IAEA SAFETY STANDARDS and ISSC Experience Related to Site Safety of Nuclear Installations

Regional Workshop on Volcanic, Seismic, and Tsunami Hazard Assessment Related to NPP Siting Activities and Requirements
June 13-17, Jakarta, Indonesia

Sujit Samaddar
Department of Nuclear Safety and Security

INTERNATIONAL SEISMIC SAFETY CENTRE, NSNI/IAEA

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International Atomic Energy Agency

Our Relationship

- Why are you here?
- Why are we here?
- How do we gain from each other

Lessons in Nuclear Safety

- Chernobyl
- Three Mile Island
- Fukushima

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The Safety Framework

- There is a fundamental and hard-learned lesson – engineered safety features are sometimes insufficient to ensure safety.

- National obligation – establish an infrastructure to ensure safety. Its features include:
  - Regulatory Independence
  - Competency
  - Technological capabilities
  - Management Capabilities
  - Safety Culture

- National infrastructure is augmented by a global nuclear safety regime

IAEA and Nuclear Power

"The Agency has a key role to play in ensuring that this expansion in nuclear power takes place in an efficient, responsible and sustainable manner.

"…countries should be able to introduce nuclear power knowledgeably, profitably, safely and securely."

Yukiya Amano
Director General

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The different elements

Global Nuclear Safety Regime

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SAFETY CONVENTIONS AND CODES OF CONDUCT

Convention on Early Notification of a Nuclear Accident

Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency

Convention on Nuclear Safety

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

Code of Conduct on the Safety and Security of Radioactive Sources

Code of Conduct on the Safety of Research Reactors

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IAEA Safety Standards are increasingly complementing international instruments

Global Nuclear Safety and Security Regime

International Legal Instruments

Conventions and Codes of Conduct

IAEA Safety Standards

IAEA Security Guidance

IAEA Safety and Security Reviews and Services

Global Knowledge Network

Global Experts' Community

National and Regional Nuclear Infrastructure

Regulation Enforcement

Operation

Research & Education

ISSC – BACKGROUND

- Recent seismic activity in MS's with nuclear facilities renewed interest in seismic safety
- A center to focus, collect and dessimenate international activity on seismic safety was established within IAEA
- International Seismic Safety Center established to address all external hazards including seismic

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THE SAFETY REVIEW SERVICES
Of the International Seismic Safety Centre

Purpose: **To assist Member States on the application of Safety Standards related to all external hazards**

Areas covered:

- Site Selection
- Site Assessment
- Preliminary Safety Report
- Hazard Assessment
  - Seismic
  - Tsunami
  - Volcanic
- External Events PSA

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International Safety Standards

- Purpose is to provide comprehensive information on appropriate regulatory requirements for safety

- Standards development is an important vehicle for international exchange of views

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CONTINUOUS IMPROVEMENT OF SAFETY

- **Safety improvements of nuclear installations (new and existing) result from:**
  - **Sharing of operating experience**
  - **Lessons from accidents and from occurrence of external events**
  - **New data, new technology, safety analysis and R&D**
  - **New IAEA and industry Safety Standards**
  - **Periodic Safety Reviews**

IAEA SAFETY STANDARDS

IAEA's Statute authorizes the Agency to

. . . establish standards of safety for the protection of

- **health,**
- **life, and**
- **property**

in the development and application of nuclear energy for peaceful purposes; . . .

