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Introduction to risk management principles and processes

UN SaferGuard
Securing ammunition, protecting lives

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Foreword

Ageing, unstable and excess conventional ammunition stockpiles pose the dual risks of **accidental explosions at munition sites** and **diversion to illicit markets**.

The humanitarian impact of ammunition-storage-area explosions, particularly in populated areas, has resulted in death, injury, environmental damage, displacement and disruption of livelihoods in over 100 countries. Accidental ammunition warehouse detonations count among the heaviest explosions ever recorded.

Diversion from ammunition stockpiles has fuelled armed conflict, terrorism, organized crime and violence, and contributes to the manufacture of improvised explosive devices. Much of the ammunition circulating among armed non-State actors has been illicitly diverted from government forces.[1] In recognition of these dual threats of explosion and diversion, the General Assembly requested the United Nations to develop **guidelines for adequate ammunition management**.[2] Finalized in 2011, the International Ammunition Technical Guidelines (IATG) provide voluntary, practical, modular guidance to support national authorities (and other stakeholders) in safely and securely managing conventional ammunition stockpiles. The UN SaferGuard Programme was simultaneously established as the corresponding knowledge-management platform to oversee and disseminate the IATG.

The IATG also ensure that the United Nations entities consistently deliver high-quality advice and support – from mine action to counter-terrorism, from child protection to disarmament, from crime reduction to development.

The IATG consist of 12 volumes that provide practical guidance for ‘through-life management’ approach to ammunition management. The IATG can be applied at the guidelines’ **basic, intermediate, or advanced levels**, making the IATG relevant for all situations by taking into account the diversity in capacities and resources available. Interested States and other stakeholders can **utilize the IATG for the development of national standards and standing operating procedures**.

The IATG are reviewed and updated at a minimum every five years, to reflect evolving ammunition stockpile-management norms and practices, and to incorporate changes due to changing international regulations and requirements. The review is undertaken by the UN SaferGuard Technical Review Board composed of national technical experts with the support of a corresponding Strategic Coordination Group comprised of expert organizations applying the IATG in practice.

The latest version of each IATG module can be found at www.un.org/disarmament/ammunition.

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[1] S/2008/258.

[2] See also the urgent need to address poorly-maintained stockpiles as formulated by the United Nations Secretary-General in his Agenda for Disarmament, *Securing Our Common Future* (2018).

Introduction

A critical element of conventional ammunition stockpile management planning and operations should be the implementation of a robust, effective and integrated risk management system, preferably in accordance with the ISO guidance. This system should examine organisational, management, administrative and operational processes and procedures.

The requirements of ISO Guide 51 have been integrated within the IATG modules, which, in themselves, form part of a risk management process. Adherence to the guidelines will mean that a conventional ammunition stockpile management organisation is already implementing many components of an integrated risk management system. The generic risk management process from ISO Guide 51 is explained within this IATG with emphasis on its application to conventional ammunition storage.

The physical phenomena of blast, fragmentation and thermal radiation resulting from explosions are well understood, as are the mechanisms that cause fatalities, injury and damage as a result of these effects. As a result of this understanding a range of techniques and models have been developed by which these effects can be estimated; these techniques and models form a key element of the overall risk management process. The term ‘estimated’ is important because the range of variables involved means that exact damage effects are unlikely to be accurately predicted; appropriate safety margins are therefore engineered into preventative measures.

Explosion effects and consequence predictive techniques and models have been developed by a number of states and organizations to support risk assessments. Some are qualitative, while others are quantitative, and they will vary in sophistication dependent on the purpose for which they have been designed. Some provide a rough indication of casualties and damage, whereas others will provide more precise estimates of explosion effects. Quite often risk assessments will involve a combination of both qualitative and quantitative risk assessment methods and tools, based on available information and techniques and models being used. Regardless of the techniques and models used to assess risk and/or consequences, it is important that those utilizing such tools in the support of risk assessments understand what those tools do, how they work, and fully comprehend any conditions and limitations associated with those tools.

Explosion effect models and predictive techniques that are relatively easy to implement have been engineered into the IATG software, which is designed to support conventional ammunition stockpile risk management.

A range of techniques for estimating risk is contained within this IATG, with emphasis placed on their application to conventional ammunition stockpile management. Risk based approaches take many forms and can be used as tools to aid in a variety of decision-making processes. New applications are always being defined, and this IATG also provides references to other options to those contained within the guideline.

Risk management should be seen by States as a fundamental preventative measure to support safe conventional ammunition stockpile management. Decisions based on more complete knowledge can be made if the likelihood of an explosive accident can be taken into account as well as the consequences. The techniques covered or referred to in this IATG module (or their equivalent) should therefore be applied.

Introduction to risk management principles and processes

1 Scope

This IATG module introduces the concept of risk management and explains the activities necessary to ensure appropriate risk management within a conventional ammunition management system. It concentrates primarily on the risks to the civilian community from ammunition storage but also provides guidance on risk estimation techniques that may be used for other functional areas of conventional ammunition stockpile management.

Risk based approaches take many forms, vary in degrees of complexity and are constantly evolving. This IATG introduces the principles of risk management and provides guidelines for relatively straightforward risk assessment techniques that can be used in the widest range of circumstances. More complex systems may be found in the informative references.

2 Normative references

A list of normative references is given in Annex A. These documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

A further list of informative references is given in Annex B in the form of a bibliography, which lists documents that contain additional information related to the contents of this IATG module.

3 Terms and definitions

For the purposes of this module the following terms and definitions, as well as the more comprehensive list given in IATG 01.40 *Glossary of terms, definitions and abbreviations,* shall apply.[3]

The term ‘explosive event’ refers to *an unexpected and undesired initiation of an explosive substance or article within an ammunition depot leading to significant or catastrophic consequences.*

The term ‘harm’ refers to *physical injury or damage to the health of people, or damage to property or the environment*.

The term ‘hazard’ refers to *a potential source of harm*.

The term ‘risk’ refers to *a combination of the probability of occurrence of harm and the severity of that harm*.

The term ‘risk evaluation’ refers to *the process based on risk analysis to determine whether the tolerable risk has been achieved*.

The term ‘risk assessment’ refers to *the overall process comprising a risk analysis and a risk evaluation*.

The term ‘risk management’ refers to *the complete risk-based decision-making process*.

The term risk mitigation is used to describe the measures taken to reduce the effects should an explosion or deflagration occur. Examples would be following compatibility mixing rules to prevent an item in an incompatible group exacerbating the effects of an explosion, and keeping inhabited buildings outside the yellow line (inhabited building distance).

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[3] All risk related terms and definitions are from ISO Guide 51 (a normative reference at Annex A).

The term ‘risk reduction’ refers to *actions taken to lessen the probability, negative consequences or both, associated with a particular risk*. Within ammunition management, risk reduction refers to those measures to be taken to reduce the risk of ammunition exploding or deflagrating. It also refers to the methods used to make the ammunition more secure. Examples would be continuous surveillance of ammunition to ensure any safety problems are detected at an early stage and storing ammunition in optimum conditions in secure areas and buildings.

The term ‘safety’ refers to *the reduction of risk to a tolerable level.*

The term ‘tolerable risk’ refers to *the risk that is accepted in a given context based on the current values of society.*

In all modules of the International Ammunition Technical Guidelines, the words 'shall', 'should', 'may' and 'can' are used to express provisions in accordance with their usage in ISO standards.

a) **'shall' indicates a requirement**: It is used to indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

b) **'should' indicates a recommendation**: It is used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form, 'should not') a certain possibility or course of action is deprecated but not prohibited.

c) **'may' indicates permission**: It is used to indicate a course of action permissible within the limits of the document.

d) **‘can’ indicates possibility and capability**: It is used for statements of possibility and capability, whether material, physical or casual.

4 Introduction

Risk is defined as *Risk = Likelihood x Consequence*. Once a measure of risk is chosen, then the terms *Likelihood* and *Consequence* can be expanded using accepted mathematical protocol. One measure of risk (see Clause 6.2) may be the likelihood that a person will be killed during one year of exposure (Annual Individual Risk of Fatality ($IR_{Fatality}$)).

Likelihood may then be expanded into the probability of a hazardous event per year (P_{Event}).

Consequence may then be defined as the probability that the continuously exposed person is killed if an event occurs ($P_{Fatality|Event}$). From which follows:

$$\text{Annual Individual Risk of Fatality } (IR_{Fatality}) \Rightarrow (P_{Event}) \times (P_{Fatality|Event})$$

Yet an individual can only be harmed if they are present during a hazardous process. Therefore, the risk (per year) is reduced in proportion to the fraction of the year they are actually exposed to a hazardous process/situation (a dimensionless ratio). If the probability of the person being present or exposed is denoted by (E_P), then:

$$\text{Annual Individual Risk of Fatality } (IR_{Fatality}) = (P_{Event}) \times (P_{Fatality|Event}) \times (E_P)$$

Other similar equations may be developed from this to meet different requirements, and the level of detail increased based on sound explosive science and engineering.

Risk-based decision-making should be a fundamental ethos embedded within conventional ammunition stockpile management processes. Risk-based decisions are routinely and instinctively made on a very frequent basis and should be generated dependent on the level of knowledge of the parameters in Table 1.

Parameter	Generic Risk Types	Example Knowledge Requirement
Frequency	▪ Individual Risk ($I_{(R)}$) ▪ Collective Risks ▪ Perceived Risks	▪ How often are there undesirable explosive events within ammunition depots in country A?
Physical Effects		▪ How much explosive is stored within a depot? ▪ What will be the blast over-pressure and impulse levels against range if it detonates?
Consequences		▪ What is the distance at which fatalities and injuries may be expected? ▪ What is the distance at which structural damage is to be expected?
Exposure		▪ How many civilian buildings are within the danger area, and what levels of damage should each expect? ▪ How many civilians are in the blast and fragmentation danger area at any one time?

Table 1: Parameters for risk-based decisions

The target of conventional ammunition stock holding organisations should be the safe, effective and efficient stockpile management of conventional ammunition, explosives, propellants and pyrotechnics.[4] There are potential hazards in this process:

a) inadequate storage conditions for conventional ammunition may result in undesired explosive events during storage;[5]

b) ineffective physical inspection and chemical analysis of ammunition as part of a technical surveillance system may result in undesired explosive events during storage due to deteriorated ammunition; and

c) inappropriate handling and processing of conventional ammunition has the potential to cause death or injury to workers or observers.

