

HAZARDS ASSESSMENT OF HUMAN INDUCED EXTERNAL EVENTS IN SITE EVALUATION FOR NUCLEAR INSTALLATIONS: IAEA SSG-79

*Interregional Workshop on Graded Approach for Site Evaluation for
SMRs in Haikou, China*

06-11 November, 2023

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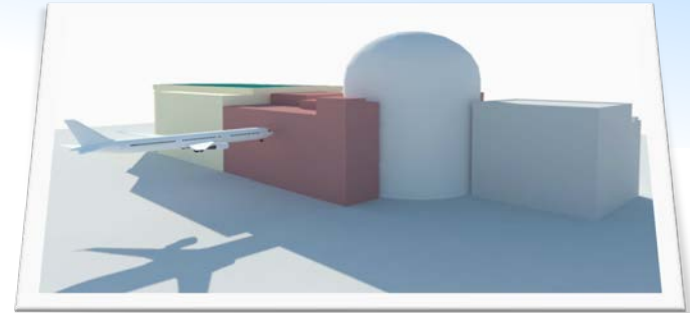
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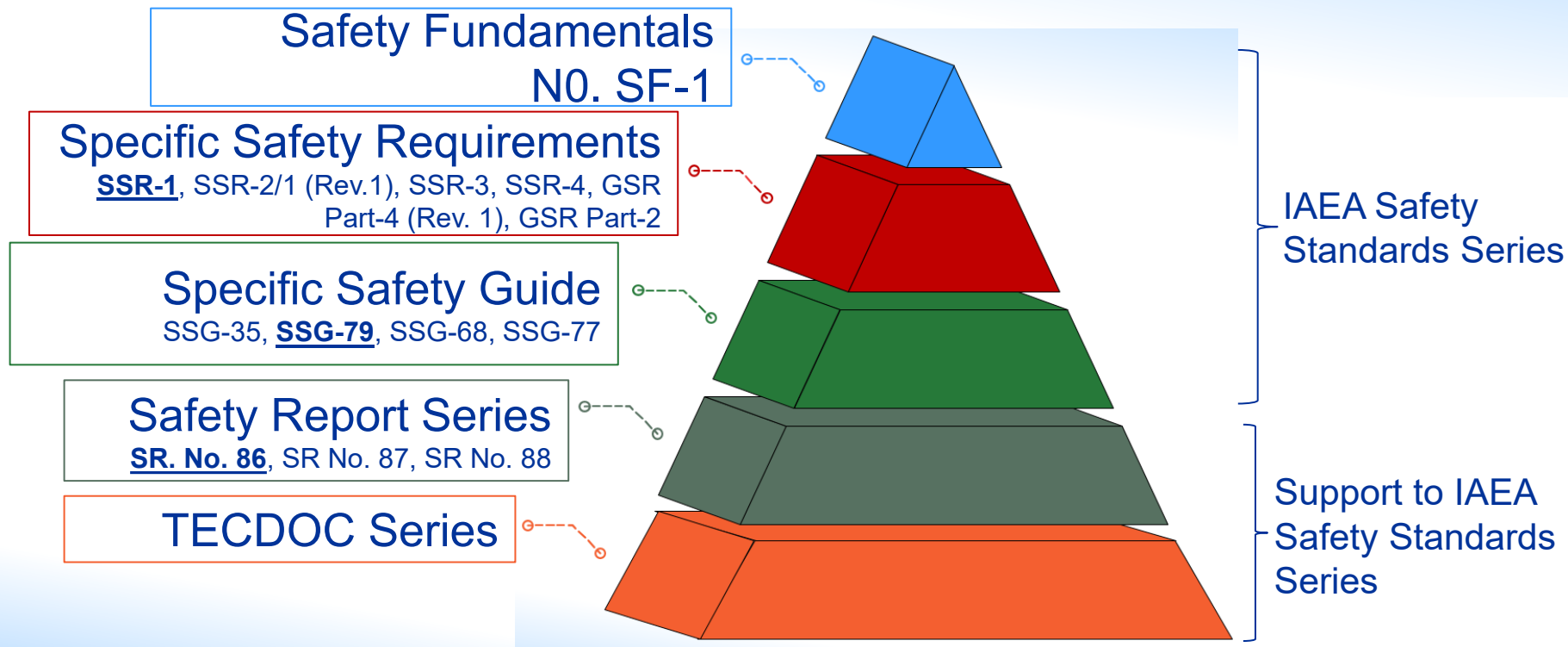
Introduction

An **external event** is any occurrence that is **unintended** by the **operator** of the nuclear facility, the **consequences** or **potential consequences** of which are **not negligible** from the point of view of **safety**.

Human Induces External Event (HIEE) is an event that is **unconnected** with the **operation** of the nuclear facility.



IAEA Safety Standards related with Hazards Associated with HIEEs in Site Evaluations





HIEEs Hazard Assessment – SSR-1 Requirements

IAEA Safety Standards

for protecting people and the environment

Site Evaluation for Nuclear Installations

Specific Safety Requirements No. SSR-1



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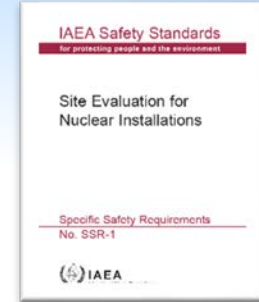
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HIEEs Hazard Assessment – SSR-1 Requirements cont'd



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.

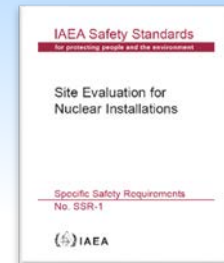


5.33. Human induced events to be addressed shall include, but shall not be limited to:

- (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

HIEEs Hazard Assessment – SSR-1 Requirements

(cont'd)



5.34. 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.

Aircraft crashes

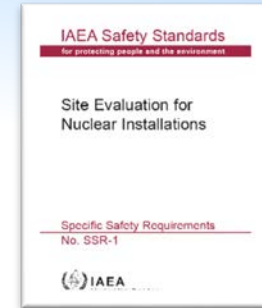
5.35. The potential for accidental aircraft crashes on the site shall be assessed with account taken, to the extent practicable, of potential changes in future air traffic and aircraft characteristics.

Chemical hazards

5.36. 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.

HIEEs Hazard Assessment – SSR-1 Requirements (cont'd)

