however, may still compromise the analysis process and limit its effectiveness in defining the true extent of the laser illumination problem. A revised laser exposure questionnaire may improve documentation of the adverse effects experienced by crewmembers and provide a better understanding of the hazards associated with laser exposure and how to best mitigate their affect. In addition, this study also suggests that low-flying aircraft, which may not be within currently established flight hazard zones around airports, need protection due to their increased vulnerability to laser illumination and their proximity to obstacles and terrain.

REFERENCES

1. U.S. Department of Transportation. Standard operating procedures for flight deck crewmembers. AC No. 120-71. 8/10/00.

2. Code of Federal Regulations. Title 21, Part 1040. Washington, DC:U.S. Government Printing Office; April 2007.

3. American National Standards Institute (ANSI) Z136.6 -2005, American National Standard for Safe Use of Lasers Outdoors.

4. Order JO 7400.2G: Procedures for Handling Airspace Matters, Part 6. Miscellaneous Procedures, Chapter 29. Outdoor laser operations. U.S. Department of Transportation, Federal Aviation Administration: April 8, 2010. At URL: www.faa.gov/air_traffic/publications/atpubs/AIR/chapter_29.htm (Accessed: August 2010).

5. Nakagawara VB, Wood KJ, Montgomery RW. A review of recent laser illumination events in the aviation environment. Federal Aviation Administration, Office of Aerospace Medicine, Washington, DC: Report No. DOT/FAA/AM-06/23. Oct 2006. At URL: www.faa.gov/library/reports/medical/oamtechreports/2000s/media/200623.pdf (Accessed: August 2010).

6. Reporting of laser illumination of aircraft. FAA-A/C No. 70-2. January 11, 2005. At URL: www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/b6507bbbc173030486256fab00716236/$FILE/AC%2070-2.pdf (Accessed: August 2010).

7. 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. Federal Aviation Administration, Office of Aerospace Medicine, Washington, DC: Report No. DOT/FAA/AM-04/9. At URL: www.faa.gov/library/reports/medical/oamtechreports/2000s/media/0409.pdf (Accessed: August 2010).

8. Wyszecki G, Stiles WS. Color science: Concepts and methods, Quantitative data and formulae (2nd ed.). NY, NY: John Wiley and Sons, Inc. (1982): pp 392-94. ISBN 0-471-39918-3.

9. EUROCONTROL Safety Regulation Commission (SRC), Safety Regulation Commission Document - SRC DOC 7; Outdoor laser operations in the navigable airspace. At URL: www.eurocontrol.int/src/gallery/content/public/documents/deliverables/srcdoc7ri.pdf (Accessed: July 2010).

10. Canadian Civil Aviation Authority, Safety Regulation Group, Air Traffic Standards, Supplementary Instruction (SI); Number 2010/03, CAP 493 MATS Part 1, Section 2, Chapter 3, Lights Signals and Pyrotechnics, 5.7 Malicious use of lasers against aircraft and ATS personnel. At URL: www.caa.co.uk/docs/33/CAP493SupplementaryInstruction201003.pdf (Accessed: July 2010).

11. ICAO DOC 9815; Manual on laser emitters and flight safety, Ed 1. At URL: http://store1.icao.int/documentItemView.ch2?ID=9425 (Accessed: July 2010).

12. 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. Federal Aviation Administration, Office of Aerospace Medicine, Washington, DC: Report No. DOT/FAA/AM-03/12. At URL: www.faa.gov/library/reports/medical/oamtechreports/2000s/media/0312.pdf (Accessed August 2010).

13. NTSB Aviation Accident Database - NTSB Report No. LAX96IA032. At URL: www.ntsb.gov/ntsb/brief2.asp?ev_id=20001207X04715&ntsbo=LAX96IA032&akey=1 (Accessed: June 2010).

APPENDIX A

LASER BEAM EXPOSURE QUESTIONNAIRE

FAX TO WASHINGTON OPERATIONS CONTROL CENTER(WOCC) at (202) 267-5289 ATTN: DEN

PILOT NAME________________ **PHONE NUMBER**________________
COMPANY ________________ **FLIGHT NUMBER**________________

1. Date and time (UTC) ?________________
2. Position of event (lat/long and/or FRD)? ________________
3. Altitude? ________________
4. What was the visibility? ________________
5. What were the atmospheric conditions? (Circle those which apply) – Clear, overcast, rainy, foggy, hazy, sunny.
6. What was the color(s) of the light? ________________
7. Did the color(s) change during the exposure? ________________
8. Did you attempt an evasive maneuver? ________________

   If so, did the beam follow you as you tried to move away?________________
9. Can you estimate how far away the light source was from your location? ________________
10. What was the position of the light relative to the aircraft? ________________
11. Was the source moving? ________________
12. Was the light coming directly from its source or did it appear to be reflected off other surfaces?________________
13. Were there multiple sources of light? ________________
14. How long was the exposure? ________________
15. Did the light seem to track your path or was there incidental contact? ________________
16. What tasks were you performing when the exposure occurred? ________________

    Did the light prevent or hamper you from doing those tasks, or was the light more of an annoyance? ________________
17. What were the visual effects you experienced (after-image, blind spot, flash-blindness, glare*)? ________________
18. Did you report the incident by radio to ATC? ________________

Any other pertinant information: ________________

This questionnaire may be filled out by the competent authority during interviews with aircrews exposed to unauthorized laser illumination. This information will be used to aid in subsequent investigation by ATC, law enforcement and other governmental agencies to safeguard the safety and efficiency of civil aviation operations in the NAS

*Examples of common visual effects:

After-image. An image that remains in the visual field after an exposure to a bright light.
Blind spot. A temporary or permanent loss of vision of part of the visual field.
Flash-blindness. The inability to see (either temporarily or permanently) caused by bright light entering the eye and persisting after the illumination has ceased.
Glare. A temporary disruption in vision caused by the presence of a bright light (such as an oncoming car's headlights) within an individual's field of vision. Glare lasts only as long as the bright light is actually present within the individual's field of vision.

Paperwork Reduction Act Statement: This form is being used to collect information regarding the unauthorized laser illumination of aircraft. We estimate that it will take 15 minutes to provide this information. The collection is voluntary. Note that an agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. The OMB control number associated with the collection is 2120-0698.