. . . and to provide assistance upon request from MS for applying and using these standards

NUCLEAR POWER PLANTS AND RESEARCH REACTORS

- 443 nuclear reactors in operation in 31 countries, 27 under construction and 112 shut-down
- About 670 Research Reactors have been built to date
- About 280 Research Reactors in 56 countries continue to operate

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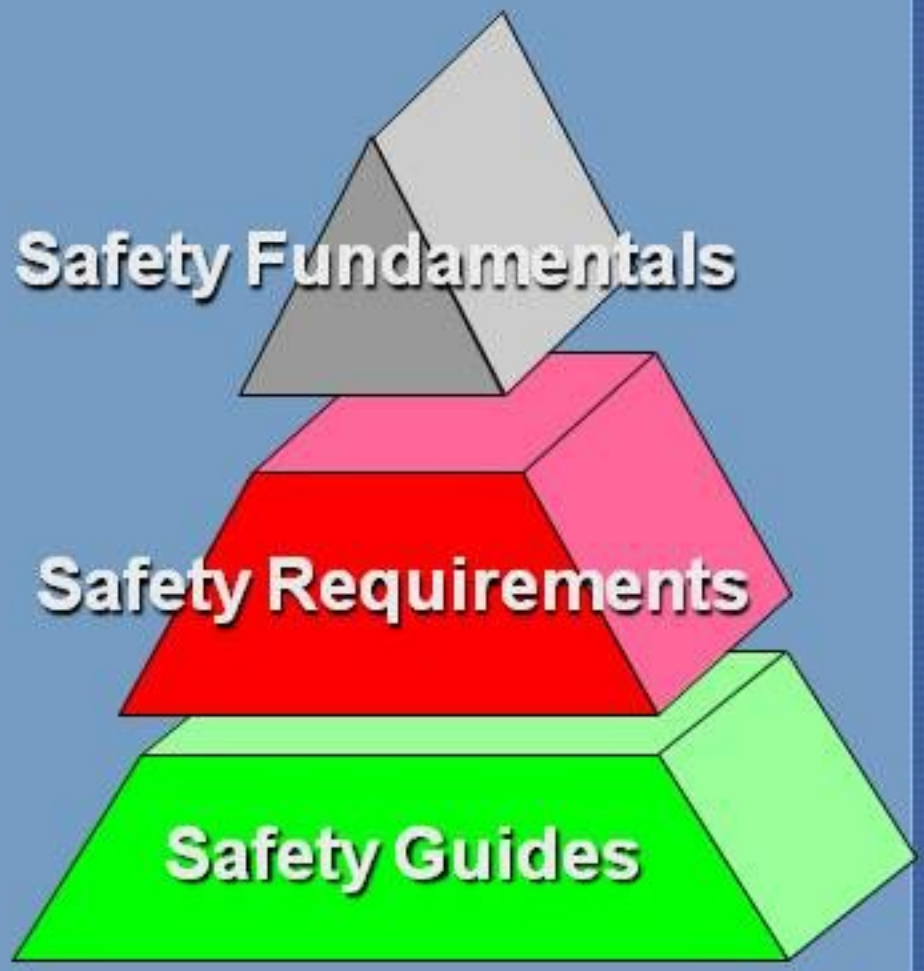
SAFETY AND SECURITY DOCUMENTS STRUCTURE

