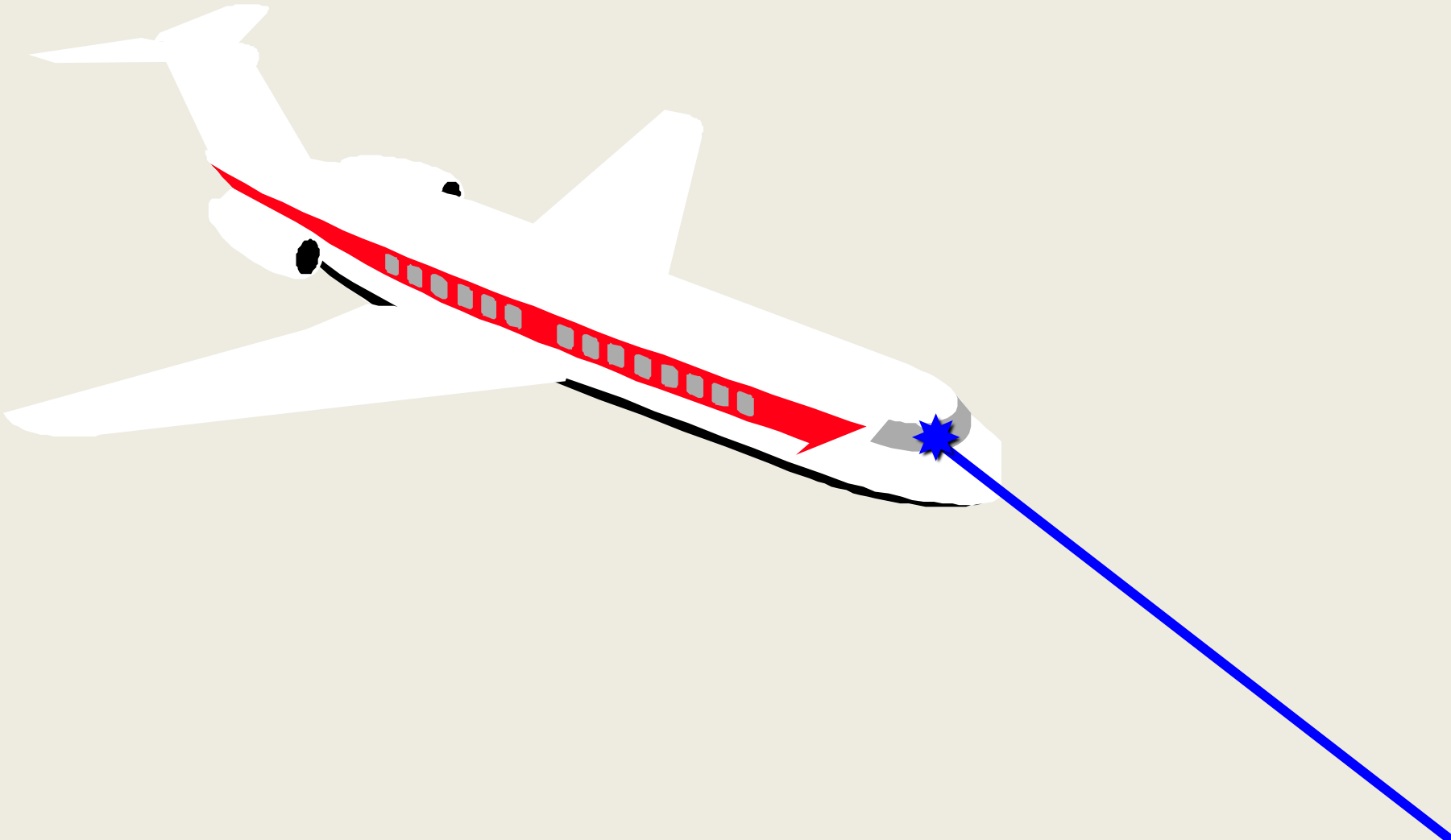
Laser beam bio effect and their hazards to flight operations

Gábor Hardicsay Dr.
Chief Medical Officer (ret.) CAA Hungary

Inflight Incidents



November 29, 1996,

Los Angeles, CA, a Skywest Airlines Embraer-120 was illuminated by a LASER at a distance of 5 miles and an altitude of 6,000 ft

They were the intentional target of a blue LASER five times during final approach

The pilot was flash blinded on the right eye and later he presented blurred vision secondary to ocular burning sensation and profuse tearing

An ocular exam reported multiple superficial corneal burns on the right eye with no permanent damage

DOT/FAA/AM-04/9

Office of Aerospace Medicine
Washington, DC 20591

The Effects of Laser Illumination on Operational and Visual Performance of Pilots During Final Approach

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Melbourne, FL 32951

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Federal Aviation Administration
Oklahoma City, OK 73125

June 2004

Final Report

Trainee pilot on crashed San Francisco flight tells investigators he was blinded by flash of light during landing - ASIANA B777 - July 11, 2013 9:13 AM ET

The pilot trainee told investigators he was blinded by a light at about 150 metres, which would have been 34 seconds before impact and the point at which the airliner began to slow and drop precipitously….

NTSB chairman Deborah Hersman said lasers have not been ruled out.

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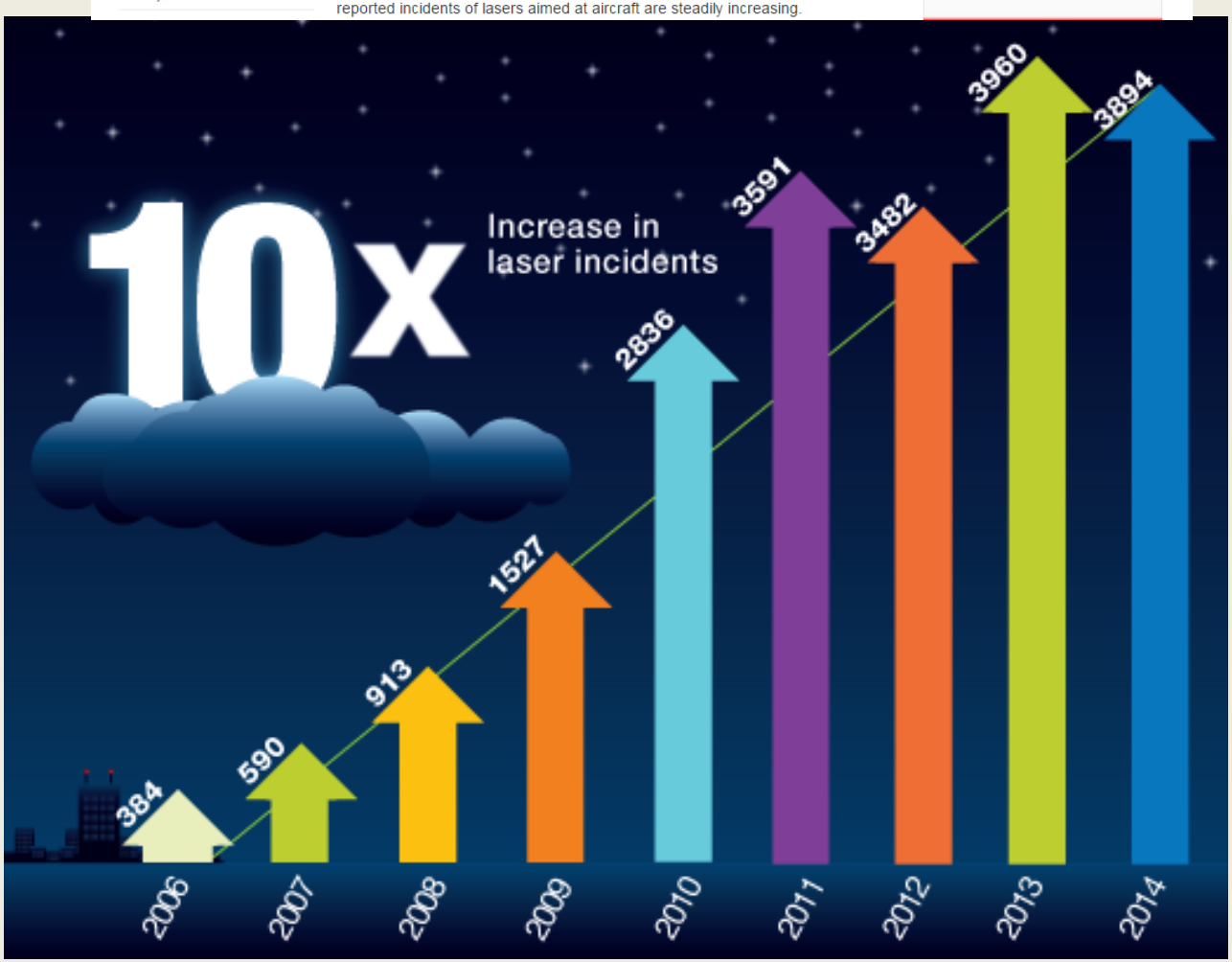
History

