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Step 8
Soliciting comments by Member States

Human induced External Hazards in Site Evaluation for Nuclear Installations

DRAFT SAFETY GUIDE NUMBER DS520

Revision of Safety Guide NS-G-3.1

FOREWORD

Later

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide provides recommendations on how to meet the requirements for nuclear installations[1] established in the IAEA Safety Standards Series No. SSR-1, Site Evaluation for Nuclear Installations [1] with regard to the evaluation of hazards associated with human induced external events[2] (HIEEs).

1.2. This Safety Guide complements other Safety Guides that provide recommendations on site evaluation and design of nuclear installations against external events excluding earthquakes [2–7].

1.3. Over the past two decades, significant new knowledge and experience has been gained of hazards associated with human induced external events. This Safety Guide incorporates:

(a) Recent developments and regulatory requirements on risk informed and performance-based approaches for assessing the safety of nuclear installations, including reference to IAEA's Safety Fundamentals and Safety Requirements relevant to hazards associated with human induced external events;
(b) Progress in practices in States relevant to human induced external events;
(c) A systematic approach to the identification, screening and subsequent hazard analysis for all human induced external events;
(d) Reference to good practice methodologies for analysing the hazards arising from the most significant human induced external events.

1.4. This Safety Guide supersedes the previous Safety Guide on External Human Induced Events in Site Evaluation for Nuclear Power Plants[3].

OBJECTIVE

1.5. The objective of this Safety Guide is to provide recommendations on evaluation of hazards associated with human induced external events that could affect the safety of nuclear

[1] The term 'nuclear installation' includes: nuclear power plants; research reactors (including subcritical and critical assemblies) and any adjoining radioisotope production facilities; spent fuel storage facilities; facilities for the enrichment of uranium; nuclear fuel fabrication facilities; conversion facilities; facilities for the reprocessing of spent fuel; facilities for the predisposal management of radioactive waste arising from nuclear fuel cycle facilities; and nuclear fuel cycle related research and development facilities.

[2] An external event is an event that originates outside the site, and for which the operating organization\z has a very limited or no control over its occurrence, and whose effects on the nuclear installation should be considered. Such events could be of natural or human induced origin and are identified and selected for design purposes during the site evaluation process. Events originating on the site but outside the buildings important to safety should be treated the same as off-site external events, but taking into account the higher level of control over these events (this includes any coupled facilities on the site, e.g. to produce hydrogen). A slightly modified definition of the term 'external event' is used in this publication.

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, External Human Induced Events in Site Evaluation for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-3.1, IAEA, Vienna (2002).

installations. These hazards need to be considered in the selection and evaluation of sites for nuclear installation, in the design of new nuclear installations, and in the operation of existing nuclear installations.

1.6. This Safety Guide is intended for use by regulatory bodies, designers of nuclear installations and for operating organizations directly responsible for the safety of nuclear installations and for the protection of people and the environment from harmful effects of ionizing radiation that might arise from such installations.

SCOPE

1.7. The recommendations in this Safety Guide are intended to be used for the evaluation of hazards associated with HIEEs for nuclear installations. The approach for evaluation of these hazards and utilizing these evaluations in the design and operation of nuclear installations need to be planned and implemented in a systematic way. This process can be divided into the following phases:

— Phase 1: Identification and screening of sources of hazards;
— Phase 2: Evaluation of hazards and characterization of loading conditions;
— Phase 3: Design and evaluation of structures, systems and components;
— Phase 4: Performance, assessment and acceptance criteria;
— Phase 5: The response of the operating organization to potential HIEEs.

This Safety Guide considers Phases 1 and 2. Phases 3 and 4 are addressed in the IAEA Safety Standards Series No. DS498, Design of Nuclear Installations Against External Events Excluding Earthquakes [7], and Phase 5 is addressed in IAEA Safety Standards Series No. DS503, Protection against Internal and External Hazards in the Operation of Nuclear Power Plants [8]. These phases are closely linked, and the needs of each phase should be recognised in other phases, especially at the interfaces between phases where the outputs from earlier phases inform and provide input data to later phases.

1.8. Phase 1 includes source identification and screening of potential sources in the region around the nuclear installation site. Phase 2 builds on Phase 1 and considers only the HIEEs screened-in by the screening exercise. Phase 2 includes detailed evaluation of hazards for characterization of loading conditions for screened-in hazards.

1.9. In this Safety Guide, the HIEEs are grouped into following event categories:

— External release of hazardous substances;
— External explosions;
— External fire;
— Aircraft crash;
— External transport events excluding aircraft crash;
— Other human induced external events.

1.10. This guide includes recommendations on consequential hazards arising from HIEEs, e.g. aircraft fuel fires following an aircraft impact. However, it does not address hazard combinations. Recommendations on hazard combinations are provided in DS498 [7].

1.11. This Safety Guide addresses a range of types of nuclear installation (see footnote 1). Many of the recommendations were originally derived for nuclear power plants, and such recommendations need to be applied to other nuclear installations through a graded approach. The recommended direction of this graded approach is to start with attributes relating to nuclear power plants and, if appropriate, to adjust these to installations with lesser radiological consequences. If a graded approach is not performed, the recommendations relating to nuclear power plants are to be applied to other types of nuclear installation.

1.12. The recommendation in this Safety Guide apply to all stages of the lifecycle of a nuclear installation from site selection to permanent shutdown.

1.13. This Safety Guide is mainly focused on the evaluation of the site of a new nuclear installation. However, the recommendations are also applicable in the re-evaluation of the sites of existing nuclear installations, and in the periodic safety reviews of such installations.

1.14. For the purpose of this Safety Guide, existing nuclear installations are those installations that are either: (a) at the operational stage (including long term operation and extended temporary shutdown periods); (b) at a pre-operational stage for which the construction of structures, the manufacturing, installation and/or assembly of components and systems, and commissioning activities are significantly advanced or fully completed; or (c) at temporary or permanent shutdown stage while nuclear fuel is still within the facility (in the core, spent fuel pool, on site waste storage).

1.15. This Safety Guide also addresses site evaluation for multiple nuclear installations and eventual coupled facilities (if any) on the same site or on adjacent sites.

1.16. The external human induced events considered in this Safety Guide are of accidental origin. Other events are out of scope of this Safety Guide, although these will be a consideration in planning the mitigation of and response to such events. Considerations relating to the nuclear security of nuclear installations against malicious activities (i.e. deliberate acts of sabotage, damage), by third parties are outside the scope of this Safety Guide. However, the methods described herein for the development of protective and mitigation measures against HIEE of accidental origin may also have application to the development of measures against malicious activities. Guidance on security considerations can be found in the IAEA Nuclear Security Series [9-14]. Due consideration should be given to sensitivity of information on externals hazards from a nuclear security perspective. For example, information on human induced external hazards that can be beyond the safety design basis is highly sensitive because terrorists could use it as a potential way for an attack. Therefore, such information should be handled carefully in cooperation with nuclear security specialists.

STRUCTURE

1.17. Section 2 provides recommendations on the evaluation of hazard associated with HIEEs for nuclear installations. Section 0 provide recommendations on the identification and screening of sources and evaluation of hazards for HIEEs. Section 4 provide recommendations on data collection and investigations. Sections 5–10 provide recommendations on hazard evaluations for event categories. Section 11 provides recommendations on applying a graded approach to the evaluation of nuclear installations other than nuclear power plants. Section 12 provides recommendations on management systems to be put in place for the performance of all activities. For definitions and explanations of the technical terms used, see the IAEA Safety Glossary [15]. Explanations of technical terms specific to this Safety Guide are provided in footnotes.

2. GENERAL RECOMMENDATIONS

APPLICABLE SAFETY REQUIREMENTS

2.1. SSR-1 [1] establishes Requirement 6 for identification of site-specific hazards in site evaluation for nuclear installations, Requirement 7 for evaluation of natural and human induced external hazards, Requirement 8 for measures for site protection, Requirement 9 for site evaluation for multiple nuclear installations on the same site and on adjacent sites, Requirement 14 for data collection and Requirement 24 for evaluation of hazards associated with human induced events. These requirements are of particular interest to the evaluation of sites for nuclear installations for hazards associated with HIEEs. Requirements 6, 7, 8, 9, 14 and 24 are reproduced here for convenience:

> **Requirement 6: Identification of site-specific hazards**
> “**Potential external hazards associated with natural phenomena, human induced events and human activities that could affect the region shall be identified through a screening process.**”
>
> **Requirement 7: Evaluation of natural and human induced external hazards**
> “**The impact of natural and human induced external hazards on the safety of the nuclear installation shall be evaluated over the lifetime of the nuclear installation.**”
>
> **Requirement 8: Measures for site protection**
> “**If the projected design of the nuclear installation is not able to safely withstand the impact of natural and human induced external hazards, the need for site protection measures shall be evaluated.**”
>
> **Requirement 9: Site evaluation for multiple nuclear installations on the same site and on adjacent sites**
> “**The site evaluation shall consider the potential for natural and human induced external hazards to affect multiple nuclear installations on the same site as well as on adjacent sites.**”
>
> **Requirement 14: Data Collection in site evaluation for nuclear installations**
> “**The data necessary to perform an assessment of natural and human induced**

external hazards and to assess both the impact of the environment on the safety of the nuclear installation and the impact of the nuclear installation on the people and environment shall be collected."

Requirement 24: Evaluation of hazards associated with human induced events
"**The hazards associated with human induced events on the site or in the region shall be evaluated.**"

2.2. In support of Requirement 24, SSR-1 [1] states:

"Human induced events to be addressed shall include, but shall not be limited to:
(a) Events associated with nearby land, river, sea or air transport (e.g. collisions and explosions);
(b) Fire, explosions, missile generation and releases of hazardous gases from industrial facilities near the site;
(c) Electromagnetic interference." (para. 5.33 of SSR-1 [1])

"Human activities that might influence the type or severity of natural hazards, such as resource extraction or other significant re-contouring of land or water or reservoir-induced seismicity, shall be considered." (para. 5.34 of SSR-1 [1])
"The potential for accidental aircraft crashes on the site shall be assessed with account taken, to the extent practicable, of potential changes in future air traffic and aircraft characteristics." (para. 5.35 of SSR-1 [1])

"Current or foreseeable activities in the region surrounding the site that involve the handling, processing, transport and/or storage of chemicals having a potential for explosions or for producing gas clouds capable of deflagration or detonation shall be addressed." (para. 5.36 of SSR-1 [1])

"Hazards associated with chemical explosions or other releases shall be expressed in terms of heat, overpressure and toxicity (if applicable), with account taken of the effect of distance, and non-favourable combinations of atmospheric conditions at the site. In addition, the potential effects of such events on site workers shall be evaluated." (para. 5.33 of SSR-1 [1])

2.3. The equivalent requirements to those listed in paras 2.1 and 2.2 for research reactors and nuclear fuel cycle facilities are provided in IAEA Safety Standards Series Nos SSR-3, Safety of Research Reactors [16] and SSR-4, Safety of Nuclear Fuel Cycle Facilities [17], respectively.

GENERAL CONSIDERATIONS

2.4. HIEEs are caused by people and the way people act creates the environment in which hazardous events can occur and propagate. The important consideration is to recognise the possibility of an event and seek data from experience to support judgements on which events are likely to be significant and how frequently they are likely to occur. Human factors relevant to the identification and analysis of HIEEs include direct human action (e.g. exceeding a safe speed limit or energising an incorrect item of equipment), indirect human action (e.g. sub-standard design of equipment, poor maintenance practice), and errors of commission and omission.

2.5. Potential sources of HIEEs are classified as either stationary or mobile and both should be considered, as follows:

(a) Stationary sources of HIEEs, are those that handle, process or store potentially hazardous substances such as explosive, flammable, corrosive, toxic or radioactive materials, and for which the location of the initiating mechanism (explosion centre, point of release of flammable or toxic gases) is fixed, such as chemical plants, oil refineries, storage depots, pipelines, and other nuclear facilities at the same or a nearby site. Structures such as dams that control large volumes of water are stationary sources of HIEEs, for which recommendations are provided in IAEA Safety Standards Series No. SSG-18, Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations [3].

(b) Mobile sources of HIEEs are those for which the location of the initiating mechanism is not totally constrained, such as any means of transport for hazardous materials or potential projectiles (by road, rail, waterways, air, pipelines). In such cases, an accidental explosion or a release of hazardous material may occur anywhere along a road, route, or pipeline.

2.6. The region in which there is a nuclear installation site should be examined for facilities and human activities that have the potential to endanger the nuclear installation over its entire lifetime. Each potential source of HIEEs should be identified and assessed to determine the potential interactions with items important to safety at the nuclear installation.

2.7. The size of the region to be investigated depends on the type of HIEE source and will range from few kilometres for fire to tens of kilometres for aircraft crashes and bombing ranges. All such HIEEs should be investigated in the site evaluation. It should not be overlooked that, in specific situations, a minor event may lead to severe effects.

2.8. Some of the effects of HIEE are more widespread than others. These effects could affect both the nuclear installation's offsite facilities and items important to safety, such as by affecting the availability of evacuation routes (the site might lose links to safe areas in the region), the possibility of implementing emergency procedures (access by operating personnel could be impaired), and the availability of the external grid and the ultimate heat sink. Special attention should be given to understand the various levels of defence in depth that may be challenged for such events.

2.9. Unlike most natural external hazards, new sources of HIEEs can evolve rapidly. Therefore, a prognosis should be made for possible regional development over the anticipated lifetime of the nuclear installation, with account taken of the degree of administrative control that could realistically be exercised over activities in the region. In this respect, allowance should be made for the fact that technologies in the chemical and petrochemical industries, as well as traffic densities, may evolve rapidly.

2.10. HIEEs initiated at a source may eventually result in different hazards at a nuclear installation site after going through an interacting mechanism. A number of potential HIEE sources (e.g. a chemical process site) are presumed to exist around a nuclear installation ;each source is capable of one or more events (e.g. plant failure causing explosion and releasing stored process gas); and each event may create one or more hazardous conditions (e.g. explosion pressure wave, release of toxic gas) with the potential to challenge nuclear safety at a nearby nuclear installation. In principle, it is necessary to perform a hazard analysis of each HIEE scenario; however, only a small subset of these is likely to represent a credible risk to nuclear safety. In order to make the overall HIEE analysis traceable, the procedure described in this Safety Guide includes identification and screening to ensure that only those sequences that are significant to nuclear installation safety are considered through the entire process. To clarify the process of HIEEs and their possible effects on nuclear installations, this guide introduces a number of interrelated terms to describe such events, the most important being source of HIEEs, event and hazard.

