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Briefing Leaflet

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The effects of laser illumination of aircraft

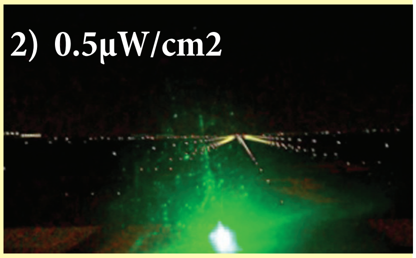
Laser illumination of aircraft has become more common during last few years. Although these illuminations may result from outdoor laser shows, recently they have frequently been the result of deliberate action. This is either because the perpetrator has a lack of understanding of the consequences, or of more concern, the perpetrator understands the hazards of lasers and illuminates aircraft with the intent of doing harm. The problem has become more pronounced with the easy availability of powerful lasers, often purchased via the internet. Furthermore, on TV, there have also been fictional scenarios about "lasering down an aircraft" which might have induced misguided people to try it for themselves. For example, in March 2008, at least four aircraft were targeted with green lasers from up to four different locations during approach to Sydney Kingsford Smith. ATC had to change the runway in use which resulted in delays of up to 30 minutes.

The effects of exposure to laser beams

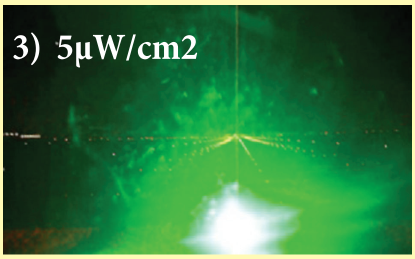
Temporary vision loss is a common effect of lasers. It can be associated with glare, flash blindness, blind spots, or after-images. Glare is considered to be a temporary disruption in vision caused by the presence of a bright light within an individual's field of vision and it lasts as long as the light exposure. In flash blindness, the temporary loss of vision persists even after the source of illumination has been removed. Blind spots are similar to flash blindness, but only part of the visual field is affected. After-image is an image that remains in the visual field after an exposure to a bright light. The US FAA has conducted a simulator study about the effects of laser illumination during final approach. Using lasers of varying power, the illumination of a legal 5 mW laser pointer in a cockpit could be established at a range of distances (Figures 1 and 2).

Example view from aircraft cockpit (in FAA flight simulator) during laser illumination flash.
The simulator is showing the aircraft on the ground, at the take off position. The laser is steady for the photo, however, in the actual FAA simulator tests, pilots were exposed to a single flash lasting 1 second. So you can imagine pilots see this for 1 second (the laser flashes because in real-life a handheld laser would not be held steady on target. The light would flash instead of remaining steady).

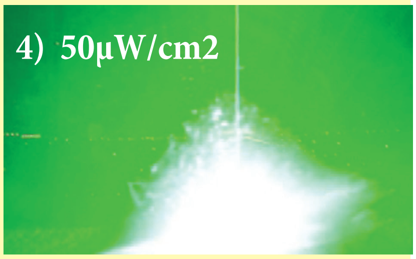
1) View from the simulator cockpit. No laser illumination. **Runway fully visible.**



2) FAA Simulator Study, level 1 (10 times greater than FAA Laser-Free Zone level). Roughly equal to bright startle or distraction. 5mW laser pointer at 3,700 ft. **Runway partially obscured.**



3) FAA Simulator Study, level 2 (FAA Critical Flight Zone), where glare is the primary hazard. 5 mW pointer at 1,200 ft. **Runway mostly obscured.**



4) FAA Simulator Study, level 3 (10 times less than FAA Sensitive Zone level), temporary flash-blindness begins. 5 mW pointer at 350 ft. **Runway completely obscured.**

All photos taken with the same setting: Kodak DC240 digital camera, aperture #2.8, shutter speed 1/6 second.

Figure 1: A view from the cockpit when the aircraft is illuminated by a 5mW laser from a variety of distances. Images are copyright with permission of Pangolin laser systems.

As can be seen, a 5mW laser can easily cause glare and distract pilots up to 3700ft and an FAA safe distance is considered to be 11,700 ft (<0,05µW/cm2).
The surface layer of the cornea may suffer from burn and the superficial cells shed off. This is called a corneal abrasion. Usually, the corneal abrasion is caused or at least exacerbated by rubbing of the eyes and is thus more or less “self-induced”. Thankfully, retinal damage due to laser exposure is rare. It is estimated that fewer than 15 retinal injuries worldwide each year are caused by industrial and military lasers. Ordinary laser pointers of energy less than 5mW require more than 10 seconds of staring at close range (Mainster et al, 2004). This, however, has to be deliberate, because it is normally terminated in less than 0.25 seconds by blinking the eye. The retina also seems to be more sensitive to the shorter wavelengths, i.e. green lasers are more harmful than the red ones. Thus, fortunately, it is very unlikely that laser incidents in aviation would cause retinal damage.

Classification of lasers

Lasers can be classified to five different classes according to their ability to damage eye or skin (U.S. Center for Devices and Radiological Health (CDRH))

- Class I: Power level less than 0.39 mW. No capability for eye or skin damage.
  For example, CD players or laser printers belong to Class I laser devices

- Class II: Power level less than 1 mW. Safe for momentary exposure, but prolonged (over 10 seconds) may cause eye damage. No skin damage. Some of the laser pointers belong to Class II devices.