NUCLEAR SAFETY STANDARDS



Mature stage through transparent consensus development process

NUCLEAR SECURITY SERIES

Early stage of development

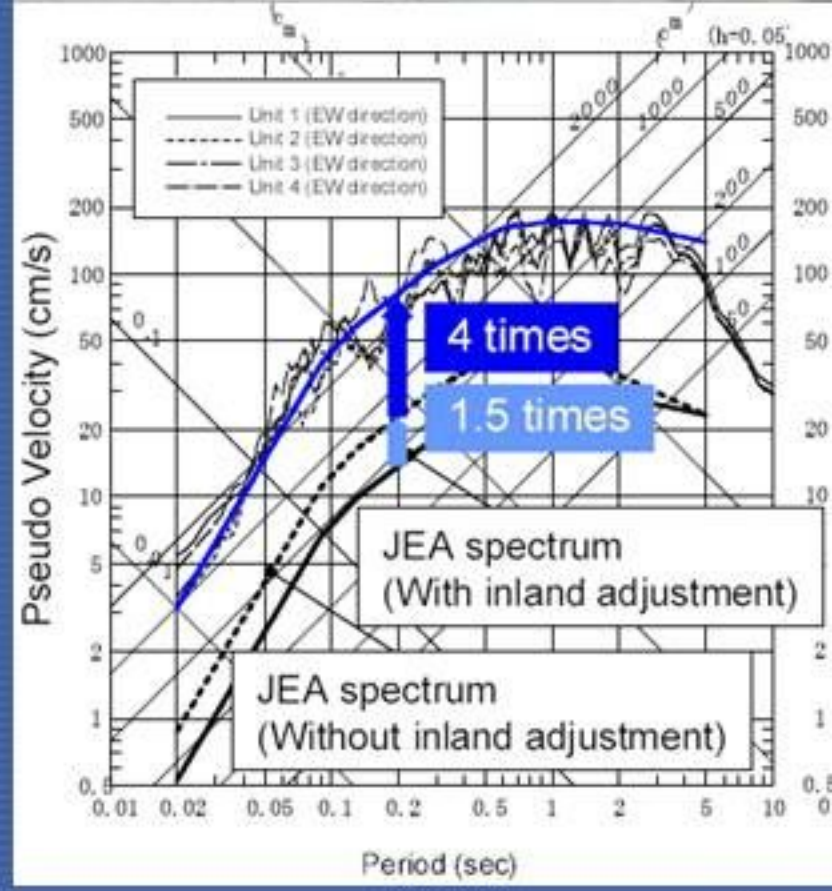
Global reference for high level of nuclear safety and security

ISSC – BACKGROUND

- Recently seismic matters are paid more attention owing to the occurrence of strong earthquakes and tsunami that have affected nuclear power plants beyond their original design levels, impacting on the operation, economics and public acceptance and credibility of these installations.
- Natural disasters worldwide: tsunamis, volcanic eruptions, landslides, hurricanes.

What we've learned from recent strong external hazards?

- **Consequences:**
  - ✓ Multi-unit Nuclear Accident at Fukushima Site
  - ✓ Impacts on safety and non-safety related systems
  - ✓ Damages to structures, equipment and infrastructure (roads, fire fighting system)
  - ✓ Seismically induced Tsunami
  - ✓ Seismically induced internal fire and flood
  - ✓ Public concern – Response to the emergency



- **Vibratory ground motions beyond the original design levels: >>SL-2 earthquake level.**
- **Realistic assessment of seismic margins. Earthquake experience data.**
- **Increased attention on findings and lessons, particularly, for new NPP projects and for "newcomers".**

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ISSC - SCOPE

1. **Site Selection and Site Evaluation**
2. **Seismic safety of nuclear installations**
3. **Other External/Internal Hazards**, e.g. flooding, tsunamis, geotechnical, volcanic and meteorological hazards, . . .
4. **Human Induced Events including malevolent origin**, e.g. aircraft crash, explosions, toxic releases, . . .
5. **Site related aspects of Environmental Impact Assessment**, e.g. dispersion in air and surface and ground water
6. **Design related aspects - Chapters 2 and 3 of Safety Analysis Report.**

STRUCTURE OF ISSC

IAEA MEMBER STATES (MSs)

Supports

INTERNATIONAL SEISMIC SAFETY CENTRE (ISSC)

Advice

SCIENTIFIC COMMITTEE (ScC)

IAEA Regular Budget Programme

- Develop. of Safety Standards
- Applicat. of Safety Standards SRM/PRM
- Capacity Building E&T
- Foster of R&D and informat. exchange

EBP TOPICAL TECHNICAL PROJECTS

1. SEISMIC:
   1. WA1
   2. WA2
   3. . . . .
2. TSUNAMI:
3. OTHER EXTERNAL FLOODS:
4. VOLCANIC HAZARDS:
5. DATABASE
6. EENS

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Services to Member States

IAEA Safety Standards

IAEA Safety Standards are structured in 3 categories:

- **SAFETY FUNDAMENTALS: SF-1 (2006)**

  , i.e. the objectives, *principles and concepts of protection*

- **SAFETY REQUIREMENTS:**

  , i.e. the requirements that must to be met to ensure the protection (*shall)*

- **SAFETY GUIDES:**

  , i.e. the recommendations and guidance on how to comply with the requirements (*should*). `

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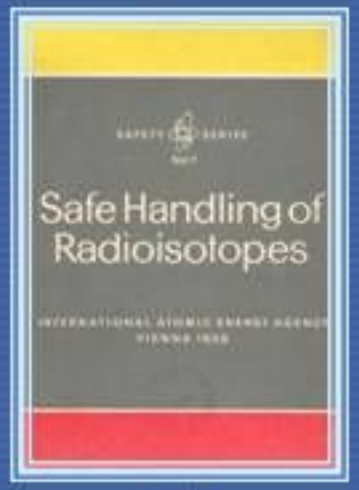
IAEA Safety Standards - Timeline (1)

Safe Handling of Radioisotopes

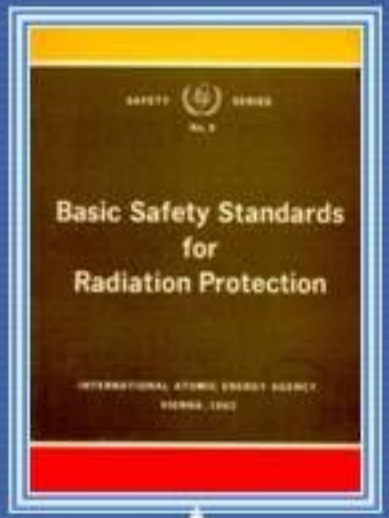


1958

Safe Transport of Radioactive Material

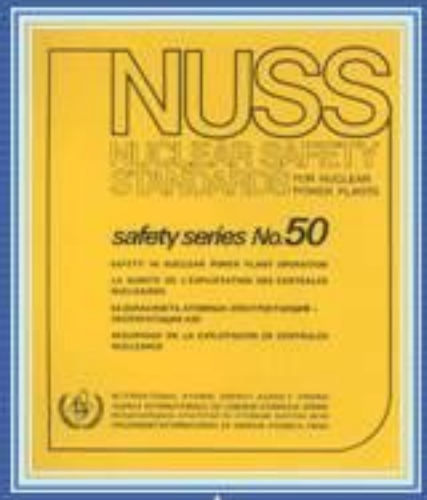
1961

BSS for Radiation Protection



1962

NUSS Programme



1974

Basic Safety Standards

1996

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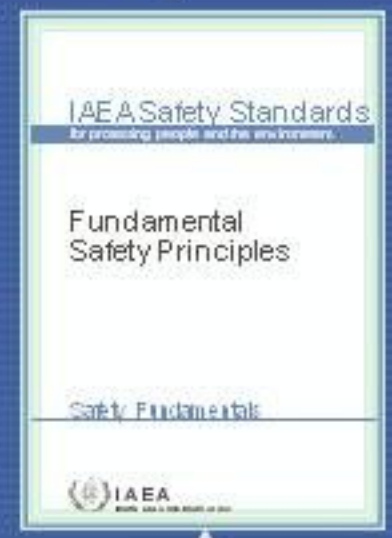
IAEA Safety Standards - Timeline (2)