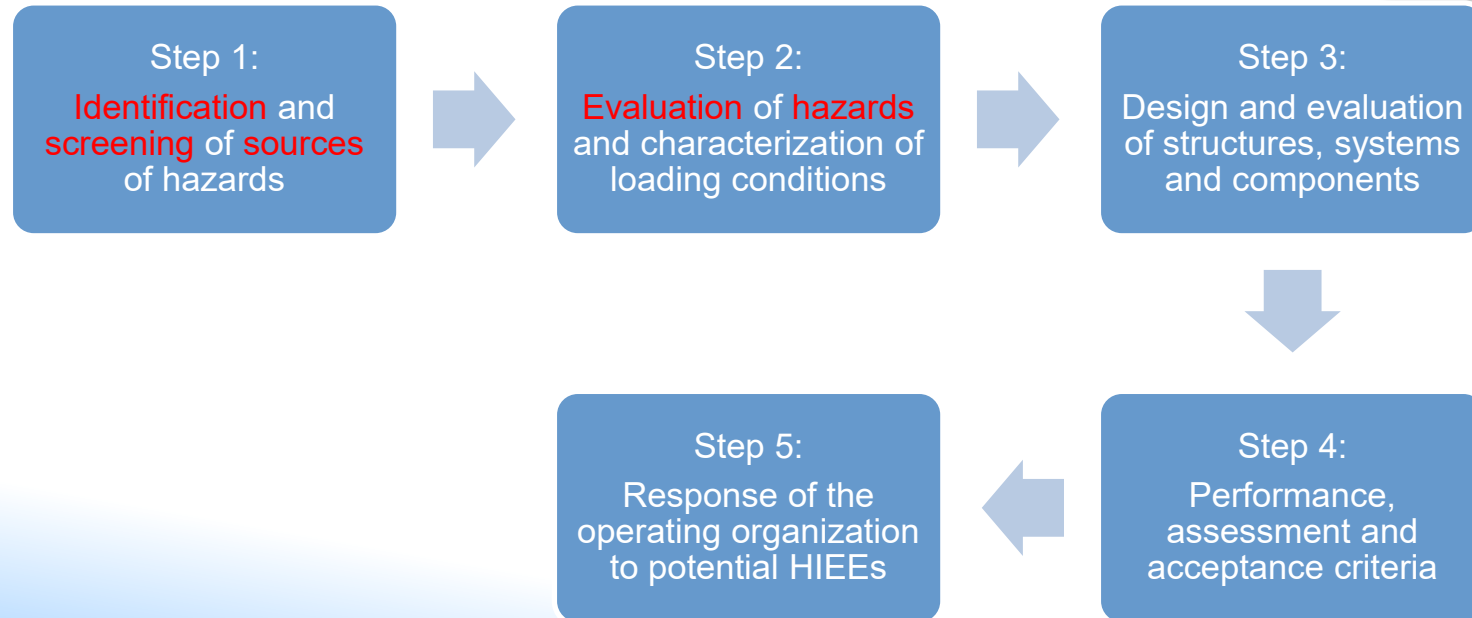
5.37. Hazards associated with **chemical explosions** or other releases shall be expressed in terms of **heat**, **overpressure** and **toxicity** (if applicable), with account taken of the effect of distance and non-favourable combinations of atmospheric conditions at the site. In addition, the potential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



HIEEs – Safety Guide SSG-79 Guidelines

SCOPE

The process for Evaluation of HIEEs can be divided into following steps:



HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

SCOPE

HIEEs are grouped into following event categories:



External release of
hazardous material

External explosions

External fire

Aircraft crash

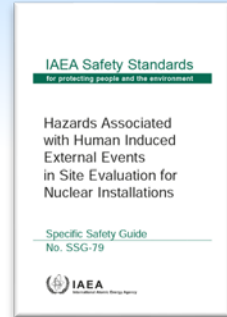
External transport
events excluding
aircraft crashes

Other HIEEs (e.g.
ground subsidence,
electromagnetic
interference)

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

SCOPE

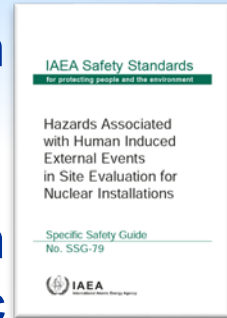
- **Consequential** hazards arising from HIEEs are included in this safety guide, however **combination** of hazards are not discussed in the safety guide.
- The recommendations in the safety guide should be applied to nuclear installations **other than NPPs** through a **graded approach**.
- The recommendations in safety guide focused on new nuclear installation. The recommendations are also applicable for re-evaluation of existing sites and in PSR.
- This guide addresses site evaluation of **multi-units** sites
- HIEEs considered in the guide are of **accident origin**, other HIEEs are outside the scope



HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

GENERAL CONSIDERATIONS

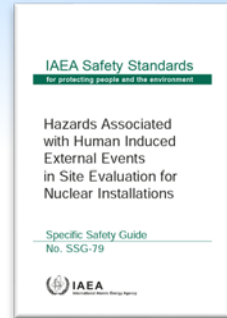
- HIEEs include **direct** human action, **indirect** human action and errors of **commission** and **omission**.
- Potential HIEEs sources are classified as:
 - Stationary sources: **location** of the initiating mechanism (explosion centre, point of release of explosive or toxic gases) **fixed** (chemical plants, oil refineries, storage depots and other nuclear facilities at the same site).
 - Mobile sources: Location of the initiating mechanism is not totally constrained, e.g. transport or movement of hazardous material or potential projectiles (by road, rail, waterways, air, pipelines). In such cases, an accidental explosion or a release of hazardous material **might occur anywhere** along a road, route or pipeline.



HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

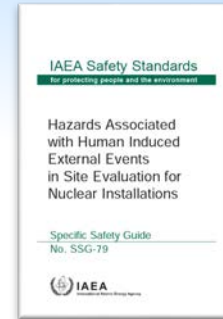
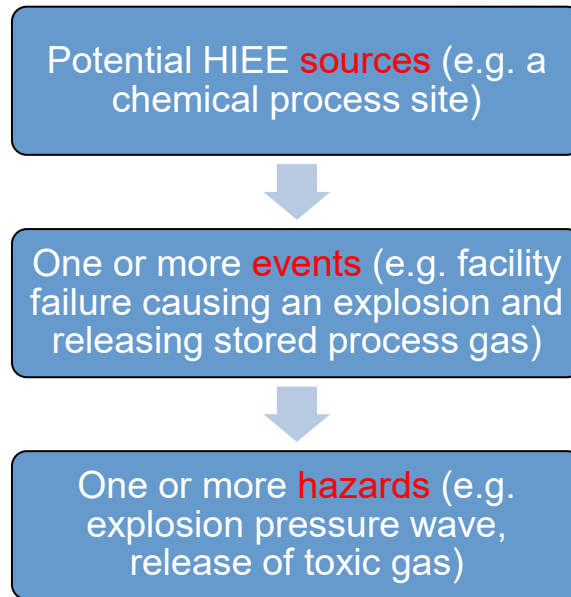
GENERAL CONSIDERATIONS

- The **region** is required to be examined for **facilities and human activities** that have the potential to endanger the NPP over its **entire lifetime**.
- Special attention should be given to understanding the various levels of defence in depth that might be challenged by HIEEs.
- A **forecast** should be made for possible regional development over **lifetime** of the nuclear installation, considering degree of **administrative control** that could be exercised over activities in the region.
- HIEEs initiated at a **source** could result in **different hazards** at a nuclear installation site following an **interacting mechanism**.



HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

GENERAL CONSIDERATIONS



- It is necessary to perform a hazard **analysis** of **each HIEE scenario**.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