Additional to these hazards there are a range of potential causes of an undesirable explosive event:

a) accidental fire in a vehicle, magazine or explosive storehouse;

b) human error due to accident, fatigue or inappropriate handling;

c) environmental (e.g. lightning strike);

d) intruder initiated (e.g. sabotage); or

e) enemy action (in periods of conflict) (e.g. improvised explosive device, direct or indirect fire).

A major objective of the risk management process during conventional ammunition stockpile management shall be to promote a culture where the stockpile management organisation seeks to achieve the target of safety by:

a) developing and applying appropriate management and operating procedures;

b) managing, and assessing, the condition of the conventional ammunition stockpile and taking appropriate actions when a dangerous condition is identified with such stocks;

c) establishing and continuously improving the skills of managers and workers;

d) ensuring that conventional ammunition is stored and processed within an appropriate physical infrastructure; and

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[4] Referred to as conventional ammunition for the remainder of this IATG.

[5] Annex C summarises the general effects of explosions.

e) procuring safe, effective and efficient equipment.

5 The concept of safety

Safety is achieved by reducing risk to a tolerable level, which is defined in this IATG as tolerable risk. There can be no absolute safety; some risk will remain - this is the residual risk. [ISO Guide 51: 2014(E)].

Therefore, in the context of conventional ammunition stockpile management the enabling processes of storage, handling, destruction etc. can never be absolutely safe; they can only be relatively safe. This is an inevitable fact of life, which does not mean that all efforts to ensure safety are not being made. It just means that it cannot be proved, with 100% confidence, that absolute safety is being achieved. The risk management systems recommended in IATG, and used within the IATG software, aim to be as close to that 100% ideal confidence level as is realistically possible, whilst allowing stockpile management organisations to determine what is the tolerable risk that they are prepared to accept in their particular environments.

6 The generic risk management process[6]

Risk management is a complex area for which there is a significant body of work to provide guidance. It would be impracticable to cover all the various options and techniques in this IATG, and therefore only those risk management processes with a proven application in conventional ammunition stockpile management have been included.

Risks may be classified as falling into one or more of three categories:

a) risks for which there may be some evidence, but where the connection between cause and injury to any one individual cannot be traced;

b) risks for which statistics of identified casualties may be available; and

c) risks for which best estimates of probability of events that have not yet happened are made by specialists.

Risks inherent in conventional ammunition stockpile management will be classified as falling under categories (b) and/or (c) above. Statistical evidence of previous explosive events within ammunition storage areas is available,[7] and established techniques to estimate risk based on empirical models or scientific equation exist.[8]

6.1 Components of risk management

Risk management is sometimes a misunderstood term, within which there are common misconceptions in terms of the relationship between, for example, risk assessment and risk analysis. Within the IATG risk management is the complete risk-based decision-making process. The matrix at Table 2 identifies the relationship between the different components of risk management that shall be used in the IATG:

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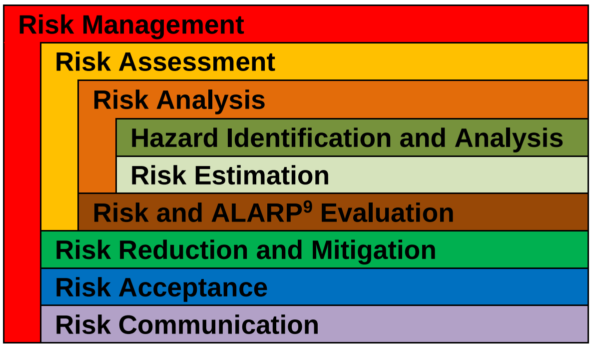
[6] From ISO Guide 51.

[7] See *The Threat from Explosive Events in Ammunition Storage Areas*. Explosive Capabilities Limited. UK. 26 September 2009.

[8] See IATG 01.80 *Formulae for ammunition management*.



- Risk Management
  - Risk Assessment
    - Risk Analysis
      - Hazard Identification and Analysis
      - Risk Estimation
    - Risk and ALARP[9] Evaluation
  - Risk Reduction and Mitigation
  - Risk Acceptance
  - Risk Communication

Table 2: Risk management matrix

Further explanations of each component of risk management, together with recommended techniques that should be used during the risk management process for conventional ammunition stockpile management are at Clauses 7 - 12. These techniques are also included in the IATG software, which automates many of the more technical processes of risk management for conventional ammunition stockpile management.

6.2 Types of risk

There are two generic types of risk that may be considered during the risk management process for explosive facilities:

a) individual risk (I_R). This is the chance of a fatality or serious injury to a particular individual in a specific location as a result of an accidental initiation of explosives; and

b) societal risk (S_R). This expresses the probability of the largest number of people that might be fatalities or seriously injured as a result of an explosives accident.

As the criteria for I_R or S_R are derived from different sources, the risk levels that have been estimated during the risk management process shall be clearly annotated to indicate whether the estimate is for I_R or S_R. The respective limits of tolerability for I_R and S_R are usually independent of each other. In practice, I_R would normally be used during the risk assessment process as S_R is often more difficult to estimate. This is because societal risk concerns often involve a much wider range of potential outcomes.

It is possible that tolerable risk may be achieved using one set of criteria but not achieved using the other criteria. In this case, remedial action should be taken to ensure that both sets of criteria are met. If this is not possible or practicable then the national technical authority shall exercise best judgment and also seek formal political approval for the continued use of the explosive facility.

6.3 Determining tolerable risk

Tolerable risk is determined by the search for absolute safety contrasted against factors such as:

a) the inherent explosive safety hazards of storing, handling and processing ammunition;

b) available resources;

c) the conventions of the society where the ammunition is being stored; and

d) the financial costs.

It follows that there is therefore a need to continually review the tolerable risk that underpins the concept behind stockpile management operations in a particular environment.

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[9] As Low As Reasonably Practicable.

The level of tolerable risk shall be determined by the appropriate national authority, but it should not be less than the tolerable risk accepted, for example, in manufacturing or industrial processes. The levels of tolerable risk (based on individual risk criteria) shown in Table 3 could be considered as reasonable and practicable:

'At Risk' Group	**Tolerable Risk Level (I_R)**	**Remarks**
Workers in Explosives Facility[10] (Maximum Tolerable Limit)	1×10^{-3}	▪ Workers may be exposed to this risk level on an occasional basis. ▪ A non-standard explosive limit licence should be issued at this risk level.[11] ▪ If the I_R is greater than 1×10^{-3} then a special case for licensing shall be submitted to the national technical authority, and political acceptance of the risk, in writing, shall be formally sought.
Workers in Explosives Facility (Warning Level)	1×10^{-4}	▪ This should be the maximum level of risk that workers are exposed to on a regular basis. ▪ A non-standard explosive limit licence should be issued at this risk level.[12]
Workers in Explosives Facility (Acceptable Limit)	1×10^{-6}	▪ This should be the ideal level of risk for daily exposure. ▪ A standard explosive limit licence should be issued at this risk level.[13]
General Public (Maximum Tolerable Limit)	1×10^{-4}	▪ The general public may be exposed to this risk level on an occasional basis and in exceptional circumstances. ▪ A non-standard explosive limit licence should be issued at this risk level.[14] ▪ If the I_R is greater than 1×10^{-3} then a special case for licensing shall be submitted to the national technical authority, and political acceptance of the risk, in writing, shall be formally sought.
General Public (Warning Level)	1×10^{-5}	▪ This should be the maximum level of risk that the general public is exposed to on a regular basis. ▪ A non-standard explosive limit licence should be issued at this risk level.[15]
General Public (Acceptable Limit)	1×10^{-6}	▪ This should be the ideal level of risk for daily exposure. ▪ A standard explosive limit licence should be issued at this risk level.[16]

Table 3: Suggested tolerable risk levels

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[10] This includes all staff that work within the explosives facility. It may be further sub-divided into Explosives Workers, who work directly with the ammunition and explosives, and Explosives Support Workers, who provide the administrative support.

[11] See IATG 02.30 *Licensing of explosive storage areas.*

[12] Ibid.

[13] Ibid.

[14] Ibid.

[15] Ibid.

[16] Ibid.

A suggested tolerable level of societal risk (S_R) should be that the maximum probability of an accident in any year that causes the death of 50 people or more shall be less than 1 in 5,000.[17]

A protocol should be established that formally records how the tolerable risk was determined and which authority accepted it. Table 4 summarises the requirements of a 'Tolerable Risk Protocol'.

Generic Area / Activity	Specific Area / Activity	Remarks
Risk Management	Identify and nominate specific individual responsible for risk management policy in explosive facilities.	▪
Risk Analysis	Identify 'Explosives Facilities'.	▪
Risk Analysis	Identify 'At Risk' Groups.	▪ Workers in Explosive Area (Unqualified) ▪ Workers in Explosive Area (Explosives Qualified). ▪ General Public Residing in Proximity to Explosive Facility. ▪ General Public Transiting in Proximity to Explosive Facility.
Risk Analysis	Decide on the appropriate level of Tolerable Risk in terms of I_R and S_R.	▪ Risk levels should be comparable with other industrial processes.
Risk Acceptance	Obtain written Approval[18] for Tolerable Risk levels.	▪ This ensures that appropriate risk acceptance authority is aware of the risk, and of their responsibilities to allocate appropriate resources to manage the risk and maintain it within tolerable levels.
Risk Communication	Widely communicate the Tolerable Risk levels being applied to Explosive Facilities.	▪ Communities in close proximity should be made aware of the risks they are exposed to by their political class.

Table 4: Tolerable risk protocol

Tolerable risk is achieved by the iterative process of risk assessment (risk analysis and risk evaluation) and risk reduction. See Figure 1.

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[17] S_R units are the number of accidents per year. So this suggested tolerable risk level is equivalent to 1 accident at the facility every 5,000 years that kills 50 people or more.

[18] The local authority has to define the appropriate approval authorities for the Tolerable Risk levels. Due to the potential consequences of an explosion event, It is not unusual that the issue of risk acceptance may reach quite high levels of government and the political level.