2.11. To further illustrate the concept of 'interacting mechanism', as to how hazardous events originating at a source can lead to sequences of further events, creating a hazardous situation at a site, examples of HIEE event categories, generic screening distance values, identification of sources of HIEEs along with the necessary information, potential HIEEs at sources, possible hazards at site, load characterisation parameters and possible consequences at a nuclear installation site are provided in Tables A.I–A.V in the Appendix.

2.12. In general, there are three types of protection against HIEE for a nuclear installation: (i) protection through a robust design of the structures, systems and components important to safety, (ii) protection through the provision of site protection measures such as sufficient distance and barriers, (iii) protection through administrative measures such as no-fly zones. Administrative measures are generally the least reliable means of protection and they should be considered as complementing the first two.

2.13. A satisfactory engineering solution should be achieved for protection against those HIEEs that have not otherwise been excluded from further consideration through the screening process (e.g. through a probabilistic screening, as discussed in para. 3.12), Appropriate administrative actions should be taken in the case of an existing nuclear installation in which satisfactory engineering solutions are not considered reasonably practicable.

2.14. Lack of confidence in the quality of the data — that is its accuracy, applicability, completeness, or quantity — may preclude the use of complex analysis techniques to characterise some HIEEs, either at the screening stage or for subsequent hazard evaluation. In such cases, a pragmatic approach based on engineering judgement should be taken, ensuring always that such judgments are demonstrably conservative. Recommendations on data collection are provided in Section 4.

3. IDENTIFICATION OF SOURCES OF HUMAN INDUCED EXTERNAL HAZARDS, SCREENING AND EVALUATION METHODS

GENERAL PROCEDURE

3.1. Evaluation of hazards associated with HIEEs is a multiple-stage approach. In the first stage, sources of HIEEs should be identified based on available data, followed by collection of data for the relevant regions. Screening is then conducted based on the established distance and probability criteria. In the next stage, detailed evaluation of screened-in hazards should be conducted. The identification of sources of HIEEs should be initially performed using limited, easily accessible data, then be refined as more data, knowledge and information of how the HIEEs might affect the site or nuclear installation becomes available. The process of identification, screening and detailed evaluation of each source of HIEEs is described in this Section and shown in Figure 1.

IDENTIFICATION AND SCREENING OF SOURCES of HUMAN INDUCED EXTERNAL EVENTS

3.2. The screening distance value (SDV) is the distance from a nuclear installation site beyond which a hazard from an HIEE is considered insignificant to the safety of the nuclear installation. SDV is as a simple and conservative tool that ignores any additional factors like involved mass or typical atmospheric conditions. For some sources, a simple deterministic study, based on information on the distance and characteristics of the source, may be enough to show that no significant event can occur.

3.3. To initiate the evaluation process, source regions centred on the nuclear installation site should be identified based on the Generic Screening Distance Values (SDV^g) for different Event Categories (see box 1 in Fig. 1) given in Table A.II in the Appendix. SDV^g's are typical values used by some States for large nuclear power plants with standardized designs. Since large nuclear power plants are more robust, these values should be checked for other nuclear installations. These values should also be checked if the nuclear power plant design and layout present any potential weakness to HIEEs.

3.4. Local topography, regional and local meteorological effects may significantly modify the SDV^g values. In case of any peculiar site condition or significant specific hazard, the source(s) of HIEEs should be taken to the next stage even if screened out with respect to distance. Safe distances from potential sources vary greatly, for example a chemical plant located close to a nuclear installation which is well protected by hills as compared to a nuclear installation located far away on flat area with predominant winds blowing towards the site.

3.5. All stationary and mobile sources of potential HIEEs in the source regions should be identified and data for these sources (e.g. source type, distance, potential events) should be collected (see box 2 in Fig. 1). Details for data collection and investigations are given in Section 4.

3.6. A Source Display Map showing all potential sources of HIEEs (both present and foreseeable sources) should be prepared and these sources should be listed along with the distances from the nuclear installation site. Uncertainties related to these should be estimated (see box 3 in Fig. 1).

3.7. For each type of effect that could arise from a HIEE, a maximum acceptable loading limit should be established, based on the vulnerabilities of structures, systems and components.

3.8. Specific Screening Distance Value (SDV^s) for each source of an HIEE (stationary and mobile) should be determined by simple calculations using source specific data, considering local site conditions. The determination of the SDV^s should consider the severity and extent of the event including relevant uncertainties, as well as the expected characteristics of the nuclear installation to be located at the site. These characteristics may be assumed for the early stages of siting process to be those corresponding to the standard nuclear installation design.

3.9. Potential HIEEs may generate different types of hazards (e.g. an event at the chemical plant may produce toxic gas and pressure wave) at the nuclear installation site (see box 4 in Fig. 1), as explained in para. 2.10. The SDV^s of both hazards will be quite different as a gas vapor cloud may travel much longer distance than the pressure wave.

3.10. After considering potential future changes in source characteristics and associated uncertainties related to distances and intensities, if the nuclear installation site is outside of all SDV^s for the specific source of HIEEs, no further analysis is necessary (see box 5 in Fig. 1).

3.11. For sources generating effects of the same nature, a further screening should be performed, which would depend on an enveloping criterion and which should exclude those sources that generate events that are enveloped by those for other selected sources of HIEEs, even if the site is inside the SDV^s for these sources. It should be ensured that the enveloped sources are considered if and when the event frequency is estimated. Care is also needed regarding the potential reduction of the number of events that could affect the nuclear installation, and thus the probability.

3.12. If the nuclear installation site is inside one or more SDV^s, relevant HIEEs should be identified and the probability of occurrence of these events should be estimated (see box 6 in Fig. 1).

3.13. If the probability of occurrence of an event under consideration is less than the specified Screening Probability Level (SPL)[4], no further analysis is necessary (see box 7 in Fig. 1). The SPL should be chosen such that the radiological risk associated with hazards is acceptable low.

[4] In some States, a value for the probability of 10^{-7} per reactor-year is used in the design of new facilities as one acceptable limit on the probability value for interacting events having serious radiological consequences, and this is considered a conservative value for the SPL if applied to all events of the same type (such as all aircraft crashes, all explosions). However, such grouping of similar events may not be appropriate where a specific single event has very severe consequences and requires a very low SPL."

Uncertainties should be considered in calculating the probabilities of occurrence for the HIEEs in probabilistic screening.

DETAILED EVALUATION INCLUDING HAZARD PARAMETERS AND LOAD CHARACTERIZATION

3.14. If the probability of occurrence of the HIEE(s) under consideration is greater than the specified SPL value, a detailed evaluation should be made. For this purpose, more detailed data should be collected to evaluate the event(s) and the interaction of a hazard(s) with the nuclear installation site (see box 8 in Fig. 1).

3.15. Hazard analysis should be performed to check whether hazards from HIEEs will interact[5] with the nuclear installation site. If the hazard analysis results show that the hazards will not interact the nuclear installation site, no further analysis is necessary (see box 9 in Fig. 1).

3.16. If any of the hazards can interact with the nuclear installation site, a detailed hazard analysis should be performed, and hazard parameters and load characterization should be established (see box 10 in Fig. 1). Tables A.IV and A.V in the Appendix list the common hazards likely to be encountered and indicate the relevant type of hazard and characterization parameters in each case.

3.17. If applicable, a second level of screening can be implemented based on the specific characteristics of the site and the nuclear installation. Typical screening parameters to be applied are probability, magnitude and distance of the HIEE and on-site characteristics (e.g. design conditions and zones of influence). Details are provided in Ref. [18]

3.18. This process should be repeated for each source. Further recommendations on the application of the process for each event category are provided in Sections 5–10.

[5] Interact means a hazard reach the nuclear installation site based on hazard analysis.

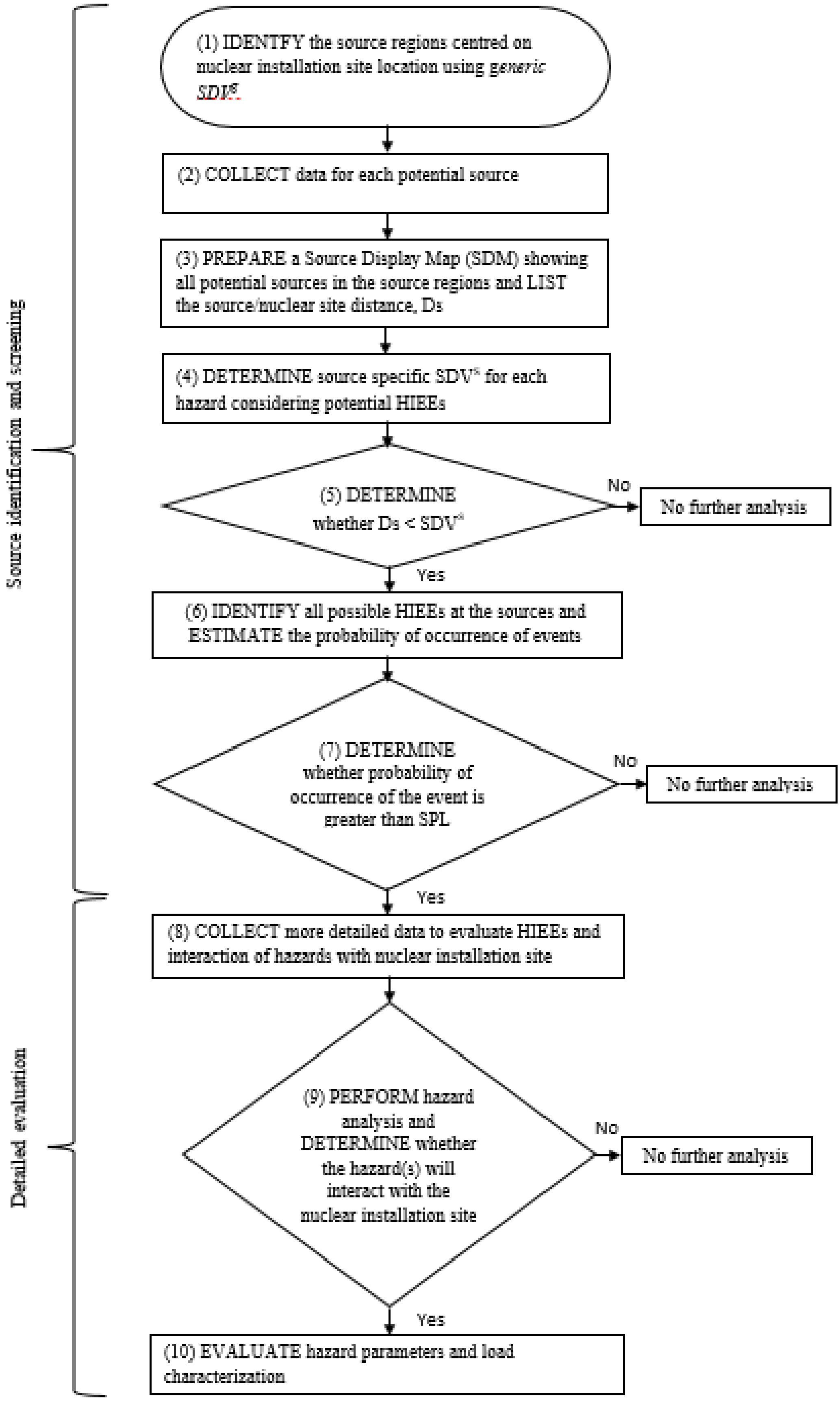

Fig. 1. Process for the source identification, screening, and detailed evaluation for each source type

4. DATA COLLECTION AND INVESTIGATIONS

GENERAL CONSIDERATIONS

4.1. The collection of data for potential sources of HIEEs should involve the collection of site specific as well as generic data on events occurring due to similar sources worldwide as such events may or may not have occurred in sources around nuclear installation sites. It should be recognized that such data may not be readily available for reasons of confidentiality.

4.2. Individual States have different methods of data collection. The recommendations in this Section provide a general approach to data and information collection that should be adapted to the specific legal framework of the State in which the nuclear installation site is situated.

DATA AND INFORMATION COLLECTION RESOURCES

4.3. The data and information collection process recommended in this guide is set out in Requirement 14 of SSR-1 [1]. The following is a list of the most salient and important data and information collection resources:

(a) Organizations and individuals responsible for potential sources of HIEEs;

(b) Local and national government organisations with an interest in controlling, licensing or authorising sources of HIEEs, including relevant health and safety regulatory agencies;

(c) Professional institutions and organizations;

(d) Generic data on HIEEs from literature, relevant documents;

(e) Experience of good practice in defining hazards that are potentially significant to nuclear installations from similar sources elsewhere;

(f) Other sources of data such as local maps, published reports and public records relevant to activities around the nuclear installation site likely to be relevant to HIEEs, public and private agencies and individuals (in additional to those identified above) likely to be knowledgeable about the characteristics of the local area.

Seeking advice from organizations and individuals responsible for potential sources of HIEEs

4.4. The most important data and information resource regarding the hazards arising from a source of HIEEs is from the operator of the source itself. Contact with the operator should be made at an early stage, with the objective of building a constructive relationship to facilitate information exchange. It is important to remember that while the source (e.g. an industrial site) presents a portfolio of hazards to the nuclear installation site, the nuclear installation also presents a portfolio of hazards to the source of HIEEs. The operator of the source of HIEEs is likely to:

(a) Understand the processes and hazards presented by its activities better than anyone else. The operator may already have well-developed data and safety analyses that could be made available, and almost certainly will be the best source of expert advice on its activities;

(b) Be subject to health and safety regulation. The appropriate regulator(s) should be consulted for advice, and in any case should be made aware of the development of the nuclear installation and the likely hazards it may pose to industrial sites in the region.

The information received from the operators of the sources of HIEEs should be verified and validated and, wherever possible, be validated by an independent reviewer.

Regional emergency plans

4.5. Industrial sites that could impose hazards on a nearby nuclear installation will likely also impose those same hazards on the local population. In these cases, state and local government authorities (in addition to the site operator) should have a responsibility for population safety and such sites should be legally obliged to provide sufficient data to enable these authorities to construct regional emergency plans. Such government authorities may have useful data on regional sources of HIEEs that should also be collected.

Land-use planning

4.6. Many States have well developed land-use planning legislation that will apply to any new or proposed nuclear or conventional development; this same legislation will likely also have been applied to any existing sources of HIEEs in the region at the time of their planning and development. An objective of land-use planning requirements is usually to ensure that all national and local government agencies requiring knowledge of a planned hazardous site are able to obtain the information they need at an appropriate stage before and during the development process (including the data needed for the development of regional emergency plans), and have the opportunity to provide advice to the planning process on any public safety issues raised by the development. A further objective is to provide a platform for informing the general public (including other industrial site operators) that may be affected by the development and for facilitating public comment on it. The government planning authority for the region surrounding the nuclear installation may be able to provide useful information on sources of HIEEs that should be collected.

