

RASG-MID SAFETY ADVISORY – 12

(RSA-12)



Revision 1 – September 2017

MID-Region

LASER Attacks Safety Guidelines

Date of Issue:	March 2017
Revision:	No. 1 dated September 2017
Document Ref. No.:	RASG-MID/MIDRAST/RGS/SEI/06
Owner:	RASG-MID

These guidelines are developed by the LASER Attacks team - Runway and Ground Safety Working Group (RGS WG), as part of MID-RAST/RGS/6 DIP deliverables, based on the work of the Egyptian Civil Aviation Authority in collaboration with the ICAO MID Regional Office.

Disclaimer

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Regional Safety Advisory

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INTRODUCTION

PURPOSE

This Guidance Material provides general information and advice on measures to protect pilots of civil aircraft from accidental laser beam strikes, on or in the vicinity of an aerodrome. This guidance should be used in the planning and control of advertising, entertainment, and similar visual displays using visible laser light. This Guidance Material is unlikely to prevent willful laser attacks against aircraft, but it is the intension of using it as a control tool for malicious laser attacks.

It should be of interest to air Traffic controllers, aerodrome operators, and to the operators of laser shows. It may also be of interest to pilots and airlines.

GLOSSARY

Irradiance (E):

The power per unit area expressed in watts per square centimeter (W/cm^2) or watts per square meter (W/m^2). Small values may be expressed as micro (10^{-6}) watts per square centimeter ($\mu W/cm^2$) or nano (10^{-9}) watts per square centimeter (nW/cm^2).

Laser:

- 1) An acronym for light amplification by stimulated emission of radiation.
- 2) A device that produces an intense, coherent, directional beam of optical radiation by stimulating emission of photons by electronic or molecular transition to lower energy levels.

Maximum Permissible Exposure (MPE):

The internationally accepted maximum level of laser radiation to which human beings may be exposed without risk of biological damage to the eye or skin.

Protected Flight Zones:

Airspace specifically designated to mitigate the hazardous effects of laser radiation.

GENERAL

The development of the laser and the industrial application of laser technology stand out as some of the most significant scientific contributions of the 20th century. Presently, lasers are found virtually everywhere, from supermarkets and schools to satellites and operating rooms.

However, if used improperly, laser energy also poses a significant biohazard. Consequently, even the most innocuous laser pointer can become a safety hazard, either through direct bio-effects or by causing a disruption of critical performance tasks in hazardous situations.

Lasers can produce a beam of light of such intensity that permanent damage to human tissue, in particular the retina of the eye, can be caused instantaneously, even at distances of over 10 km. At lower intensities, laser beams can seriously affect visual performance without causing physical damage to the eyes.

Protection of pilots against accidental laser beam strike has become a serious factor in aviation safety with the advent of the laser light display for entertainment or commercial purposes.

Chapter 1

REGULATORY

The need of provisions which establishes and enforces regulations for commercially available laser devices based on safe exposure criteria derived from current medical knowledge is highly considered.

First, lasers fall into five general categories: (the higher the class number, the greater the hazard) Class I, Class II, Class IIIa, Class IIIb, and Class IV. Class I includes devices, such as laser printers and DVD players, that have enclosed lasers designed to prevent the escape of any harmful radiation. Class II lasers emit visible light and are considered too bright to view for extended periods, but momentary viewing is not considered hazardous. Class IIIa devices are hazardous if the beam is viewed directly, but cannot produce a reflected beam hazard unless viewed for extended periods at close range. Most commonly available laser devices, such as laser pointers and laser levels, are either Class II or Class IIIa devices.

Furthermore, although not manufactured for use as “legal” laser pointers, some Class IIIb lasers packaged as laser pointers can be purchased over the Internet. Momentary exposure to a Class IIIb laser can cause eye damage. More powerful Class IV lasers used in research, medical, industrial, and military applications can pose fire hazards, damage skin, and can cause significant eye damage even when viewed indirectly. Various safety precautions, including eye protection, are needed when working around these devices. While not widely available, these powerful lasers could potentially be used as a terrorist weapon to attempt to incapacitate a flight crew.

Most of the recent laser incidents may be attributable to the increasing availability and reduced cost of green laser pointers. Green lasers pose particular hazards to pilots because they are perceived to be about 35 times brighter than equivalently powered red lasers due to the fact that humans are so much more sensitive to green light.