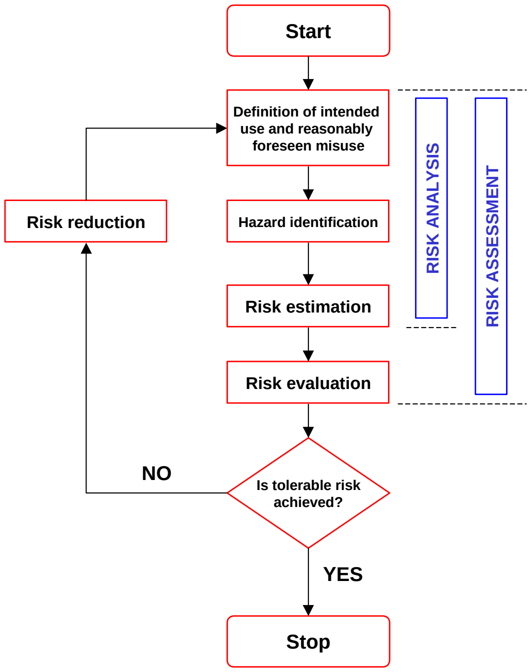

Figure 1: Iterative process of risk assessment[19]

Effective risk assessment has a range of benefits that include:

a) it helps in ranking the importance of individual risk contributions to the overall risk;

b) it helps to identify risks that are easily reduced or eliminated;

c) it helps to clarify what is known and what is not known about the potential risk;

d) it can provide an objective basis for decisions on controlling risks, especially those applying to the local civilian communities near ammunition storage areas;

e) it can provide important quantitative information as input to decisions for allocating resources to conventional ammunition stockpile management;

f) it makes it possible to rank risk reduction or remediation alternatives in terms of risk to workers, the environment, and the public; and

g) it can provide a process for consensus-building and a forum for the participation of stakeholders in the development of the risk assessment process and the identification of tolerable risk. This process will hopefully lead to greater acceptance of that risk.

6.4 Achieving tolerable risk

The following generic procedure should be used to reduce risks to a tolerable level during conventional ammunition stockpile management:

a) identify the likely stakeholders in the conventional ammunition stockpile management process, (i.e. local civilian community, ammunition depot workers, management etc.);

b) identify each hazard (including any hazardous situation and harmful event) arising in all stages of the stockpile management process;

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[19] This flow process, slightly amended, will appear in other IATG where required.

c) estimate and evaluate the risk to each identified user or group, (for example the consequences of an explosive event in terms of fatalities, injuries, property damage, environmental pollution and financial loss);

d) judge if that risk is tolerable (e.g. by comparison with other risks to the user and with what is acceptable to society); and

e) if the risk is not tolerable then reduce or mitigate the risk until it becomes tolerable.

When conducting the risk reduction process, the order of priority should be as follows:

a) inherently safe design of equipment and processes;

b) imposition of appropriate safe separation distances between ammunition storage and exposed sites;

c) inherently safe operating procedures, where the risk has been reduced or mitigated to a tolerable level for each procedure and activity;

d) appropriate and effective training of staff;

e) use of personal protective equipment during ammunition processing, where appropriate; and

f) information for stockpile management personnel and local communities.

7 Risk assessment (ammunition storage)

7.1 Qualitative risk assessment

Qualitative risk assessments are descriptive, rather than using measurable or calculable data, and they are by far the most widely used approach to risk analysis in many circumstances. Probability data is not required and only estimated potential loss is used. A qualitative risk assessment can be a helpful first step, when a State decides to implement risk assessment procedures, but they should not be used as a replacement for the scientifically accepted and proven techniques which are available to allow for a more quantitative risk assessment. They may be used though for specific processes that support ammunition management where little quantitative data is available, such as technical procedures for ammunition processing tasks.

An example of a Qualitative Risk Assessment technique is at clause 8.2.4.

7.2 Quantitative risk assessment

Quantitative Risk Assessment (QRA) is a powerful tool for the investigation and reduction of risk. It should be used to estimate the approximate probability of an accidental explosion during ammunition storage and then estimate the fatalities, injuries, damage and other losses from such an explosion (referred to as the consequences). This enables professional judgement to be applied as to whether or not the risk meets the ALARP[20] principal.

QRA provides an advantage over more subjective methods in that a more complete set of available information is used to quantify 'risk' as a parameter. This allows for consistency and repeatability from decision to decision, (for example when comparing the hazard presented by each explosive storehouse within an ammunition depot).

The primary limitation of some of the techniques used within QRA (for explosives) is a degree of inherent uncertainty in the calculated parameter (see Clause 14); this is often due to the wide range of variables. Nevertheless, accuracy in the absolute or overall sense can be discussed within 'orders of magnitude' (factors of 10) and still allow for appropriate decision-making. Fidelity[21] may be quite

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[20] As Low As Reasonably Practicable. Technical and explosive engineering judgement is required to determine whether the level achieved is as low as reasonably practicable.

[21] Fidelity in this case means 'the extent to which the QRA model is likely to be in comparison to a real life event'.

good, and relative options can be compared with a degree of confidence (within a factor of 2 or better).

An example of a Quantitative Risk Assessment technique is at Annex E.

8 Risk analysis

8.1 Hazard identification and analysis

Hazard identification and analysis is a reasonably simple process for the risk management process that supports conventional ammunition storage. As hazards are defined as a potential source of harm, then the hazard from, for example, individual explosive storehouses (ESH) will depend on the quantity, hazard classification,[22] physical condition and chemical stability of the ammunition contained within that ESH.

If the inter-magazine distances (IMD) are not in accordance with the recommendations contained in IATG 02.20, *Quantity and separation distances,* then further risk analysis will be required. Normally each ESH is considered to be an individual Potential Explosion Site (PES). Yet, if there is a risk of practically instantaneous propagation (PIP) due to inadequate IMD between the ESH, then they may have to be treated as one PES, and the explosive quantity aggregated.

8.2 Risk estimation

As 'risk' is defined as *a combination of the probability of occurrence of harm and the severity of that harm*, then for explosive events in ammunition storage areas the estimation of risk should establish and/or estimate:

a) the probability of an unplanned and undesirable explosive event;

b) the physical effects of such an explosion;

c) the number of casualties to be expected; and

d) the levels of damage to be expected.

Clauses 8.2 b) to d) above cover what is known as the 'consequence analysis' (see Clause 13.3).

8.2.1. Probability estimation of an undesirable explosive event (LEVEL 1)

In many cases, it will be difficult to establish the probability of an unplanned and undesirable explosive event at a particular explosive storage area. Yet data is available on the number of such events annually[23] and a stockpile management organisation should be aware of previous similar events in their region; this will assist the organisation in assessing frequency, and hence probability. This is known as the 'historical' approach and an example model is at Clause 8.2.1.1. A more qualitative approach is at Clause 8.2.1.2.

Alternative methods for establishing frequency, and hence the probability of explosive events, during the risk estimation process include analytical techniques such as attempts to define and quantify all of the potential scenarios in which an explosive event can occur. Logic or fault tree approaches are often used depending upon the complexity of and number of proposed scenarios leading to an event. It can be a complex and sophisticated process, and further guidance is available in the informative references at Annex B.

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[22] See IATG 01.50 *UN explosive hazard classification systems and codes.*

[23] Approximately 20+ per annum.

8.2.1.1. Example probability estimate model (historical) (LEVEL 1)

The following example probability model for an undesirable explosive event due to inappropriate stockpile management systems or processes may be used, or adapted, if there is no other data or evidence available. Data for this simple model is based on the following:

a) there are 193 UN Member States. If it is conservatively assumed that the average of ammunition depots of a significant size in each State is 10, then there are 1,920 significantly sized ammunition depots globally;

b) it is then further assumed, based on experience gained during site visits by international observers, that at least 60% of these depots are not in line with international best practices for explosive safety; and

c) there is also documented evidence[24] of an average of 24.5 known undesirable explosive events taking place annually from 2002 to 2017; the vast majority of which took place where inadequate stockpile management processes were in place.

It could therefore be reasonably argued that the annual probability of an undesirable explosive event taking place within an ammunition depot, with inadequate stockpile management systems or processes, is currently approximately:

$$P_{Event} = (24.5/(1920 \times 0.6) = 0.021 = 2.1 \times 10^{-2} \quad (2.1\%)$$

This probability estimate is certainly within one order of magnitude and may be used for planning purposes.

A probability of 2.1×10^{-2} for an explosive event at an ammunition depot with inappropriate stockpile management processes may be perceived as fairly high when assessed against tolerable risk in most societies. Particularly as the impact in terms of the average fatality rate (2002 – May 2017) for each undesirable explosive event in an ammunition storage area is 13.85 fatalities,[25] with a casualty (injured) rate of 47.08 per explosive event.[26]

If we attribute one accident per year (which is probably very high) to a well-managed depot we can calculate 1/(1930 x 0.4) = 0.13% which is sufficient to state that a poorly managed depot is (at least) over 16 times more likely to have an accident.

8.2.1.2. Example probability estimate model (qualitative) (LEVEL 1)

Table 5 illustrates a more qualitative means of estimating the probability of an explosive event:

Generic Description	Probability	Qualitative Definition
Likely	Frequent	▪ Expected to occur once or more times.
	Almost Certain	
	Very Probable	
	Probable	
Occasional	Possible	▪ Unlikely, but possible to occur.
Unlikely	Seldom	▪ It may be assumed that it will not occur.
	Rare	

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[24] Small Arms Survey Unexpected Explosions at Munition Sites (UEMS) database. www.smallarmssurvey.org/weapons-and-markets/stockpiles/unplanned-explosions-at-munitions-sites.html

[25] 5,100 fatalities and 17,326 injuries during2,760 fatalities during 20024 –2017. Source Ibid.

[26] 22,426 combined (deaths and injuries) casualties averaging 61 casualties/incident during 2002 –2017, Source Ibid. The actual rate is likely to be higher.

Generic Description	Probability	Qualitative Definition
	Improbable	

Table 5: Qualitative estimation of explosive event probability

8.2.2. Physical effects estimation of an unplanned or undesirable explosive event (LEVEL 2)

The physical effects of an undesirable explosive event within an ammunition depot can be estimated by using the appropriate equation contained within IATG 01.80 *Formulae for ammunition management* (Clause 6.2). This can be used to determine the blast over-pressure and impulse at the distance from a potential explosion site to an exposed site from a known explosive mass.

Threshold blast over-pressures for effects on humans have been established by experimentation, (34,5kPa for onset of hearing damage, 207kPa for lung damage and 690kPa for fatality),[27] and therefore if the population density is known within the appropriate ranges an estimate of the total number of fatalities and casualties can then be derived. Alternatively, the *ESTC Outdoor Model* may be used. (Both in Clause 11.2 to IATG 01.80 *Formulae for ammunition management*).

Similarly, the effects of blast on buildings within and outside the perimeter of the ammunition depot can be estimated. (Clause 10 of IATG 01.80 *Formulae for ammunition management)*.