4.7. Consideration should be given to sources of HIEEs that are planned or under commercial developments, watercourse developments such as dams, and marine developments such as new or modifications to ports and harbours (and associated changes to sea lanes) and barrages, and any sources of HIEEs that are undergoing decommissioning. Such developments may lead to additional sources of hazards in the future and potentially to an increased risk of radiological consequences over the life of the nuclear installation. Also important are developments that could change the population distribution in the region around the nuclear installation, since this may have implications for nuclear emergency planning.

4.8. Particular consideration should be given to the possibility that new sources of HIEEs may present hazards that are currently screened out as being insignificant from existing sources, and to the potential for adverse interaction of any new hazards introduced with those from existing sources (e.g. the possibility of fire spreading from a new source of HIEEs to an existing source). In both cases, it may be necessary to provide additional protection and/or mitigation measures either at the nuclear installation site, or as part of the new development. The progression of industrial development should be strictly followed by maintaining a continuous liaison with the local authorities.

Military sites and civil sites undertaking national defence work

4.9. These sites will almost always be subject to extensive restrictions on the dissemination of information about the processes and activities that take place, which may make it impossible for the operating organization of a nuclear installation to undertake a credible safety analysis of potential HIEEs arising from such sites. National regulators, as government agencies themselves, may have preferential access or even information exchange agreements with the defence agencies controlling these sites. Operating organizations of nuclear installations should seek advice from the regulatory body on the need for and the extent of HIEE safety analysis that is necessary in these cases. If specific information is not made available, generic data can be used.

DATA AND INFORMATION

Data Source

4.10. Paragraph 1.9 lists six major categories of HIEE that should be considered. The region surrounding the nuclear installation site should be investigated for the presence of any human activities that have the potential to cause events in these categories. The size of the region to be investigated will depend on the nature of the human-induced activities taking place. For example, the presence of a large petrochemical site storing very large quantities of hazardous materials may have the potential to affect a larger geographical area in the event of an accident than, say, a small quarrying site, storing and using only limited quantities of mining explosives. Table A.II provides generic screening distance values that are considered representative of common hazards belonging to each event category and their ability to affect a nuclear installation site.

Data uncertainty and the use of expert judgement

4.11. For many HIEEs there is often insufficient information available locally to permit a reliable evaluation of probability of occurrence and of the probable severity of the event. It may therefore be useful to obtain statistical data on a national, regional or global basis. Values thus obtained should be examined to determine whether they should to be adjusted to compensate for unusual characteristics of the source, or the nuclear installation site and its environs. Where there is no reliable basis for calculating the severity of the effects of an external human induced event using local data, all available information and assumptions about that event should be obtained on a global basis and the hazard analysis undertaken also using expert judgement.

STATIONARY SOURCES OF HUMAN INDUCED EXTERNAL EVENTS

4.12. The following information for stationery sources should be collected but the necessary level of detail could vary according to the specific site evaluation stage:

(a) The nature of hazardous material involved and the quantities in storage, being processed and in transit on the source site;
(b) The types of storage (physical conditions) and processes (flow sheets);

(c) The dimensions of major vessels, stores or other forms of containment;

(d) The locations of these forms of containment, their construction and their isolation systems;

(e) The operating conditions of these forms of containment (including the frequency of maintenance);

(f) The active and passive safety features of these forms of containment.

4.13. The severity of the hazard may not bear a direct relation to the size of the facilities on the source site, but the maximum amount of hazardous material present at any given time and the processes in which it is used should be taken into consideration in establishing the significance of the source to nuclear safety. Furthermore, the progression of an accident with time, such as fire spreading from one tank to another on the source site, should also be considered.

4.14. Pipelines carrying hazardous materials that leave or transit between different stationary source locations should be included as mobile sources.

4.15. Other sources to be considered are construction yards, mines and quarries that use and store explosives and may cause the temporary damming of water courses with the possibility of subsequent flooding, subsidence, or collapse of ground at the site should also be considered.

4.16. Mines and quarries are hazardous because the explosives used in their exploitation can generate pressure waves, projectiles and ground shock; moreover, mining and quarrying entail the possibility of ground collapse and landslides. Information should be obtained on the locations of all past, present and possible future mining and quarrying work and the maximum quantities of explosives that may be stored at each location. Information on geological and geophysical characteristics of the subsurface in the area should also be obtained to ensure that the nuclear installation is safe from ground collapse or landslide caused by such activities.

4.17. Fracking[6] activities should also be considered as they may be hazardous to nuclear installations and are similar to mining activities in that they can cause ground vibrations, subsidence and even ground failure.

4.18. At military installations, hazardous materials are handled, stored and used, and may be associated with hazardous activities such as firing range practice and handling of munitions. In particular, military airports and their associated air traffic systems, including training areas, should be considered potential sources.

MOBILE SOURCES OF HUMAN INDUCED EXTERNAL EVENTS

4.19. Mobile sources of HIEEs are typically aircraft (and other aerial vehicles), road and rail vehicles, sea and river transport vessels.

Transport by air

4.20. With Regard to aircraft crash hazards, a study should be made of:

[6] Fracking is a proven drilling technology used for extracting oil, natural gas, geothermal energy, or water from deep underground.

(a) Local airports, their layout, take off, landing and holding patterns and procedures, types of aircraft and movement frequencies.

(b) Air traffic corridors (airways) and other designated restrictions to flight transit (e.g. restricted and prohibited zones).

(c) Information on aircraft accidents for the region and for similar types of airport and air traffic. Information should be collected for general aviation, civil and military air traffic. Of particular interest are military aircraft training areas (especially low flying areas) within the region, since these may indicate areas of relatively high crash probability.

(d) Information on crash rates of each aircraft type flying near the nuclear installation in the respective flight mode (enroute, landing, and taking off including normal or special flight mode for military aircraft).

4.21. The size of the geographical region considered for aircraft crash hazard should, in general, be larger than that for other sources because of the high speeds associated with air transport.

Transport by sea and river

4.22. The conveyance of hazardous materials by sea or inland waterways may present a significant hazard. Besides the accidental release of flammable or toxic gases and/or vapours, vessels, together with their loads and the possibility of water borne debris, could have the potential for mechanically blocking or damaging cooling water intakes and outfalls associated with ultimate heat sinks. Other cargo that is not formally classified as hazardous material, like pasty liquids or swelling bulky freight (e.g. wood pellets) and sticky chemicals could also jeopardize cooling water intakes and outfalls associated with ultimate heat sinks.

4.23. Experience indicates that the bulk of sea traffic accidents occur in coastal waters or harbours, so it is important that shipping lanes near the site should be identified. Information should be collected on the characteristics of traffic flows in the region, such as:

(a) The location of shipping lanes local to the nuclear installation site;
(b) The nature, type and quantities of material conveyed along a route in a single transport movement;
(c) The sizes, numbers and types of vessels;
(d) The point of closest approach to the nuclear installation site;
(e) Accident statistics including consequences.

Harbours should be also studied due to the presence of dangerous cargo.

Transport by road and rail

4.24. Railway rolling stock and road traffic, together with their loads, are potential sources that should be given careful attention, particularly for busy routes, junctions, marshalling yards and loading areas. Information should be collected on the characteristics of traffic flows in the region, such as:

(a) Location of road and rail routes local to the nuclear installation site;
(b) The nature, type and quantities of material conveyed along a route in a single transport movement;

(c) The sizes, numbers and types of vehicles;
(d) The point of closest approach to the nuclear installation site;
(e) Speeds, control systems and safety devices;
(f) Accident statistics including consequences.

Marshalling yards should be also studied due to the presence of dangerous cargo.

Transport by pipelines

4.25. The following is a typical set of data and information that should be collected for pipelines:

(a) Location of pipe routes local to the nuclear installation site;
(b) Whether the pipeline is on the surface or buried near the nuclear installation site and the diameter of the pipe;
(c) The nature of the substance transported, flow capacity, internal pressure;
(d) The distances between valves or pumping stations;
(e) The point of closest approach to the nuclear installation site;
(f) Safety features, and relevant accident records including consequences.

4.26. The hazards to a nuclear installation arising from surface transport (by road, rail, sea, inland waterways and pipelines) are similar to those from industrial plants. On-site transport of hazardous material relevant to collocated nuclear installations should also be considered as potential sources of HIEEs. Air traffic presents a different type of mobile source of HIEEs because of the possibility of an aircraft crash directly on to the nuclear installation and this should be taken into consideration.

SOURCE DISPLAY MAP

4.27. Source display maps should be prepared, preferably using a Geographical Information System platform, showing the locations and distances from the nuclear installation of all sources identified in the data collection stage along with the size of the regions considered for each hazard type. Stationary and mobile sources should be indicated, noting transport routes close to the site, the regions considered and identifying the most hazardous point (normally the point of closest approach) for each route. Any unusual features should be shown, such as sources of HIEEs whose hazards interact to provide an increased challenge to nuclear safety.

4.28. These maps should also reflect any foreseeable developments in human activity that may affect safety over the projected lifetime of the nuclear installation.

5. RELEASE OF HAZARDOUS SUBSTANCES

GENERAL CONSIDERATIONS

5.1. Hazardous substances (flammable, corrosive and toxic, including liquefied gases) are normally kept in closed containers but upon release could cause a hazard to items important to safety and to human life at a nuclear installation site. The following substances should be considered:

(a) Flammable gases, liquids and vapours that can form explosive clouds and can enter ventilation system intakes and burn or explode;
(b) Toxic and asphyxiant gases and liquids that can threaten human life and impair safety functions;
(c) Corrosive and radioactive gases and liquids that can threaten human life and directly impair safety functions associated with structures, systems and components.

5.2. HIEEs and dispersion mechanisms are discussed in this section; explosive effects are discussed in Section 6. The ways in which these different substances affect structures, systems and components and personnel at a nuclear installation vary substantially and are covered in detail in other Safety Guides (e.g. DS498 [7]), but the propagation phenomena from the source of HIEEs to the nuclear installation site are discussed in this section.

5.3. This section considers each of the major groups of hazardous substance in turn[7]:

(a) Hazardous liquids;
(b) Hazardous gases.

HAZARDOUS LIQUIDS

5.4. A significant factor affecting the dispersion mechanisms for liquids is the local topography between the source of HIEEs and the nuclear installation site. Liquids disperse across land primarily under gravity by flowing downhill; their dispersion is therefore heavily dependent on regional and source-to-site topographical features and is very likely to be directional and this should be considered.

5.5. Care should be taken to consider the secondary factors especially the local meteorological conditions in the region. Ambient temperature, for example, will govern the rate of evaporation of a discharged liquid and will control the rate of release of volatile vapours from a pooled liquid.

5.6. If the hazardous liquid is volatile, such as petroleum, it can give rise to hazardous vapour clouds, whose dispersion as a plume will be consistent with the characteristics of gas cloud dispersion and this should be considered.

5.7. The extent of dispersion of liquids (i.e. the extent of pooling given a rate of release) typically would involve the release of large quantities of liquid to affect directly an adjacent nuclear installation. The liquid substance will pool and give off toxic or flammable or explosive vapours, and it is these secondary hazards that are likely to pose the most significant hazard to nuclear safety and should be considered.

5.8. Liquids dispersing underground are typically under high pressure and seek fissures and lines of weakness through which to disperse. As above, these may be strongly directional, and this aspect should be considered.

5.9. Chemicals including hazardous liquids stored at the nuclear installation site may vary

[7] Substances considered here are fluids since these can flow and therefore spread from sources of HIEEs to the nuclear installation. Hazardous solids of concern in this guide are explosives, which are considered in Section 6.

from case to case. The safe distances for explosivity, toxicity and heat flux of these hazards should be determined and considered in the layout and appropriate measures should be taken.

5.10. On multi-unit sites, a possible source of hazardous liquids is likely to be adjacent units, since these will be nearby and may be sited at the same level or higher than the host installation and should be considered.

5.11. The dispersion of liquids on bodies of water depends on the characteristics of the liquids (e.g. density compared to the density of water) and the characteristics of the body of water (e.g. sea, river or lake). Whereas on standing water bodies, dispersion is slow, hazardous liquids on bodies of flowing water may be transported over large distances quickly. The concentration of hazardous liquids in a given distance from the source will depend on the specific situation. Besides the toxic, corrosive or explosive properties of the liquid, its potential to clog the cooling water intake should also be considered.

HAZARDOUS GASES

5.12. Gases, vapours and aerosols from volatile liquids or liquefied gases may, upon release, form a cloud and drift. The drifting cloud may adversely affect the safe operation of the nuclear installation. For example, if it permeates installation buildings, it may pose a hazard to personnel and items important to safety. It can also affect the habitability of the control room and other important plant areas and should be considered.

5.13. The most practical method of defence against a hazard of this type is to ensure protection from the potential source by means of distance. Otherwise, the hazard should be evaluated in order to include design measures such as protective barriers and/or ventilation systems.

5.14. Clouds of toxic or asphyxiant gases can have severe effects on the personnel of a nuclear installation with special attention to be devoted to the habitability of the control room and emergency centres. Corrosive gases can damage safety systems and may, for example, cause loss of insulation in electrical systems. These matters should be given careful consideration in the evaluation of the hazards.

5.15. Drifting clouds of explosive or flammable gases or vapours can also adversely affect the nuclear installation without entering buildings; consequently, suitable protection measures should be taken. More details on the protection against explosions and fires can be found in Sections 6 and 7.

5.16. Local meteorological conditions should be considered in estimating the danger due to a drifting cloud. In particular, dispersion studies based on probability distributions of wind direction, wind speed and atmospheric stability class should be made. A secondary consideration is local topography between the source of HIEEs and the nuclear installation site, especially for dense (heavier than air) gases that will tend to form gravity flows downhill in a similar way to liquids.

5.17. For an underground release of hazardous gases or vapours, consideration should be given to escape routes and to seepage effects that might result in high concentrations of hazardous gases in buildings or the formation of hazardous gas clouds within the SDV.

5.18. On multi-unit sites, a source of hazardous gases can be the adjacent units, since these will be nearby and the opportunity for dispersion of the gas plume will be limited, and this should be considered.

HAZARD ASSESSMENT

Identification of sources of HIEEs

5.19. Stationary and mobile sources of hazardous liquids and gases are included in Table A.III. Recommendations on data collection are provided in Section 4. First the regions should be located based on SDV^g values (Table II). Sources within this region should be identified. In recognition of the uncertainty associated with screening distance values, sources should also be identified just beyond these regions if these are large or especially hazardous sources. Data in this region on potential sources of HIEEs should be collected and source–nuclear installation site distance values, D_S, should be calculated.

Screening by distance

5.20. Based on collected source data, simple and conservative calculations can be made and SDV^s values for the hazardous fluids can be estimated as these can travel long distances originating from both liquid and gas sources. Those sources that lie further away from the nuclear installation site ($D_S > SDV^s$) can be screened out. Meteorological and topographical considerations are important in this evaluation.