Laser Safety Initiative

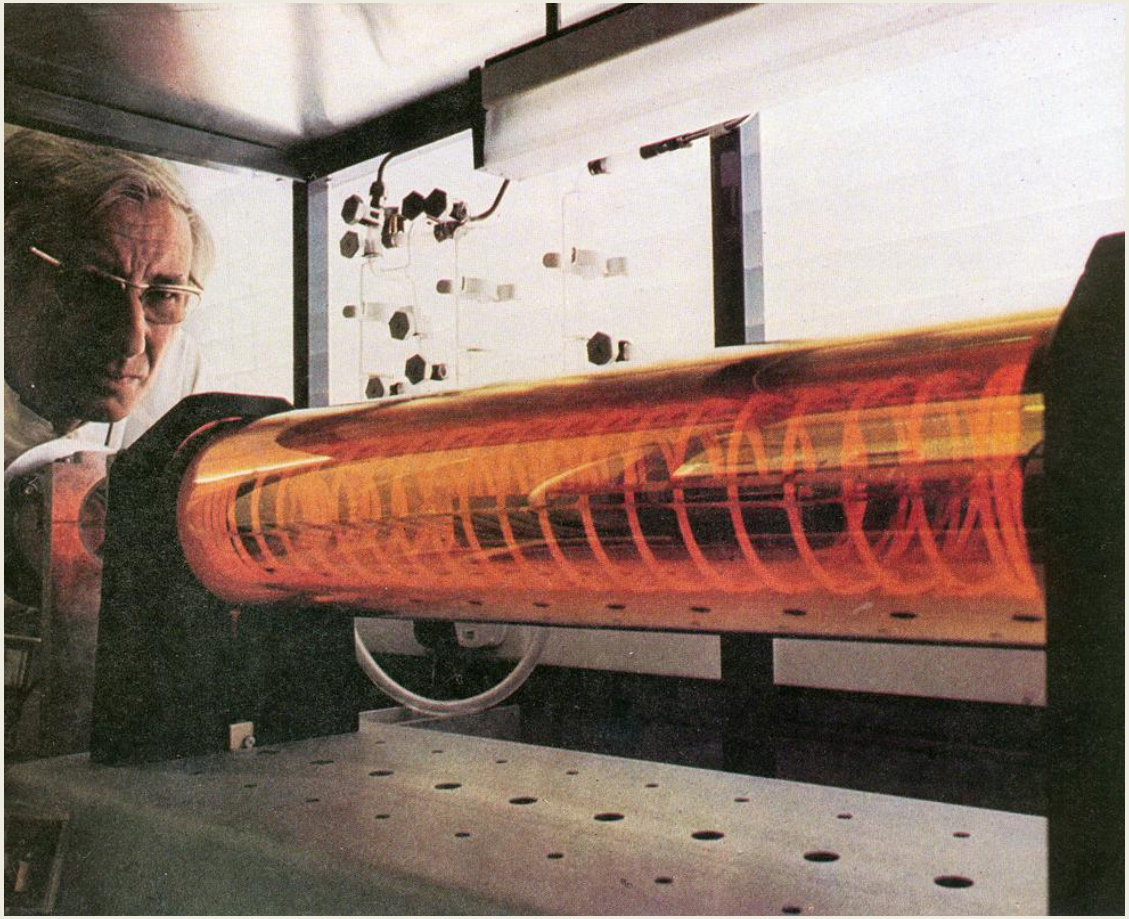
Print | Share

Aiming a laser at an aircraft is a serious safety risk and violates federal law. Many high-powered lasers can completely incapacitate pilots who are trying to fly safely to their destinations and may be carrying hundreds of passengers. Unfortunately, reported incidents of lasers aimed at aircraft are steadily increasing.

Report a laser incident



What is a LASER ?



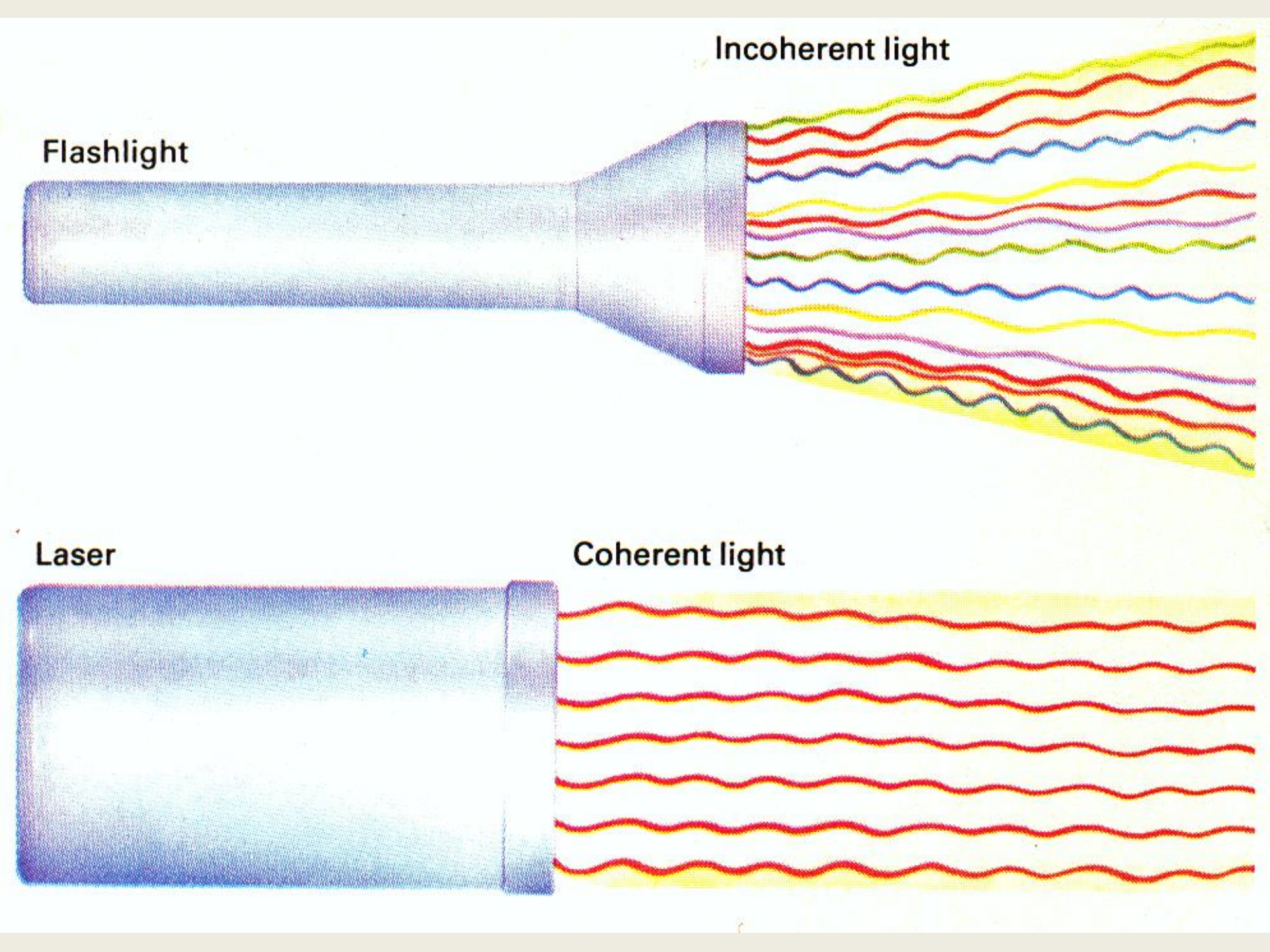
Light **A**mplification by **S**timulated **E**mission of **R**adiation