8.2.3. Individual risk estimation (LEVEL 2)

Risk is defined as '*likelihood x consequences*'. Where national data on accidents of all types is available the Individual Risk of Fatality ($IR_{fatality}$) (Table 6) as a result of an undesired explosion may be compared to the accepted 'tolerable risk' of other activities or industrial processes. From Clause 4, the annual IR is defined as:

$\mathbf{IR_{Fatality} \Rightarrow P_e \text{ x } P_{Fatality\|Event} \text{ x } E_p}$	$IR_{Fatality}$ = Annual Individual Risk of Fatality P_e = Probability of hazardous event per Year $P_{Fatality\|Event}$ = Probability of Fatality[28] E_p = Probability of Exposure to Hazard

Table 6: Annual Individual Risk of Fatality ($IR_{Fatality}$)

As an example, if the estimated data from Clause 8.2.1 is used for an exposed site that is within the appropriate separation distance[29] for a fatal blast over-pressure at an exposed site (i.e. outside a civilian house) should there be an explosive event, then the IR at that house can be estimated as follows:

- P_e (Probability of hazardous event per Year) = 2.1 x 10^{-2}
- $P_{f|e}$ = Probability of Fatality = 0.99
- E_p = Probability of Exposure to Hazard = 0.0833 (Assuming an individual is outside their home for 2 hours)[30]
- $IR_{Fatality}$ = 2.1 x 10^{-2} x 0.99 x 0.0833 = 1.73 x 10^{-3} (0.18%)

An alternative qualitative categorization of risk is contained within Table 7:

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[27] *Estimate of Mans Tolerance to the Direct Effects of Air Blast*. Bowen. October 1968.

[28] For a continually exposed person.

[29] See IATG 02.20 *Quantity and separation distances.*

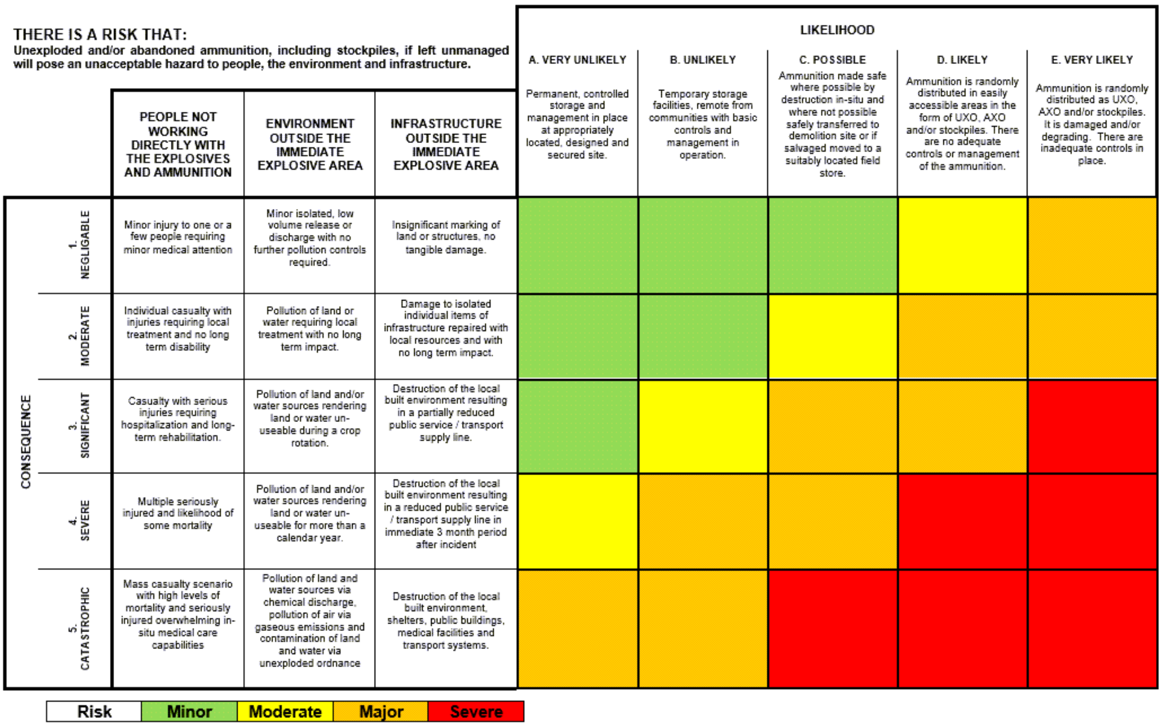
[30] For individuals inside the house this method must be used in parallel with those at Clauses 10 and 11.3 of IATG 01.80 *Formulae for ammunition management.*

Description	Qualitative Definition
Catastrophic	▪ Undesirable event leading to multiple fatalities and/or serious injury to individuals and/or significant loss or damage to critical equipment or infrastructure.
Major	▪ Undesirable event leading to some fatalities and/or serious injury to individuals and/or significant loss or damage to critical equipment or infrastructure.
Minor	▪ Undesirable event leading to minor injuries to individuals and minimal impact on equipment or infrastructure.

Table 7: Qualitative categorization of risk

8.2.4. Qualitative risk index

A combination of the qualitative estimates at Tables 5 and 7 may then be used to develop a qualitative risk index as shown at Table 8:



THERE IS A RISK THAT:
Unexploded and/or abandoned ammunition, including stockpiles, if left unmanaged will pose an unacceptable hazard to people, the environment and infrastructure.

					LIKELIHOOD				
		PEOPLE NOT WORKING DIRECTLY WITH THE EXPLOSIVES AND AMMUNITION	ENVIRONMENT OUTSIDE THE IMMEDIATE EXPLOSIVE AREA	INFRASTRUCTURE OUTSIDE THE IMMEDIATE EXPLOSIVE AREA	A. VERY UNLIKELY Permanent, controlled storage and management in place at appropriately located, designed and secured site.	B. UNLIKELY Temporary storage facilities, remote from communities with basic controls and management in operation.	C. POSSIBLE Ammunition made safe where possible by destruction in-situ and where not possible safely transferred to demolition site or if salvaged moved to a suitably located field store.	D. LIKELY Ammunition is randomly distributed in easily accessible areas in the form of UXO, AXO and/or stockpiles. There are no adequate controls or management of the ammunition.	E. VERY LIKELY Ammunition is randomly distributed as UXO, AXO and/or stockpiles. It is damaged and/or degrading. There are inadequate controls in place.
CONSEQUENCE	1. NEGLIGABLE	Minor injury to one or a few people requiring minor medical attention	Minor isolated, low volume release or discharge with no further pollution controls required.	Insignificant marking of land or structures, no tangible damage.	🟩	🟩	🟩	🟨	🟧
	2. MODERATE	Individual casualty with injuries requiring local treatment and no long term disability	Pollution of land or water requiring local treatment with no long term impact.	Damage to isolated individual items of infrastructure repaired with local resources and with no long term impact.	🟩	🟩	🟨	🟧	🟧
	3. SIGNIFICANT	Casualty with serious injuries requiring hospitalization and long-term rehabilitation.	Pollution of land and/or water sources rendering land or water un-useable during a crop rotation.	Destruction of the local built environment resulting in a partially reduced public service / transport supply line.	🟩	🟨	🟧	🟧	🟥
	4. SEVERE	Multiple seriously injured and likelihood of some mortality	Pollution of land and/or water sources rendering land or water un-useable for more than a calendar year.	Destruction of the local built environment resulting in a reduced public service / transport supply line in immediate 3 month period after incident	🟨	🟧	🟧	🟥	🟥
	5. CATASTROPHIC	Mass casualty scenario with high levels of mortality and seriously injured overwhelming in-situ medical care capabilities	Pollution of land and water sources via chemical discharge, pollution of air via gaseous emissions and contamination of land and water via unexploded ordnance	Destruction of the local built environment, shelters, public buildings, medical facilities and transport systems.	🟧	🟧	🟥	🟥	🟥

Risk	🟩 Minor	🟨 Moderate	🟧 Major	🟥 Severe

Table 8: Qualitative risk index

9 Risk and ALARP evaluation

The aim of risk evaluation is to compare the estimated effects, in terms of human fatalities and injuries, financial costs and political impact of an explosive event against what is tolerable in society. If the risk is assessed as tolerable then no remedial action should be required, although it should also be considered if that risk is As Low as Reasonably Practicable (ALARP).

A method of assessing the estimated $IR_{Fatality}$ against tolerable risk in a particular society may be to compare against other $IR_{Fataility}$ that may be available for events such as: 1) fatalities due to road traffic accident; 2) fatalities from industrial processes; or 3) fatality through disease[31] etc.

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[31] Information on this is available by country from the World Health Organization Information Statistics (WHOIS) database. www.who.int/whois.

If the risk is not assessed as being tolerable, then appropriate remedial action should be taken in order to reduce the risk (see Clause 10).

10 Risk reduction and mitigation

In order to reduce the estimated risk from an unplanned or undesirable explosive event at an ammunition storage area, one or a combination of the following actions should be taken:

a) closure of the ammunition depot and the transfer of stocks to an ammunition depot with spare capacity, mitigation; (LEVEL 1) or

b) a reduction of ammunition stock levels within the explosive storage area until appropriate predicted blast over-pressure levels are reached at the exposed site, mitigation; (LEVEL 1)

c) the probable impact of the estimated risk to the local community is formally accepted at the appropriate political level, acceptance. (LEVEL 1)

d) an increase in the separation distance between the potential explosion site and the exposed site until tolerable blast over-pressure levels are reached at the exposed site, mitigation; (LEVEL 1)

e) improvements in the physical infrastructure of ammunition storage to achieve tolerable estimated blast over-pressure levels at the exposed site, mitigation; (LEVEL 2 and 3)[32]

f) instigation of effective ammunition surveillance and proof systems to identify ammunition and propellant that has deteriorated to a dangerous condition (see IATG 07.20 *Surveillance and proof*), reduction; (LEVEL 3)

11 Risk acceptance (LEVEL 1)

Risk acceptance criteria will result from three factors:

a) local perceptions of societal risk and hence the detailed specification of ‘tolerable risk’;

b) the potential economic cost and losses due to an undesired explosive event (which will include: 1) explosive ordnance disposal remediation costs; 2) reconstruction costs (for public and civilian buildings); 3) injury compensation costs; and 4) ammunition replacement costs). A supporting cost benefit analysis (CBA) may be required before the risk may be formally accepted as it could impact on tolerable risk and hence require a reiteration of the risk assessment process (see Clause 15); and

c) environmental impact.

Where tolerable risk has been achieved, and, if necessary, supported by CBA, then that risk and the residual risk should be formally accepted by the appropriate authority within a conventional ammunition stockpile management organisation. In terms of ammunition storage this should usually take the form of issuing Explosive Licences for the ammunition storage area (see IATG 02.30 *Licensing of explosive storage areas*).