Screening using probability

5.21. If a hazard cannot be screened out by distance, generic events data can be used. Pragmatic conservative judgment can be applied to establish the occurrence of potential event(s) that can release hazardous fluid. If the probability of occurrence of that particular event, P_{PE} is less than SPL, it can be screened out. The screening exercise of each event that could lead to the generation of a hazardous fluid at the nuclear installation site should be completed, and the screened-in sources should be listed.

Detailed evaluation

5.22. Hazard analysis of screened-in sources should be performed to check the interaction with the nuclear installation. If there is an interaction, hazard characterization should be performed.

5.23. In broad terms the evaluation process should consider the leakage of hazardous liquid at a specified location in terms of leak rate and possibly other factors if storage was not at ambient atmospheric conditions. The evolution of the release is driven by local topography for overland spills and the local marine or watercourse conditions for spills into the hydrosphere. These aspects should be modelled explicitly or extremely conservative assumptions should be made. Liquids released into the hydrosphere and gases emanating from liquids are extremely important and should be considered.

5.24. The vapour clouds released after an event can travel to the nuclear installation site with different damaging potential to an item important to safety or may impact control room habitability. Different chemicals have different hazardous effects relating to explosion, thermal radiation and toxicity. In the evaluation, the worst case meteorological conditions should be assumed as inputs to the model within bounding conditions of temperature, atmospheric stability class, and wind speed for each chemical modelled and each hazard condition until the bounding (maximum potential effect) is confirmed. The toxic vapour cloud may travel large distances and should be carefully studied.

5.25. The nearest point to the nuclear installation where hazardous liquids may collect in pools should be determined, with account taken of the topography of the land and the layout of the installation. Similarly, the gas release should be modelled by assuming a maximum credible inventory and assuming that it occurs at the point of closest approach to the nuclear installation site, or the most unfavourable release point if this is different. Mobile sources, such as barges and ships carrying large amounts of hazardous liquids or gases within the SDVs, should be assumed to become stranded at the point of approach to the nuclear installation for which the most unfavourable effects would result.

5.26. For evaluating the generation of hazardous gases, vapours, or aerosols and interaction with items important to safety, distinction should be made between:

(a) Subcooled liquefied gases;
(b) Gases liquefied by pressure and non-condensable compressed gases.

5.27. Usually the release of a subcooled liquefied gas will occur as a steady leak over a considerable period (at a given leak rate), but the possibility of an effectively instantaneous release (a total sudden release) should also be considered, depending on the following conditions associated with the release:

(a) The type of storage container and its associated piping;
(b) The maximum size of the opening from which the material might leak;
(c) The maximum amount of material that might be involved;
(d) The relevant circumstances and mode of failure of the container.

5.28. The starting point for the detailed hazard analysis is the evaluation of a range of leak rates and related failure probabilities, or the total amount of gas released (equivalent to the maximum credible release) and related failure probability. If a large amount of subcooled liquefied gas is released, much of it might remain in the liquid phase for a long time. It should be treated as a liquid throughout this period, although a fraction will vaporize almost instantaneously.

5.29. The characteristics of the pool formed by the liquid, such as its location, surface area and evaporation rate, should be evaluated, with account taken of the wind speed and the permeability and thermal conductivity of the soil (if the spillage occurs on soil). If the source site has arrangements for containing any spills or releases, these should be accounted for in the hazard modelling. However, giving credit to such arrangements should be well justified.

5.30. To evaluate the maximum concentration at the site, the models presented in IAEA Safety Standards Series No. NS-G-3.2, Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants [5] may be used. They should be used with caution, since often the gases released are at a very low temperature and the models may not be strictly applicable to a gas–air mixture of negative or positive buoyancy.

5.31. The formation of a large cloud is more likely for gases liquefied by pressure and non-condensable compressed gases than it is for subcooled liquefied gases. The detailed analysis is easier because the source is more easily defined and in some cases dispersion of the plume is governed by simpler phenomena.

5.32. As with subcooled liquefied gases, the release gases liquefied by pressure and non-condensable compressed gases should be characterized by a leak rate or by a sudden total release, and a similar evaluation should be carried out. The assumptions to be used will depend on the type of storage tank, the process vessels, their associated piping, pipelines with associated flow rate and operating pressure, and the associated failure probability.

5.33. In making an appropriate assumption for the amount of material available to be released in the event of an accident, account should be taken of the time interval before action is taken to stop the leak. For example, pipeline valves may close automatically, thus isolating the ruptured section quickly.

5.34. With buried pipelines, the soil cover is usually insufficient to prevent the escape of gases released from the pipelines. Seepage may occur or gas may escape through fractures or discontinuities. In all cases, when the characteristics of the gaseous release to the atmosphere have been established, a model should be selected to determine the dispersion of the gas towards the nuclear installation site. As noted above, the dispersion of the plume is primarily governed by the prevailing meteorological conditions assumed at the time of release. Given the large degree of uncertainty with meteorological and other factors involved in plume modelling, consideration should be given, at least initially, to use a simplified dispersion model with assumptions made on a conservative basis.

Hazard parameters

5.35. The following are example of parameters that should be considered and are given in Table A.III:

(a) Nature of substance

— Physical properties:

- o density, temperature and pressure as contained;
- o density, temperature (including freezing/boiling temperatures), partial vapour pressures under ambient conditions;
- o flow characteristics under ambient conditions.

— Chemical properties

- o Composition;
- o reactivity with environmental and atmospheric substances.

(b) Radiochemistry.
(c) Flashpoint or ignition temperature.
(d) Maximum credible release, or frequency versus quantity release curve.
(e) Meteorological and topographical characteristics of the region.
(f) Bathymetric and tidal characteristics of the coastal region.
(g) Water course and flooding characteristics of the fluvial region
(h) For underground sources, geological seepage routes and opportunities for liquid concentration.
(i) Existing protective/mitigative measures at the source location.

Load characterisation parameters

5.36. The following are example of parameters that should be considered and are given in Table A.V (5) and (6):

(a) Asphyxiant/toxic effects:
- — Concentration and quantity as a function of time;
- — Volatility in ambient conditions;
- — Toxicity and asphyxiant limits.

(b) Corrosive/radioactive liquids:
- — Concentration and quantity as a function of time;
- — Corrosive and radioactive content.

(c) Provenance (origin over/in sea or over/under ground).

6. EXPLOSIONS

GENERAL CONSIDERATIONS

6.1. The word explosion is used in this Safety Guide broadly to mean any exothermic chemical reaction between solids, liquids, vapours or gases that may cause a substantial increase in pressure, possibly owing to impulse loads, drag loads, fire or heat, or a rapid release of liquid or gas from a pressurised container. The explosive potential of a given mass of chemical substance is often quoted in terms of an equivalent mass of trinitrotoluene (TNT). This facilitates comparison of the explosive potential of different substances and many empirical formulae for predicting the effects of explosives are derived on the basis of TNT equivalence [19]. These should be used with care.

6.2. Explosions are highly energetic and often destructive events and they can occur for many reasons. Once an explosion has occurred, its effects are propagated into the surrounding environment by means of an expanding pressure wave. There are two types to consider:

(a) Deflagrations, which generate moderate pressures, heat or fire;
(b) Detonations, which generate high near field pressures and associated drag loading but usually without significant thermal effects.

6.3. These pressure waves, also known as blast waves, propagate approximately as spherical waves expanding away from the source location and should be considered. However, they are influenced by the ground and other confining surfaces. The specific energy in a spherical wave front attenuates according to the inverse square law based on distance from the source if no further energy is being added (e.g. by continued burning) to the wave. However, constrained blast waves may attenuate much more slowly[8]. More details are provided in Ref. [19].

[8] The attenuation referred to is geometric attenuation as this is normally the most significant effect. For comparison purposes, cylindrical waves geometrically attenuate as the inverse of distance from the source, and one-dimensional waves do not attenuate at all. Blast waves will also suffer viscous attenuation with time of travel, but this phenomenon is relatively slow acting. Note that attenuation refers to energy of the wave front. Since energy is related to the square of particle velocity and strain, these parameters attenuate as the square root of energy.

6.4. Explosions at an industrial site usually occur due to over-pressurization of contained liquids and/or gases, or due to deflagrations of liquid pool fires, leaks from or failure of storage tanks and pipelines, and accidents with explosives. In addition, dust explosions can also occur where any dispersed powdered combustible material is present in high-enough concentrations in the atmosphere or other oxidizing gaseous medium gaseous medium. Explosions caused by any reason should be considered.

6.5. Explosions normally arise from hazardous (often flammable) substances and the way they are contained or handled. The release of hazardous substances is addressed in Section 5. The ways in which explosion hazards affect structures, systems and components and personnel at a nuclear installation are covered in detail in other Safety Guides (e.g. DS498 [7]), but the propagation phenomena from source to nuclear installation site are discussed in this section.

6.6. An over-pressurisation event is an event arising from an over-pressurised container of liquid or gas that can result in an explosive release of the liquid or gas if the container fails. When such a release is also associated with heating, or the released substance ignites, the result can be an extremely energetic form of release known as a BLEVE (Boiling Liquid Expanding Vapour Explosion). BLEVEs can occur to all sorts of contained substances, but generally occur when tanks containing pressurised liquid Petroleum Gas (LPG), Liquid Nitrogen Gas (LNG) or propane fail catastrophically. If such tanks are accidentally heated, as might be the case if they are immersed in an external fire, the pressure in the tank rises until eventually it bursts. The mechanical overpressure effects of the burst itself may be sufficient to cause a BLEVE, but if the LNG vapour ignites, this adds substantially to the energy of the explosion and can lead to an extremely destructive event, characterised by a detonation blast wave and should be considered.

6.7. In case of hydrocarbon liquid pool fires or similar, the hydrocarbon has escaped containment and ignited. In flammable atmospheres, the explosion pressure wave is characterised by a flame front. The speed of propagation of the flame front depends on the availability and rate of burning of the fuel source (e.g. petroleum vapour). These events generally produce deflagration pressure waves and should be considered.

6.8. Dust explosions are especially dangerous and can easily lead to detonations because of the rapid rate of combustion of fine particles. The rate of combustion is related to the surface area of fuel in contact with air, so a large number of fine particles (or vapour droplets from such particles) burns more effectively than a small number of larger ones. The presence of obstacles that are often found in powder stores (e.g. grain stores) can cause intense mixing as the blast wave propagates, leading to more rapid burning and hence a more intense blast wave, often with very dramatic effects and should be considered.

6.9. Blast waves cause a sudden increase in pressure on one side of a structure with insufficient time for pressure on the other side to equalise through the action of normal ventilation processes. This results in large pressure forces across the affected structure surface and hence large stresses that must be reacted by the structures load paths and should be considered.

6.10. An explosion can produce pressure waves (dominant hazard), projectiles, heat, smoke, dust and ground shaking. A vapour cloud explosion is also possible if relevant conditions are met and these should also be considered.

6.11. Explosions are very likely to create secondary hazards. For example, structural damage close to the event can generate projectiles and initiate fire. Secondary hazards associated with explosions should be considered.

6.12. A significant factor affecting the propagation of blast waves is the presence of obstacles between the source of the HIEEs and nuclear installation site and inside the vapor cloud; local topography may also play a role and both effects should be considered.

6.13. The interactions between units collocated at a multi-unit site should be considered carefully for their contribution to HIEE explosion hazards.

6.14. Particular attention should be paid to potential hazards associated with large explosive loads such as those transported on railway freight trains or in ships.

6.15. Unless there is adequate justification, a conservative assumption should be made that the maximum amount of explosive material usually stored at the source of HIEEs will explode, and an analysis should then be made of the effects of hazards (incidence of pressure waves, ground shock and projectiles) on items important to safety. The secondary effects of fires resulting from explosions should also be considered, as discussed in Section 7.

6.16. The probability with which explosions occur should be calculated based on experience data or derived from general national or worldwide data. More information on explosion hazards can be found in Ref. [19].

HAZARD ASSESSMENT

Source identification

6.17. Sources of explosions are listed in Table A.III. Guidance on data collection is provided in Section 4. First, the regions should be located based on SDV^g values (SE Table A.II). Sources of HIEEs within this region should be identified. In recognition of the uncertainty associated with screening distance values, sources of HIEEs should also be identified just beyond these regions if these are large or especially hazardous sources.

6.18. Data on potential sources should be collected and source–nuclear installation site distance values, D_S, should be calculated.

Screening using probability

6.19. Using source data, SDV^s for overpressure (the dominant hazard) should be estimated by means of a simplified conservative approach based on the engineering relationship between the TNT equivalent mass and the distance. This is applicable for high explosives with the potential for mass casualties. For hydrocarbon-air vapor cloud explosions, other appropriate methodologies should be used. Sources of explosion can be screened out if they lie further away from the nuclear installation site (D_S > SDV^s). Meteorology, topography, and existing protective measures at the source are important considerations.

6.20. If a hazard cannot be screened out by distance, generic event data can be used. Pragmatic conservative judgment can be applied to establish the occurrence of an event that can create an explosion. if the probability of occurrence of that particular event, P_{PE} is less than SPL, it can be screened out. Appropriate methods for calculating the probability of an explosion should be used. If there are not enough statistical data available for the region to permit an adequate analysis, reference should be made to global statistics, to pertinent data from similar regions and/or to expert opinion. The screening exercise of each event that could create a pressure wave at the nuclear installation site should be performed and the screened-in sources should be listed.

Detailed evaluation

6.21. Hazard analysis of screened-in sources should be performed to check the interaction with the nuclear installation. If there is an interaction, hazard characterization should be performed.

6.22. In this phase, the list of screened-in hazards should be refined by more detailed assessment of the range of potential events for their applicability to the specific nuclear installation. Typical screening parameters that should be applied in this phase are design robustness, distance and magnitude and probability, and zones of influence.

6.23. The pressure waves drag level and local thermal effects at the nuclear installation will differ according to the nature and amount of the explosive material, the configuration of the explosive, meteorological conditions, the layout of the nuclear installation and the topography. Certain assumptions are usually made to develop the design basis for explosions, with data on the amounts and properties of the chemicals involved taken into account. TNT equivalents are commonly used as first approach to estimate safe distances for given amounts of explosive chemicals and for a given pressure resistance of the structures concerned. This is applicable for high explosives with potential for mass casualties. For hydrocarbon-air vapor cloud explosions, other appropriate methodologies should be used. For certain explosive chemicals, the pressure–distance relationship has been determined experimentally and should be used directly.

6.24. Projectiles that may be generated by an explosion should be identified by using experience data and engineering judgement by taking into account the source of these projectiles. In particular, the properties of the explosive material concerned and the characteristics of the facility in which the explosion is assumed to occur should be considered.