One policy option that may be considered, is whether to apply different standards for laser output based on the color (wavelength) emitted by the device. Another option is to restrict the sale or establish tighter controls on the use of certain laser devices, i.e.: restricted sales of Class IIIa laser pointer devices in response to several incidents involving lasers directed at aircraft (it can be expressed in terms of power).

The Civil Aviation Authority has the right to adopt all protective measures required to prevent the committing of acts and offences against the safety and security of civil aviation, or on board aircraft of the national carrier, in accordance with the relevant international rules

To protect the safety of aircraft against the hazardous effects of laser emitters, the following protected zones should be established around aerodromes:

- a) a laser-beam free flight zone (LFFZ);
- b) a laser-beam critical flight zone (LCFZ); and
- c) a laser-beam sensitive flight zone (LSFZ).

Geographical Identification of Hazard From Aerodrome Reference Point
Free Zone : Within 3 Nautical Miles (5.5 kilometers)
Critical Zone: within 10 Nautical Miles (18.5 kilometers) radius of the Extended Runway Centerline.
Sensitive Zone : beyond than 10 NM
NOTE : 1- If this is not possible, then the light display may represent a threat to flight safety and should not proceed. 2- Aerial fireworks displays should be limited to a height of 1500 ft above ground level.

ICAO Annex 14 figures, as shown below, may be used to determine the exposure levels and distances that adequately protect flight operations.