GENERAL CONSIDERATIONS

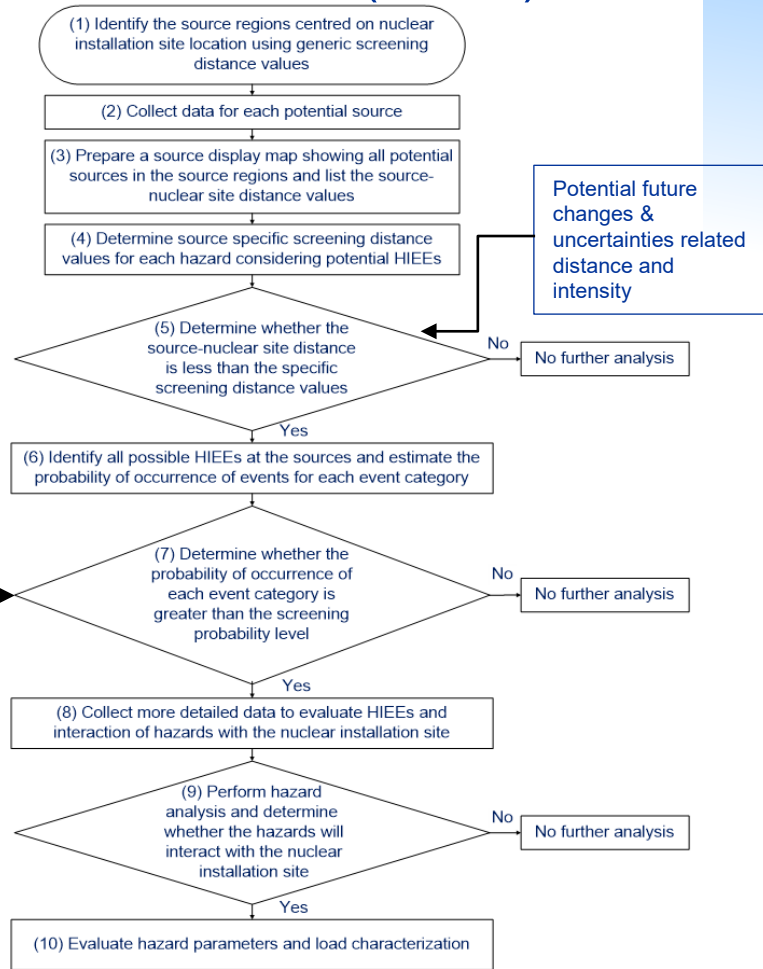
- There are **three** types of **protection** against HIEEs
 - **Robust design** of SSCs;
 - Provision of **site protection measures** (e.g. sufficient distance and barriers;
 - **Administrative measures** (no-fly zones and restrictions on transport of hazardous materials in the vicinity of site.
- If **available data** is **not sufficient** characterization of some HIEEs may be not possible at screening or hazard evaluation stages. A **pragmatic** approach based on **conservative** engineering **judgement** should be taken.
- HIEEs hazards in the region should be periodically re-evaluated within framework of the PSRs



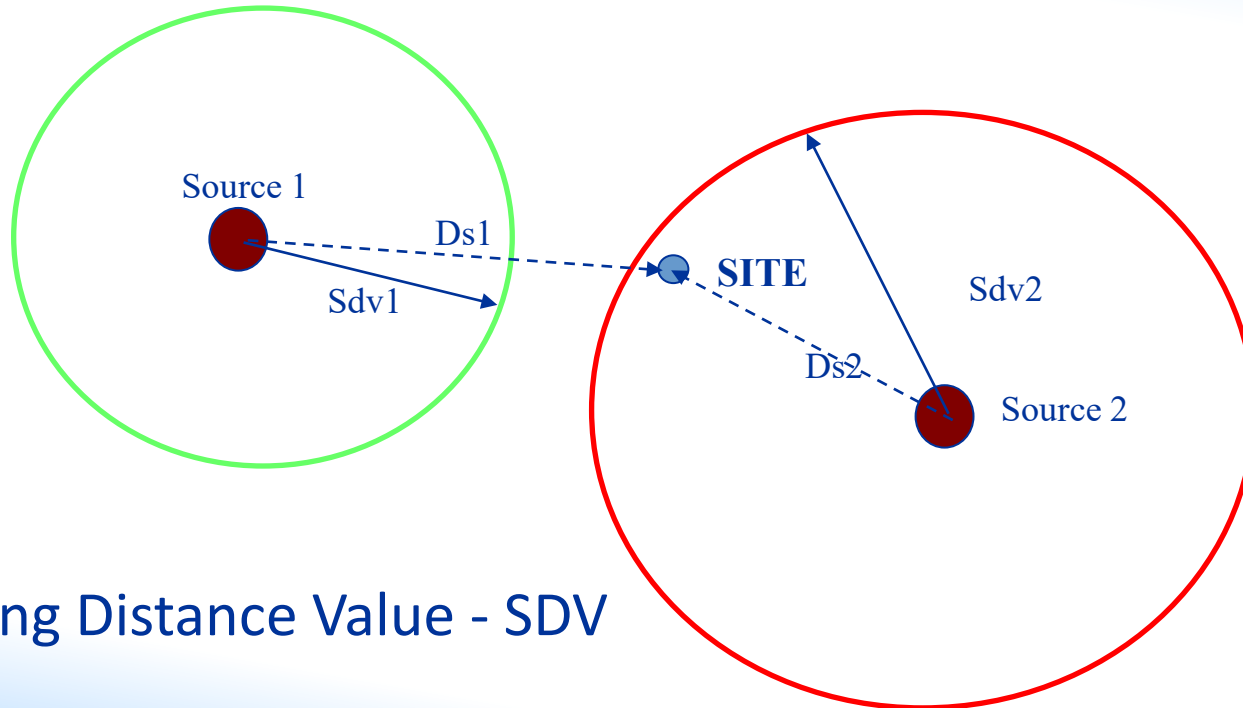
HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

IDENTIFICATION OF SOURCE OF HIEEs, SCREENING AND EVALUATION METHODS

In some States, a 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 with serious radiological consequences



HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



Screening Distance Value - SDV

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

IDENTIFICATION OF SOURCE OF HIEEs, SCREENING AND EVALUATION METHODS

- Generic screening distance values for different event categories

See also Table II-1 of SSG-35:

TABLE II-1. EXAMPLES OF SCREENING VALUES

No.	Characteristics	Screening values	Remarks
3	Distance from airport with attributes of Type 2 event ^a	7.5 km [II-4]	Discretionary criterion
4	Distance from small airports	10.0 km [II-4]	Discretionary criterion
5	Distance from large airport: — for yearly flight operations $>500 d^2$ — for yearly flight operations $>1000 d^2$	$< (d \approx) 16.0$ km $> (d \approx) 16.0$ km [II-4]	Discretionary criterion

TABLE A-1. TYPICAL GENERIC SCREENING DISTANCE VALUES	
Sources	Generic screening distance value
(1) Facilities for storing or handling flammable, corrosive or explosive material	5–10 km
(2) Sources of hazardous clouds, vapours or 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 km
(5) Aircraft crash events:	
(i) An aircraft crash at the site resulting from the general air traffic in the region (Type 1 aircraft crash)	Not applicable, see para. 8.11
(ii) An aircraft crash at the site resulting from take-off or landing manoeuvres at a nearby airport (Type 2 aircraft crash)	8 km
(iii) An aircraft crash at the site resulting from air traffic in the main civil traffic corridors and military flight zones (Type 3 aircraft crash)	4 km
(6) Distance from military installations or air space usage such as bombing and firing ranges	30 km

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS

- Data and information collection resources:
 - Organizations and individuals responsible for **potential sources**;
 - Local and national **government** organizations;
 - Professional institutions and organizations;
 - Regional data and relevant documents from government organizations;
 - Experience of good practices;
 - Local maps, published reports etc.;
 - Public and private agencies and individuals knowledgeable about local area.

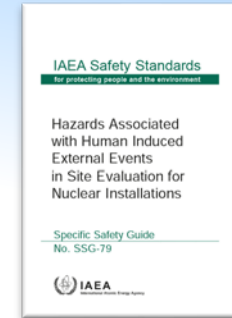


HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



DATA COLLECTION AND INVESTIGATIONS

- Stationary sources:
 - Nature and quantity of hazardous materials;
 - Type of storage and processes;
 - Dimensions of major vessels, stores or confinement;
 - Location and distances to the nuclear installations site;
 - Operating conditions of means of confinements
 - Active and passive safety features of means of confinements.