6.25. Consideration should also be given to possible ground motion and to other secondary effects such as the outbreak of fire, the release or production of toxic gases and the generation of dust.

Hazard parameters

6.26. The following are example of parameters that should be considered and are given in Table A.III:

(a) Nature of the explosive substance:
- — Physical properties;
- — Chemical properties;
- — Radiochemistry;
- — Flashpoint/ignition temperature.

(b) Maximum credible pressure and thermal release, or frequency of explosion versus the severity relationship.
(c) Meteorological and topographical characteristics of the region.
(d) Existing protective and/or mitigative measures at the source location.

Load characterisation parameters

6.27. The following are example of parameters that should be considered and are given in Table A.V (1), (2), (3), (4) and (7):

(a) Overpressure as function of time.
(b) Hard and soft missiles.
(c) Heat:
    —Maximum temperature flux and duration
(d) Smoke and dust:
    —Composition;
    —Concentration and quantity as a function of time.
(e) Ground shaking:
    — Frequency response spectrum for vibrational motion.

7. EXTERNAL FIRE

GENERAL CONSIDERATIONS

7.1. There are several possible sources of external fire that could threaten a nuclear installation including fires starting in adjacent units or installations on the same site. Fires from aircraft crashes are discussed in detail in Ref. [19].

7.2. A survey should be made at and around the site to identify potential sources of fire, such as forests, peat, storage areas for low volatility flammable materials (especially hydrocarbon storage tanks), wood or plastics, factories that produce or store such materials, their transport lines, vegetation, pipelines or chemical plants, and accidents on major highways. Fires can be accompanied by other hazards such as explosion and release of hazardous substances because of their ability to cause the failure of containment structures such as tanks. Fire is often also a secondary or consequential hazard following such events.

7.3. Fires arising from highly flammable materials such as petroleum products typically occur as fireballs, e.g. ignition of a flammable vapour cloud, or pool fires from ignition of a pool of liquid material.

7.4. Fire can spread horizontally in different ways: either by radiation heating from the thermal flux associated with the fire, via flammable material situated between the fire source and the site or installation or by sparks. Significant passive protection can therefore be afforded by the presence of fire breaks or ensuring that areas immediately external to the site or installation are free from flammable material. In the case of external fires, alternative fire spread paths should also be identified such as airborne dispersion of firebrands (embers) or transportation of liquid fuel in the sewer system.

7.5. The heat flux in quiescent conditions will obey the inverse square law of energy attenuation, however some fire related hazards such as smoke and dust may propagate directionally due to the prevailing wind direction and attenuate slowly in this direction. The fire itself will spread preferentially in the downwind direction, especially if there is a supply of flammable material along the route such as dry vegetation and this should be considered.

7.6. Installations may have a substantial ability to withstand thermal heating before loss of safety function occurs, but smoke damage may quickly lead to loss of safety function if, for example, it impairs operating personnel from performing an important safety function or blocks an air filter. Multi-unit sites especially should be considered carefully for their contribution to HIEE fire hazards.

7.7. The protective measures at the nuclear installation against fires and taken against fire hazards at the source of the fire should also be considered in evaluating the effects of external fires on the nuclear installation. However, before giving credit to these in the hazard evaluation, sufficient justification should be provided.

HAZARD ASSESSMENT

Source identification

7.8. Sources of fire are listed in Table A.III. Recommendations on data collection are provided in Section 4. First the regions should be located based on SDV^g values (Table A.II). Sources of HIEEs within this region should be identified. In recognition of the uncertainty associated with screening distance values, sources of HIEEs should also be identified just beyond these regions if these are large or especially hazardous sources.

7.9. Data on potential sources should be collected and source–nuclear installation site distance values, D_S should be calculated. Sources within this region should include forests, peat, vegetation, storage areas for low volatility flammable materials (especially hydrocarbon storage tanks), industrial facilities that process flammable materials and associated transport routes.

Screening by distance

7.10. Based on source data, SDV^s for heat flux (the dominant hazard) can be estimated by means of a simplified conservative approach. Sources of fire can be screened out if they lie further away from the nuclear installation site ($D_S > SDV^s$). Meteorology, topography, and existing protective measures at the source and nuclear installation are important considerations.

Screening using probability

7.11. If a fire hazard cannot be screened out by distance, generic event data can be used. Pragmatic conservative judgment can be applied to establish the occurrence of an event that can initiate a fire. If the probability of occurrence of that particular event, P_{PE} is less than SPL, it can be screened-out.

7.12. If the potential hazard from screened-in sources of HIEEs is likely to be less than that due to similar materials stored on the nuclear installation site itself and against which protection has already been provided, then it can be screened out. If several sources are screened out on the same basis, it may be necessary to reflect the frequency contribution arising from the sum of all such sources by nominating a bounding source and screening using this. The screening exercise of each event that could initiate a fire and affect the nuclear installation site should be performed. The screened-in sources should be listed.

Detailed evaluation

7.13. Hazard analysis of screened-in sources should be performed to check the interaction with the nuclear installation. If there is an interaction, hazard characterization should be performed.

7.14. In this phase, the list of screened-in hazards is refined by more detailed assessment of the range of potential events for their applicability to the specific nuclear installation. Typical screening parameters that should be applied in this phase are design robustness, distance and magnitude and probability, and zones of influence.

7.15. A hazard evaluation considers the source location and assumes a type of fire and/or flammable substance and ignition mechanism. The probability of fires can be found from experience data or derived from general national or worldwide data.

7.16. To avoid fire effects from forests and/or bushes, it should be ensured that a zone around the nuclear installation site is devoid of any vegetation and a fire safety program at the site should be implemented to avoid fires from other sources that could affect the safety of the nuclear installation.

7.17. The thermal exposure to external nuclear installation structures, systems and components should be quantified in terms of radiative and convective heat flux incident on the target surface and the duration of the exposure. Methods to assess external fireballs and pool fires from a sudden release and ignition of combustible liquid or gas are provided in Ref. [19]. Smoke is another important hazard to be evaluated as it travels longer distances.

Hazard parameters

7.18. The following are example of parameters that should be considered and are given in Table A,III:

(a) Nature of flammable substance
 — Flashpoint, flammability concentrations in air, or other ignition criteria
 — Max. credible substance/thermal release, or fire frequency v. severity relationship
 — Thermal load vs time
(b) Meteorological and topographical characteristics of the region
(c) Existing protective measures at the source location, e.g. fire breaks

Load characterization parameters

7.19. The following are example of parameters that should be considered and are given in Table A.V (1), (2), (3), (4) and (5):

(a) Overpressure as function of time.
(b) Projectiles.
(c) Heat:
 — Maximum temperature flux and duration.
(d) Smoke and dust
 — Composition;
 — Concentration and quantity as a function of time.
(e) Asphyxiant and toxic substance:
 — Concentration and quantity as a function of time;

— Volatility in ambient conditions;
— Toxicity and asphyxiant limits.

8. AIRCRAFT CRASH

GENERAL CONSIDERATIONS

8.1. Methods currently in use for considering an aircraft crash as a HIEE may contain differences of detail, however, they all contain the same basic elements which should be considered:

(a) Categorisation of aircraft by type, mass, velocity and size.
(b) Categorisation of airspace by the type of flying rules or restrictions that apply (e.g. commercial airways, airspace around airports, restricted airspace).
(c) Frequency analysis to determine the crashes per year per km^2 at the location of the nuclear installation site for each aircraft category.
(d) Frequency analysis to determine the aircraft crash onto nuclear installations that could lead to a consequential release of radioactivity. This includes calculating that area of the nuclear installation site, called variously the target area, zone of influence, damage footprint.

8.2. Aircrafts should be considered to be a mixture of hard and soft missiles and impact onto reinforced concrete structures typically results in damage modes such as perforation, penetration, scabbing, local punching, bending failure and vibrations.

8.3. In some nuclear installations, specific protection is provided against malicious aircraft crash; such protection measures are generally sufficient to envelope the risk from accidental aircraft crash hazard significantly, such that it can be screened out. Nevertheless, it should be carefully checked whether the assumed scenarios for malicious aircraft crashes fully cover potential accidental scenarios and whether the protection measures are suitable for accidental aircraft crashes. Malicious aircraft crash is not considered in this Safety Guide however some of the methods recommended herein, may also be applicable to malicious aircraft crash.

8.4. Aircraft crash is potentially one of the most significant of all HIEEs and a great deal of research work has been conducted, both into the methods for crash probability analysis and into the effects of impact events onto heavy concrete targets. This research and experience should be considered in the aircraft crash hazard evaluation.

8.5. It is important to consider all the potential effects of the aircraft crash event on the nuclear installation if any aircraft crash is not screened out, as follows:

(a) Direct effects:
  — Impact damage to structures including perforation and penetration;
  — Vibration effects;
  — Global stability.
(b) Secondary effects:
  — Secondary missiles ejected from the impact site and scattering widely;

— Rapid spread of flammable liquid from the point of impact, including impulsive damage to structures from the released momentum of the liquid when ejected from the aircraft;
— Entry of combustion products into ventilation or air supply systems;
— Fire and explosion generating heat and blast effects and generating tertiary missiles,
— Release of hazardous substance carried as cargo.

8.6. The main component in the loading function resulting from a collision of the deformable fuselage can be predicted assuming a soft missile impact. Aircraft engines and landing gear can be classified as semi-hard or hard missiles and should be considered. Use of concrete constitutive models should be verified by numerical analysis.

8.7. Fire from fuel spillage can result into fireball or pool fire or both and should be considered. Details are provided in Ref. [19].

8.8. On multi-unit sites, there may be multiple safety related items serving different units. Impact on structures associated with an adjacent unit might not directly impact the unit under consideration, but secondary hazards such as missiles, fire and explosion might and should be considered.

HAZARD ASSESSMENT

8.9. The process includes three types of aircraft crashes. It is recognised that air traffic encounters several different operational environments that critically affect the probability of the crash events. The following types of aircraft operations should be considered:

— Type 1: Aircraft crash occurring from general traffic, sometimes called the background crash rate.

— Type 2: All aircraft crash hazard arising from take-off and landing manoeuvres at a local airport.

— Type 3: Aircraft crash occurs at the site owing to air traffic in the main civil traffic corridors and military flight zones.

Type 1 events

Source identification

8.10. Information of aircraft crashes in respective country should be collected from the civil and military aviation authorities of the country or other departments working in the aviation industry. Details should include aircraft crashes of all types of different aircrafts flying in the country. SDV^g is not applicable for this type event.

Screening by distance (SDV^s)

8.11. Screening by distance is not applicable for this type event.

Screening using probability

8.12. Aircraft crash data covering a regional circular area of 100-200 km in radius for each type of both civil and military crashes should be determined. The probability of Type 1 events should be carefully evaluated, in particular in densely populated regions with several civil airports and more flights. Appropriate zoning of the area considered should be carried out to avoid averaging that is insufficiently conservative.

8.13. The probability of occurrence of all types of aircraft crashes should be evaluated by considering the site as a tract or circular area of 0.1–1 km^2, by dividing site area by the regional area and multiplying by crashes/year for different types. Those classes of aircraft for which probability of occurrence, P_{PE} is less than the SPL can be screened out. Otherwise it should be retained for detailed evaluation.

Type 2 events

Source identification

8.14. Sources are included in Table A.III and SDV^g in Table A.II. Guidance on data collection is provided in Section 4. The probability of aircraft crashes is usually higher in the vicinity of airports, both civil and military. A separate check should be carried out for both types. Most aircraft crashes tend to occur within approximately semi-circular areas of 8 km (SDV2) in radius centred at the ends of the runways.

Screening by distance (SDV^s)

8.15. If regional or national specific values were developed or regulated, they can be used. Otherwise SDV^g should be used.

Screening using probability

8.16. If a hazard cannot be screened out by distance, the probability of occurrence of particular types of crashes should be determined and it should be compared with the SPL. Those aircrafts for which probability of occurrence, P_{PE} is less than the SPL can be screened out. Otherwise it should be retained for detailed evaluation.

Type 3 events

Source identification

8.17. Sources are included in Table A.III and SDV^g in Table A.II. Recommendations on data collection are provided in Section 4. The potential hazards arising from aircraft crashes due to air traffic in the main civil traffic corridors and military flight zones if airways or airport approaches pass within 4 km (SDV3) of the site should be considered.

Screening by distance (SDV^s)

8.18. If regional or national specific values were developed or regulated, they can be used. Otherwise SDV^g should be used.

Screening using probability

8.19. If a hazard cannot be screened out by distance, the probability of occurrence of particular types of crashes should be determined and compared with the SPL. Those aircrafts for which probability of occurrence is less than the SPL can be screened out. Otherwise it should be retained for detailed evaluation.

Detailed evaluation for all type of event

8.20. Hazard analysis should be performed for the screened-in sources and hazards should be characterized.

8.21. In this phase, the list of screened-in hazards should be refined by more detailed assessment of the range of potential events for their applicability to the specific nuclear installation.

8.22. This second level of screening is based on specific characteristics of the site and the nuclear installation. Typical screening parameters that should be applied in this phase are design robustness, distance and magnitude and probability, and zones of influence. An additional consideration is the type and number of co-located installations on the site that can have positive or negative effects on prevention, detection, control of consequences (normal and severe conditions) and emergency response. Details are provided in Ref. [18].

8.23. Significant effort has been expended internationally to develop cost effective approaches to addressing the issues of extreme human induced external events by following a systematic approach. An approach similar to the zone of influence approach is recommended. The concept of defining areas of consequence for each of the hypothesized impact locations is employed. The areas of consequence are denoted as damage footprints. Damage footprints are defined for impact, shock and fire loading conditions.

8.24. The systematic approach to the evaluation should consider the buildings containing nuclear material and the buildings housing the SSC important for safety (e.g. equipment for heat removal), as follows:

(a) Impact locations to be considered are defined, which are identified based on the aircraft parameters (such as type of aircraft, nature of flight, angle of impact), shielding by topography, nuclear installation buildings, transmission lines and other considerations.
(b) Conservative assumptions about the angle of aircraft impact, for example perpendicular to the centreline of the containment building and perpendicular to the spent fuel storage building are made.
(c) Local response, global response and vibration loading conditions are considered.

Damage footprints due to any consequences of the aircraft crash should be developed, including structure failure modes, fire and vibration effects. The end product is aircraft impact locations and damage footprints. Studying the effects of an aircraft crash requires evaluations of global structural response, local response, vibration effects and fire, as detailed in Ref. [19].