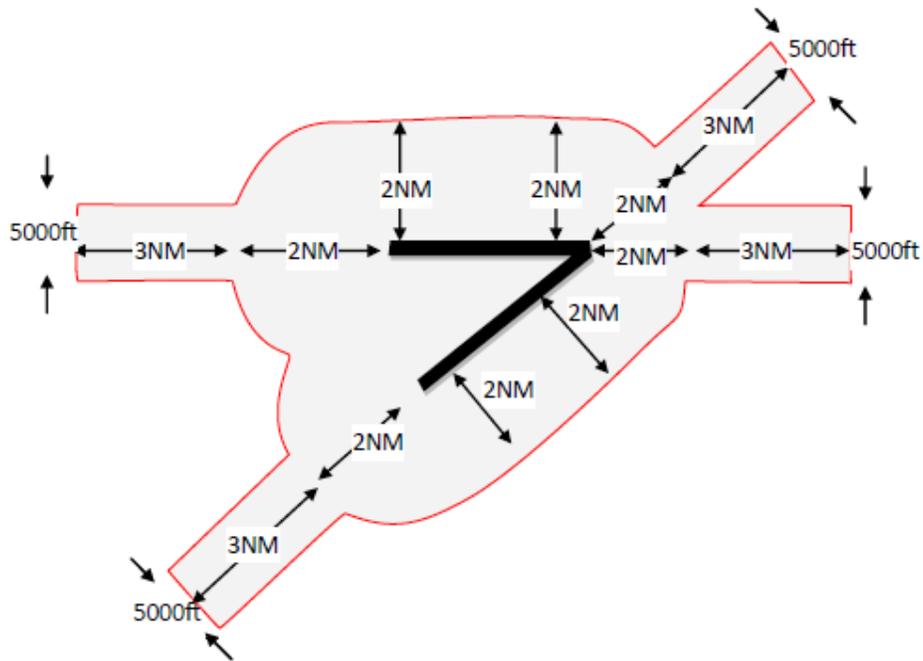


Figure 1: Multiple Runways LFFZ

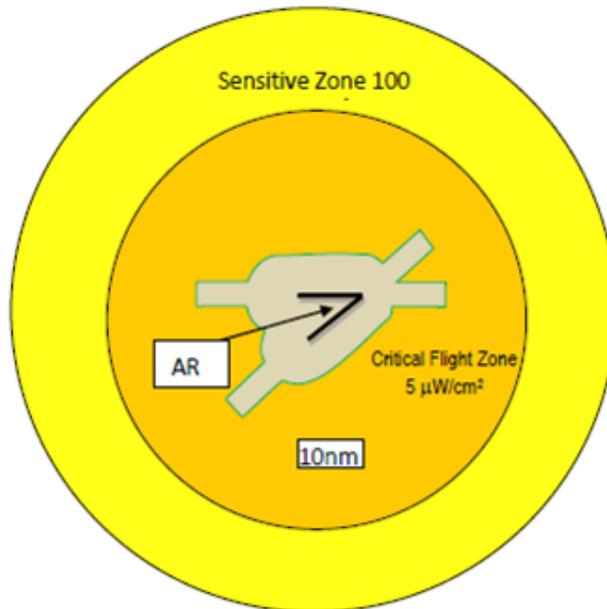


Figure 2: Multiple Runways LCFZ

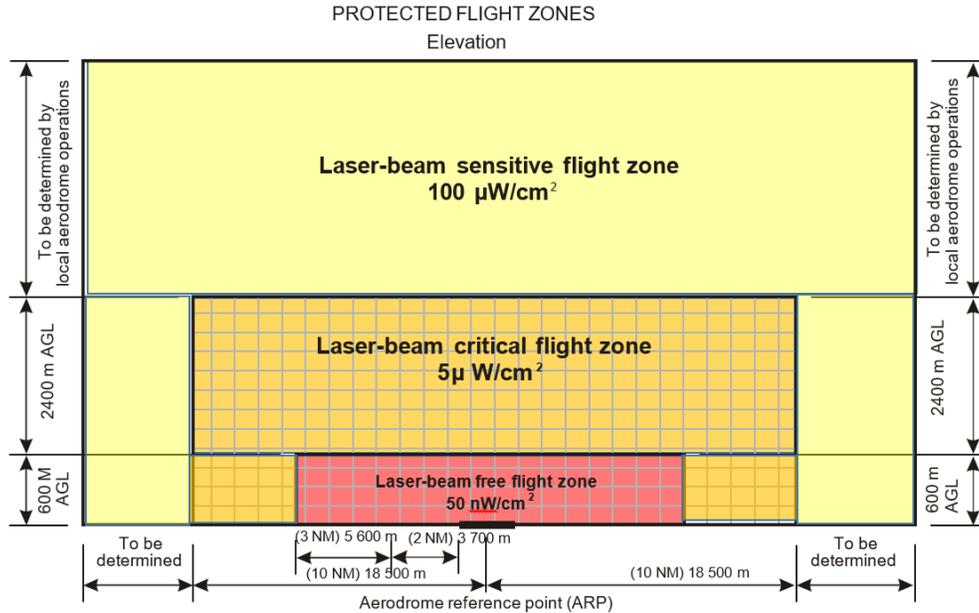


Figure 3: Maximum Irradiance Levels

The restrictions on the use of laser beams in the three protected flight zones, LFFZ, LCFZ, and LSFZ, refer to visible laser beams only.

Laser emitters operated by authorities in a manner compatible with flight safety are excluded from these restrictions. Typical examples of lasers used to support aviation include some cloud base or visibility measurement equipment, some bird harassing devices, and some aircraft docking guidance systems. Aerodrome authorities are to ensure that these lasers have the beam aimed in such a direction, and/or that the times of operation are controlled, to ensure no hazard is posed to aircraft operations.

In all navigable air space, the irradiance level of any laser beam, visible or invisible, is expected to be less than or equal to the maximum permissible exposure (MPE) unless such emission has been notified to the authority and permission obtained.

The protected flight zones are established in order to mitigate the risk of operating laser emitters in the vicinity of aerodromes.

The dimensions indicated for the various zones are given as guidance, but ICAO Doc 9815 advises that they have been found to provide for the safe operation of aircraft in the vicinity of aerodromes.

Laser-Beam Free Flight Zone

Within this zone, the intensity of laser light should be restricted to a level that is unlikely to cause any visual disruption. The irradiance should not exceed 50 nW/cm² unless some form of mitigation is applied. The level of brightness thus produced is indistinguishable from background ambient light.

Laser-Beam Critical Flight Zone

While the suggested extent of this zone is shown in the Figures, this zone may have to be adjusted to meet air traffic requirements.

Within this zone the irradiance should not exceed $5 \mu\text{W}/\text{cm}^2$ unless some form of mitigation is applied. Although capable of causing glare effects, this irradiance will not produce a level of brightness sufficient to cause flash-blindness or after-image effects.

Laser-Beam Sensitive Flight Zone

The extent of this zone should be determined by the operations at the particular aerodrome. The LSFZ need not necessarily be contiguous with the other flight zones.

