Quantitative risk assessment - an alternative approach to laser safety?

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Introduction

The current international laser safety standard (IEC 825) gives a system of laser classification based solely upon the laser parameters without reference to the intended use. The procedure makes pessimistic assumptions to arrive at a "safe" classification related to the maximum hazard.

Hazard [1] *A hazard is something with the potential to do harm*

The manufacturer's requirements and the user guidance go on to manage the hazard by mitigating the potential for harm of higher classifications by introducing interlocks etc. Risk management is not considered in current laser safety standards.

Risk [1] *Risk expresses the likelihood that the harm from a particular hazard is realised*

It can be argued that the classification should also be based upon the intended use to which the laser will be put. The basis for this type of hazard analysis would have to be a risk assessment. Such a system of classification has an obvious advantage in that it would allow a wider variety of products to fall into the lower classes by virtue of their low risk.

This idea is attractive but the authors have reservations about its practicability. There are many different possible methods for making a risk assessment which vary in complexity and in the criteria used. It is difficult to see how a laser standard could adequately specify risk assessment techniques which are suitable for use in any and all situations. Furthermore, labelling would have to ensure that the intended use was unambiguously identified.

Such a system can only be necessary if classification is used as an overriding indicator of "safety", which currently it is not. It is risk that indicates the level of safety, being related to both the harmful consequences and the likelihood of occurrence.

Legislation and Risk Assessment

In 1974 the Health and Safety at Work etc Act (HSWA) came into force in the UK. This Act places duties on employers in respect of their employees and other persons (eg visitors and the general public etc) affected by work activities. The UK Ministry of Defence (MOD) is not exempt from this Act or Regulations which are made under it.

These impose on UK employers a "duty of care" to their employees (in the case of MOD this includes its sailors, soldiers and airmen) and the requirement to provide "a safe place of work" under HSWA. In addition they have to abide by the specific Regulations. MOD can seek exemptions from these on grounds of national security. However, it is policy to use this provision sparingly and only where truly essential and not for administrative convenience.

A European Union (EU) Directive caused the Management of Health and Safety at Work Regulations 1992 to be made in the UK. These require employers to assess all risks in the workplace even where specific Regulations do not exist. Similar regulations should also exist in all EU member states. In making such assessments MOD conforms to national or international standards and guidance wherever practicable. The assessment must be recorded if the risks are "significant". Assessments are open to inspection by the enforcing authority for the legislation, in the UK this is the Health and Safety Executive (HSE). After inspection HSE may instruct the MOD to make improvements or prohibit the practice.

In most cases quantitative risk assessment (QRA) will not be required to demonstrate safety. The deterministic methods used in current laser safety standards will be quite adequate. However, in some cases, deterministic methods lead to unrealistically large, and therefore unduly restrictive, hazard areas [2]. Where these exist QRA may be justified depending upon the complexity and the resources needed to carry it out.

Quantitative risk assessment - an example

Current laser safety standards are based upon preventing an exposure above the level of a Maximum Permissible Exposure (MPE). There is an implicit assumption made therefore that circumstances can be arranged such that this can be guaranteed.

When one considers a class 3B laser rangefinder, being operated from an aircraft, the opportunities for failure make such a guarantee is difficult to give. Figure 1 illustrates the off axis angular limits of a forward firing laser rangefinder being used with the Nominal Ocular Hazard Distance (NOHD) to sweep out a deterministic laser hazard area trace (LHAT).

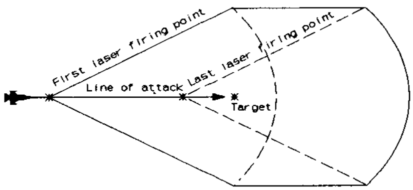

Figure 1 - Deterministic Laser Hazard Area Trace

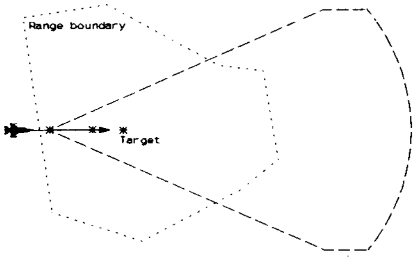

Figure 2 - Deterministic LHAT and range boundary

Often the deterministic LHAT may extend beyond the range boundary, Figure 2, and thus appear unacceptable. This certainly occurs in the UK and Europe, but perhaps not in the US or where ranges cover larger areas.

Under these circumstances a question needs to be answered - "what is the risk?" MOD uses QRA[3,4] to investigate the probability that the laser would in fact point at anything other than the target and the consequences if this should happen.

The elements used in the QRA are:

- equipment performance and fault condition parameters
- an eye damage model for the wavelength concerned
- atmospheric models for scintillation and absorption
- population models for the areas around the range

Since the MPE is an exposure at which no harm is caused it is more appropriate to use another criterion to assess the risk of harm. The eye model therefore uses the "minimum ophthalmoscopically visible lesion" (MOVL). [5]

Using a risk of 1 in 10^8 MOVL per attack the LHAT obtained is typically of the form shown in Figure 3. It has 2 components made up of a fault-free LHAT and a fault condition LHAT.