8.25. All building housing the structure, system and components necessary to prevent an accident should be identified for screening or evaluation. For example, front line and support systems needed for safe shutdown of the reactor or continued cooling of the spent fuel pool should be identified. Exterior faces of the buildings should be evaluated to screen out the need for further evaluation or to determine impact locations:

(a) The faces or partial faces of buildings could be screened out from further consideration due to shielding by adjacent structures, intervening structures, or other site features.
(b) Faces of buildings that are partially screened out are subdivided into portions for which aircraft impact is possible and not possible;
(c) The impact of multiple buildings during the event is considered, the result being the identification of multiple buildings vulnerable to a single aircraft crash;
(d) Candidates for aircraft impact assessment are the end products.

Damage footprints for each building and each impact location of the buildings should be developed for evaluation.

8.26. After evaluation, loading functions for the screened-in human induced external events should be defined for the engineering evaluation.

8.27. The load characterization is the link between the events and the definition of the loading environment for evaluation. The resulting matrix of loading conditions produced by the events should be applied to the entire facility or to portions of it (see Table 4, Scenario-1 in Ref. [18]).

8.28. Tables 5–7 of Ref. [18] expand on Scenario 1 in Table 4 (aircraft impact event) to identify the following parameters for engineering evaluation: impact, heat/fire and vibration. Ref. [19] describes the complete evaluation methodology for structural impact, induced vibrations, thermal effects from fire, local and global effects and acceptance criteria.

Hazard parameters

8.29. The following are example of parameters that should be considered and are given in Table A.III:

(a) Characteristics of aircraft by type, nature of flight, and crash rate.
(b) Aircraft movements and flight frequencies from:
  — Airfields;
  — Airways;
  — Controlled airspace around commercial and military airfields;
  — Restricted and other forms of special airspace;
  — Location of aircraft sources, runway directions and other related data, and direction of approach to the nuclear installation site;
  — Airfield plates[9] for take-off, landing and manoeuvring.
(c) Parameters derived from regional or national aircraft crash data:
  — Probability distributions for direction of approach and angle of descent by aircraft type;
  — Skid and footprint distances and rate of energy and momentum attenuation with distance by aircraft type.

Load characterization parameters

8.30. The following are example of parameters that should be considered and are given in Table A.V 1,2,3,4 and 6, and also in Ref. [19]:

(a) Impact energy at the nuclear installation:
  — Mass;
  — Velocity.
(b) Impact parameters;
  — Components of aircraft classified as hard missiles and as soft missiles;
  — Size and cross-section area in plane of impact or each component.
(c) Derived from hazard analysis:
  — Probability distributions for direction of approach and angle of descent onto the nuclear installation site by aircraft type;

[9] Plates are (paper based and now digital) information providing all the navigational information needed by a pilot manoeuvring around a major airport. They are prepared by national authorities and specific to the airport, runway, runway direction and navigational procedure being used. They are publicly available for all international airports and many local ones.

— Skid and footprint distances and rate of energy and momentum attenuation with distance by aircraft type;
— Data needed for analysis of secondary hazards;
— Fuel load by aircraft type and stage of flight;
— Hazardous cargo, substances and volumes.

9. TRANSPORT EVENTS EXCLUDING AIRCRAFT CRASH

GENERAL CONSIDERATIONS

9.1. Mobile sources excluding air traffic which may create HIEEs are (see Table A.III and A.IV):

(a) Road transport:
—Trucks carrying hazardous substances.
(b) Rail transport:
—Trains carrying hazardous substances.
(c) Marine transport:
—Ships carrying hazardous substances (cargoes);
—Ships that possess significant kinetic energy.
(d) River transport:
—Barges carrying hazardous substances (cargoes);
—Barges that possess significant kinetic energy.
(e) Pipelines:
— Pipelines conveying hazardous substances.

9.2. This section considers some general features of road, rail and water borne transport events before dealing collectively with all sources that present a direct impact hazard to nuclear structures, systems and components and those that can release hazardous substances.

9.3. Water borne vessels have the potential to interact with coastal and offshore structures belonging to a nuclear installation site. Nuclear reactor cooling water intakes and outfalls are a concern, as are docks and jetties that are used for loading and unloading nuclear materials onto vessels for transport. The potential for water borne vessels to interact with coastal and offshore structures of a nuclear installations should be considered.

9.4. Road, rail, marine and river vehicles and vessels routinely transport dangerous goods and the potential for release of hazardous substances are always a potential risk to nearby nuclear installations and should be considered. All hazards should be dealt in accordance with the recommendations provided in the previous sections by taking minimum distance from the nuclear installations. Similarly, pipelines routinely convey hazardous liquids and gases and should also be considered.

MARINE AND RIVER VESSELS THAT POSSESS SIGNIFICANT KINETIC ENERGY

9.5. The effects of marine and river vessels that possess significant kinetic energy on a nuclear installation will depend on the nature of any shoreline and offshore structures, their layout and whether there is any natural or human-made protection. The most significant hazard is collision between a massive vessel and a shoreline (dock or loading facility) or submerged safety structure (e.g. cooling water intakes), where substantial structural damage is possible. Such events can be regarded as soft missile impacts, where significant deformation to both the vessel and the coastal structure is likely and should be considered.

9.6. The primary hazard is impact, but secondary effects of oil spill, fire, explosion and release of gases are possible and should be considered in accordance with the recommendations provided in the previous sections. Other cargo that is not formally classified as hazardous material, like pasty liquids or swelling bulky freight (e.g. wood pellets) and sticky chemicals should also be considered to jeopardize the water intake.

9.7. Large commercial ships can also drift by tide and river currents. The local bathymetry around the nuclear installation should be considered, and tide and river flow conditions should be selected to identify the most onerous conditions of vessel reach and speed relative to the nuclear installation structures.

HAZARD ASSESSMENT FOR MARINE AND RIVER VESSELS THAT POSSESS SIGNIFICANT KINETIC ENERGY

Source identification

9.8. Marine and river vessels include ships and barges (see Table A.III). Data on potential sources of HIEEs should be collected and source–nuclear installation site distance values, D_S, should be calculated. Data collection should include information on ships coming to the site area in the loading and unloading area, commercial ships moving in the designated lanes and maintenance vessels for dredging. Publicly available information from local marine and river authorities on the location of shipping lanes, the local bathymetry and tide and river flows throughout the year, data on the frequency and nature of vessel movements should be collected.

Screening by distance

9.9. Based on the collected data and the protective measures at the site, it should be checked whether a ship(s) can impact an intake structure. Local bathymetry and predominant tide and wind direction are important considerations, but worst met conditions should be considered. If it does not impact, the hazard can be screen out.

Screening using probability

9.10. If it cannot be screened out by distance, generic event data can be used. Pragmatic conservative judgment can be applied to establish the occurrence of an event that can initiate an impact. If the probability of occurrence of that particular event, P_{PE} is less than the SPL, it can be screened out. The probability of an impact of a commercial ship with the intake structure could be very low if protective embankments are constructed with an opening for the cooling water. Ships entering the intake channel to meet the needs of the installation can impact the intake structure due to human error if necessary protective measures are not taken to limit their movement towards the intake structure. A maintenance vessel used for dredging in the intake bay could also impact the intake structure. The screening exercise of each event that could initiate an impact should be performed and the screened-in sources should be listed.

Detailed evaluation

9.11. Hazard analysis of screened-in sources should be performed to check the interaction with the nuclear installation. If there is an interaction, load characterization should be performed by considering a ship or barge moving with a conservatively estimated velocity.

9.12. In broad terms the evaluation process considers a distressed or incorrectly navigated vessel impacting a submerged, offshore or coastal structure of a nuclear installation. Such impacts depend on the number of vessel movements per year by size and inventory, the location of shipping lanes in relation to the location of the structure, and the ability to model accurately how a distressed vessel might come to impact such a structure. These aspects should be considered in the screening process.

9.13. Once the potential for impact has been established, the energy of impact should be calculated, and other load characterisation parameters estimated. Although in principle there are similarities between vessel impacts with marine structures and other types of projectile impacts discussed in this Safety Guide, the nature of vessels (high mass, low speed) and the type of structures being considered may be quite different and this should be taken into consideration.

Hazard parameters

9.14. The following are example of parameters that should be considered and are given in Table A.III:

(a) Passage routes (e.g. seaways) and frequency of passage;
(b) Frequency, type and route of movements to and from the source of HIEEs;
(c) Existing protective measures on passages or routes.

Load characterisation parameters

9.15. The following are example of parameters that should be considered and are given in Table A.V (2):

(a) Impact energy at nuclear installation shoreside or offshore facility location:
    — Mass;
    — Velocity;
    — Size, cross-section area in plane of impact, and penetrative capability.
(b) Type of missile
    — soft missile.
(c) Direction of approach.

CARGOES CONSISTING OF, AND PIPELINES CONVEYING, HAZARDOUS SUBSTANCES

9.16. Hazards under this topic include hazardous liquids and gases released on the ground (see Section 5), explosions (see Section 6) and fire (see Section 7). The same methodology should be used as for the mobile sources of HIEEs by taking the minimum distance from the nuclear installation site. Hazardous liquids discharged in sea and river are also discussed in this section.

9.17. Major pipelines in the region of the site should be evaluated as they may carry hazardous fluids and gases. Such pipelines can leak from valves or during an accident and should therefore be treated in a similar manner.

9.18. An important route for hazardous interaction with the nuclear installation is provided by the water intake; the hazard may arise owing to spillage at an adjacent installation or tanker accidents, often after an uncontrolled drifting. Parameters for the dilution and dispersion of the liquid and its entry into the water intake should be evaluated and the nuclear installation should be adequately protected. Consideration should be given to the fact that spillage of explosive or highly flammable liquids on water may produce floating pools, which might approach a nuclear installation on the shore or along a riverbank. A conservative estimate should be made, and dispersion characteristics should be considered. Consideration should also be given to the possibility that liquids with low flash points might be extracted from contaminated sources of intake water. Other cargo that is not formally classified as hazardous material, like pasty liquids or swelling bulky freight (e.g. wood pellets) and sticky chemicals should also be considered to jeopardize the water intake.

9.19. Liquids discharged from marine and river vessels disperse in response to local tide and/or river current conditions and can be carried several kilometres from the release point. For liquids released into a large body of water, dilution can be anticipated as distance from the release point and elapsed time increase, but the rate of dilution can be very dependent on the local tide and current flow conditions at the time of release. Modelling of the way discharges are dispersed should be carried out. Alternatively, it can be assumed conservatively that no dilution occurs.

HAZARD ASSESSMENT FOR CARGOES CONSISTING OF, AND PIPELINES CONVEYING, HAZARDOUS SUBSTANCES

Source identification

9.20. Sources of hazardous liquids and gases are listed in Table A.III. Recommendations on data collection are provided in Section 4. First, regions should be located based on SDV^g values (Table A.II). Sources within this region should comprise of hazardous materials transported by the commercial shipping companies and information should be available from relevant local or national government agencies with responsibility for controlling access to transport routes (types and quantities of hazardous substances, frequency, routes). Data in this region of potential sources should be collected and source–nuclear installation site distance values, D_S, should be calculated.

Screening by distance

9.21. Based on the collected data, simple calculations can be made and SDV^g values can be estimated for the possible maximum spills as these can travel long distances, assuming conservative parameters for dispersion and local tide and current flow conditions at the time of release. Those sources that lie further away from the nuclear installation site ($D_S > SDV^s$) can be screened out.

Screening on probability

9.22. If a hazard cannot be screened out by distance, generic events data can be used, and pragmatic conservative judgment can be applied to establish the occurrence of potential event(s) for spillage. If the probability of occurrence of that particular event, P_{PE} is less than SPL, it can be screened out.

9.23. If the potential hazard from screened-in sources is likely to be less than that due to similar materials stored on the nuclear installation site itself and against which protection has already been provided that is also effective against hazards from off-site sources, then it can be screened out. If several sources are screened-out on the same basis, it may be necessary to reflect the frequency contribution arising from the sum of all such sources by nominating a bounding source and screening on this. The screening exercise of each event that can affect the nuclear installation site from spillage in sea or river should be completed and the screened-in sources should be listed.

Detailed evaluation

9.24. Hazard analysis of screened-in sources should be performed for load characterization. Substances released into the sea or river water could disperse and dilute in complex ways that require explicit modelling by subject matter experts to determine how the different types of hazardous fluids travel in the sea or river and affect the structures or equipment of the nuclear installation, and to calculate the load characterization parameters required.

Hazard parameters

9.25. The following are hazard parameters that should be considered for load characterization:

(a) The location of the transport route around the closest approach to the nuclear installation site;

(b) The nature and quantities of substances transported and in spillages;

(c) Meteorological and hydrological conditions;

(d) Relevant bathymetric, tidal and river current conditions around this route that might influence the dispersion and hazardous characteristics of a release.

Load characterisation parameters

9.26. The following are load characterisation parameters that should be considered:

(a) Concentration of hazardous substances in the cooling water at the intake;

(b) The impact on a once through cooling water system.

10. OTHER HUMAN INDUCED EXTERNAL EVENTS

GENERAL CONSIDERATIONS

10.1. This section deals with those HIEEs that are not addressed by Sections 5–9. The following hazards arising from these HIEEs are listed in Table A.IV. Some regions surrounding a nuclear installation site may contain other hazards; however, it is not possible to comprehensively identify all possible hazards in this Safety Guide.

GROUND SUBSIDENCE HAZARDS FROM HUMAN INDUCED EXTERNAL EVENTS

10.2. The ground at a nuclear installation site can subside due to a local geotechnical issue under the site or outside the site area due to human-made features such as mines, exploitation of natural gas fields, water wells and oil wells if such activities are foreseen in the site vicinity area.

10.3. All geotechnical and geological issues that can exclude a nuclear installation site should be taken up during the site selection stage. Recommendations on local geotechnical issues are provided in IAEA Safety Standard Series No. NS-G-3.6, Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants [6] and recommendations on geological issues are provided in IAEA Safety Standard Series No. DS507, Seismic Hazards in Site Evaluation for Nuclear Installations [2].

10.4. For existing sites, whenever new construction work is planned either on-site or nearby, subsidence issues should be studied, especially where deep excavation work is planned (e.g. for nuclear power plants). The issue is more complicated when nuclear installations are founded on saturated soft soils with a high water table, and dewatering is necessary. In such cases, it should be justified that dewatering does not lead to unacceptable (differential) settlement of the existing nuclear installation and this should be monitored. Reinjection of the extracted water may be necessary to keep pore pressures at the existing nuclear installation unaltered during dewatering and the restoration period thereafter.

10.5. Large scale mining activities, exploitation of natural gas fields, extraction of oil and ground water in the vicinity of the site can lead to subsidence. A specific assessment should be conducted in such cases and no SDV can be provided as it will depend on the volume of mining or oil or ground water extraction activities and distance from the nuclear installation site.

Detailed evaluation

10.6. Engineering solutions are available to handle the subsidence from local effects but depend on the type of work to be undertaken and may not always be feasible. Engineering solutions to counter subsidence from HIEEs can be established after a detailed evaluation: such solutions might not be possible but administrative measures might be available. As such, a decision to select a site should be taken after detailed evaluation.