Where tolerable risk has not been achieved, and where resources are not being made available to achieve tolerable risk in the short term, then the residual risk should be formally accepted in writing by the entity responsible for the allocation of resources to the stockpile management organisation. Provided measures to achieve tolerable risk have been identified, then the residual risk is now an issue of resource allocation and not one of technical knowledge.

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[32] The degree of improvement will determine the appropriate Level achieved.

Should the resource allocation entity refuse to formally accept the risk in writing, then the issue should be referred to the next level of government for reconciliation of the issue. If this stage is reached it is then a political responsibility to free up the required resources, or the risk should be formally accepted in writing at that level of government. Formal acceptance of risk means taking individual and personal responsibility should there be future consequences; hence it is likely that the issue of risk acceptance may reach quite high levels of government and the political level. This assures accountability should there be an undesirable explosive event in the future, as politicians should have accepted the consequences of a decision not to allocate sufficient resources to achieve tolerable risk. This process should take place annually during the budget development process for the stockpile management organisation.

12 Risk communication (LEVEL 1)

Risk communication is an interactive process of exchange of information and opinion on risk among risk assessors, risk managers, and other stakeholders, which should include representatives from the local civilian community that may be impacted by the risk.

Risk communication is an integral and ongoing part of the risk management process, and ideally all stakeholder groups should be involved from the start. Risk communication makes stakeholders aware of the results of the risk assessment, the logic behind the risk analysis process and the remedial measures taken to ensure a level of tolerable risk.

The identification of particular interest groups and their representatives should comprise a part of an overall risk communication strategy. This risk communication strategy should be discussed and agreed upon between risk managers early in the process to ensure two-way communication. This strategy should also cover who should present information to the public, and the manner in which it should be done. The risk communication strategy should aim to improve the perceptions of safety for the personnel within the ammunition depot and also the local community.

13 Techniques of risk estimation

The technique used to estimate risk should be easily explainable, even if the formulae used are complex. There is sometimes scepticism towards risk assessments, and it may therefore be worth the effort to develop explanations that are easily understood. This does not mean the selection of methods that are simple but inaccurate. It means that the time needed to develop clear understandable analysis and explanation is well worth the effort. If it cannot be explained and justified using accepted explosive engineering or science, it may not be accepted by consensus. If it does not command consensus it may not stand up in court.

13.1 Tests (LEVEL 3)

Where there is insufficient data readily available it may be desirable to conduct a physical test, at full or reduced scale, to gain specific data where the events have been rare or inadequately recorded. In terms of undesirable or unplanned explosive events in ammunition storage areas such tests are very expensive, rarely conducted and are usually conducted on a bi-lateral basis. Luckily, the results of previous tests[33] have been made available, and they form the basis of the recommended quantity and separation distances used in a range of international ‘best practices’.[34]

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[33] Including full-scale tests in Australia over the last 40 years on behalf of a range of governments working together.

[34] NATO AASPT-1, UK MSER etc.

13.2 Separation and quantity distances (LEVEL 1)

The use of Quantity Distances (QD) to develop appropriate separation distances between potential explosion sites (PES) and areas exposed to the effects of such an explosion (exposed sites (ES)) is standard practice for many conventional ammunition stockpile management organisations. IATG 02.20 *Quantity and separation distances* provides more detailed information on the application of this technique, and the appropriate distances to be used. The IATG Implementation Support Toolkit provides an Explosives Limits Licence[35] tool that uses the scaled distance formulae from IATG 01.80 to aid the explosives safety practitioner in applying QD.

The models used for the evaluation of quantity distance criteria provide results that err on the side of safety, as this provides confidence that the effects of an explosion are not underestimated. As the outcome of accidental explosions in explosive storage areas depends on many factors, not all of which are easily modelled accurately, there are limitations in the practicality of applying quantity distance criteria in all circumstances. Although the use of quantity distance criteria is a reasonably simple process, the appropriate protection level can only be formulated for broad categories of PES and ES. Building design, state of repair, topography etc. will vary in different scenarios and hence QD criteria only provide accurate estimations for the building types for which data is available.

It is not always possible to provide the separation distances called for by QD, in which case an Explosion Consequence Analysis (ECA) should be considered.

13.3 Explosion consequence analysis (LEVEL 2)

Explosion Consequence Analysis (ECA) can be defined as *a structured process, utilising explosives science and explosives engineering, to provide scientific evidence of the potential risk to individuals and property from blast effects and fragmentation in the event of an undesirable explosive event*.

The ECA can be a core component of the risk analysis process during the development of a Quantitative Risk Assessment. The initial component of an ECA should be compiled using the appropriate scientific formula(e) from IATG 01.80 *Formulae for ammunition management*. The IATG Implementation Support Tool provides an Explosion Consequence Analysis[36] tool that calculates the blast overpressure element for the analysis. Other tools, such as the Gurney equations for Fragment Velocity[37] and Explosion Danger Area Calculator[38] might also be used to support the analysis.

The objectives of an ECA should be to:

a) consider a realistic explosion threat scenario;

b) estimate the explosion effects on nearby personnel and structures; and

c) highlight particularly vulnerable risk areas that may require special protection requirements.

An example of a simple ECA methodology that could be used is at Annex E. A fuller ECA should also consider the following additional external hazards and contributions to initiation frequency:

a) lightning strikes. Where lightning protection in accordance with IATG 05.40 *Safety standards for electrical installations* is not provided;

b) flooding. Where the explosives facility is within a known flood plain;

c) aircraft crash. Where the explosives facility is close to commercial air routes or if in an area of high use by light aircraft;

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[35] www.un.org/disarmament/un-saferguard/explosives-limit-license/

[36] www.un.org/disarmament/un-saferguard/explosion-consequence-analysis/

[37] www.un.org/disarmament/un-saferguard/gurney/

[38] /www.un.org/disarmament/un-saferguard/explosion-danger-area/

d) nearby hazardous installations. Where the explosive facility is close to, or co-located with, for example, petroleum depots or ammunition disposal sites;

e) malicious destruction. The threat from sabotage or terrorist attack; and/or

f) consequential initiation. Where the potential explosion sites (PES) are within inappropriate separation distances and an explosion in one causes the initiation of explosives in nearby PES.

The IATG software includes an 'automated' ECA which just requires the input of basic readily available data.[39] Details of the IATG software are at Annex F.

13.4 Explosive Safety Cases (LEVEL 2)

For the construction of temporary ammunition storage sites (see IATG 04.10) when full compliance with Outside Quantity Distances and Inside Quantity Distances is not possible, an Explosive Safety Case (ESC) shall be compiled. This is done to ensure that the explosive risk carried is as low as possible, does not jeopardise operational capability and that health and safety requirements, and duty of care responsibilities, are properly considered.

There will be instances, particularly in post conflict environments, where a multitude of stakeholders are involved in ammunition stockpile management advisory or operational functions for humanitarian purposes. It is highly desirable that in such circumstances all stakeholders should use a common format for explosive safety cases, which integrates requirements from across the IATG. Such a format is at Annex G.

Explosive Safety Cases shall only be accomplished by individuals whom are appropriately qualified and experienced in ammunition safety management.

14 Uncertainty in risk estimation

Uncertainties are inevitable in risk estimation when predicting the consequences of explosive events due to the range of variables involved. Assumptions during the process should always be clearly stated, as should data sources. It may also be possible to include error margins and confidence levels, although this will require access to a range of statistical data that may well be unavailable. It is possible that uncertainties in the probability of events (see the example at Clause 8.2.3) may be of a factor of two or three; in some cases, even a factor of 10. In mathematical terms, this would be undesirable during, for example, a financial budgeting process, but in risk estimation it may be acceptable.

To explain, many nations accept that an $IR_{fatality}$ to workers from an industrial process should be in the region of 1×10^{-5} to 1×10^{-6}, and therefore if an $IR_{fatality}$ was estimated for an undesirable explosive event to be 1×10^{-3} then this would clearly not be tolerable risk, as it is two to three orders of magnitude away from the societal risk levels acceptable in those particular nations.

Risk estimation is a powerful tool in ensuring the safety of conventional ammunition stockpiles, but it should be used judiciously and by individuals who understand the hazards and have the technical experience to evaluate when it produces unlikely results. It is not a precise technique and the results will only be approximate, but in the field of explosive engineering, it is a proven technique that has significantly improved explosive safety when it has been applied.

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[39] More complex systems have been designed by countries. These include AMMORISK (Norway and Switzerland), AUSRISK (Australia), NOHARM (USA), RISKWING (UK), SAFER (USA). States should consider trying to obtain these systems on a bi-lateral support basis.

15 Cost benefit analysis (LEVEL 2)

15.1 Expected monetary values (LEVEL 2)

One technique of cost benefit analysis that can be used to estimate the costs of remediation measures versus the financial costs of an undesired explosive event within an ammunition storage area is that of Expected Monetary Value (EMV).[40] This is a technique that is extensively used by actuaries in the insurance sector.

Table 9 illustrates the indicative financial costs of remediation following an undesired explosion within an ammunition depot. It considers three scenarios:

a) a minor fire resulting in: 1) damage to ammunition stocks; and 2) limited infrastructure damage;

b) a major fire leading to minor explosions resulting in: 1) destruction of ammunition stocks; 2) destruction of the explosive storehouse; 3) limited damage elsewhere in the depot; 4) limited UXO contamination within the ammunition depot; 5) minor injuries to the civilian population; and 6) minor damage to civilian property outside the ammunition depot; and

c) a major fire leading to major explosions resulting in: 1) destruction of the explosive storehouse; 2) destruction of surrounding explosive storehouses; 3) destruction of a significant proportion of the ammunition stocks within the ammunition depot; 4) significant UXO contamination outside the perimeter of the explosives area; 5) fatalities and injuries to the civilian population; and 6) destruction and damage to civilian property outside the ammunition depot.

Due to the wide variance in economic costs in different regions of the world, it is not possible to allocate finite financial costs, but it is possible to indicate the order of magnitude of the costs, shown in Table 9 as ‘x’.

Financial Cost Area	Costs of Event ($x)		
	Minor Fire **(No Explosion)**	**Major Fire** **(Minor Explosion)**	**Major Fire** **(Mass Explosion)[41]**
EOD Clearance Costs	**x**	**xx**	**xxxxx**
Repair Costs (Ammunition Depot)	**xx**	**xxxx**	**xxxxx**
Repair Costs (Civilian Buildings)		**x**	**xxxx**
Reconstruction Costs (Ammunition Depot)	**xx**	**xxxx**	**xxxxx**
Reconstruction Costs (Civilian Buildings)			**xxx**
Injury Compensation Costs		**x**	**xxxx**
Replacement Ammunition Costs	**xxx**	**xxxx**	**xxxxx**
Staff Training Costs (New Staff)		**xx**	**xxxx**
Total Costs	**8 x**	**18 x**	**35 x**

Table 9: Indicative EMV orders of magnitude for explosive events

Table 10 illustrates the indicative financial costs of possible risk reduction measures that should be adopted to reduce the probability of an undesired explosion within an ammunition depot.