Within this zone the irradiance should not exceed $100 \mu\text{W}/\text{cm}^2$ unless some form of mitigation is applied. The level of brightness thus produced may begin to produce flash-blindness or after-image effects of short duration; however, this limit will provide protection from serious effects.

Normal Flight Zone

The NFZ is any navigable airspace not defined as LFFZ, LCFZ or LSFZ. The NFZ should be protected from laser radiation capable of causing biological damage to the eye.

The maximum irradiance level (MIL), should be equal to or less than the maximum permissible exposure (MPE).

Chapter 2

HAZARD

The red laser pointer commonly seen in classrooms and conference venues are low-powered devices of less than one milliwatt (mW). These are normally with insufficient power to cause actual physical harm, although they still require care in their operation and use.

Green laser pointers are readily available with a maximum power rating of 5 mW, and are classified as more hazardous. The eye's maximum sensitivity to visible light is around the wavelength of a green laser, and the eye will interpret a green laser light of a given power as being up to 30 times brighter than a red laser of the same power. Direct eye exposure to a green laser beam can result in temporary visual impairment.

Some effort would be required to inflict actual eye damage with a 5 mW green laser pointer as both the low power and the eye's natural defense (blinking reflex) would combine to limit potential damage. However, some vendors are now advertising higher-powered (from 10 to 400 mW) green laser pointers which are definitely harmful, and can cause permanent eye damage.

The severity and duration of the vision impairment varies significantly, depending on the intensity and wavelength of the light, the individual's current state of light (or dark) adaptation, and even the person's skin pigmentation (eye colour). The effects of exposure to a laser beam include:

Distraction: The dazzling effect on the eye can be a major distraction, particularly in situations of high workload (e.g. take-off, approach, and landing).

Temporary Visual Impairment: Adverse visual effects that include: glare (a temporary disruption in vision caused by bright light within an individual's field of vision); flash-blindness (the inability to see, caused by bright light entering the eye) that persists after the illumination has ceased; and after-image (an image that remains in the visual field after exposure to a bright light).

Eye Injury: Temporary or permanent damage to the eye caused by exposure to laser light. Normally the result of direct exposure to prolonged or high power laser light.

Laser illumination of aircraft can cause distraction, disorientation, and discomfort for pilots resulting in a potentially hazardous situation during critical phases of flight.

Chapter 3

ROLE OF AVIATION KEY PLAYERS

Airline

The time and place of an unauthorized illumination of an aircraft by a laser is difficult to predict, although there is evidence that aircraft operating in certain locations, particularly around aerodromes, are increasingly likely to be subject to unauthorized illumination. Whenever practicable, flights within areas of recently reported laser or bright light activity should be avoided. Pilots operating in controlled airspace should obtain an ATC clearance before deviating from their cleared flight path, having first dealt with their immediate safety.

Pre-flight Procedures:

- Notices to airmen (NOTAMs) should be consulted for location and operating times of laser activates and alternate routes should be considered.
- Aeronautical charts should be consulted for permanent laser activities (theme parks, research facilities, etc.).

All AOC holders should ensure that their exposition contains guidance information for crews on the immediate actions to be taken to mitigate the effects if their aircraft is targeted by a laser illumination. In the event that a pilot encounters an unauthorized laser illumination of an aircraft, the following actions are recommended:

- Pilots should avoid looking directly at the source (priority is to minimize exposure effects).
- If your vision is affected, hand over control (assuming a two-pilot crew, and that the other pilot has not been affected).
- Crews manually flying aircraft fitted with modern autopilots and Flight Management Systems (FMS) might need to consider autopilot re-engagement, and use of FMS to aid flight path control.
- Turning up cockpit lighting may assist in overcoming the 'flash' after-effects (peripheral vision may still be effective).
- Do not rub the eyes after exposure.
- If any lingering effect is experienced, crew members should be encouraged to seek medical attention if the eye exposure to a laser is of more than transient duration.
- Report the occurrence immediately to ATC, and as soon as possible through your normal reporting channel.

An unauthorized illumination of an aircraft by a laser considered as an aircraft incident and therefore a pilot experiencing a laser illumination occurrence is required to take a follow-up action through reporting the details of the incident.

Air Traffic Service

As soon as possible following laser illumination occurrence, the flight crew should report the incident by radio to the appropriate ATC unit. Expeditious reporting will assist the Police in locating the source of the laser transmission(s).