- Class IIIa: Power level less than 5 mW. Safe for momentary exposure, but prolonged (over 10 seconds) may cause eye damage. No skin damage. *Most laser pointers belong to Class IIIa devices.*

- Class IIIb: Power level less than 500 mW. Momentary exposure may cause eye damage. No skin damage.
  Some laser pointers fall into Class IIIb devices.

- Class IV: Power level more than 500 mW. May cause eye and skin damage even from reflected laser beams.
  Most of the outdoor, military, and industrial lasers belong to this category.

Factors affecting lasers in aviation

Weather: Clouds inhibit laser beams.

Time of day: Eyes adapt to the darkness separately, and it may take time up to 30 minutes. When the adapted eye is hit by light, it loses its adaptation, and in turn, it takes several seconds for the eye to adapt to bright light. During this adaptation phase vision is distracted. This why the problems with lasers occur mainly during the hours of darkness.

Power of the laser: The more powerful the laser is, the more distraction and damage it can cause.

Colour of the laser beam: The retina is most sensitive to green light wavelengths.

Distance and relative angle of the laser and aircraft: The closer the laser is from the aircraft the more powerful it is and the lower the relative angle of the beam the more dangerous it is (a laser beam from straight ahead is the worst case)

Speed of the aircraft: The higher speed the aircraft has, the more difficult it is for the perpetrator to hit the aircraft and so exposure risk will be reduced.

Exposure time: The longer the exposure time, the more dangerous it is. Fortunately, aircraft speed and the fact that most of the laser pointers are handheld will reduce exposure time.

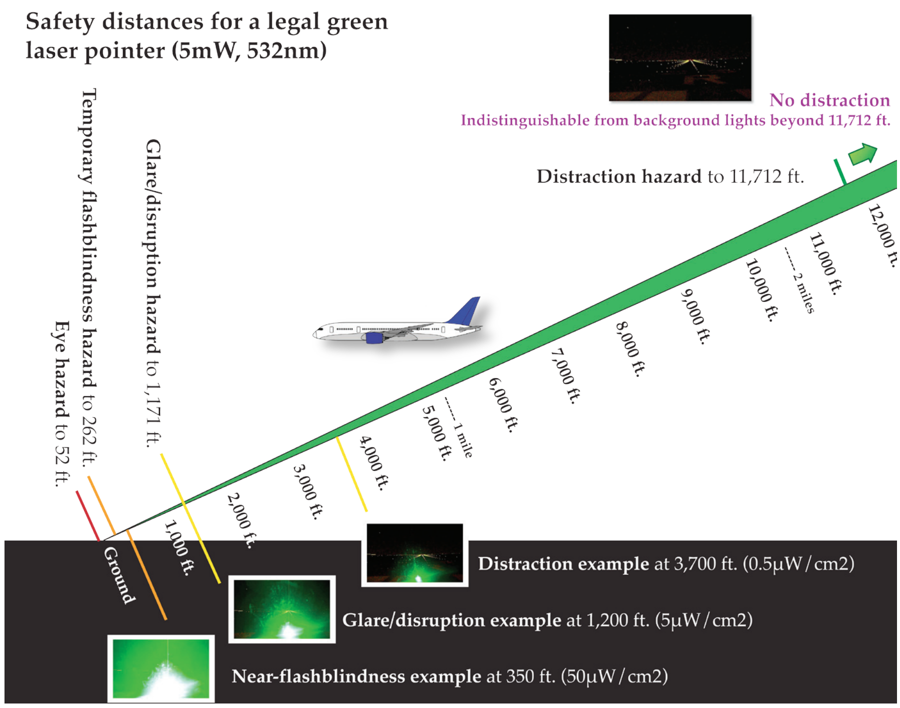


Figure 2: “Safety distances for a legal green laser pointer (5mW, 532nm)”

Recommended actions in the event of laser illuminations

- Look away from the laser beam and shield your eyes if possible.
- Avoid rubbing of eyes so as to reduce the potential for corneal abrasion.
- Determine if other crew members are also exposed. If not, consider handing over the control of the aircraft to the non-exposed crewmember.
- Depending upon the situation and ATC clearance, maneuver to avoid the laser beam. (For instance, if on an approach the commencement of a missed approach may be appropriate.)
- Consider engaging the autopilot and other relevant flight modes.
- Turn up the cockpit lights to minimize any further illumination effects.
- As soon as flight safety allows, check for dark/disturbed areas in vision, one eye at a time. If either pilot is incapacitated to a degree that may affect the safety of the aircraft, declare an emergency (PAN or MAYDAY as appropriate).
- Inform ATC and, if the situation allows, provide as much information as possible (laser direction, colour, length of exposure, flash or intentional tracking, etc.). The use of the "IDENT" button may assist ATC and authorities in pin pointing the location of origin of a laser attack.
- Fill in an Air Safety Report (ASR).
- If any visual symptoms persist after landing, get an ophthalmologic examination.
- For more information, refer to ICAO Document 9815 "Manual on Laser Emitters and Flight Safety".

Conclusions

Most of the lasers used in illumination seem to have been ordinary handheld laser pointers. Because it is very hard for the perpetrator to acquire and maintain steady illumination of a moving target, in the cockpit, the illumination will appear as a series of flashes. During these illumination incidents, fortunately, the risk of permanent damage to the eye is very small, however when the event occurs at low altitude it can be extremely dangerous because of the glare, flash blindness and afterimages. Crews should therefore be aware of the threat and consider how they will react in the event that they are targeted.

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