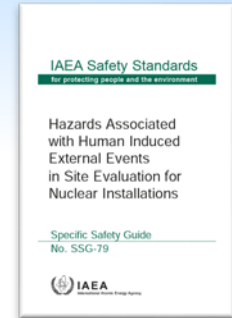
HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS



- Mobile sources
 - Air transport

- (a) Local airports and 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 and for civil and military air traffic. Of particular interest are military aircraft training areas (especially low flying areas) and areas within the region used for filling firefighting aircraft with water, since these might be 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 (i.e. in flight, landing and taking off, including normal or special flight modes for military aircraft).



HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS



- Mobile sources
 - Transport of hazardous material by sea and inland waterways
 - (a) The location of shipping lanes local to the nuclear installation site;
 - (b) The nature, types and quantities of hazardous material conveyed along a route in a single transport movement;
 - (c) The sizes, numbers and types of vessels;
 - (d) The points of closest approach to the nuclear installation site;
 - (e) Accident statistics including consequences.
 - Transport for hazardous material by road and rail
 - (a) The location of road and rail routes local to the nuclear installation site;
 - (b) The nature, types and quantities of hazardous material conveyed along a route in a single transport movement;
 - (c) The sizes, numbers and types of vehicle;
 - (d) The points of closest approach to the nuclear installation site;
 - (e) Speed limits, control systems and safety devices;
 - (f) Accident statistics including consequences.

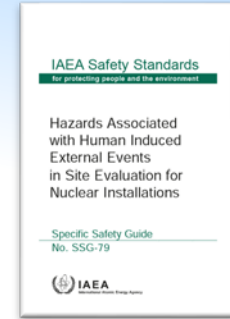


HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS (cont'd)



- Mobile sources
 - Transport of hazardous material by pipeline
 - (a) The 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 materials transported and the flow capacity and 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.
- Source display map should be prepared using GIS platform showing the locations and distances from the site of all sources identified in the data collection stage and size of region considered for each hazard type.



HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS

TABLE 2. IDENTIFICATION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS, EVENT CATEGORIES, HUMAN INDUCED EXTERNAL EVENTS AND SOURCE RELATED INFORMATION

Types of source	Category of event	HIEEs	Relevant source related information to be collected
<i>Stationary sources</i>			
(1) Oil refineries, chemical plants, storage depots, broadcasting networks, mining or quarrying operations, dams and dock facilities, peat and forests, other nuclear installations, underground gas storage, fracking, ground works adjacent to the nuclear installation site	(a) External release of hazardous material	<ul style="list-style-type: none"> — Release of flammable, explosive, asphyxiant, corrosive or toxic material — Radioactive release from nearby nuclear facilities 	<ul style="list-style-type: none"> — Quantity and nature of all materials and physical properties, chemistry, radiochemistry, flashpoint, toxicity or definition of other hazardous effects — Detailed information of nearby nuclear facilities (e.g. type, power) — Maximum credible release, or frequency versus quantity release relationship — Meteorological and topographical characteristics of the region — Below ground flows — geological seepage and flow routes and opportunities for material concentration — Existing protective measures at the source location (e.g. bunds)

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS

TABLE 2. IDENTIFICATION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS, EVENT CATEGORIES, HUMAN INDUCED EXTERNAL EVENTS AND SOURCE RELATED INFORMATION (cont.)

Types of source	Category of event	HIEEs	Relevant source related information to be collected
			<ul style="list-style-type: none"> Parameters allowing the determination of the release rate of the flammable source (e.g. evaporation rate in the case of a flammable pool of hydrocarbon and release rate for flammable gas release) Types and features of nuclear facilities
	(b) External explosions	<ul style="list-style-type: none"> Deflagration wave (over-pressurization) Detonation wave Boiling liquid expanding vapour explosion Exothermic chemical reaction Dust explosion 	<ul style="list-style-type: none"> Nature of explosive material 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)

DATA COLLECTION AND INVESTIGATIONS

TABLE 2. IDENTIFICATION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS, EVENT CATEGORIES, HUMAN INDUCED EXTERNAL EVENTS AND SOURCE RELATED INFORMATION (cont.)

Types of source	Category of event	HIEEs	Relevant source related information to be collected
	(c) External fire	<ul style="list-style-type: none"> — Hydrocarbon fire — Chemical fires other than hydrocarbon 	<ul style="list-style-type: none"> — Nature of flammable material (e.g. soot, toxic products) and thermal release — Flashpoint, flammability concentrations in air or other ignition criteria — Maximum credible material or thermal release, or fire frequency versus severity relationship — Meteorological and topographical characteristics of the region — Existing protective measures at the source location (e.g. fire breaks)
	(d) Aircraft crash	— See (3)	
	(e) External transport events excluding aircraft crashes	— See (4)	<ul style="list-style-type: none"> — See (4)(e) — Frequency, type and route of movements to and from the source

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS

TABLE 2. IDENTIFICATION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS, EVENT CATEGORIES, HUMAN INDUCED EXTERNAL EVENTS AND SOURCE RELATED INFORMATION (cont.)

Types of source	Category of event	HIEEs	Relevant source related information to be collected
	(f) Other HIEEs	<ul style="list-style-type: none"> — Projectiles and missiles — Ground subsidence — Electromagnetic interference — Bombing and firing ranges — Miscellaneous HIEEs 	<ul style="list-style-type: none"> — Nature of projectile or missile (e.g. mass, initial velocity, trajectory) — Maximum 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, hydrogeological and geotechnical ground conditions — Frequency band and energy of electromagnetic emissions — Existing protective measures against electromagnetic interference at the source location — Details of mining and fracking
(2) Military facilities (permanent and temporary)	(a) External release of hazardous material	<ul style="list-style-type: none"> — Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive material 	<ul style="list-style-type: none"> — See (1)(a).

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS

TABLE 2. IDENTIFICATION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS, EVENT CATEGORIES, HUMAN INDUCED EXTERNAL EVENTS AND SOURCE RELATED INFORMATION (cont.)

Types of source	Category of event	HIEEs	Relevant source related information to be collected
(b)	External explosions	<ul style="list-style-type: none"> — Deflagration — Detonation — Dust explosion 	— See (1)(b)
(c)	External fire	<ul style="list-style-type: none"> — Hydrocarbon fire — Chemical fire 	— See (1)(c)
(d)	Aircraft crash	— See (3)	<ul style="list-style-type: none"> — See (3)(d) — Frequency, type and route of movements to and from the source
(e)	External transport events excluding aircraft crashes	— See (4)	<ul style="list-style-type: none"> — See (4)(e) — Frequency, type and route of movements to and from the source
(f)	Other HIEEs	<ul style="list-style-type: none"> — Projectiles and missiles — Electromagnetic interference — Bombing and firing ranges 	— See (1)(f)

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS

TABLE 2. IDENTIFICATION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS, EVENT CATEGORIES, HUMAN INDUCED EXTERNAL EVENTS AND SOURCE RELATED INFORMATION (cont.)

Types of source	Category of event	HIEEs	Relevant source related information to be collected
Mobile sources			
(3) Airport facilities, air traffic	(a) External release of hazardous material	— Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive material	— See (1)(a)
	(b) External explosions	— Deflagration — Detonation	— See (1)(b)
	(c) External fire	— Hydrocarbon fire	— See (1)(c)
	(d) Aircraft crash	— Initiating events not covered in (3)(a, b, c, f) — Crash related to take-off and landing — Other sources of aircraft crash (e.g. background crash rate, airways)	— Information not covered in (3)(a, b, c, f) — Types and characteristics of aircraft — Aircraft movements and flight frequencies from airports — Runway orientation, length and location

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS

TABLE 2. IDENTIFICATION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS, EVENT CATEGORIES, HUMAN INDUCED EXTERNAL EVENTS AND SOURCE RELATED INFORMATION (cont.)