Properties of LASER Light

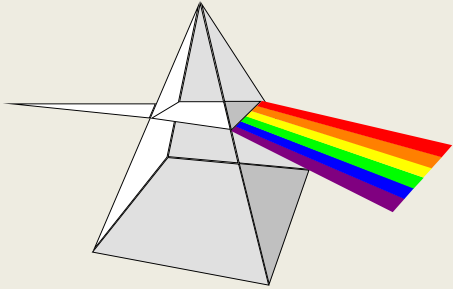
MONOCHROMATIC: **It is of one color, in contrast to ordinary white light which is a combination of many colors**

DIRECTIONAL: **LASERS emit a narrow beam of light in one specific direction. Ordinary light (light bulb) is emitted in many directions**

COHERENT: **The wavelengths of the LASER light are in phase in space and time**


Incoherent light
Flashlight
Laser
Coherent light

Types of LASERS



VISIBLE:

LASERS that produce a beam of light with a wavelength in the visible portion of the electromagnetic spectrum (400-780 nm).

Used for outdoor light shows

INVISIBLE:

LASERS that produce a beam of light with a wavelength in the invisible portion of the electromagnetic spectrum (UV 200-400nm and IR 780nm-1mm)

Classification of Lasers (FDA)

CLASS I:

- Visible LASERS that do not cause biological damage
- Emit <0.39 microwatts (μW) - CD-Player

CLASS II:

- Visible LASERS that can cause eye damage after direct and prolonged exposure
- Eye blinking provides protection
- Emit >0.39 microwatts (μW) and <1 milliwatt (mW) - Supermarket Checkout Scanners

Classification of Lasers (FDA)

CLASS IIIa:

- Visible LASERS that can cause eye damage after a short exposure
- Emit between 1 mW and <5 mW (LASER pointers, gun LASER sights)

CLASS IIIb:

- Visible LASERS that can cause tissue damage after a short exposure (direct or reflected)
- Emit between 5 mW and <500 mW

Type of LASER and Affected Airspace

Class IV:

- Emit ≥500 mW
- Represent a risk to the occupants of aircraft
- The magnitude of the risk depends upon the level of energy of the LASER and the divergence of the light beam

Mechanisms of Tissue Damage

THERMAL:

- **Major cause of tissue damage**
- **The degree of thermal damage depends upon**
  - *the **thermal sensitivity** of the tissue,*
  - ***wavelength** of the light,*
  - ***amount** of tissue exposed,*
  - ***energy** of the beam, and exposure **time***
- **Tissue damage can range from erythema to a burning**

ACOUSTIC:

- Localized vaporization of tissue creates mechanical shockwaves that spread through the tissue
- These shockwaves cause tearing of the tissue

PHOTOCHEMICAL:

- LASERS can cause tissue damage by changing the chemical composition of the cells

- **The energy output of a LASER can be increased by decreasing (concentrating) the diameter of the light beam using an optical lens**

- **The accommodation power of the lens in the human eye can increase up to 100,000 times the energy output of a LASER**

- **An energy output of 1w produced by a Class IV LASER can be intensified by the lens to produce a temperature on the surface of the retina that is higher than the temperature measured on the surface of the sun**

Bioeffects: Eye Tissues

CORNEA:

- Superficial epithelial lesions are temporal (48 hrs)
- Deeper corneal lesions are permanent (corneal opacities)

LENS:

- Thermal lesions of the lens can cause cataracts

RETINA:

- Thermal lesions of the fovea can cause permanent loss of central vision and/or color vision
- Thermal lesions of the peripheral retina can cause permanent localized loss of vision (scotoma)

Visible and Near Infrared (IR-A) LASER light wavelengths (400-1400nm) are known as the "Retinal Hazard Region"

Temporary Effects

- Flash Blindness: visual loss during and after exposure to a high intensity flash of light

- After-Images: a persisting sensation or image perceived after exposure to the LASER beam - pilots miss critical flight information

- Glare: dazzling sensation of a bright light that produces discomfort, blinking, and squinting - pilots miss critical flight information

- **Startle: disrupts cockpit procedures and information flow**
- **Headache and Nausea: cause distraction**
- **Eye Burning Sensation ⟹ Profuse Eye Tearing**
- **Intraocular Floaters: detached death cells from the retina and the choroid**
- **Loss of Night Vision Adaptation: Partial re-adaptation takes 3-5 min and total 40-45 min**

Potential Visual Effects vs. Distance From Laser Source

Startle
Distraction
50 nW/cm²

Glare
5 µW/cm²

Flashblindness
Afterimages
100 µW/cm²

Ocular Lesions
2.6 mW/cm²

Nominal Ocular Hazard Distance (NOHD)

Safety distances for a legal green laser pointer (5 mW, 532 nm)

No distraction

Indistinguishable from background lights beyond 11,712 ft.

Distraction hazard to 11,712 ft.

12,000

11,000 ft.

2 miles

10,000 ft.

9,000 ft.

8,000 ft.

7,000 ft.

6,000 ft.

5,000 ft.

1 mile

4,000 ft.

3,000 ft.

2,000 ft.

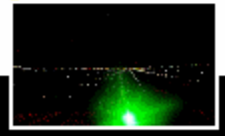
1,000 ft.

Ground

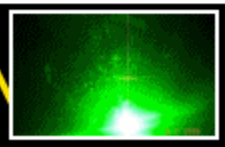
Glare/disruption hazard to 1,171 ft.

Temporary flashblindness hazard to 262 ft.

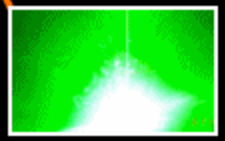
Eye hazard to 52 ft.



Distraction example at 3,700 ft. (0.5 μW/cm²)



Glare/disruption example at 1,200 ft. (5 μW/cm²)



Near-flashblindness example at 350 ft. (50 μW/cm²)

International Laser Display Association

Lasers and Aviation Safety - 2009

Patrick Murphy

Eye and visual hazard distances for 532 nm (green) lasers of various powers

Laser power	Power increase, compared to 5 mW	Square root of power increase	Maximum eye hazard distance, feet / *meters*	Maximum flashblindness hazard distance, feet / *meters*	Max. glare/ disruption hazard distance, feet / *meters*	Maximum distraction hazard distance, feet / *meters*	"Safe" distance (laser is not considered a distraction)
5 mW	1	1	52 / *16*	260 / *80*	1200 / *366* **1/4 mile**	11700 / *3560* **2.2 miles**	Beyond 2.2 miles
50 mW	10x	3.162	164 / *50*	822 / *250*	3794 / *1156* **7/10 mile**	36995 / *11276* **7 miles**	Beyond 7 miles
125 mW	25x	5	260 / *79*	1300 / *396*	6000 / *1829* **1.1 miles**	58500 / *17830* **11 miles**	Beyond 11 miles
250 mW	50x	7.071	368 / *112*	1838 / *560*	8485 / *2586* **1.6 miles**	82730 / *25216* **15.7 miles**	Beyond 15.7 miles
500 mW (1/2 watt)	100x	10	520 / *160*	2600 / *800*	12000 / *3660* **2.3 miles**	117000 / *35600* **22.2 miles**	Beyond 22.2 miles

Figure 5: *Eye and visual hazard distances for 532 nm (green) lasers of various powers*

Suspected Laser Incident Report

- ✈ Date and local time of incident
- ✈ Aircraft location/ disposition:
  - Near (airport/city)
  - Phase of flight
  - Heading
  - Altitude
  - Aircraft bank and pitch angles
- ✈ Light source location
- ✈ Direction light entered cockpit
- ☎ Light description:
  - Color
  - Static or moving
- ☎ Affect on crewmember(s)
- ☎ Type of aircraft
- ☎ Weather conditions
- ☎ Crewmember age
- ☎ Glasses, contact lenses, etc.