Due to the wide variance in economic costs in different regions of the world, it is again not possible to allocate finite financial costs, but it is possible to indicate the order of magnitude of the costs, shown in Table 10 as ‘y’.

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[40] Concept source for the use of EMV. Keeley R. *The Economics of Landmine Clearance*. www.dissertation.de. 2006.

[41] Assuming propagation from one explosive storehouse to the next.

Financial Cost Area	**Risk Reduction Costs against Event ($y)**		
	Minor Fire (No Explosion)	**Major Fire (Minor Explosion)**	**Major Fire (Mass Explosion)**[42]
Robust Explosive Storehouse (ESH) Buildings[43]		**yyy**	**yyyyy**
Barricades[44]		**yy**	**yy**
ESH and Barricades Annual Maintenance	**y**	**y**	**y**
Effective Fire Fighting Equipment	**y**	**yy**	**yy**
Vegetation Clearance Costs	**y**	**y**	**y**
Effective Staff Training	**y**	**yy**	**yyy**
Effective Ammunition Depot Procedures	**y**	**y**	**y**
Effective Contraband Measures	**y**	**y**	**y**
Total Costs	**6 y**	**13 y**	**16 y**

Table 10: Indicative EMV orders of magnitude for risk reduction costs

EMV uses a payoff matrix to estimate the annual financial costs of either taking remedial action or not taking remedial action. The EMV is calculated thus:

$$\textit{EMV (\$) = (Remedial Costs Taken or Not Taken x } P_{Event}) + (\textit{Remedial Costs Taken or Not Taken x } P_{Non\text{-}Event})$$

An example of the use of EMV indicative figures for a real ammunition depot, where an explosion took place due to fire, is explained at Annex H; this covers the Major Fire / Mass Explosion scenario shown in Tables 9 and 10.

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[42] Assuming propagation from one explosive storehouse to the next.

[43] Initial procurement and construction costs.

[44] Initial procurement and construction costs.

Annex A
(normative)
References

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this part of the guideline. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of the guideline are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO maintain registers of currently valid ISO or EN:

d) IATG 01.40 *Glossary of terms, definitions and abbreviations*. UNODA. 2020;

e) IATG 01.80 *Formulae for ammunition management*. UNODA. 2020;

f) IATG 02.20 *Quantity and separation distances*. UNODA. 2020;

g) ISO Guide 51 *Safety aspects – Guidelines for their inclusion in standards*. ISO. 2014; and

h) *Selection and use of explosion effects and consequence models for explosives.* (ISBN 07176 1791 2). Health and Safety Executive. UK. 2000. http://books.hse.gov.uk

The latest version/edition of these references should be used. The UN Office for Disarmament Affairs (UNODA) holds copies of all references[45] used in this guideline and can be found at: www.un.org/disarmament/un-saferguard/references/. A register of the latest version/edition of the International Ammunition Technical Guidelines is maintained by UNODA, and can be read on the IATG website: www.un.org/disarmament/convarms/ammunition/. National authorities, employers and other interested bodies and organisations should obtain copies before commencing conventional ammunition stockpile management programmes.

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[45] Where copyright permits.

Annex B
(informative)
Bibliography

The following informative documents contain provisions, which should also be consulted to provide further background information to the contents of this guideline:

i) *Explosion Hazards and Evaluation*. W E Baker et al. (ISBN 0 444 42094 0). Elsevier. Amsterdam. 1983;

j) IATG 02.30 *Licensing of explosive storage areas*. UNODA. 2021

k) AASTP-3, Edition 1, Change 3, *Manual of NATO Safety Principles for the Hazard Classification of Military Ammunition and Explosives*. NATO Standardization Organization (NSO). March 1995. (Note: restricted distribution)

l) AASTP-4 Edition1, Change 4, *Explosives Safety Risk Analysis*. NATO Standardization Organization (NSO). September 2016. (Note: Part 2 has restricted distribution);

m) AASTP-5, Edition 1, Version 3, *NATO Guidelines for the Storage, Maintenance and Transport of Ammunition on Deployed Missions or Operations*. NATO Standardization Organization (NSO). June2016;

n) Technical Paper 14. *Approved Methods and Algorithms for DoD Risk-Based Explosives Siting*. Revision 4. US Department of Defense Explosives Safety Board (DDESB), Alexandria, Virginia, USA. 17 March 2017;

o) Technical Paper 23. *Assessing Explosives Safety Risks, Deviations, and Consequences*. US Department of Defense Explosives Safety Board (DDESB), Alexandria, Virginia, USA. 31 July 2009.

The latest version/edition of these references should be used. The UN Office for Disarmament Affairs (UNODA) holds copies of all references[46] used in this guideline and these can be found at: www.un.org/disarmament/un-saferguard/references/. A register of the latest version/edition of the International Ammunition Technical Guidelines is maintained by UNODA, and can be read on the IATG website: www.un.org/disarmament/ammunition National authorities, employers and other interested bodies and organisations should obtain copies before commencing conventional ammunition stockpile management programmes.

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[46] Where copyright permits.

Annex C
(informative)
General effects of explosions

C.1 General

An explosion is a sudden release of energy caused by a very rapid chemical reaction that turns a solid or liquid into heat and gas. This reaction takes place in less than a millisecond. In the process of turning a solid or liquid into a gas expansion occurs, so in the case of an explosion the expanding gas is produced extremely rapidly and pushes the surrounding air out in front of it, thus creating a pressure wave, known as the Blast Wave.

When an explosion occurs at ground level there are several effects created that cause damage and injury. The extent of these effects will be generally dependent on the power, quality and the quantity of explosive deployed.

The six basic effects are:

a) thermal radiation;
b) brisance or shattering;
c) primary fragments;
d) blast wave;
e) ground shock;
f) debris (secondary fragments); and

g) confinement effects.

Each of these effects are summarised in the following sections.

C.2 Thermal effects

The thermal effects can be considered to be a ‘ball of fire’ created as part of the explosive process. It is very local to the seat of the explosion and is very short lived (a few milliseconds).

The thermal effects are particularly hazardous to those very close to the blast (i.e. taking shelter in a hardened structure) as the heat is able to penetrate small openings in a structure. For those in the open the blast wave and fragment effects have a greater range for inflicting damage.

C.3 Brisance

Brisance is the shattering effect, and it is very local to the seat of the explosion and is generally associated with high explosives. The effect of brisance can be severe when an explosive device is placed directly in contact with a structural component. A small air gap between the explosive and the target is effective at mitigating the onset of brisance-induced failures.

C.4 Primary Fragments

These are the fragments of the device or container of the device, which have been shattered by the brisance effect and are propelled at high velocity over great distances. Primary fragments can travel ahead of the blast wave and have the potential to cause injuries at a greater range than the blast wave.

C.5 Blast Wave

The blast wave is a very fast moving high-pressure wave created by the rapidly expanding gas of the explosion, which gradually diminishes with distance. The blast wave is capable of reflecting off surfaces and in the process can magnify itself. This is typically displayed when large devices are detonated in urban environments and the blast is ‘funnelled’ down narrow streets.

The blast wave has the potential to cause fatalities and serious injuries including lung and organ damage, rupture of the eardrums and the like. It can also cause injury due to whole body translation (or throwing) of individuals.

C.6 Ground Shock

Ground shock is produced by the brisance effect of the explosion shattering the ground local to the seat of the explosion, i.e., creating the crater of the explosion. The shock wave resulting from the crater’s creation continues through the ground and is known as ground shock.

The ground shock has the potential to cause damage to underground services (e.g. water, electricity etc) as well as structures below ground. It is not uncommon for floods to occur after a vehicle bomb attack, caused by the rupture of water mains.

C.7 Debris

These are the secondary fragments that have been created by the blast wave imparting pressure onto frangible materials that are unable to withstand this pressure or loose articles. The energy imparted to the fragments created by the blast can be such as to throw them large distances at great speed. Typical frangible materials that form debris are glass, roof slates, timber, metal frames and the like.

Due to the human body’s moderate resistance to the effects of the ‘blast wave’, debris is likely to cause injury at greater distance than the blast wave. Debris can cause fatalities and serious injury.

C.8 Confinement Effects

The detonation of an explosive within a building is more severe than in an open environment. This is because the blast wave is able to undergo multiple reflections (off walls, floors etc.), which leads to an increase in the amplitude and duration of the blast pressure. This increases the severity of damage to both structural elements as well as humans.

For internal explosions within robust rooms, it is possible for even more severe confinement effects to occur. This is a result of the confinement of the extremely hot gases that are produced by detonation. By suppressing the expansion of the gases, very high pressures/forces are applied to the room enclosure. The smaller the room the higher the resulting pressure.

Annex D
(informative)
Example Quantative Risk Assessment methodology (LEVEL 1 and 2)

SECTION A - GENERAL RISK ASSESSMENT SUMMARY SHEET[47]

Complete this sheet once Sections B to D have been used to conduct the Risk Assessment. This sheet then acts as a front page summary and review record.

ASSESSMENT NO:	IATG Example 1	**TASK LOCATION:**	APB 1	**DATE:**	25 August 2019
TASK DESCRIPTION:	Removal of Fuze from 152mm Artillery Shells by remote hydraulic fuze removal tool.				

#[48]	RESIDUAL RISKS IDENTIFIED	ACTION REQUIRED TO RECTIFY (ADDITIONAL TO CURRENT CONTROL MEASURES)
1	Failure of hydraulic pressure system for the remote fuze removal system, resulting in broken hoses.	▪ **Guards for hydraulic pipes.**
2	Static electricity present on individuals working in the APB initiating Electro-Explosive Devices r bare explosive dust.	▪ **Invoke control measures as for risk #5.**
3	Injury due to lifting of packs of 152mm artillery shells, and of individual shells from their packaging.	▪ **Consider installation of mechanical lifting devices.**
8**	Accidental initiation of shell when fuzes removed due to crystallization of TNT explosive filling in screw thread.	▪ **Actions as shown for #6 and #7.**

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[47] The risk assessment has been completed for a 4 person team removing the fuzes from artillery shells in an ammunition process building.

[48] From Section C.