Types of source	Category of event	HIEEs	Relevant source related information to be collected
			<ul style="list-style-type: none">— Airfield plates for take-off, landing 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)— National and regional crash data
(e)	External transport events excluding aircraft crashes	— See (4)	
(f)	Other HIEEs	— Projectiles, missiles and drones	— See (1)(f)

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS

TABLE 2. IDENTIFICATION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS, EVENT CATEGORIES, HUMAN INDUCED EXTERNAL EVENTS AND SOURCE RELATED INFORMATION (cont.)

Types of source	Category of event	HIEEs	Relevant source related information to be collected
(4) Railway trains and wagons, road vehicles, ships, barges, pipelines	(a) External release of hazardous material	<ul style="list-style-type: none"> — Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive material — Blockage, contamination (such as from an oil spill) or damage to cooling water intake structures 	<ul style="list-style-type: none"> — See (1)(a) — Location of transport routes and the closest approach to the nuclear installation site — Relevant topographic features in the region around these routes 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) External explosions	<ul style="list-style-type: none"> — Deflagration — Detonation 	<ul style="list-style-type: none"> — See (1)(b) — Tidal and bathymetric characteristics of the region
	(c) External fire	<ul style="list-style-type: none"> — Hydrocarbon fire — Chemical fire 	<ul style="list-style-type: none"> — See (1)(c) — Tidal and bathymetric characteristics of offshore and near-shore region
	(d) Aircraft crash	<ul style="list-style-type: none"> — See (3) 	

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

DATA COLLECTION AND INVESTIGATIONS

TABLE 2. IDENTIFICATION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS, EVENT CATEGORIES, HUMAN INDUCED EXTERNAL EVENTS AND SOURCE RELATED INFORMATION (cont.)

Types of source	Category of event	HIEEs	Relevant source related information to be collected
(e)	External transport events excluding aircraft crashes	<ul style="list-style-type: none">— Initiating events not covered in (4)(a, b, c, f)— Vehicle or vessel impact— Vehicle derailment, or misdirection— Leak of hazardous material from a pipeline	<ul style="list-style-type: none">— Information not covered in (4)(a, b, c, f)— Passage routes and frequency of passage (e.g. road and rail routes, seaways)— Location and routing of pipelines and associated pumping stations— Frequency, type and route of movements to and from the source— Existing protective measures for vehicles, vessels and routes— Transportation accidents data
(f)	Other HIEEs	<ul style="list-style-type: none">— Projectiles and missiles— Electromagnetic interference	<ul style="list-style-type: none">— See (1)(f)

HIEEs – Safety Guide SSG-79 Guidelines



HAZARD ASSESSMENT FOR AIRCRAFT CRASH

- The potential for aircraft crashes should be considered in the **early stages** of the site evaluation process and it should be **assessed** over the entire **lifetime** of the plant.
- The potential will result from the contributions to the probability of occurrence of an aircraft crash of one or more of the following events:
 - Type 1: crash arising from the **general air traffic** in the region. To evaluate the probability of occurrence of such crashes, the site is considered as a tract or circular area of 0.1–1 km² and the region as a circular area of 100–200 km in radius. Screening using distance is **not applicable** for type 1 event.
 - Type 2: crash after **takeoff or landing operation** at a **local airport**.
 - Type 3: crash arising from air traffic in the **main civil traffic corridors** and the **military flight zones**.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



HAZARD ASSESSMENT FOR AIRCRAFT CRASH

- The information collected on air traffic should include the **locations of airports** and **air traffic corridors** in the region, the airports **takeoff**, **landing** and **holding patterns**, the types of warning and control devices available, the **types** and **characteristics** of **aircraft** and their **flight frequencies**.
- Information on aircraft **accidents** for the **region** and for similar types of airport and air traffic should be collected.
- Information should be collected for both **civil** and **military** air traffic.
- Particular interest should be given to **military** aircraft **training** areas which may show a comparatively high frequency of crashes in their vicinity.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

HAZARD ASSESSMENT FOR AIRCRAFT CRASH

Example of Statistics in FRANCE for aircraft crashes versus traffic

Commercial aircraft

General aircraft

Military aircraft



Flights per year:

1 000 000

Flights per year:

3 500 000

Flights per year:

600 000

Crash per flight :

10^{-6}

Crash per flight :

10^{-4}

Crash per flight :

10^{-5}

Airport : 80

Airport : 400

Airport : 40

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



HAZARD ASSESSMENT FOR AIRCRAFT CRASH

- **Screening Distance Value (SDV) Approach:**
 - The SDV is developed from a deterministic and a probabilistic evaluation of a spectrum of aircraft hazards.
 - The **information** to be collected for evaluating the **SDV** includes:
 - a) **distance** from the nearest **major airport** to the site and the **locations of landing**;
 - b) the **types** and **frequency** of air traffic;
 - c) the **routes** of air traffic corridors and the **locations** of air route crossings;
 - d) the **distances** from the plant to **military installations** such as **military airports** and **bombing** and **firing practice ranges**.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



HAZARD ASSESSMENT FOR AIRCRAFT CRASH

- One State adopts following criteria for estimating the SDV (example). The potential hazards arising from aircraft crashes are taken into account:
 - If airways or airport approaches pass within 4 km of the site;
 - If airports are located within 10 km of the site for all but the biggest airports;
 - For large airports, if the distance d in kilometer to the proposed site is less than 16 km and the number of projected yearly flight operations is greater than $500d^2$.
 - For large airports where the distance is greater than 16 km, if the number of projected yearly flight operations is greater than $1000d^2$.
- For military installations or air space usage such as practice bombing or firing ranges, the hazard will be considered if there are such installations within 30 km of the proposed site.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

HAZARD ASSESSMENT FOR AIRCRAFT CRASH



- **Screening Probability Level (SPL) Approach:**
 - If the site is **within** the **SDV**, then the **probabilistic** approach should be used for **screening** purposes.
 - The probability of aircraft crashes should be evaluated:
 - a) **Type 1** events: probability should be evaluated, in particular in **densely populated regions** with **several civil airports** and thus more flights.
 - b) **Type 2** events: probability of aircraft crashes in the **vicinity of airports**, both **civil** and **military** because it is usually higher.
 - c) **Type 3** events: probability of crashes of **civil aircraft** near **air traffic control corridors** should be examined.
- If the probability is equal to or greater than the specified SPL (e.g. $10^{-7}/a$), then a detailed evaluation should be conducted.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



HAZARD ASSESSMENT FOR AIRCRAFT CRASH

- **Example:** Probability of an aircraft crash affecting the plant due to aircrafts passing in the corridors.