The initial radio report to ATC should include the following:

- Aircraft call sign
- Nature of report (laser/ Illumination) & Colour
- Aircraft position & altitude at time of occurrence
- Location of origin of light source or relative direction and estimated distance from aircraft
- Any other information that might assist law enforcement.

All ATS units advised of a laser illumination occurrence will take mitigation actions (as appropriate) to provide relevant information for pilots:

- Announce to any following aircraft.
- Forward report to the aerodrome management for liaison to react.

Aerodrome Management

Aerodrome authorities are to ensure that any lasers around have the beam not aimed in the aircraft direction, and/or that the times of operation are controlled, to ensure no hazard is posed to aircraft operations.

In case of LASER attack reported, coordinate with the local police force to establish the most expeditious reaction to such events and provide them with a detailed report to assist in locating the source of the laser in order to enforce stop of such hazard.

Advise AIS to issue cautionary NOTAM in case of repeated exposure.

Contact the CAA as soon as possible following report of a Laser illumination Incident.

Additionally, Aerodrome should monitor the laser-beam free flight zone as part of aerodrome serviceability inspections.

Laser emissions of which exceeds any of the limits or penetrates the protected zones described shall be extinguished, screened or otherwise modified so as to eliminate the source of danger.

If laser violation detected during inspections, it should be assessed and surveyed as soon as possible to determine the extent of the infringements. If they exceed the limits specified, the aerodrome will raise a NOTAM.

For any new light works in the vicinity of the aerodrome, aerodrome notify to CAA which has the authority to take action in case of any potential deficiency.

Aerodrome management should direct Laser, light and firework Organizers to seek CAA acceptance prior to displays.

Refer to **Appendix A** Form 1, for a model of suspected laser beam /firework incident report.

Chapter 4

GUIDELINES FOR LASER, LIGHT AND FIREWORK DISPLAY ORGANIZERS

This chapter refers to procedures concerned with temporary laser light and firework displays.

For light and firework displays, Organizers should notify the appropriate authority (normally CAA, or through aerodrome management) of their proposed activity. To allow time to de-conflict or co-ordinate the activity, as well as promulgate warnings to the aviation community and establish any control measures considered necessary, notification needs to be given at appropriate time in advance.

The appropriate authority will examine the proposal based on the following guidelines. If no further information is required then appropriate warning action will be carried out. While the Display Organizer will not routinely receive written confirmation of this, if further information or action is required from the Display Organizer, the appropriate authority may contact the originator of the proposal to discuss suitable future courses of action.

It is of prime importance that light displays and fireworks are never directed at or towards aircraft or aerodromes. The Light Display organizer should also nominate a single point of contact, who will be directly responsible for the conduct of the actual event.

A person proposing to operate a light or a laser shall notify the appropriate authority if:

1. because of its glare or affect on a pilot's vision, the light or laser is liable to endanger aircraft;
2. for a laser, it would produce exposures in navigable airspace exceeding the maximum permissible exposure defined;
3. it is likely to endanger aircraft by being mistaken for:
 - i. a light or part of a system of lights established or approved for display at or near an aerodrome; and
 - ii. a light marking a hazard in navigable airspace; and
4. the location falls within the laser protection zones around an aerodrome.

Display organizers should be aware of the following geographical zone, within which CAA considers it necessary to impose restrictions in order to protect flight operations:

Within 18500m (10 NM) of an aerodrome's notified Aerodrome Reference Point (ARP) or similar, the following procedures should be adhered to:

- a) Ideally, measures should be in place to prevent light escaping towards the aerodrome or along the extended runway centerline.
- b) If this proves impractical, other precautions are to be taken to ensure that light displays do not impinge on safe flight operations, such as arranging for a direct telephone or radio communications link between the point of contact and relevant aerodrome, through which the Light Display can be terminated immediately on request from either an aircraft or the affected aerodrome.

NOTE: If this is not possible, then the light display may represent a threat to flight safety and should not proceed.

Elsewhere, although the light display is unlikely to affect aerodrome flight operations, the Light Display organizer should notify the authority to ascertain if there are any other aviation activities that may be affected by the display.

Refer to **Appendix A** Form 2, for a model of notice of proposal to conduct outdoor laser, light /firework operation(s).