SECTION B - GENERAL RISK ASSESSMENT SUMMARY SHEET

Use this section to identify Hazards and Sub-hazards. Detail the hazards identified here in Section C of the assessment.

HAZARDS	**MECHANICAL**		**ELECTRICAL**		**ACCESS AND ENVIRONMENT**		**HANDLING LIFTING AND TRANSPORT**		**EXPLOSIVES AND DANGEROUS SUBSTANCES**		**NOISE AND BLAST**		**RADIATION AND ENVIRONMENT**	
SUB HAZARDS	**Abrasion**		**Static**	2	**Slips, Trips etc.**		**Manual Handling**	3	**Primary**		**Launch**		**RF**	
	Cutting		**Piezo-Electric**		**Falling Objects etc.**		**Mechanical Equipment**		**Secondary**	5	**Impact**		**Radar**	
	Shearing		**Spark Ignition**		**Height**		**Lifting Tackle**		**Propellants**		**Static Initiation**		**Ionising**	
	Stabbing		**Connections**		**Trenching**		**Heavy Objects**		**Pyrotechnics**		**Blast Wave**	6	**Non-Ionising**	
	Impact				**Confined Space**		**Transport Explosives**	4	**WP**		**Fragmentation**	7	**Laser Cl 1**	
	Crushing				**Exposed Areas**		**Transport Dangerous Goods**		**Chemical**		**Shock Transfer**		**Laser Cl 2**	
	Pressure System	1			**Noise**				**Lachrymatory**				**Laser Cl 3A**	
	Machine Tools				**Vibration**				**Toxic**				**Laser Cl 3B**	
	Cavitation				**Humidity**				**Corrosive**				**Laser Cl4**	
	Grit				**Temperature**				**Irritant**					
					Weather				**Paints and Solvents**					
									Dusts					
									Fumes					

Now use Section C to expand on the Hazards identified, evaluate existing protective measures and "Rate" the Risk.

GENERAL RISK ASSESSMENT SUMMARY SHEET - SECTION C

Use this Section to record the hazards identified in Section B in more detail and evaluate current control measures, if any. Then using Section D as a guide, assess the risk and give it a rating.

Record the ratings in this Section and identify the Residual Risks.

ASSESSMENT NO:	IATG Example 1	**TASK LOCATION:**	APB 1	**DATE:**	25 August 2019
TASK DESCRIPTION:	Removal of Fuze from 152mm Artillery Shells by remote hydraulic fuze removal tool.				

#[49]	FURTHER DETAILS OF HAZARD FROM SECTION B	CURRENT CONTROL MEASURES	RISK RATE	RESIDUAL RISK
1	Failure of hydraulic pressure system for the remote fuze removal system, resulting in broken hoses.	▪ Effective initial and refresher staff training. ▪ Supervision by ammunition qualified staff. ▪ Regular maintenance of hydraulic systems.	**120**	▪Very High ▪Action immediately
2	Static electricity present on individuals working in the APB initiating Electro-Explosive Devices r bare explosive dust.	▪ Ensure use of static discharge system on access to APB. ▪ Use of static discharge leads on staff wrists.	**45**	▪High ▪Action as soon as possible
3	Injury due to lifting of packs of 152mm artillery shells, and of individual shells from their packaging.	▪ Ensure staff trained in manual lifting techniques.	**60**	▪High ▪Action as soon as possible
4	Explosion during movement of explosives from explosive storehouses (ESH) to ammunition process building.	▪ In accordance with IATG 08.10	**0.3**	▪Acceptable ▪Accept risk and keep under review

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[49] From Section B.

#[49]	FURTHER DETAILS OF HAZARD FROM SECTION B	CURRENT CONTROL MEASURES	RISK RATE	RESIDUAL RISK
5	Exposure of bare explosive to atmosphere when fuze removed.	▪ Category C operating conditions in place. ▪ Shells are immediately plugged after fuze removal.	0	▪Acceptable ▪Accept risk and keep under review
6	Accidental initiation of shell when fuze removed due to crystallization of TNT explosive filling in screw thread.	▪ Use of remote hydraulic fuze removal system. ▪ Screw thread of shells wiped with acetone to ensure no explosive can be trapped when plugs fitted. ▪ Man limit of 4 staff imposed within APB. Work ceases if these limits are reached.	0	▪Acceptable ▪Accept risk and keep under review
7	Fragmentation from shell body in the event of 6 above.	▪ Use of remote hydraulic fuze removal system. ▪ Remote fuze removal system behind armoured screens. ▪ Man limit of 4 staff imposed within APB. Work ceases if these limits are reached.	0	▪Acceptable ▪Accept risk and keep under review
8**[50]	Accidental initiation of shell when fuze removed due to crystallization of TNT explosive filling in screw thread.	▪ NIL	150	▪Very High ▪Action immediately

Now complete the Risk Assessment Summary Sheet, Section A, transferring the Residual Risks and identifying appropriate corrective action.

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[50] This has been included to show the difference in risk if NO control measures are taken.

GENERAL RISK ASSESSMENT - RISK RATING TABLES - SECTION D

Use this section to identify Hazards and Sub-hazards. Detail the hazards identified here in Section C of the assessment

Use this Section to assess Risks and calculate a Rating for each Risk. The ratings should then be annotated as applicable in Section C.

ASSESSMENT NO:	IATG Example 1	**TASK LOCATION:**	APB 1	**DATE:**	25 August 2019
TASK DESCRIPTION:	Removal of Fuze from 152mm Artillery Shells by remote hydraulic fuze removal tool.				

HAZARD # FROM SECTION C	**PROBABILITY OF EXPOSURE ‘E’**	**FREQUENCY OF EXPOSURE ‘F’**	**MAXIMUM LOSS ‘L’**	**PERSONS AT RISK ‘N’**	**RISK RATING E x F x L x N**	**SCORING TABLES**							
						‘E’		**‘F’**		**‘L’**		**‘N’**	
1	15	4	2	1	**120**	**Impossible**	0.0	**Infrequent**	0.1	**Fatality**	15.0	**1 - 2 Persons**	1
2	15	2.5	0	1	**45**	**Almost Impossible**	0.1	**Annually**	0.2	**Permanent Serious Injury**	8.0	**3 - 7 Persons**	2
3	15	4	1	1	**60**			**Monthly**	1.0			**8 - 15 Persons**	4
4	2	0.1	15	1	**0.3**	**Highly Unlikely**	0.5	**Weekly**	1.5	**Temporary Serious Injury**	4.0	**16 - 50 Persons**	8
5	15	4	0	1	**0**			**Daily**	2.5			**> 50 Persons**	12
6	2	0.1	0	1	**0**	**Unlikely**	1.0	**Hourly**	4.0	**Break major bone or major illness**	2.0		
7	2	0.1	0	1	**0**	**Possible**	2.0	**Constantly**	5.0				
8**	2	5	15	1	**150**	**Even Chance**	5.0						
						Probable	8.0			**Lacerations or mild ill health**	1.0		
						Very Likely	10.0						
						Certain	15.0			**Scratch or Bruising**	0.5		

RISK RATING	RISK	ACTION TIMETABLE	RISK RATING	RISK	ACTION TIMETABLE
0 - 0.9	Acceptable	Accept Risk, but keep under review	50 - 100	High	Action as soon as possible
1.0 - 4.9	Very Low	Consider action and set timetable for completion	100 - 200	Very High	Action immediately
5.0 - 9.9	Low	Consider action and set timetable for completion	200 - 300	Extreme	Consider stopping activity - Action immediately
10.0 - 49.9	Significant	Consider action and remedy as soon as possible	300 +	Unacceptable	Stop activity

Take into account existing Control Measures when assessing these values.

Now complete the Summary Sheet at Section C, Section A and ensure the assessment is signed by the appropriate persons.

Annex E

(informative)

Explosion Consequence Analysis methodology (LEVEL 2)

The ECA methodology at Table E.1 below is only one concept and example of how an ECA may be conducted. It is modelled on a single explosive storehouse (ESH), and only considers the consequence to the local civilian population; a more detailed model should also examine the potential loss of operational capability. An ECA for a complete ammunition depot will be a lot more complex, but the same principles used in Table E.1 should apply.

The phases of the ECA are explained using the risk management terminology relationships from Table E.1. Therefore, an ECA is primarily a risk assessment process, as it provides the technical and scientific analysis and evaluation to allow for risk-based decisions to be then made. It is not the role of an ECA to make decisions, although it may contain recommendations.

An ECA should not be required if the requirements of IATG 02.20 *Quantity and separation distances* can be met.

Risk Assessment Process Component	Ser	ECA Activity	Data Source
Risk Analysis (Hazard Identification and Analysis)	1	Determine UN Hazard Division of Ammunition.	▪ IATG 01.50 *UN Explosive Hazard Classification System and Codes*
	2	Determine Net Explosive Quantity (NEQ) of ammunition by Hazard Division in ESH or Temporary Storage Area.	▪
	3	Aggregate to HD 1.1 if applicable.	▪
	4	Determine level of protection of ESH or Temporary Storage Site.	▪ IATG 02.20 *Quantity and separation distances.* (Type of ESH). ▪ IATG 04.20 *Temporary storage.*
	5	Determine Range (m) to nearest public road.	▪ Google Earth. ▪ Site Plans or maps. ▪ Laser range finder. ▪ Tape measure. ▪ Pacing.
	6	Determine Range (m) to nearest inhabited building (civilian house).	
	7	Determine Range (m) to nearest vulnerable building (hospital).	
	8	Determine Range (m) to any Secondary Hazards.	
	9	Determine condition of ammunition and likelihood for spontaneous ignition of propellant.	▪ Historical. ▪ Surveillance results.
Risk Analysis (Risk Estimation)	10	Determine physical effects (reflected overpressure and reflected impulse) at each range to Serials 5 - 8.	▪ IATG 01.80, Clause 6.2. (using IATG Software[51]).
	11	Estimate ranges for thresholds of impact on humans (from *Bowen*).	▪ IATG 01.80, Clause 11.2
	12	Determine number of humans likely to be in open within ranges at Serial 11. **(Human casualties in the open now estimated for blast effects).**	▪
	13	For the NEQ at Serial 2 determine the ranges at which various levels of damage to buildings may be expected.	▪ IATG 01.80, Clause 10.1
	14	Determine the number of buildings within each damage criteria range estimated at Serial 13. **(Damage to buildings from blast now estimated)**	▪
	15	For the NEQ at Serial 2 estimate the range at which Ground Shock is likely to cause damage.	▪ IATG 01.80, Clause 10.3

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[51] www.un.org/disarmament/un-saferguard/kingery-bulmash/

Risk Assessment Process Component	Ser	ECA Activity	Data Source
	16	Determine the number of buildings within Ground Shock range. Check that they are not also damaged by blast, to avoid 'double counting'. **(Damage to buildings from Ground Shock now estimated)**	▪
	17	Apply the probability values for secondary blast injury to the Serial 14 results. **(Probability of secondary blast injuries for each building now established.)**	▪ IATG 01.80, Clause 11.3, Table 36
	18	Estimate occupancy levels and exposure probabilities for houses at Serial 16. Then estimate casualty numbers. **(Human casualties in the open now estimated for blast effects).**	▪
	19	Estimate financial values of stocks, costs to rebuild/repair storage infrastructure, repair/rebuild civilian damaged building.	▪
	20	Use Serial 19 data in EMV model to estimate likely financial consequences of an explosive event.	▪ Clause 15.1
Risk and ALARP Evaluation	21	Compare estimated predicted casualties at Serials 12 and 18 to other industrial accident levels. Are the predicted casualties tolerable?	▪
	22	Are the financial consequences at Serial 20 acceptable to the government? If no, then is the MOD prepared to accept lower stock levels. If yes to both, then risk tolerable. If no to both or one, then risk not tolerable.	▪

Annex F
(informative)
Risk management and IATG software (LEVEL 1 and 2)

See IATG Implementation Support Tool Kit:www.un.org/disarmament/ammunition .