Commission and Committees

Overall Structure

Action Plan

Unified Safety Fundamentals



1996

2003

2004

2006

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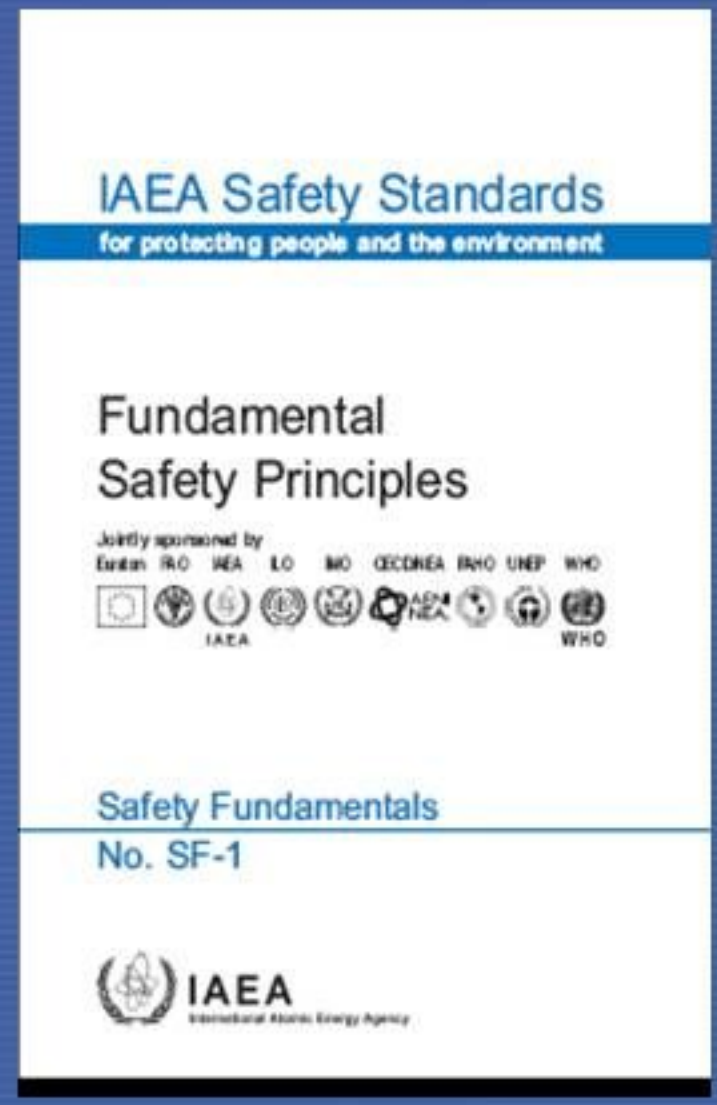
IAEA Fundamental Safety Principles

- Global reference point for the high level of safety required for use of nuclear energy
- 1 Safety Objective:

  "The fundamental safety objective is to protect people and the environment from the harmful effects of ionizing radiation"

- 10 Safety Principles



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Safety Fundamentals - Ten principles

1. *The prime responsibility for safety must rest with the operator*
2. *An effective legal and governmental framework for safety, and a competent, independent nuclear safety regulatory body with sufficient authority to ensure compliance*
3. *.....*
8. *All practical efforts must be made to prevent and mitigate nuclear or radiation accidents*

10.*.....*

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Principle 8 – Prevention of Accidents

- The primary means of preventing and mitigating the consequences of accidents is ***"defence in depth"***
- The ***"defence in depth"*** is implemented through a combination of **consecutive and independent levels of protection**. . .

  . . . which would have to fail before harmful effects could be caused to people or to environment.
- If properly implemented, it ensures that no **single** technical, human or organizational failure could lead to harmful effects, and

  . . . that **combination of failures** –that could lead to harmful effects- are of very low probability.

Principle 8 – Prevention of Accidents

"Defence in depth" is provided by combination of:

1. Effective management system – safety culture
2. Adequate site selection, good design and engineering safety features providing safety margins, diversity and redundancy, by use of:
   - Design, technology, materials of high quality and reliability.
   - Control, limiting and protection systems and surveillance features.
   - Appropriate combination of inherent and engineered safety features.
3. Comprehensive operational procedures and practices, as well as accident management procedures

   to provide the means for regaining control and for mitigating harmful consequences.

"Defence in depth"

Applied through a series (5) of levels of defence:

LEVEL 1: Prevention of Abnormal Operation and Failures

↓

LEVEL 2: Control of Abnormal Operation and Detection of Failures

↓

LEVEL 3: Control of Accidents within the Design Basis

↓

LEVEL 4: Control of severe plant conditions, including prevention of accident progression and mitigation of severe accidents.