Federal Aviation Administration

Mobile

Laser Incident Reporting Form

Your Details

Name of pilot/crew member reporting

First and last name

Email address

example@domain.com

Flight Details

Flight number, call sign, and aircraft registration number

e.g. SWA572, Southwest, N12345...

Aircraft Make and Model

e.g. Boeing 737, Cessna 172, Airbus A320...

Laser Incident Details

Laser light color:

Select Beam Color

Date

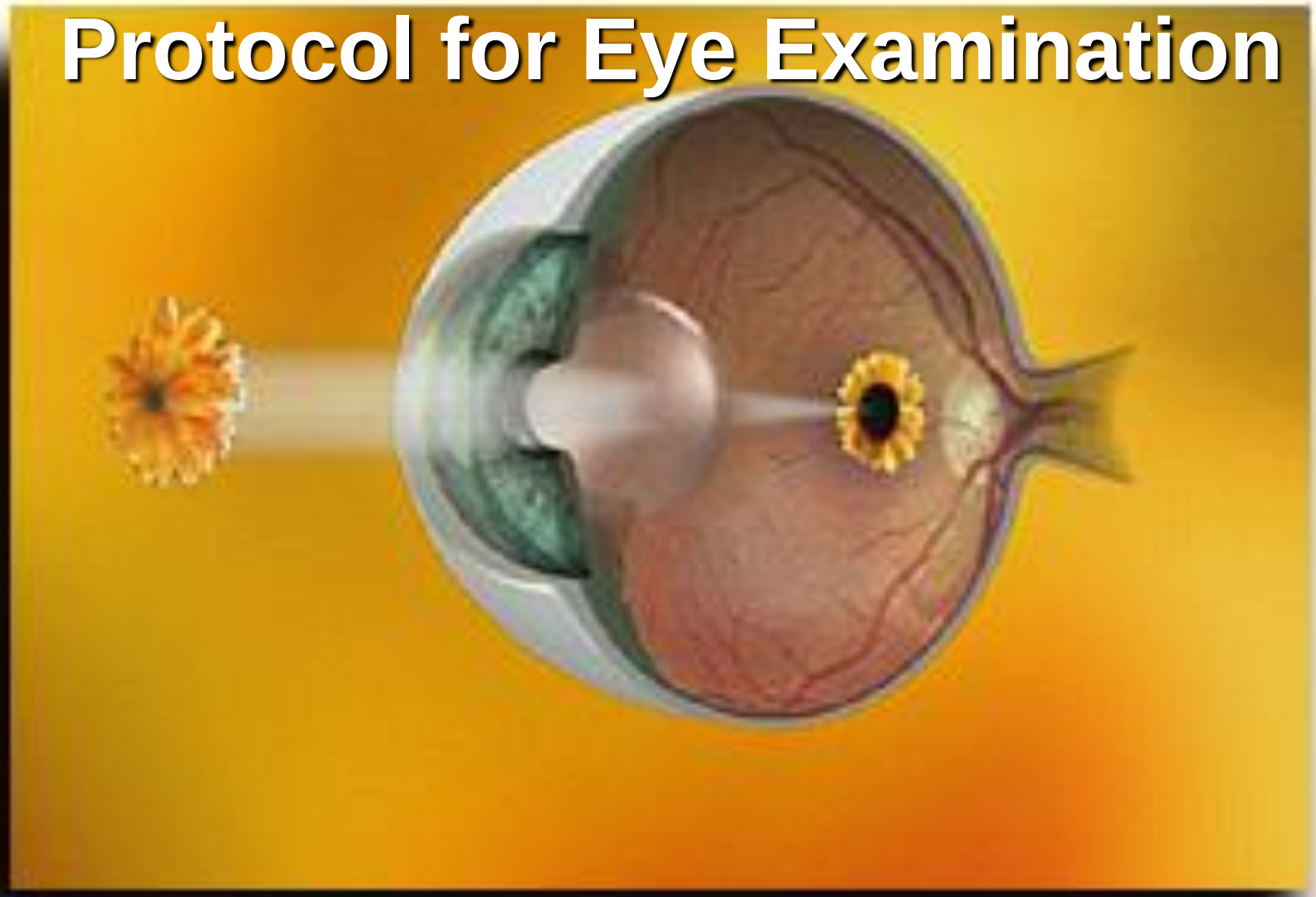
2013-01-16

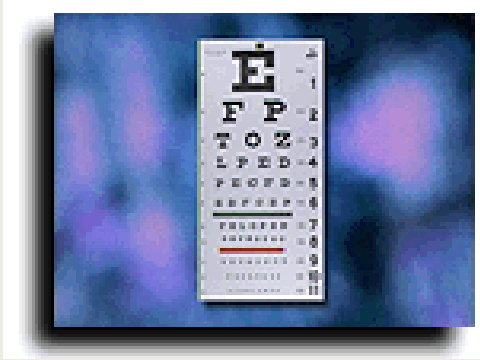
Time (UTC/Zulu)

21:29

Location of aircraft during incident

Protocol for Eye Examination





Basic Examination:

- History
- External examination, including skin
- Best visual acuity (near and far) O.D., O.S.
- Amsler Grid O.D., O.S.
- Stereopsis Test
- Color Vision
- Nondilated Fundoscopy O.D., O.S.
- Confrontation Visual Fields O.D., O.S.

- **Intermediate Examination:**
  - Pupils O.D., O.S.
  - Slit Lamp
  - Dilated Fundoscopy
  - Motility (Ductions and Versions)
  - Automated Visual Fields

- **Advanced Ocular Examination:**
  - Stereo 35mm fundus photographs
  - Fluorescein Angiography
  - Electrodiagnostic tests

Flight Surgeon Exam and Actions

Dilated Retinal Exam

Evaluate for retinal changes, blood, burns, white lesions

Laser Physical Effects

- Glare “Dazzle”
- Flash-blindness
- Irritation
- Photophobia
- Headache & eye pain
- Sub-clinical tissue damage
- Visible retina and ocular damage
- Retinal hemorrhage

Laser Aviation Effects

- Surprise / Startle effect
- Distraction
- Inability to discern instruments and landing lights

- Mission compromise or failure
- Loss of aviator temporarily or permanently to flight

In-Air Exposure Procedures

- Look Away & shield eyes (don LEP=Laser **Eye Protection** if available)
- DO NOT rub the eyes – increases irritation
- Turn up instrument lights
- Mark the position, time, and report to ATC
- Unexposed co-pilot gets on instruments
- Query other crew members for exposure
- Self-examination using small print or Amsler grid (if available)
- 'Self-triage' vision
  - ⊡ able to read small print,
  - ⊡ check individual eyes,
  - ⊡ check pocket Amsler grid, nav charts, HUD or MFD for any visual defects
- Determine mission viability, if significant vision symptoms prevent safe continuance

"Aircraft Laser Illumination" edited version of FAA & Air Force video

https://www.youtube.com/watch?v=RtKSdy2KAW4


Aircraft Laser Illumination
Awareness for the Aviation Community
NORTHROP GRUMMAN

The CAA Accident Prevention Leaflet 2/2004 issued June

Civil Aviation Authority

What are these ◯?