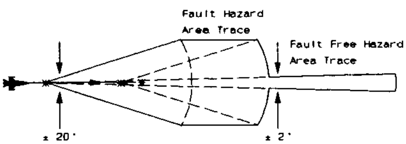

Figure 3 - Components of a QRA LHAT

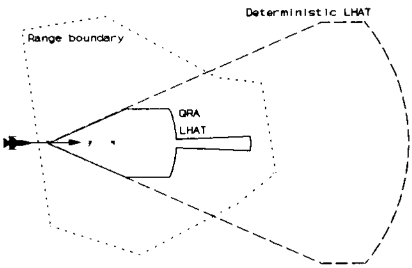

Figure 4 - Deterministic and QRA LHATs compared

It is usual that the QRA LHAT obtained by combining both the fault and fault-free LHATs is contained within the range boundary. Figure 4 illustrates this by overlaying the range boundary with both the deterministic and QRA LHATs.

Consideration of the Extended NOHD and the equivalent probabilistic modelling are beyond the scope of this paper. Never the less, the possibility of persons using binoculars is modeled and contained within the overall risk criterion endorsed by MOD of 1 in 10^8 of achieving a MOVL per attack. Particular attention is paid to areas where the probability of binocular use is high, e.g. bird sanctuaries etc.

Tolerability of risk

The risk of 1 in 10^8 MOVL compares favourably with some other figures quoted by HSE[6], particularly as it is non-fatal:

Levels of fatal risk per annum (average figures, approximated)	
1 in 100	risk of death from five hours of solo rock climbing every weekend
1 in 1000	risk of death due to work in **high risk groups** within relatively risky industries such as mining
1 in 10 000	general risk of death in a traffic accident
1 in 10 000	risk of death in an accident at work in the very safest parts of industry
1 in 1 million	general risk of death in a fire or explosion from gas at home
1 in 10 million	risk of death by lightning

or indeed the results from practical examples of QRA:[7]

- 1 in 10^6 per 8 h shift for failure of 3 safety interlocks on an injection moulding machine (usually non-fatal)
- fatal risk of 1·5 in 10^8 per hour of winding of a coalmine elevator (carried out after an accident caused 18 fatalities and which caused improvements to be made)

It might be suggested that the figure of 1 in 10^8 MOVL is impossibly small to be used as a practical estimate of risk. The authors tend to agree, but argue that while it may not be useful as an absolute measure, it is useful as an quantitative indicator of relative risk. So although it may not be combined with other estimates of risk, eg aircraft crash probability, to give an overall mission risk, it does indicate that laser safety is a minimal factor. In a similar way the authors would argue that such an assessment cannot and indeed should not seek to include factors for deliberate or negligent misuse of the laser. Consideration should certainly be given to the prevention of such occurrences and measures may need to be taken to prevent them, ie by adequate pilot/navigator training and supervision, backed by good design. However, unless they are shown to be reasonably foreseeable, they should not form part of the laser safety risk assessment.

The future

Current legislation and the regime of enforcement in the UK are adequate to enforce laser safety. QRA as a technique to assess the tolerability of risk is in use by both MOD and UK industry in various areas of safety.

The enforcing authority, HSE, recognise this and give guidance on its use:[8]

> "Assessing risks is necessary in order to identify their relative importance and to obtain information about their extent and nature. ....
>
> Risk assessments should be carried out by competent people, and professional health and safety advice may be necessary in some cases, especially in the choice of appropriate QRA techniques and the interpretation of results."

Specific laser safety legislation based solely upon MPEs would therefore, in our opinion, be too restrictive. If proposed EU legislation[9] on physical agents continues to call solely upon the European Standard or anything similar, MOD must seek to ensure that its current techniques and safe practices are not unduly affected. The authors suggest that industry and other users might also wish to preserve the flexibility of approach offered by risk analysis which does not either degrade or prevent the improvement of laser safety.

References

1. HSC. Management of health and safety at work (Approved code of practice). London:HMSO 1992
2. P A Smith. Probability and risk in laser safety. 1992 International Laser Safety Conference. Orlando:Laser Institute of America 1993
3. Ministry of Defence. JSP 390: Military Laser Safety - 1991 Edition. MOD, Ordnance Board, D/OB/2407/2
4. NATO. Standardization Agreement - STANAG 3606: Evaluation and control of laser hazards on military ranges - 5th edition 1991
5. P A Smith. Ocular damage models for probabilistic laser safety. IAM Report 726 (1992)
6. HSE. The tolerability of risk from nuclear power stations. London:HMSO 1992
7. HSE. Quantified risk assessment: its input to decision making. London:HMSO 1989
8. HSE booklet HS(G)65. Successful health and safety management. London:HMSO 1991
9. Official Journal of the European Communities. No C 230. Office for official publications of the European Communities 19 August 1994