Hazard parameters

10.7. The following are example of parameters that should be considered and are given in Table A.III:

(a) Location and nature of adjacent ground works;
(b) Location and nature of underground works;
(c) Relevant geological and geotechnical ground conditions;
(d) Details of planned activities in the site vicinity (mining, oil and water extraction).

Load characterisation parameters

10.8. The following are example of parameters that should be considered and are given in Table A.V (9) if a site can be selected:

(a) Settlement, differential settlement and settlement rate;
(b) Existing engineered mitigation measures (existing sites) or anticipated engineered measures for new sites.

ELECTROMAGNETIC INTERFERENCE HAZARDS FROM HUMAN INDUCED EXTERNAL EVENTS

10.9. Electromagnetic interference can affect the functionality of electronic devices. It can be initiated by both on-site sources of electromagnetic radiation (e.g. high voltage switchgear, portable telephones, portable electronic devices, computers) and off-site sources (e.g. radio transmitters, military radar stations, particle accelerators, high voltage transmission lines, telephone network). Particular attention should be provided to jamming facilities that may be used by the on-site security organization or by transmitters operated by national security authorities (airborne, seaborne or ground-located on- or off-site), as the actual power and antenna amplification of these transmissions might not be public, and the electromagnetic radiation power of the transmissions may be increased significantly with little or no warning. When information on these cannot obtained, the regulatory body should be asked to estimate the significance of these hazards.

10.10. The process of identification of potential sources of electromagnetic interference and quantification should be continued during the lifetime of the nuclear installation to ensure proper protection of plant components as the greater use of digital equipment in instrumentation and control systems is increasing the vulnerability to electromagnetic interference.

10.11. Generic SDV have not been developed for electromagnetic interference by States and therefore, it should be managed on a site specific basis for each nuclear installation site.

Detailed evaluation

10.12. A detailed evaluation should be conducted to establish the hazard parameters and load characterization.

10.13. The electromagnetic conditions at the point of installation for important to safety instrumentation and control systems should be assessed to identify any unique electromagnetic radiation sources that may generate local interference. The sources could include both portable and fixed equipment (e.g. portable transceivers, arc welders, power supplies, and generators). Steps should be taken during installation to ensure that systems are not exposed to levels of electromagnetic radiation that are greater than the specified operating envelopes.

10.14. To ensure that the operating envelopes are being used properly, equipment should be tested in the same physical configuration as that specified for its actual installation in the nuclear installation. In addition, the equipment should be in its normal mode of operation (i.e. performing its intended function) during the testing. Following the tests, the physical configuration of the instrumentation and control system important to safety should be maintained and all changes in the configuration should be controlled.

10.15. Exclusion zones should be established through administrative controls to prohibit the activation of portable emitters of electromagnetic radiation (e.g. welding equipment, transceivers) in areas where instrumentation and control systems important to safety have been installed. The size of the exclusion zones should be site-specific and depend on the effective radiated power and antenna gain of the portable emitters of electromagnetic radiation used within a particular nuclear installation.

Hazard parameters

10.16. The following are example of parameters that should be considered and are given in Table A.III:

(a) Frequency band and energy of emissions of electromagnetic radiation from sources at and around the site;
(b) Existing protective measures at the source locations.

Load characterisation parameters

10.17. The following are example of parameters that should be considered and are given in Table A.V (10):

(a) Frequency band and energy rating of protective measures against electromagnetic interference;
(b) Existing engineered mitigation measures (existing sites) or anticipated measures for new sites.

HAZARDS DUE TO HUMAN INDUCED EXTERNAL EVENTS AT BOMBING AND FIRING PRACTICE RANGES

10.18. This hazard should be handled in a special way if the bombing and firing ranges are within the SDVg of 30 km. Information is not easily available: for military sites, efforts should be made through Governmental channels to obtain the necessary information about the activities on the bombing and firing ranges[10]. The history of events and incidents outside the designated area relating to their activities should be collected and used in the assessment. Information on the frequency of overhanging ordnance, flight path(s) taken to a recovery site, and frequency of dropped ordnance should be collected. A confidentially agreement may need to be signed to not disclose any information. Any screened-in hazards should be evaluated in a similar way. Alternatively, a site inside the SDV should be ruled out.

[10] If there exist undisclosed national security locations (e.g. permanent underwater minefields, electronic warfare installations or concealed munitions depots) near the site that might cause a hazard for the nuclear installation, the operating organization of the installation or the regulatory body should make their best efforts to contact the responsible authorities to determine and minimize the hazard caused to the installation.

11. EVALUATION OF EXTERNAL HUMAN INDUCED HAZARDS FOR NUCLEAR INSTALLATIONS OTHER THAN NUCLEAR POWER PLANTS

11.1. For the purpose of HIEE hazard assessment, a graded approach should be applied to nuclear installations on the basis of their complexity and the potential radiological hazards and other hazards. HIEE hazard assessment should be performed in accordance with this grading. This approach may be applied for each HIEE separately.

11.2. Prior to categorizing a nuclear installation for the purpose of adopting a graded approach, a conservative screening process should be applied in which it is assumed that the entire radioactive inventory of the installation is released by an accident initiated by a HIEE event. If the potential result of such a radioactive release were that no unacceptable consequences would be likely for workers, the public or the environment, and provided that no other specific requirements are imposed by the regulatory body for such an installation, the installation may be screened out from further HIEE hazard assessment.

11.3. If the results of the conservative screening process show that the potential consequences of such a release would not be acceptable, a HIEE hazard assessment and a safety evaluation of the nuclear installation should be carried out, in accordance with the recommendations provided in paras11.5–11.14.

11.4. The likelihood that an HIEE will give rise to radiological consequences will depend on the characteristics of the nuclear installation (e.g. its purpose, layout, design, construction and operation) and. Such characteristics include the following:

(a) The amount, type and status (e.g. whether solid or fluid, processed or only stored) of the radioactive inventory at the site;

(b) The intrinsic hazard associated with the physical processes (e.g. criticality) and the chemical processes that take place at the installation, if applicable;

(c) The thermal power of the nuclear installation, e.g. heat loading of high level waste for example, if applicable;

(d) The configuration of the installation for different activities;

(e) The distribution of radioactive sources in the installation (e.g. for research reactors, most of the radioactive inventory will be in the reactor core and fuel storage pool, while in fuel processing and storage facilities it may be distributed throughout the installation);

(f) The changing nature of the configuration and layout of installations designed for experimental work (such activities have an associated intrinsic unpredictability);

(g) The need for active safety systems and/or actions by operating personnel for the prevention of accidents and for mitigation of the consequences of accidents;

(h) The characteristics of engineered safety features for the prevention of accidents and for mitigation of the consequences of accidents (e.g. the containment and containment systems);

(i) The characteristics of the processes or the engineering features that might show a cliff edge effect in the event of an accident;

(j) The characteristics of the site relevant to the consequences of the dispersion of radioactive substances in the atmosphere and in the hydrosphere (e.g. size, demographics of the region);

(k) The potential for on-site and off-site contamination.

11.5. Although most nuclear installations are located at surface sites, some smaller nuclear installations may be located below the surface. Most HIEEs are expected to have limited potential to affect the safety of a subsurface installation, although those that can induce ground failure should be considered. However, any effects will depend on the HIEEs to which the installation is subjected to and the nature of the installation.

11.6. Depending on the criteria used by the regulatory body, some or all of the factors mentioned in para. 11.4 should be considered. For example, fuel damage, radioactive release or dose may be the conditions or metrics of interest.

11.7. The application of a graded approach should be based on the following information:

(a) The current safety analysis report for the installation, which should be the primary source of information, if available;
(b) The results of a HIEE hazard assessment, if one has been performed;
(c) The characteristics of the installation specified in para. 11.4.

11.8. The application of a graded approach can be used to produce a categorization of the installation. This may have been performed at the design stage or later. In general, the criteria for categorization should be based on the radiological consequences of the release of radioactive from the installation, ranging from very low radiological consequences to potentially severe radiological consequences. As an alternative, the categorization may range from radiological consequences within the installation itself, to radiological consequences confined to the site boundary of the installation, to radiological consequences to the public and the environment outside the site.

11.9. As a result of applying a graded approach, three or more categories of installation may be defined on the basis of national practice and criteria. As an example, the following categories may be defined:

(a) The lowest hazard category includes those nuclear installations for which national building codes for conventional facilities (e.g. essential facilities, such as hospitals) or for hazardous facilities (e.g. petrochemical or chemical plants), at a minimum, should be applied.
(b) The highest hazard category contains installations for which standards and codes for nuclear power plants should be applied.
(c) There is often at least one intermediate category of hazardous installation, for which, at a minimum, codes dedicated to hazardous facilities should be used. The number of intermediate categories will depend on the nature of the installation and also whether the site contains a single or multiple nuclear installations or units.

11.10. In applying the graded approach to nuclear installations, it should be noted that most installations other than NPPs may not have sufficient inherent robustness against HIEEs. It may also be inappropriately costly to protect them against some HIEE through design, e.g. the crash of a large aircraft. Therefore, necessary precautions should be taken at an early stage to protect the nuclear installation through appropriate siting whereby ample SDVs are provided for major HIEEs.

11.11. The HIEE hazard evaluation should be performed in accordance with the following recommendations:

(a) For installations in the lowest hazard category, the HIEE hazard evaluation may be based on national building codes and standards, as established for important facilities within the State.
(b) For installations in the highest hazard category, the HIEE hazard evaluation should be implemented in the same manner as for nuclear power plants.
(c) For installations categorized in the intermediate hazard category, the following may be applicable:
    (i) If the HIEE hazard assessment is performed using methods similar to those described in this Safety Guide, a lower HIEE Hazard level (than for NPPs) for designing these installations may be adopted at the design stage, in accordance with the design requirements for the installation;
    (ii) If the database and the methods recommended in this Safety Guide are found to be disproportionately complex, time consuming and demanding for the nuclear installation in question, simplified methods for HIEE hazard assessment may be used. In such cases, the hazard parameter finally adopted for designing the installation should be commensurate with the reduced database and the simplification of the methods, with account being taken of the fact that both factors tend to increase uncertainties.

12.APPLICATION OF THE MANAGEMENT SYSTEM

12.1. A management system is required to be established, applied and maintained in accordance with IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [20]. It should be applied for the activities performed in relation to the hazards associated with HIEEs in site evaluation for the nuclear installation.

ASPECTS OF PROJECT MANAGEMENT

12.2. A project work plan for addressing HIEEs should be established that, at a minimum, addresses the following topics:
(a) The objectives and scope of the project;
(b) Applicable regulations and standards;
(c) Organization of the roles and responsibilities for management of the project;
(d) Work breakdown, processes and tasks, schedule and milestones;

(e) Interfaces among the different types of tasks (e.g. data collection tasks, analysis tasks) and disciplines involved, especially the various specialists required for the different types of HIEEs encountered with all necessary inputs and outputs;
(f) Project deliverables and reporting procedures.

12.3. The project scope should identify all the hazards generated by HIEEs that are relevant to the safety of the nuclear installation and that will be investigated within the framework of the project. If some HIEEs are not included within the scope, an explanation should be provided.

12.4. The project work plan should include a description of all requirements that are relevant for the project, including applicable regulatory requirements in relation to all the hazards considered to be within the project scope. The applicability of these regulatory requirements should be reviewed by the regulatory body prior to the operating organization conducting the HIEE hazard analysis.

12.5. All approaches and methodologies that reference lower tier legislation (e.g. regulatory guidance documents, industry codes and standards) should be clearly identified and described. If procedures for experts' interaction are used to better capture epistemic uncertainties, the sophistication and complexity of these approaches should be chosen by the study sponsor based on the project requirements. The details of the approaches and methodologies to be used should be clearly stated in the project work plan.

12.6. At least the following generic management system process should be applied to ensure quality of the project: document control, control of products, controls for measuring and testing equipment, control of records, control of analyses, purchasing (procurement), validation and verification of software, audits (self-assessment, independent assessments and review), control of non-conformances, corrective actions and preventive actions [21]. Processes covering field investigations, laboratory testing, data collection, and analysis and evaluation of observed data should be applied. Communication processes for the interaction among the experts involved in the project should be also applied.

12.7. The project work plan should ensure that there is adequate provision, in the resources and in the schedule, for collecting new data and/or analyses that might be important for the conduct of the HIEE hazard assessment. This may arise where potential HIEEs have been identified at sources where the associated safety analysis is appropriate to the industry with which the source is associated, but level of detail is considered inadequate for inclusion in a nuclear safety analysis.

12.8. To make the hazard evaluation associated with HIEEs traceable and transparent to users (e.g. peer reviewers, the operating organization, the regulatory body, the designers, the vendors, the contractors and the subcontractors of the operating organization), the documentation for the analysis should provide a description of all elements of the analysis process and include the following information:

(a) A description of the study participants and their roles;
(b) Background material that comprises the data collection tasks, analysis documentation, including the source display map;

(c) A description of the computer software used, and input and output files;
(d) Reference documents;
(e) All documents supporting the treatment of uncertainties, opinion and related discussions;
(f) Results of intermediate calculations and sensitivity studies.

This documentation should be maintained in an accessible, usable and auditable form by the operating organization.

12.9. The documentation and references should identify all sources of information used in the HIEE hazard analysis, including information on where to find important citations that might be difficult to obtain. Unpublished data that are used in the analysis should be included in the documentation in an appropriately accessible and usable form. Where data has been used that is restricted for security or commercial reasons (see para. 4.1), it may be necessary to prepare redacted versions of significant project documentation. However, where such documents are used by as part of the HIEE hazard analysis or passed to others (e.g. by peer reviewers or nuclear installation designers), it will be the project organization's responsibility to ensure that sufficient information is provided so that such people are able to carry out their tasks effectively and in the best interests of nuclear safety.

ENGINEERING USES AND OUTPUT SPECIFICATION

12.10. An HIEE hazard assessment is usually conducted for the purposes of design and/or safety assessment of the nuclear installation. Therefore, from the beginning, the work plan for the HIEE hazard assessment should identify the intended engineering uses and objectives of the assessment and should incorporate an output specification that describes all the results necessary for the intended engineering uses and objectives of the study: see also para. 4.1. Given the large number of potential HIEEs that might be relevant to safety of a nuclear installation, it is not possible to define in a guide of this nature all the elements that are necessary, since these will vary from project to project and from one nuclear installation to another.

INDEPENDENT PEER REVIEW

12.11. An independent peer review should be conducted and implemented to provide assurance that: (i) a proper process has been duly followed in conducting the HIEE hazard analysis, (ii) the analysis has addressed and evaluated the involved uncertainties (both, epistemic and aleatory), and (iii) that the documentation is complete and traceable.