Readers who consult their latest charts for the south of England may have noticed a new red marking "◯ Laser site unlim". This marking indicates the position of these sites where visible and infrared lasers of varying powers may be activated. It is similar to the marking for a gas venting station.

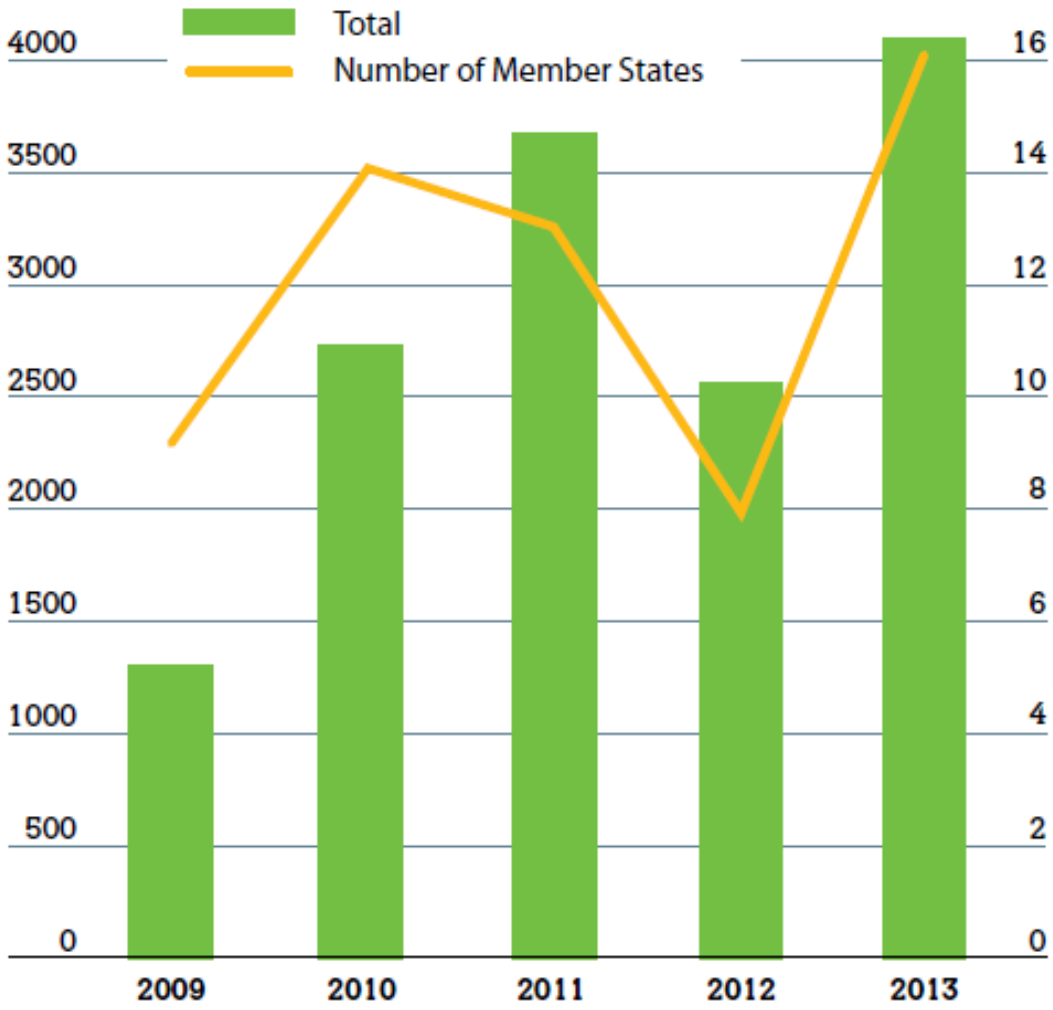
These Laser Hazard Areas have been published for some time in the AIP at ENR 5-3-11, and were mentioned in a GASIL article a few years ago. Although an accidental release of laser beams from these sites is extremely unlikely and would only result from total failure of all safety systems, the consequences if it should happen could be extremely hazardous. High power laser beams such as those on test, unlike those low-powered ones used for decorative purposes, can cause permanent eye damage. It has therefore been decided to mark the sites where this potential hazard might exist on the charts, and advise pilots to avoid overflying them.

EUROCONTROL

Annual Safety Report 2014

Safety Regulation Commission

Laser interferences reported by Member States via the AST mechanism



'……it should be noted that, for some Member States, laser interference' constitutes a security rather than a safety issue, hence they are not included in the above statistics.'

Laser Interference

The Safety Regulation Comission has **continued to monitor** the malicious use of high powered lasers, as this has been **identified as a global concern**. This type of incident is a possible hazard to aircraft safety, especially during final approach.

The SRC, through the AST-FP Group, continues to follow and support the developments, activities and initiatives in this area. It should also be noted that at its meeting in March 2013, the AST-FP Group concluded that a **"new" even more powerful so-called "blue laser" device is being used more often**, which could further endanger flight-crews and others.

In this context, a number of Member States expressed the view that a **ban on the buying and selling of laser pointers was under discussion at national level, with a solution expected for 2014.** It was underlined that the matter is quite serious and cannot be postponed until harmonised EC legislation is available, as was concluded at the Laser Seminar in EUROCONTROL in October 2011. Therefore, related legislative proposals and other actions have already been initiated in some ECAC States.

ÉGETŐ BRUTÁL erős látható fényű ZÖLD LÉZER POINTER

4 / 5

SDLaser 303 1000mW Green Laser

ebay Shop by category | Search... | All Categories

Back to previous page | Listed in category: Consumer Electronics > Gadgets & Other Electronics > Laser Pointers

NEW 450nm Blue Most Powerful Military Focusable Laser Pointer Pen Burn Beam Kit

2 viewed per hour

Price: US $109.00
Approximately 30,756.21 HUF

Buy It Now

Add to cart

Best Offer: Make Offer

196 watching

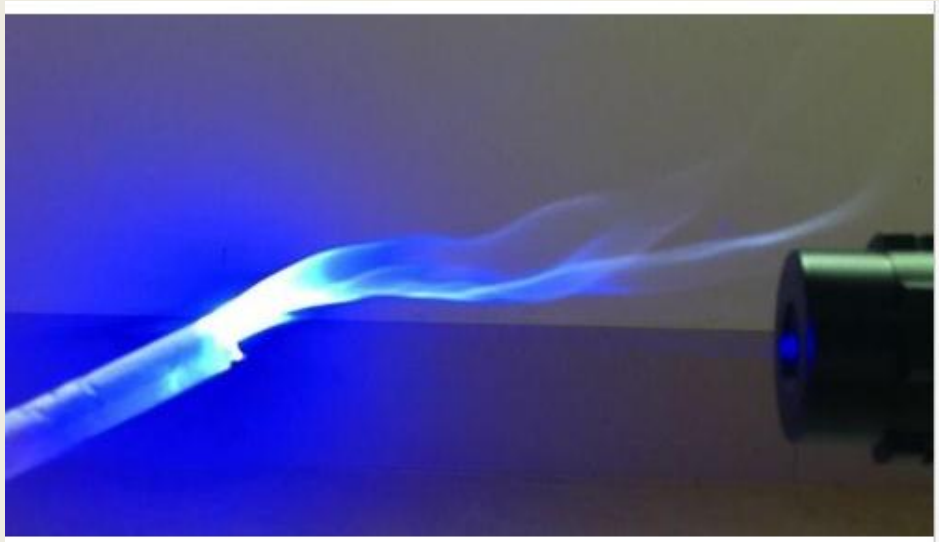
Add to watch list

Add to collection

66 Sold | Free Shipping | More than 87% Sold

Shipping: FREE Economy Int'l Shipping | See details
International items may be subject to customs processing and additional charges.
Item location: guangzhou,gungdong, China
Ships to: Worldwide See exclusions

NEW 450nm Blue Most Powerful Military Focusable Laser Pointer Pen Burn Beam Kit



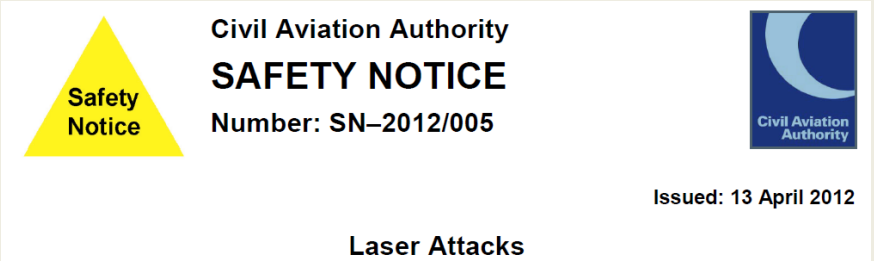
The United Kingdom
had 30 instances in 2007 and there have been around 1,600 up until September 2011.