The IATG Implementation Support Toolkit includes a Risk Reduction Checklist[52] tool that gives the user a determination of the Risk Reduction Process Level (RRPL) for a stockpile at a single site. If this tool is used to determine a baseline, it can then be used subsequently to determine how the level of risk being accepted by the authorities is being reduced as the storage facility develops over time.

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[52] www.un.org/disarmament/un-saferguard/risk-reduction-process-levels

Annex G
(informative)
Explosive Safety Case (ESC) **Format** **(LEVEL 2)**

1. Introduction

Include an explanation of the explosive storage area and summarise why full IATG compliance is not possible. This should include location, infrastructure type, total numbers of persons at the site or in the immediate area of the site.

2. Explosion Consequence Analysis (ECA)

Include the ECA in accordance with Annex E to IATG 02.10.

3. Summary of Non-Compliances

List all non-compliance issues referenced against the appropriate IATG and Clause. For example:

The maximum Outside Quantity Distance (OQD) that may be achieved is only 220m. This is 120m less than the recommended OQD as at IATG 04.10, Clause 8.5.2, Table 11.

4. Summary of Hazard Mitigation Measures

List all hazard mitigation measures applied in order to reduce risk. These should be referenced against each non-compliance area.

5. Residual Risks

List the residual risk for each non-compliance issue. For example:

The required storage levels of 35,000kg of HD1.1 means that in the event of an undesired explosive the reflected blast over-pressure at 220m will be 41.8kPa. This is in excess of the 34.5kPa level at which permanent hearing damage is to be expected (249m). There are routinely 40 persons working within the 220m to 249m zone who would be inversely affected by suffering permanent hearing damage.

6. Probability of Event

The ESC compiler should try to determine the probability (likelihood) of an event at the site. This may be based on past historical data within the country and the security environment at the time the ESC is complied. Alternatively, estimate can be made on past global explosive events at ammunition storage areas, (data in IATG 02.10, Clause 8.2.1.1).

7. Acceptance of Risk

(IATG 02.10, Clause 11, IATG 04.10, Clause 5,2)

The ESC and the residual risk identified shall be formally acknowledged by the risk owner. Include here the full details of the risk owner.

The wording of the 'risk acceptance letter' is extremely important and a draft should be provided by the compiler of the ESC as an Annex to the ESC. Due to the large number of possible scenarios and variables, it is not possible to provide an example draft of such a letter.

Name of ESC Compiler:		**Signature of ESC Compiler:**	
Qualifications of ESC Compiler:		**Date of ESC:**	
Organization of ECA Compiler:			
Contact Details of ECA Compiler:			

Annexes

A. Safety Map (indicating areas of risk).
B. Site Plan.
C. Draft Explosive Limits Licence (from IATG 02.30).
D. Draft Acceptance of Risk Letter.

Annex H
(informative)
Expected Monetary Value Estimation (LEVEL 2)

An example of the use of EMV indicative figures for a real ammunition depot, where an explosion took place due to fire, is explained below; this covers the Major Fire / Mass Explosion scenario shown in Tables 5 and 6. This event, that took place in April 2000, resulted in 2 fatalities, 10 injured and the loss of US$ 90m of ammunition stock.

Input data for the EMV analysis is assumed as follows which will provide indicative costs.

a) The probability of an explosive event P_e (Events per Year) at the ammunition depot was 2.78 x 10^{-2} (Clause 8.2.1). This is because of inadequate ammunition stockpile management;

b) The probability of that explosive event being caused by fire = 0.455; [53]

c) The probability of an explosive event P_e (Events per Year) at the ammunition depot, had effective stockpile management processes being in place, is assumed to be two orders of magnitude less, i.e. 2.78 x 10^{-4};

d) The probability of that explosive event being caused by fire remains at 0.455, as there is no available evidence to suggest that the causes of such events will change this probability;

e) The financial costs in Year 1 to reduce the probability of the event taking place have been estimated at US$ 200,000. This reduces to US$ 50,000 for Year 2 onwards. (This figure obviously needs to be estimated for each case.);

f) The annual financial cost of operating the depot with no actions taken to reduce the probability of an event was US$ 5,000;

g) The declared loss of ammunition stocks, which will require replacement, equates to US$ 90m if remedial action is not taken;

h) The predicted loss of ammunition stocks, which would have required replacement, equates to US$1M had remedial action being taken prior to the event. (As the remedial action protected other stocks in the depot.);

i) The compensation cost in Year 1 for each fatality that occurred is assumed to be US$ 10,000. (This is low, but this is due to the explosion taking place in a lesser developed country.);

j) The compensation cost in Year 1for each injury that occurred is assumed to be US$ 5,000;

k) There are no compensation costs for Year 2 as it assumed that the remedial action is effective, even if there should be an explosive event.

In this example, as remedial action would require a 'one off' financial cost of infrastructure improvement to the ammunition depot and technical staff training, two calculations are required: Year 1 and Year 2. These are shown in Tables G.1 and G.2.

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[53] From data contained within Explosive Capabilities Limited, *The Threat from Explosive Events in Ammunition Storage Areas.* Annex B. 01 April 2009. This includes fires started due to propellant instability, as well as external and internal fires.

Remedial Actions	Financial Costs (US$)		EMV (US$)
	Incident Scenario Doesn't Occur	Incident Scenario Does Occur	
Taken (Storage depot improved and operated in accordance with IATG recommendations) (Stock loss minimised to $ 100,000)	**$ 200,000**	**$ 300,000**	**$ 201,265**
Not Taken Stock loss of $90M and $ 100K compensation costs)	**$ 5,000**	**$ 90,080,000**	**$ 1,144,359**
		EMV Differential	**$ 943,094**

Table G.1: Indicative EMV values (US$) based on the April 2002 explosive event (Year 1)

So, for Year 1 of this incident scenario, there would be a US$ 943,094 EMV benefit if US$ 200,000 was spent on remedial action to reduce the probability of an explosive event caused by fire within the ammunition depot. As the EMV of not taking any action is US$ 1,144,359, then financial investment in training and infrastructure necessary to comply with the IATG guidelines during Year 1 could be justified up to a cash level of US$ 1,155,175[54] solely on the EMV financial benefit.

Assuming that the infrastructure and training remedial actions were taken in Year 1, then the operating costs of the ammunition depot fall significantly for Year 2 onwards, until major maintenance or refurbishment work is required (usually after 20 years). In Table G.2 the probability of an event is two orders of magnitude less than for Table 1, but the stock loss levels remain the same should an event take place.

Remedial Actions	Financial Costs (US$)		EMV (US$)
	Incident Scenario Doesn't Occur	Incident Scenario Does Occur	
Taken (Storage depot improved and operated in accordance with IATG recommendations) (Stock loss minimised to $100,000)	**$ 50,000**	**$ 1,000,000**	**$ 50,120**
Not Taken (In Years 1 and 2) Stock loss of $90M and $100K compensation costs)	**$ 5,000**	**$ 90,080,000**	**$ 1,144,359**[55]
		EMV Differential	**$ 1,094,239**

Table G.2: Indicative EMV values (US$) per year based on the April 2002 explosive event (Years 2 - 20)

So, for Years 2 to 20 of this incident scenario, there would be a US$ 1,094,239 EMV benefit per year if US$ 50,000 was spent on continued remedial action to reduce the probability of an explosive event caused by fire within the ammunition depot. As the EMV of not taking any action in Years 1 and 2 is still US$ 1,144,359, then theoretically financial investment in training and infrastructure necessary to comply with the IATG guidelines during Years 2 to 20 could be justified up to a cash level of US$ 1,144,378 solely on the EMV financial benefit.

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[54] This figure is achieved by using the spreadsheet contained within the IATG Software. The data entry for the Financial Costs (Incident Scenario Doesn't Occur / Remedial Action taken) is adjusted until the EMV's of Action Taken and Action Not Taken balance.

[55] The probability for this EMV remains at 1.11 x 10^{-2} as no remedial action taken in Years 1 and 2.

This example illustrates the usefulness of the EMV system when comparing the financial requirements necessary to be compliant with the IATG Guidelines against the real financial costs of an explosive event within an ammunition depot. EMV analysis should be done for each generic type of scenario that is likely to result in an explosive event, compared against the financial costs of remedial action necessary to reduce the probability and consequences of such an event to tolerable risk levels (for financial, reduced defence capability, human and political costs).

Amendment record

Management of IATG amendments

The IATG are subject to formal review on a five-yearly basis. This does not preclude amendments being made within these five-year periods for reasons of operational safety, efficacy and efficiency or for editorial purposes.

As amendments are made to this IATG module they will be given a number, and the date and general details of the amendment will be shown in the table below. The amendment will also be shown on the cover page of the IATG by the inclusion of the amendment number and date.

As the formal reviews of each the IATG module is completed, new editions will be issued. Amendments will be incorporated into the new edition and the amendment record table cleared. Recording of amendments will then start again until a further review is carried out.

The most recently amended, and thus extant, IATG module is posted on www.un.org/disarmament/ammunition

Number	**Date**	**Amendment Details**
0	01 Feb 15	Release of Edition 2 of IATG.
1	31 March 21	Release of Edition 3 of IATG.