12.12. The independent peer review team members should include the multidisciplinary expertise to address all technical and process related aspects of the HIEE hazard analysis. The peer reviewer(s) should not have been involved in other aspects of the project and should not have a vested interest in the outcome. The level and type of peer review can vary, depending on the application of the HIEE hazard analysis.

12.13. One of the following two methods of peer review should be used: participatory peer review or, late stage peer review. A participatory peer review is carried out during the assessment, allowing the reviewer(s) to resolve comments. A late stage (follow-up) peer review is carried out towards the end of the assessment. Participatory peer review will decrease the likelihood of the assessment being found unsuitable at a late stage.

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APPENDIX

TABLE A.I. HUMAN INDUCED EXTERNAL EVENT CATEGORIES

	Event Category	Generic Screening Distance Value (SDV[g]) in Table A. II
(a)	*Release of hazardous substances*. These include radioactive and other hazardous gases and liquids, pressurized and liquefied gasses and flammable gases and liquids.	(1) (2) (3) (4)
(b)	*Explosions*. These can arise from operational plants and/or stores containing potentially explosive materials and/or undertaking processes with such materials that create situations where an enhanced potential for explosions exists.	(1) (2) (4)
(c)	*External fire*.	(1) (3)
(d)	*Aircraft crash*. This includes how to categorise different types of aircraft for hazard analysis purposes, how to characterize aircraft movements near to a site, and how to model an aircraft crash event so that the hazard can be parameterised and quantified. Air corridors should also be included when characterizing aircraft movements.	(5)
(e)	*Transport events excluding aircraft crash.* These can arise from road and rail vehicles, pipelines, river barges and sea vessels. Hazards from this category normally arise directly from crash events, which in turn can lead to consequential release of hazardous gases, fire and explosion events.	(1) (2) (3) (4)

(f)	*Other human induced external events*. These include hazards arising from stationary and mobile sources not included in (a) – (e). Four types of HIEEs are included: Subsidence, electromagnetic interference, ground borne eddy currents and bombing and firing ranges, all except the last one without generic SDVs.	NA and (6) for bombing and firing ranges

TABLE A.II. GENERIC SCREENING DISTANCE VALUES (SDV^g) WHICH ARE USED BY SOME MEMBER STATES

	Sources	***Generic Screening Distance Value (SDV^g)***[11]
1	Facilities for storing or handling flammable, corrosive or explosive material	5-10 km
2	Sources of hazardous clouds, vapours and gases	8-10 km
3	Sources of fire such as forests, peat, storage areas for low volatility flammable materials (especially hydrocarbon storage tanks), wood or plastics, factories that produce or store such materials, their transport lines, and vegetation	1–2 km
4	Military installations storing munitions	8.0 km
5	Aircraft crash events	
	i) A crash at the site resulting from the general air traffic in the region.	100–200 km
	ii) Airports with attributes of accidental aircraft crash at the site such as in a take-off or landing operation at a nearby airport. (SDV2)	8.0 km
	iii) Flight paths approaching an airport (SDV3)	4.0 km
6	Distance from military installations or air space usage such as practice, bombing and firing ranges	30.0 km

[11] SDV^g values are intended to be conservative values. When using these values, analysts should ensure that they are appropriate to the HIEEs likely to occur at each source considered.

TABLE A.III. IDENTIFICATION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS, EVENT CATEGORIES, HUMAN INDUCED EXTERNAL EVENTS AND SOURCE RELATED INFORMATION

Source Type	Event Category	HIEEs	Relevant source-related information to be collected
STATIONARY SOURCES			
(1) Oil refinery, chemical plant, storage depot, broadcasting network, mining or quarrying operations, dams and dock facilities, forests, other nuclear facilities, high energy rotating equipment, underground gas storage, fracking, ground works adjacent to the nuclear installation site	a) Release of hazardous substances	• Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances	• Nature of substance – physical properties, chemistry, radiochemistry, flashpoint, toxicity, or definition of other hazardous effects • Max. credible release, or frequency v. quantity release curve • Meteorological and topographical characteristics of the region • Below ground flows – geological seepage and flow routes and opportunities for substance concentration • Existing protective measures at the source location, e.g. bunds
	b) Explosion	• Deflagration wave (over	• Nature of explosive substance

Source Type	Event Category	HIEEs	Relevant source-related information to be collected
		pressurization) • Detonation waves • BLEVE • Exothermic chemical reaction • Dust explosion	• Maximum credible pressure (over/under) and thermal release at source location, or explosion frequency versus severity relationship • Meteorological and topographical characteristics of the region • Existing protective measures at the source location, e.g. blast walls
	c) External fire	• Hydrocarbon fire • Chemical fires other than hydrocarbon	• Nature of flammable substance (soot, toxic products) / thermal release) • Flashpoint, flammability concentrations in air, or other ignition criteria • Maximum credible substance/thermal release, or fire frequency versus severity relationship • Meteorological and topographical characteristics of the region • Existing protective measures at the

Source Type	Event Category	HIEEs	Relevant source-related information to be collected
			source location, e.g. fire breaks
	d) Aircraft crash	• See (3)	
	e) Transport events excluding aircraft crash	• See (4)	• See (4) (e) • Frequency, type and route of movements to/from the source
	f) Other HIEEs	• Projectiles and missiles • Ground Subsidence • Electromagnetic interference	• Nature of projectile or missile (mass, initial velocity, trajectory) • Max. credible projectile or missile, or frequency of release • Location and nature of adjacent ground works • Location and nature of underground works • Meteorological and topographical characteristics of the region • Relevant geological/geotechnical ground conditions • Frequency band and energy of Electromagnetic emissions

Source Type	Event Category	HIEEs	Relevant source-related information to be collected
			• Existing protective measures against electromagnetic interference at the source location • Details of mining and fracking
(2) Military facilities (permanent and temporary)	a) Release of hazardous substances	• Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances	• See (1) (a)
	b) Explosion	• Deflagration • Detonation • Dust explosion	• See (1) (b)
	c) External fire	• Hydrocarbon fire • Chemical fire	• See (1) (c)
	d) Aircraft crash	• See (3)	• See (3) (d) • Frequency, type and route of movements to/from the source
	e) Transport events excluding aircraft crash	• See (4)	• See (4) (e) • Frequency, type and route of movements to/from the source

Source Type	Event Category	HIEEs	Relevant source-related information to be collected
	f) Other HIEEs	• Projectiles and missiles • Electromagnetic interference	• See (1) (f)
MOBILE SOURCES			
(3) Airport, air traffic	a) Release of hazardous substances	• Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances	• See (1) (a)
	b) Explosion	• Deflagration • Detonation	• See (1) (b)
	c) External fire	• Hydrocarbon fire	• See (1) (c)
	d) Aircraft crash	• IEs not covered in (3) (a, b, c, f) • Crash related to take-off and landing • Other sources of aircraft crash: background, airways	• Information not covered in (3) (a, b, c, f) • Types and characteristics of aircraft • Aircraft movements and flight frequencies from airfields • Runway orientation, length and location • Airfield plates for take-off, landing

Source Type	Event Category	HIEEs	Relevant source-related information to be collected
			and manoeuvring • Traffic type and frequencies in airways • Location, elevations and cross-section characteristics of airways • Location and characteristics of restricted, controlled and other forms of airspace • Types and characteristics of aircraft, e.g. mass, fuel load, speeds for various stages of flight
	e) Transport events excluding aircraft crash	• See (4)	
	f) Other HIEEs	• Projectiles and missiles	• See (1) (f)
(4) Railway trains and wagons, road vehicles, ships, barges, pipelines	a) Release of hazardous substances	• Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances • Blockage, contamination	• See (1) (a) • Location of transport route around the closest approach to the nuclear installation site • Relevant topographic features in the

Source Type	Event Category	HIEEs	Relevant source-related information to be collected
		(such as from an oil spill) or damage to cooling water intake structures	region around this route that might influence the dispersion and hazardous characteristics of a release • Relevant bathymetric, tidal and river current conditions around this route that might influence the dispersion and hazardous characteristics of a release
	b) Explosion	• Deflagration • Detonation	• See (1) (b) • Tidal and bathymetric characteristics of the region
	c) External fire	• Hydrocarbon fire • Chemical fire	• See (1) (c) • Tidal and bathymetric characteristics of offshore and nearshore region
	d) Aircraft crash	• See (3)	
	e) Transport events excluding aircraft crash	• IEs not covered in (4) (a, b, c, f) • Vehicle impact • Vehicle derailment, or	• Information not covered in (3) (a, b, c, f) • Passage routes and frequency of passage, e.g. road and rail routes,

Source Type	Event Category	HIEEs	Relevant source-related information to be collected
		misdirection	seaways • Location and routing of pipelines and associated pumping stations • Frequency, type and route of movements to and from the source • Existing protective measures on vehicles or routes
	f) Other HIEEs	• Projectiles and missiles • Electromagnetic interference	• See (1) (f)

TABLE A.IV. EVOLUTION OF SOURCES OF HUMAN INDUCED EXTRERNAL EVENTS AND POSSIBLE EFFECTS ON THE NUCLEAR INSTALLATION

Event Category	HIEEs	Possible hazard at the NI site	Possible hazard effects on the installation
a) Release of hazardous substances	• Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances o Explosion o Hydrocarbon fire o Other types of chemical fire o Projectiles and missiles • Release of large volumes of water or change of watercourse	• Clouds or liquids can drift towards the installation and burn or explode before or after reaching it, outside or inside the installation • Clouds or liquids can also migrate into areas where operators or safety related equipment can be prevented from functioning • Flooding on to the nuclear installation site, or change of water table	(5) (6) (8)
b) Explosion	• Deflagration • Detonation • Dust explosion o Release of flammable, explosive, asphyxiant, corrosive, toxic or	• Explosion pressure wave • Projectiles • Smoke, gas and dust produced in explosion can drift towards the installation	(1) (2) (3) (4) (7)

	radioactive substances o Hydrocarbon fire o Chemical fires other than hydrocarbon o Projectiles and missiles		
c) External fire	• Hydrocarbon fire • Chemical fires other than hydrocarbon o Explosion o Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances o Projectiles and missiles	• Associated flames and fires. Sparks can ignite other fires • Smoke and combustion gas of fire can drift towards the installation • Heat (thermal flux)	(1) (2) (3) (4) (5)
d) Aircraft crash	• Crash related to take-off and landing • Other sources of aircraft crash: background, airways o Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances o Explosion o Hydrocarbon fire	• Direct effects o Impact damage to structures including perforation, penetration o Vibration effects o Global stability • Secondary effects o Secondary missiles ejected from the impact site and scattering widely	(1) (2) (3) (4) (6)

	o Projectiles and missiles	o Rapid spread of flammable liquid from the point of impact, including impulsive damage to structures from the released momentum of the liquid when ejected from the aircraft o Fire and explosion generating heat and blast effects and generating tertiary missiles o Release of hazardous substance carried as cargo` • Ground shaking	
e) Transport events excluding aircraft crash	• Vehicle impact • Vehicle derailment, or misdirection o Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive substances o Blockage, contamination (such as from an oil spill) or damage to cooling water intake structures o Explosion o Hydrocarbon fire	• Direct impact damage • Secondary projectiles • Fire • Explosion of fuel tanks/cargo	(2) (4) (7) (8) (11)

	o Chemical fires other than hydrocarbon o Projectiles and missiles		
f) Other HIEEs	• Projectiles and missiles • Subsidence of ground • Electromagnetic interference	• Missile impact with structure • Ground failure under structures • Direct damage to structures and equipment • Fire • Electromagnetic fields around electrical equipment leading to failure, malfunction, or spurious electrical signals • Electric potential into ground leading to failure, malfunction of equipment, or spurious electrical signals	(2) (9) (10)

Symbols used:

Primary HIEE •

Secondary HIEE ◦

Possible impact/hazard at the nuclear installation () - Table V

TABLE A.V. IMPACT ON THE NUCLEAR INSTALLATION AND CONSEQUENCES

Possible hazard effects on the installation		**load characterisation parameters**	**Consequences of hazard effects**
1)	Pressure wave	Local overpressure at the installation as a function of time	Collapse of parts of structure or disruption of systems and components
2)	Projectile	Impact energy at nuclear installation location – mass, velocity Compass direction and angle of approach from horizontal Missile hardness and penetrative capability in structures important to safety – shape, size, type of material Existing protective measures at the source location	Damage to structures – penetration, perforation, spalling, scabbing, collapse of structures Disruption/failure of structures, systems and components including buried systems and services Induced vibration Loss of access or egress for emergency and/or safety related operator actions Secondary hazards – fire, explosion, release of hazardous substances
3)	Heat	Maximum temperature flux and duration	Impaired habitability of control room Disruption of systems or components Damage to structures Ignition of combustibles

Possible hazard effects on the installation	load characterisation parameters	Consequences of hazard effects
4) Smoke and dust	Composition Concentration and quantity as a function of time	Blockage of intake filters Impaired habitability of control room and other important installation rooms and affected areas
5) Asphyxiant and toxic substance	Concentration and quantity as a function of time Volatility in ambient conditions Toxicity and asphyxiant limits	Threat to human life and health and impaired habitability of safety related areas including the main control room Incapacitation of operating personnel or reduced ability to discharge safety related tasks
6) Corrosive and radioactive liquids, gases and aerosols	Concentration and quantity as a function of time Corrosive, radioactive limits Provenance (sea, land)	Threat to human life and health and impaired habitability of safety related areas Corrosion and disruption of systems or components, loss of strength Electrical short circuits Blockage of water intakes, site drains Prevention of fulfilment of safety functions
7) Ground shaking	Frequency response spectrum for vibrational motion	Mechanical damage

Possible hazard effects on the installation		load characterisation parameters	Consequences of hazard effects
8)	Flooding (or drought)	Elevation of site above main water course/mean sea level Level of water with time Velocity of impacting water	Damage to structures, systems and components due to inundation Damage to structures, systems and components directly or functional failure due to water impact Damage to structures, systems and components or functional failure due to secondary effects such electrical short circuit
9)	Subsidence of the ground	Settlement, differential displacement, settlement rate Existing engineered mitigation measures (existing sites), or anticipated (new sites)	Collapse of structures, disruption/failure of structures, systems and components including buried systems and services Secondary hazards: Fire, explosion release of hazardous substances
10)	Electromagnetic interference	Frequency band and energy rating of protection against electromagnetic interference Existing engineered mitigation measures (existing sites), or anticipated (new sites)	Incorrect or spurious electrical signals in items important to safety leading to spurious operation or action

Possible hazard effects on the installation	load characterisation parameters	Consequences of hazard effects
11) Damage to water intake	Mass of the ship, lost cargo, impact velocity and area, degree of blockage	Unavailability of cooling water

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