6.1 This Safety Notice shall remain in force until 31 January 2016.

The Threat

Laser attacks on aircraft started some years ago when laser pointers became readily available and have now escalated such that 2,300 events were recorded on the CAA's Mandatory Occurrence Reporting database for 2011.

The main threat posed by a laser attack on an aircraft or an ATC tower is from the reaction of the pilot/controller to the laser light. **The earliest laser attacks were from red-light lasers; most current attacks are from green-light lasers** (around the wavelength of 532 nm). The human eye is much more sensitive to green light, so for an equivalent laser output power the green light appears to be much brighter.



Safety Notice

Civil Aviation Authority

SAFETY NOTICE

Number: SN–2012/005

Civil Aviation Authority

Issued: 13 April 2012

Laser Attacks

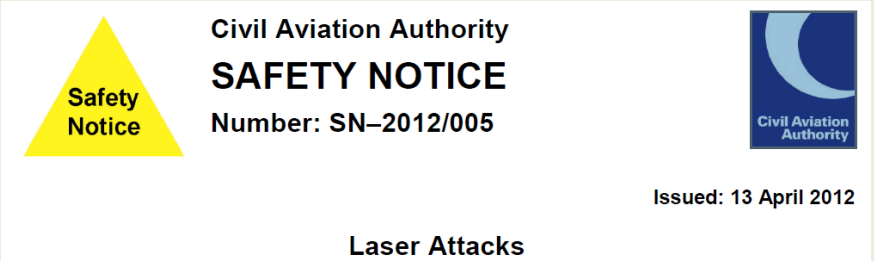
The Threat

The main problems with a laser attack are that they are always sudden, very bright, distracting, and can cause temporary visual disturbance for some time after the attack. So far, there have been no documented cases anywhere in the UK where civil aircrew have suffered permanent eye damage as a result of an attack.

Although this possibility cannot be totally discounted, current knowledge and experience suggests that permanent eye damage is unlikely. This is principally because the power levels available to hand-held lasers are low and the distances from the laser to the aircraft or tower together with the presence of tower and cockpit transparencies provide some protection from the beam.

Nevertheless, the possibility of permanent eye damage at some time in the future due to higher power laser availability cannot be discounted.

The CAA has published a **self-assessment tool** designed to help those exposed to a laser to make an immediate assessment of their vision and determine whether or not they need to consult an eye specialist.


Safety Notice

Civil Aviation Authority

SAFETY NOTICE

Number: SN–2012/005

Civil Aviation Authority

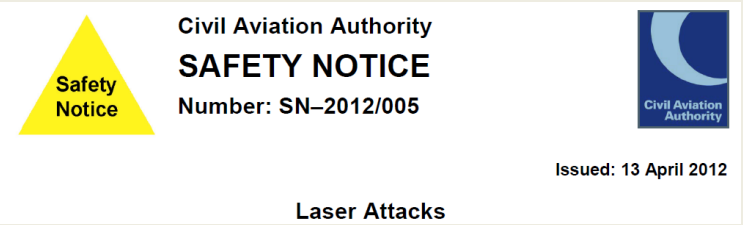
Issued: 13 April 2012

Laser Attacks

The Threat

The immediate effects of a laser attack are distraction and anxiety. The following are characteristics of a laser attack:

- it is always very sudden;
- it is always very bright;
- it is distracting;
- the glare may obscure many (if not all) instruments;
- night vision may be disrupted;
- even if the eyes are not directly illuminated there will be a temptation to look into the beam; and
- for some time after the attack there may be retinal ‘after images’ or even short-lived ‘flash’ blindness leading to concern that the eye has been permanently damaged.



Mitigation Strategies -aircrew/cockpit perspective

Before Flight

Assume that at some stage in your career your aircraft or control tower will be the subject of a laser attack or inadvertent laser illumination. Be reassured by the fact that no crew have suffered permanent eye damage from a laser attack.

Prepare yourself for the sudden shock that such an attack can have by reading this and similar communications and by following the advice in the links provided at the end of this notice.

Finally, view the training material provide in the links and view the video on laser attack.

Operators should establish Laser Awareness Training and detailed SOPs for crews and ATC controllers, as appropriate (this should use a structured approach and be comparable to guidance already published).

Mitigation Strategies -aircrew/cockpit perspective

During and Immediately After an Attack

In the event that your aircraft or your tower is deliberately and persistently illuminated (attacked) by a laser, the following immediate actions are recommended:

- ✓ Do not look into the beam and shield eyes to the maximum extent possible.
- ✓ Inform ATC as soon as possible and in particular if a decision has been made to diverge from the cleared flight path.
- ✓ Consider re-engaging the autopilot (if disengaged), or handing control of the aircraft to the other pilot (if there is another pilot in the cockpit and he/she is less affected by the attack).
- ✓ If the aircraft is on the approach, consider executing a missed approach.
- ✓ Turn up cockpit lighting.
- ✓ Avoid rubbing eyes to reduce the potential for corneal abrasion (*see the instructions that accompany the self-assessment tool*).

Mitigation Strategies -aircrew/cockpit perspective

After the Attack

- As soon as possible after the attack provide ATC with as much detail as possible concerning the event so that law enforcement organisations can take appropriate action. If possible include a description of the location of the source of the laser beam, its direction and colour, and the length of exposure. Follow any additional company reporting procedures.
- Report the occurrence to the CAA as a Mandatory Occurrence Report (MOR).

- Use the **CAA published self-assessment tool to examine eyesight and, if necessary, seek assistance from an optometrist or ophthalmologist.**

Mitigation Strategies

3.2 Air Traffic Service Units are also reminded of the current guidance in the Manual of Air Traffic Services Part 1 (MATS Part 1) which at Section 2, Chapter 3 states:

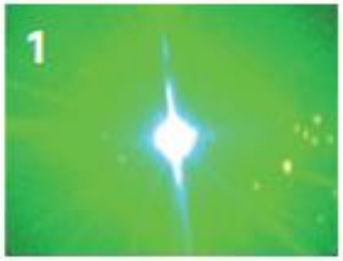
- Look away from the laser beam if possible – **Do not attempt to find the light source by staring at the laser.**
- Shield eyes and consider lowering/raising 'sun blinds' to reduce the effects.
- Advise aircraft under your control that a laser is illuminating you.
- Avoid rubbing eyes to reduce the potential for corneal abrasion (see the instructions that accompany the self-assessment tool).
- Consider the feasibility of increasing ambient light levels to minimise any further illumination effects.
- Consider handing over the control position to a colleague in a position not exposed to the laser.
- Where local arrangements have not been established, inform a Supervisor who, in turn, can:
- decide on restricting traffic in/out of the aerodrome;
- inform the aerodrome operator; and
- dial 999 and pass all relevant information to the local police.
- Ensure the event is recorded in the ATC watchlog and reported for further investigation by completing an ATC Occurrence Report (**SRG 1602).**
- In addition, ATC personnel exposed to a laser attack may also wish to use the **CAA published grid to self-assess eyesight or seek assistance from an optometrist or ophthalmologist.**

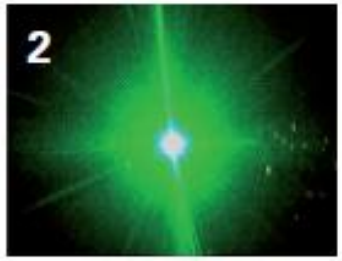
AVIATION LASER EXPOSURE
SELF-ASSESSMENT (ALESA)

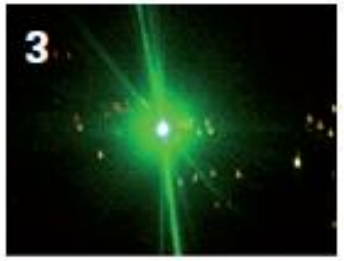
Civil Aviation Authority

This self-assessment is designed to aid pilots, air-traffic controllers, or flight crew members who have been exposed to a laser beam in making a decision on whether or not to see an eye specialist.