$$P_{FA} = C \times N \times \frac{A}{w}$$

from NUREG-0800
SRP 3.5.1.6, USA

where

C: inflight crash rate per mile for aircraft using airway,

N: number of flights per year along the airway, and

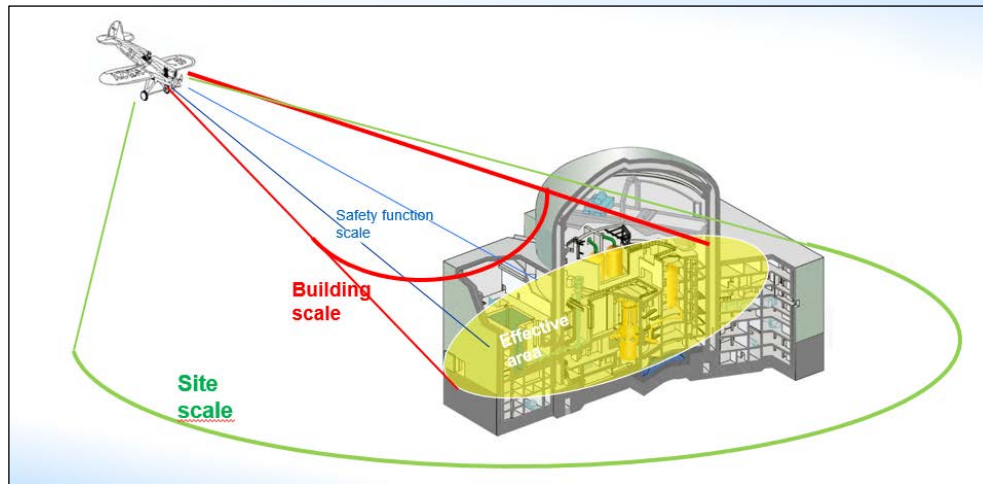
A: effective area of plant in square miles.

w: width of airway (plus twice the distance from the airway edge to the site when the site is outside the airway) in miles,

e.g. for commercial aircraft a value of $C = 4 \times 10^{-10}$ per aircraft mile

HAZARD ASSESSMENT FOR AIRCRAFT CRASH (cont'd)

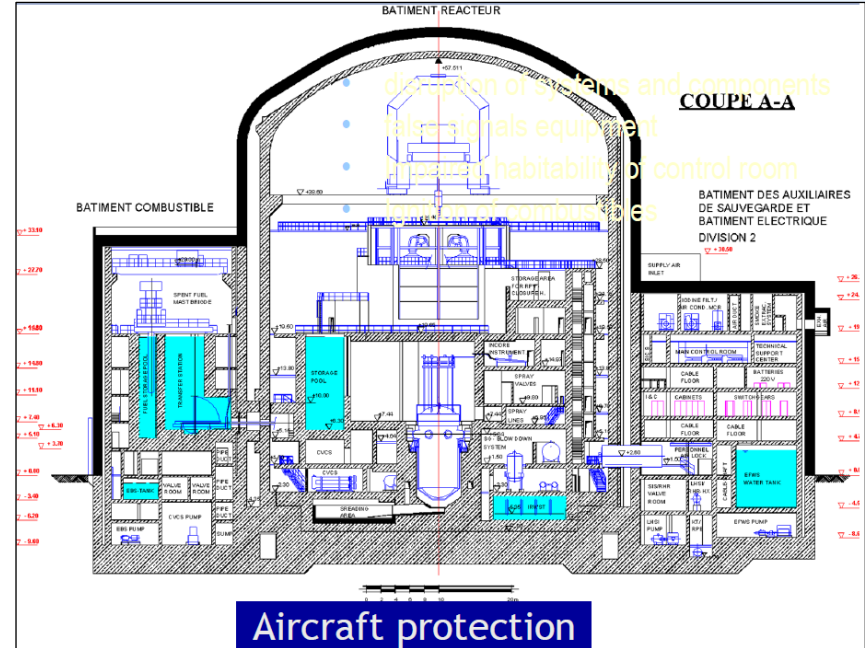
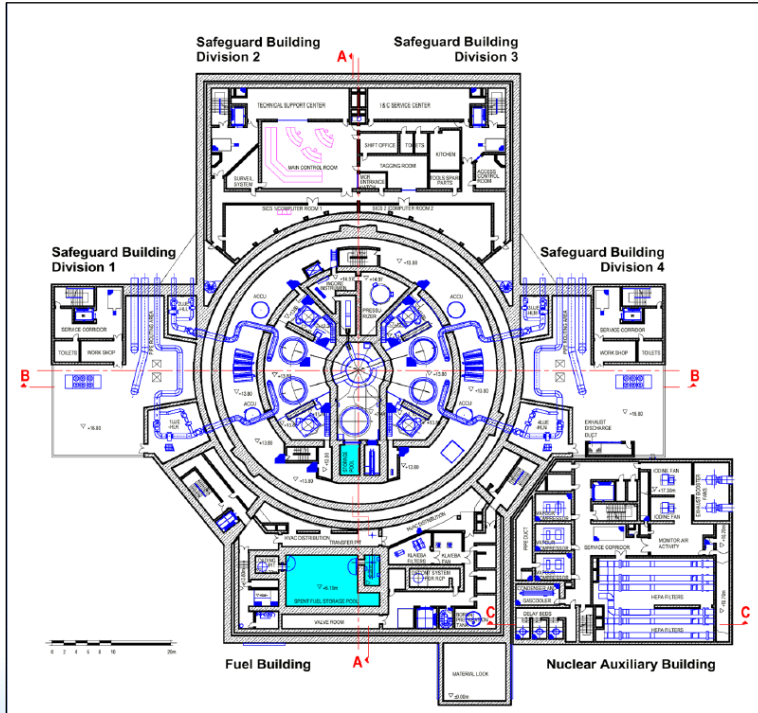
- In general, values of **10,000 m²** to 40,000 m² used for the **effective area**.
- Some States have decided to design **all NPPs** against aircraft crashes, having found a probability of about 10^{-6} per year for aircraft crashing on an area of 10,000 m² anywhere in the country.
- This value corresponds to the size in terms of effective area of a nuclear island.
- Calculation of these values assumed a trajectory angles of 10° – 45° to the horizontal.



HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

HAZARD ASSESSMENT FOR AIRCRAFT CRASH

- Example: Protection against airplane crash



HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

HIEEs INVOLVING RELEASE OF HAZARDOUS MATERIAL

- Hazardous fluids (explosive, flammable, corrosive and toxic, including liquefied gases) which are normally kept in closed containers but which upon release could cause a hazard to items important to safety and to human life:
 - **Flammable gases** and vapours which can form explosive clouds and can enter **ventilation system** intakes and **burn** or **explode**.
 - **Asphyxiate** and **toxic gases** which can threaten human **life** and **impair** crucial **safety functions**.
 - **Corrosive** and **radioactive** gases and liquids which can threaten **human life** and impair the **functionality** of **equipment**



HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



HIEEs INVOLVING RELEASE OF HAZARDOUS MATERIAL

Preliminary Screening for Hazardous Liquids:

- **Identify** all activities and facilities involving the processing, handling, storage or transport of **flammable**, **toxic** or **corrosive liquids** within the **SDV**.
- The **SDV** selected will depend on a number of factors :
 - physical properties of the substance,
 - **Meteorological** and **topographical** aspects of site and region
 - type and extent of industrialization.
- If the potential hazard within the SDV to **items important to safety** arising from these activities and facilities is **less** than that due to similar materials to be stored on the site and against which protection has been provided, then no further investigation should be carried out.
- Otherwise the potential hazards due to off-site activities should be evaluated.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

HIEEs INVOLVING RELEASE OF HAZARDOUS MATERIAL

Detailed evaluation and hazard parameters:

TABLE 3. EVOLUTION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS AND POSSIBLE EFFECTS ON NUCLEAR INSTALLATIONS

Event category	HIEEs	Possible hazard at the nuclear installation site	Possible effects on the nuclear installation (see Table 4)
(a) External release of hazardous material	<ul style="list-style-type: none"> — Release of flammable, explosive, asphyxiant, corrosive or toxic material — Release of radioactivity from nearby nuclear facilities — Explosion — Hydrocarbon fire — Other types of chemical fire — Projectiles and missiles 	<ul style="list-style-type: none"> — Clouds or liquids can drift toward the nuclear installation and burn or explode before or after reaching it, outside or inside the installation — Clouds or liquids can also migrate into areas and affect operating personnel or items important to safety — Radiation exposures to operating personnel at the nuclear installation 	<p>(5) (6) (8)</p> <p>(5) Asphyxiant and toxic material</p> <p>(6) Corrosive and radioactive liquids, gases and aerosols</p> <p>(8) Flooding or drought</p>
(b) External explosions	<ul style="list-style-type: none"> — Deflagration — Detonation — Dust explosion — Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive material 	<ul style="list-style-type: none"> — Explosion pressure wave — Projectiles — Smoke, gas and dust produced in explosion can drift toward the nuclear installation 	<p>(1) (2) (3) (4) (7) (8)</p>