Public Awareness

Product warning labels and product information shipped with laser devices could be enhanced to specifically warn of the dangers these devices pose to aviation safety. While current product labeling on lasers inform operators of the eye hazards posed by lasers, there may be widely held misperceptions that lasers cannot affect a pilot's vision because of the large distances the beam travels before reaching the aircraft. The general public may also lack a full appreciation for the visual demands during critical phases of flight and the potential consequences of visual distractions in the cockpit.

Besides conveying this information in materials shipped with laser products, such information could also be disseminated through public awareness campaigns.

Additionally, public education materials could convey strong messages regarding available criminal penalties and potential legal consequences of using lasers to maliciously target aircraft.

Appendix A

Forms

FORM 1

SUSPECTED LASER BEAM /FIREWORK INCIDENT REPORT	
Name	
Position (pilot, co-pilot, controller, etc.)	
Phone	
Type of vision correction worn at time of incident (spectacles/contact lenses) -	
Type of aircraft	
Aircraft Id or call	
Date and time of incident (UTC)	
Date and time report is being completed (UTC)	
Position (pilot, co-pilot, controller, etc.)	
Phone	
ENVIRONMENTAL FACTORS	
Weather conditions	
VMC/IMC	
Ambient light level (day, night, sunlight, dawn, dusk, starlight, moonlight, etc.)	
LOCATION OF INCIDENT	
Near(aerodrome/city/NAVID)	
Radial and distance	
Phase of flight	
Type/name of approach or departure procedure	
Heading/approximate heading if in turn	
Altitude(AGL), (MSL)	
Aircraft bank and pitch angles	
Angle of incidence	
Did the light hit your eye(s) directly or from the side?	
Light description	
Colour	
Nature of beam (constant/flicker/pulsed)	
Light source (stationary or moving)	
Do you feel you were intentionally tracked?	
Relative intensity (flashbulb, headlight, sunlight)	
Duration of exposure (seconds)	
Was the beam visible prior to incident?	
Position of light source (relative to geographical feature or aircraft)	
Circle the window where the light entered the cockpit: (Left) (left-front) (centre) (right-front) (right) other -----	
Elevation of the beam from horizontal (degrees)	
EFFECT ON INDIVIDUAL	
Describe visual*/psychological/physical effects	
Duration of visual effects (seconds/minutes/hours/days)	
Do you intend to seek medical attention? <i>Note: This is recommended if even minor symptoms were experienced.</i>	
Effect on operational or cockpit procedures	

***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.

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

FORM 2

NOTICE OF PROPOSAL TO CONDUCT OUTDOOR LASER, LIGHT /FIREWORK OPERATION(S)	
To:	
From: (Applicant)	
Date:	
GENERAL INFORMATION	
Event or facility	
Applicant	
Address of activity	
Date(s) of activity	
Time(s) of activity	
Geographic Location of activity	
Longitude	----- deg (°) ----- min (') ----- sec(")
Latitude	----- deg (°) ----- min (') ----- sec(")
Determined by:	<input type="checkbox"/> GPS <input type="checkbox"/> Map <input type="checkbox"/> Other (specify) -----
Ground elevation at site (above Mean Sea Level)	
Laser/Firework activity height (above ground level)	
Testing and alignment	
Operation	
BRIEF DESCRIPTION OF OPERATION	
ON-SITE OPERATION INFORMATION	
Operator(s):	
On-site phone 1	
On-site phone 2	
Brief Description Of Control Measures	
ATTACHMENTS	
Number of laser / Firework configurations :	
List any additional attachments needed to evaluate this operation (could include maps, diagrams, and details of control measures).	
DESIGNATED CONTACT PERSON (IF FURTHER INFORMATION IS REQUIRED)	
Name:	
Position:	
Phone:	
Fax:	
E-mail:	
STATEMENT OF ACCURACY	
To the best of my knowledge, the information provided in this Notice of Proposal is accurate and correct.	
Name (if different from contact person):	
Position:	
Signature:	

References:

- ICAO Annex 14 Item 5.3.1.
- ICAO Doc 9815, Manual on Laser Emitters and Flight Safety.
- Egyptian Advisory Circular 00-23.
- UAE Civil Aviation Advisory Publication 49.
- UAE Civil Aviation Advisory Publication 65.
- Bahrain Civil Aviation Authority Obligation for the Operation Fireworks, Laser (Draft).