AVIATION LASER EXPOSURE
SELF-ASSESSMENT (ALESA)







1. **Flash blindness**
   A visual impairment during and after exposure to a very bright light. It may last for seconds or minutes.
2. **Glare**
   Difficulty seeing in the presence of a bright light.
3. **Distraction**
   A light bright enough to disrupt attention.

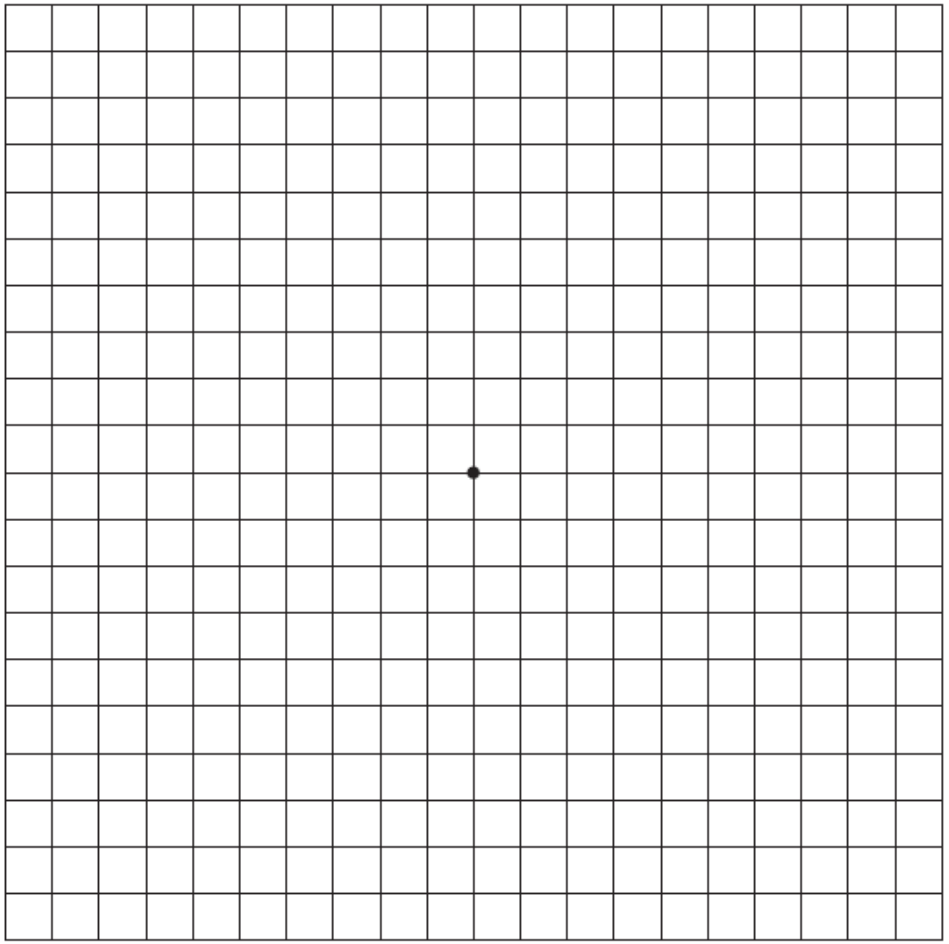
AVIATION LASER EXPOSURE
SELF-ASSESSMENT (ALESA)

Civil Aviation Authority

While viewing the grid from 30cm in front of your eyes, please test one eye at a time to answer the following questions:

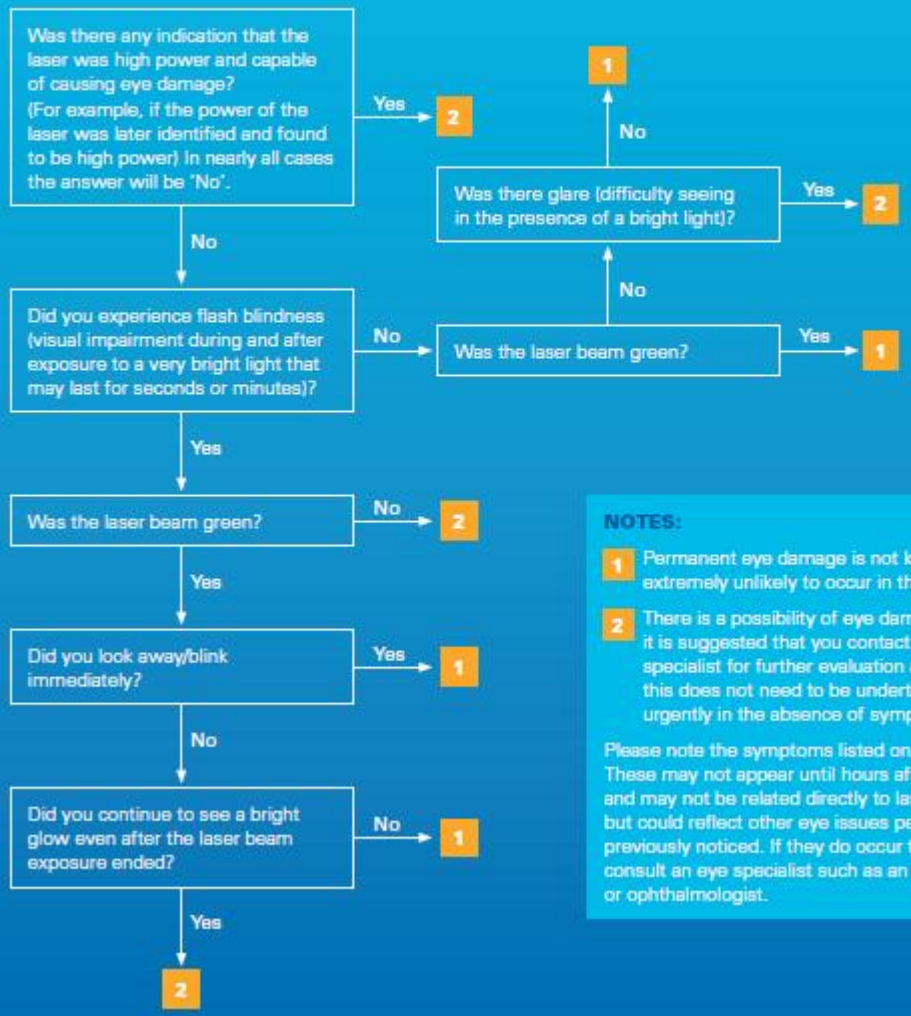
1. Can you see a dot in the centre of the grid?
2. While looking at the centre dot, can you see all four sides and corners of the grid?
3. While looking at the centre dot, do all of the lines appear straight with no distortions or blank or faded areas?

If you answered **YES** to all three questions then please turn to page 2. If you answered **NO** to any of the above questions then you may wish to remove yourself from flying or controlling duties as soon as it is safe to do so and consult an eye specialist.



The dimensions of the grid should be 10cm x 10cm.