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



HIEEs INVOLVING EXPLOSIONS

- An **explosion** is any **chemical reaction** between **solids, liquids, vapours or gases** which may cause a substantial **rise in pressure**, possibly owing to **impulse loads, drag loads, fire or heat**.
- An explosion can take the form of :
 - a **deflagration**, which generates **moderate pressures, heat or fire**, or
 - a **detonation**, which generates **high near field pressures** and associated **drag loading** but usually **without** significant **thermal** effects.
- All potential sources lying within the SDV should be considered to evaluate explosions.
- This process involves evaluation of the following parameters:
 - The nature and maximum amount of the material that may simultaneously explode,
 - The distance and orientation from the explosion centre to the site, where the **explosive mass** is usually expressed in terms of **TNT equivalent mass** for generic explosive substances.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



HIEEs INVOLVING FIRE

- 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, and vegetation.
- The area to be examined for the possible occurrence of fires that may affect items important to safety **should have a radius equal to the SDV for this type of hazard. This radius is some 1–2 km** from the NPP.
- The precautions taken to protect the NPP against internal fires also offer some protection **against external fires** and should be taken into account in evaluating the effects of external fires on the plant.
- Fires may also be caused by an event such as an aircraft crash or a chemical explosion.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



HIEEs INVOLVING FIRE

- The **protection** provided against fire hazards **at the source of the fire** should also be taken into account (automatic sprinkler systems or permanent local fire fighters).
- The main **fire** related **hazard** to the NPP site is the **burning of parts of the plant and the resulting damage** (structural collapse..).
- Smoke and toxic gases may affect plant operators and certain plant systems.
- Particular attention should be paid to sources causing possible **common mode failures**:
 - For instance, the **off-site emergency power supply** could be interrupted by fire, while the emergency diesel generators may fail to function owing to smoke being drawn into their air intakes.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)

HIEEs INVOLVING FIRE



- Parameters and properties that define the magnitude of a fire are:
 - the **maximum heat flux**,
 - the magnitude of hazards from burning fragments and smoke,
 - the **duration of the fire**.
- It should be taken into consideration that the heat flux is inversely proportional to the distance from the fire, although other factors may affect this relationship.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



HIEEs INVOLVING SHIP COLLISION

- Ship collision may constitute a particular hazard to the water intake structures of a NPP.
- If the ship collision probability is found to be greater than the SPL, a detailed analysis should be conducted to assess the consequences of such an impact.
 - The simulation of uncontrolled drifting of ships and recreational boats (especially sailing vessels) should be conducted, according to the direction of dominant winds and currents.
 - The collision of large ships in normal cruising can usually be screened out by the implementation of administrative measures and safeguards.
 - Impact velocity, area, mass/ stiffness, substance transported, spills etc.

HIEEs – Safety Guide SSG-79 Guidelines (cont'd)



HIEEs INVOLVING FIRE ELECTROMAGNETIC INTERFERENCE

- **Electromagnetic interference** can affect the functionality of electronic devices.
- It can be initiated by both:
 - **On-site** (high voltage switchgear, cellular phones, laptops, electronic devices)
 - **Off-site** sources (radio interference, military radar stations, high voltage transmission lines the telephone network).
- The presence of **telephone exchange installations** close to the site could give rise to **specific provisions for the design stage**, but usually such high frequency waves **do not represent exclusion criteria** for sites since:
 - specific engineering measures for the qualification of equipment should be taken
 - administrative procedures should be adopted on site .
- In the site characterization stage, **potential sources of interference should be identified** and quantified (for example, intensity, frequency) and **monitored** over the lifetime of the plant.

HIEEs – Specific Grading Approach for SMRs

- Efforts/time consumed in siting activities for HIEEs is much shorter as compared to seismic or some other hazards as a much smaller area is required to be investigated by using the screening distance values;
- Most of the HIEE sources are located within 10 km of the site and majority of them would be screened out if a good site selection process has been implemented;
- The radiological hazard categories for handling HIEEs should be defined before application of graded approach;
- For installations in the highest hazard category, the hazard evaluation for HIEEs should be implemented in the same manner as for nuclear power plants;
- For installations categorized in the intermediate hazard category (e.g., SMRs) graded approach should be adopted;

HIEEs – Specific Grading Approach for SMRs

- In relation to effects of accidents from transportation routes involving hazardous chemicals, HIEEs hazard evaluation for an intermediate radiological hazard category facility may follow the same rules as for a regular NPP as reducing the database and simplifying the methods are not worthwhile in terms of savings of time and human resources;
- In general, SMRs may not be as robust as large NPPs with respect to their design against HIEEs associated loads such as impact, blast, thermal, and vibration which may lead to larger values for the SDVs;
- On the other hand, the exposed profile of SMR structures may be significantly smaller than those of a large NPP, especially if the safety related parts of an SMR are embedded. This could be a consideration for the possibility of screening out of some missile impact scenarios including, for example, aircraft crash;

HIEEs – Specific Grading Approach for SMRs

- On the contrary, in case of a marine based SMRs where the plant is exposed, and the impact of a large aircraft would potentially result in unacceptable consequences;
- A risk informed perspective for HIEEs may be considered if sufficient site specific data is available or can be assumed based on expert judgement. Information on accident probabilities is site specific and performance targets can be set for HIEEs as done for natural hazards;
- Accidental aircraft crashes can be ruled by using SDVs or probabilistically. A threshold of $4 \times 10^{-7} \text{ yr}^{-1}$, for screening the event in medium radiological hazard installations may be considered.

TABLES TO BE USED IN EVALUATION OF HAZARDS ASSOCIATED WITH HIEEs

TABLE 3. EVOLUTION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS AND POSSIBLE EFFECTS ON NUCLEAR INSTALLATIONS (cont.)

Event category	HIEEs	Possible hazard at the nuclear installation site	Possible effects on the nuclear installation (see Table 4)
	<ul style="list-style-type: none"> — Hydrocarbon fire — Chemical fires other than hydrocarbon — Projectiles and missiles 		
(c) External fire	<ul style="list-style-type: none"> — Hydrocarbon fire — Chemical fires other than hydrocarbon — Explosion — Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive material — Projectiles and missiles 	<ul style="list-style-type: none"> — Associated flames and fires; sparks can ignite other fires — Smoke and combustion gas can drift towards the nuclear installation — Heat (thermal flux) 	(3) (4) (5)
(d) Aircraft crash	<ul style="list-style-type: none"> — Crash related to take-off and landing — Other sources of aircraft crash: <ul style="list-style-type: none"> • Background crash rate, airways 	<ul style="list-style-type: none"> — Primary effects: <ul style="list-style-type: none"> • Impact damage to structures including perforation, penetration • Vibration effects 	(1) (2) (3) (4) (6)

TABLES TO BE USED IN EVALUATION OF HAZARDS ASSOCIATED WITH HIEEs

TABLE 3. EVOLUTION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS AND POSSIBLE EFFECTS ON NUCLEAR INSTALLATIONS (cont.)