In some circumstances it may be possible to have retinal damage without obvious symptoms. The relevance of this is uncertain in the absence of abnormal visual signs (e.g. answering "yes" to all three Amsler Grid questions on page 1) as it is unlikely to have an operational impact or be amenable to treatment. The following is designed to aid a pilot or ATCO in deciding whether or not an assessment should be sought with an optometrist or ophthalmologist after an exposure.



NOTES:

1. Permanent eye damage is not known or is extremely unlikely to occur in this situation.
2. There is a possibility of eye damage and it is suggested that you contact an eye specialist for further evaluation although this does not need to be undertaken urgently in the absence of symptoms.

Please note the symptoms listed on page one. These may not appear until hours after exposure and may not be related directly to laser exposure but could reflect other eye issues perhaps not previously noticed. If they do occur then please consult an eye specialist such as an optometrist or ophthalmologist.

Flash Blinding - different than laser

Mental case man used mirror / polished sheet-metal for disturbing landing airplanes

Flash Blinding - different than laser

Mental case man used mirror / polished sheet-metal for disturbing landing airplanes

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Manual on Laser Emitters and Flight Safety

Approved by the Secretary General
and published under his authority

First Edition — 2003

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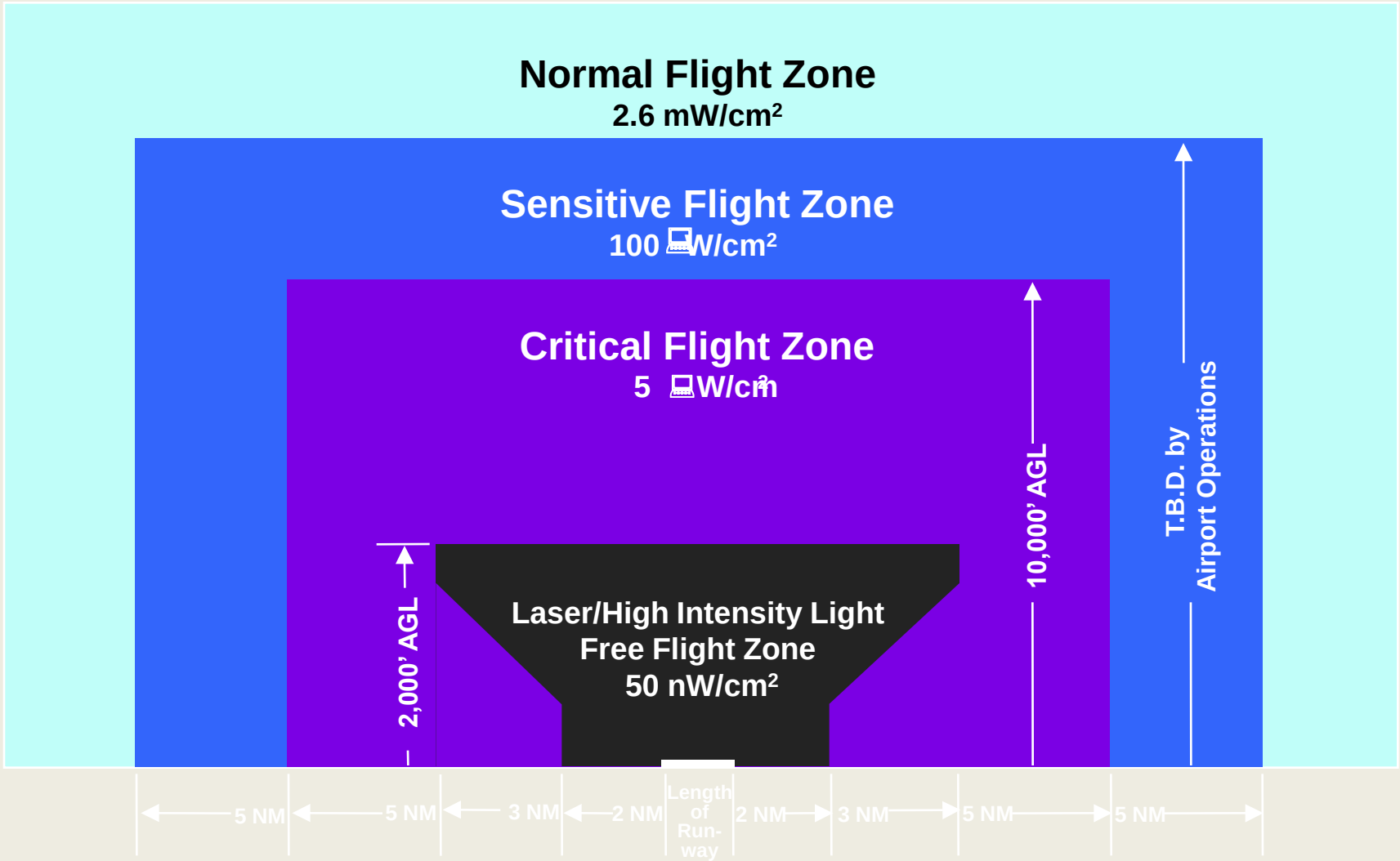


Side Elevation

Appendix B

SUSPECTED LASER BEAM INCIDENT REPORT AND SUSPECTED LASER BEAM EXPOSURE QUESTIONNAIRE

SUSPECTED LASER BEAM INCIDENT REPORT

This form may be used by local ATC or airline authorities to report a suspected laser beam exposure. When completed, the report should be forwarded to the competent authority as soon as possible for further investigation.

Appendix C

AMSLER GRID TESTING PROCEDURE

The Amsler grid test is designed to detect defects in the central visual field of an eye, corresponding to retinal lesions as small as 50 micrometres.

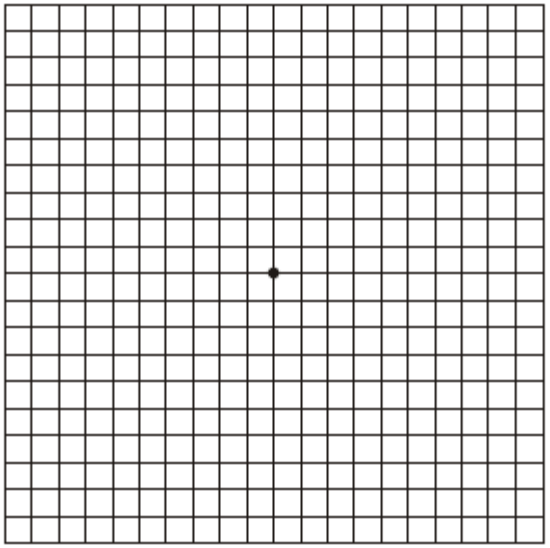
The chart below is sized to be viewed at a distance of 28–30 cm, the usual distance for reading tests. At this distance the test will examine the central 20 degrees of the patient's field of vision for abnormalities, with each small square equivalent to 1 degree. Before using this chart:

a) the refraction of the eye in question must be exactly corrected for this distance;

b) the chart must be clearly and evenly illuminated as for a reading test;

c) all artificial mydriasis and any ophthalmoscopy immediately before the examination must be avoided; and

d) the other eye should be covered, preferably with an occluder.



Summary

- The incidence of illumination is significantly increasing.
- Almost 70% of laser incidents occur between 2K and 10K feet AGL
- Almost 70% of all incidents occur between the hours of 7 to 11 pm (25% between 9 – 10 pm) .
- The fewest incidents occur during the months of May, June, and July (16%).
- Percentage of incidents by type of flight:
    - 66% Commercial
    - 6% Helicopters (Med Evac./Law Enf.)

Conclusion

- **Incidents associated with authorized laser operations are rare, but illumination reports from handheld lasers have increased in recent years. This may be due to increased awareness and a better reporting system.**
- **Handheld lasers are cheaper and more powerful.**
- **Better consumer awareness may be needed concerning misuse and potential penalties (e.g. labeling).**
- **Continued monitoring by aviation & law enforcement is warranted.**

Sources of this slideshow

Documents, presentations of

- FAA
- NTSB
- ICAO
- Eurocontrol
- CAA UK

Mainly available on their website.

Thank you for your attention ☺

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