Event category	HIEEs	Possible hazard at the nuclear installation site	Possible effects on the nuclear installation (see Table 4)
	<ul style="list-style-type: none"> • Release of flammable, explosive, corrosive, toxic or radioactive material • Explosion • Hydrocarbon fire • Missiles 	<ul style="list-style-type: none"> • Global stability — Secondary effects: <ul style="list-style-type: none"> • 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 momentum of the released liquid when ejected from the aircraft • Fire and explosion generating heat and blast effects and generating tertiary missiles 	

TABLES TO BE USED IN EVALUATION OF HAZARDS ASSOCIATED WITH HIEEs

TABLE 3. EVOLUTION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS AND POSSIBLE EFFECTS ON NUCLEAR INSTALLATIONS (cont.)

Event category	HIEEs	Possible hazard at the nuclear installation site	Possible effects on the nuclear installation (see Table 4)
		<ul style="list-style-type: none"> • Release of hazardous material carried as cargo • Ground shaking 	
(e) External transport events excluding aircraft crashes	<ul style="list-style-type: none"> — Vehicle impact — Vehicle derailment, or misdirection — Release of flammable, explosive, asphyxiant, corrosive, toxic or radioactive material — Blockage, contamination (such as from an oil spill) or damage to cooling water intake structures — Explosion — Hydrocarbon fire — Chemical fires other than hydrocarbon — Projectiles and missiles 	<ul style="list-style-type: none"> — Direct impact damage — Secondary projectiles — Fire — Explosion of fuel tanks or cargo 	(2) (4) (7) (8) (11)

TABLES TO BE USED IN EVALUATION OF HAZARDS ASSOCIATED WITH HIEEs

TABLE 3. EVOLUTION OF SOURCES OF HUMAN INDUCED EXTERNAL EVENTS AND POSSIBLE EFFECTS ON NUCLEAR INSTALLATIONS (cont.)

Event category	HIEEs	Possible hazard at the nuclear installation site	Possible effects on the nuclear installation (see Table 4)
(f) Other HIEEs	<ul style="list-style-type: none"> — Projectiles and missiles — Subsidence — Electromagnetic interference — Release of large volumes of water or change of watercourse — Bombing and firing ranges 	<ul style="list-style-type: none"> — Missile impact with structure — Ground failure under structures — Flooding onto the nuclear site, or change of water table — Direct damage to structures and equipment — Fire as secondary effect — Electromagnetic fields around electrical equipment leading to failure, malfunction or spurious electrical signals 	(2) (7) (8) (9) (10) (11)

TABLES TO BE USED IN EVALUATION OF HAZARDS ASSOCIATED WITH HIEEs

TABLE 4. IMPACT ON THE NUCLEAR INSTALLATION AND CONSEQUENCES

Possible hazard effects on the nuclear installation	Load characterization parameters	Consequences of hazard effects
(1) Pressure wave	<ul style="list-style-type: none"> — Local overpressure at the installation as a function of time 	<ul style="list-style-type: none"> — Damage or collapse of parts of structure or disruption of systems and components — Secondary hazards (e.g. fire, explosion, release of hazardous material)
(2) Projectile	<ul style="list-style-type: none"> — 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 (e.g. shape, size, type of material) — Existing protective measures at the source location 	<ul style="list-style-type: none"> — Damage to structures (e.g. penetration, perforation, spalling, scabbing, collapse of structures) — Disruption or 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 (e.g. fire, explosion, release of hazardous material)
(3) Heat	<ul style="list-style-type: none"> — Maximum temperature flux and duration 	<ul style="list-style-type: none"> — Impaired habitability of control room — Disruption of systems or components — Damage to structures — Ignition of combustibles — Secondary effects (e.g. sparks, fires, smoke)

TABLES TO BE USED IN EVALUATION OF HAZARDS ASSOCIATED WITH HIEEs

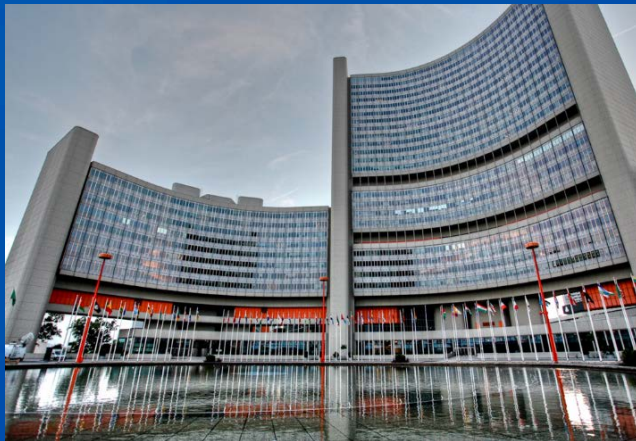
TABLE 4. IMPACT ON THE NUCLEAR INSTALLATION AND CONSEQUENCES (cont.)

Possible hazard effects on the nuclear installation	Load characterization parameters	Consequences of hazard effects
(4) Smoke and dust	<ul style="list-style-type: none"> — Composition — Concentration and quantity as a function of time 	<ul style="list-style-type: none"> — Blockage of ventilation intake filters and diesel engine air filters — Impaired habitability of control room and other areas important to the safety of the nuclear installation
(5) Asphyxiant and toxic material	<ul style="list-style-type: none"> — Concentration and quantity as a function of time — Volatility in ambient conditions — Toxicity and asphyxiant limits 	<ul style="list-style-type: none"> — Threat to operating personnel and impaired habitability of the main control room and other areas important to the safety of the nuclear installation — Incapacitation of operating personnel or reduced ability to perform safety related tasks
(6) Corrosive and radioactive liquids, gases and aerosols	<ul style="list-style-type: none"> — Concentration and quantity as a function of time — Corrosive, radioactive limits — Provenance (sea, land) 	<ul style="list-style-type: none"> — Threat to operating personnel and impaired habitability of areas important to the safety of the nuclear installation — 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	<ul style="list-style-type: none"> — Frequency response spectrum for vibrational motion 	<ul style="list-style-type: none"> — Mechanical damage

TABLES TO BE USED IN EVALUATION OF HAZARDS ASSOCIATED WITH HIEEs

TABLE 4. IMPACT ON THE NUCLEAR INSTALLATION AND CONSEQUENCES (cont.)

Possible hazard effects on the nuclear installation	Load characterization parameters	Consequences of hazard effects
(8) Flooding or drought	<ul style="list-style-type: none"> — Elevation of site above main water course or mean sea level — Level of water with time — Velocity of impacting water 	<ul style="list-style-type: none"> — 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 — Loss of safety functions requiring water (in case of drought)
(9) Subsidence	<ul style="list-style-type: none"> — Settlement, differential settlement, settlement rate — Existing engineered mitigation measures (existing sites), or anticipated measures (new sites) 	<ul style="list-style-type: none"> — Collapse of structures, disruption or failure of structures, systems and components including buried systems and services — Secondary hazards (e.g. fire, explosion, release of hazardous material)
(10) Electromagnetic interference	<ul style="list-style-type: none"> — Frequency band and energy rating of protection against electromagnetic interference — Existing engineered mitigation measures (existing sites), or anticipated measures (new sites) 	<ul style="list-style-type: none"> — Incorrect or spurious electrical signals in items important to safety leading to spurious operation or action
(11) Damage to water intake	<ul style="list-style-type: none"> — Mass of the ship, lost cargo, impact velocity and area, degree of blockage 	<ul style="list-style-type: none"> — Unavailability of cooling water



Thank you!
Questions?

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