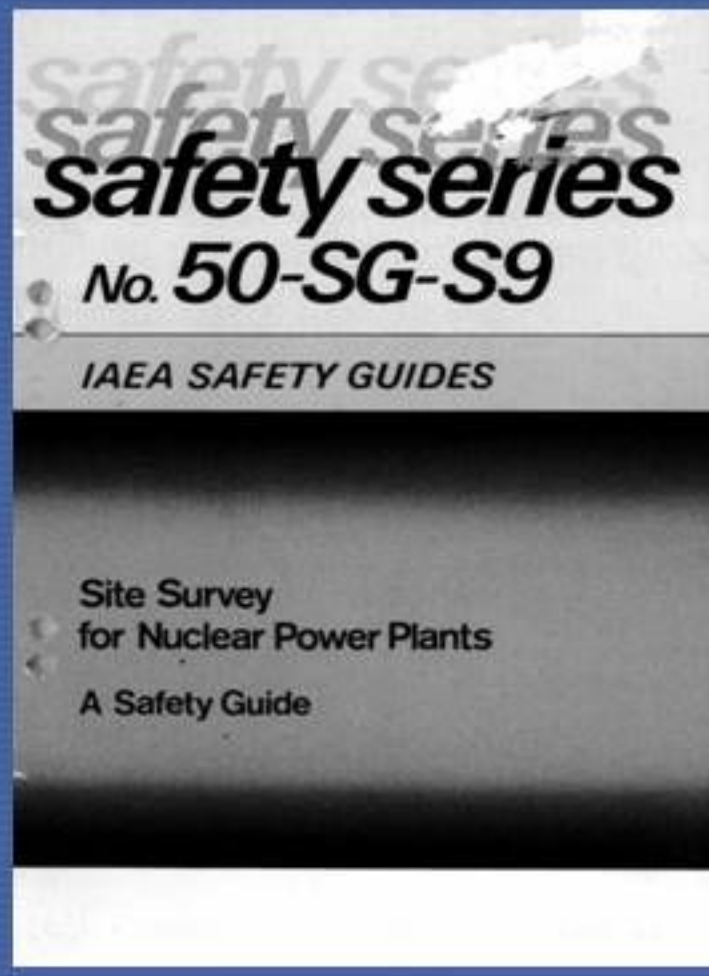
↓

LEVEL 5: Limit Dose Levels to acceptable values through implementation of off-site emergency measures.

Defense in Depth and Site Selection

- Level 1-Prevention= sites with acceptable hazard levels
- Level 5-Mitigation = sites naturally supportive of emergency measures
- Ease of Site access and egress
- Predominant wind direction away from population centers

DS433 Site Survey and Site Selection for Nuclear Installations (under preparation)



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The "site"

The selection and the evaluation of the site for a nuclear power plant are crucial parts of establishing a nuclear power programme and can be significantly affected by costs, public acceptance and safety considerations.

DEFINITIONS

- **SITE:** The area containing the plant, defined by a boundary and under effective control of the Plant Management.
- **SITING:** The process of selecting a suitable site for a facility.
- **EXTERNAL EVENTS:** are events unconnected with the operation of a facility or activity which could have an effect on the safety of the facility or activity

STAGES OF THE FULL PROCESS

- **SITE SURVEY**
  (potential sites ⟶ candidate sites)
- **SITE EVALUATION: subdivided as follows:**
  - **SITE SELECTION**
    (candidate sites ⟶ selected site)
  - **SITE ASSESSMENT (the selected site)**
    - Preparation of SER/EIR
    - Bidding process
    - Project activities until construction starts: 1st Concrete Pour.
  - **PRE-OPERATIONAL**
  - **OPERATIONAL**

covering the complete lifecycle of the nuclear installation.

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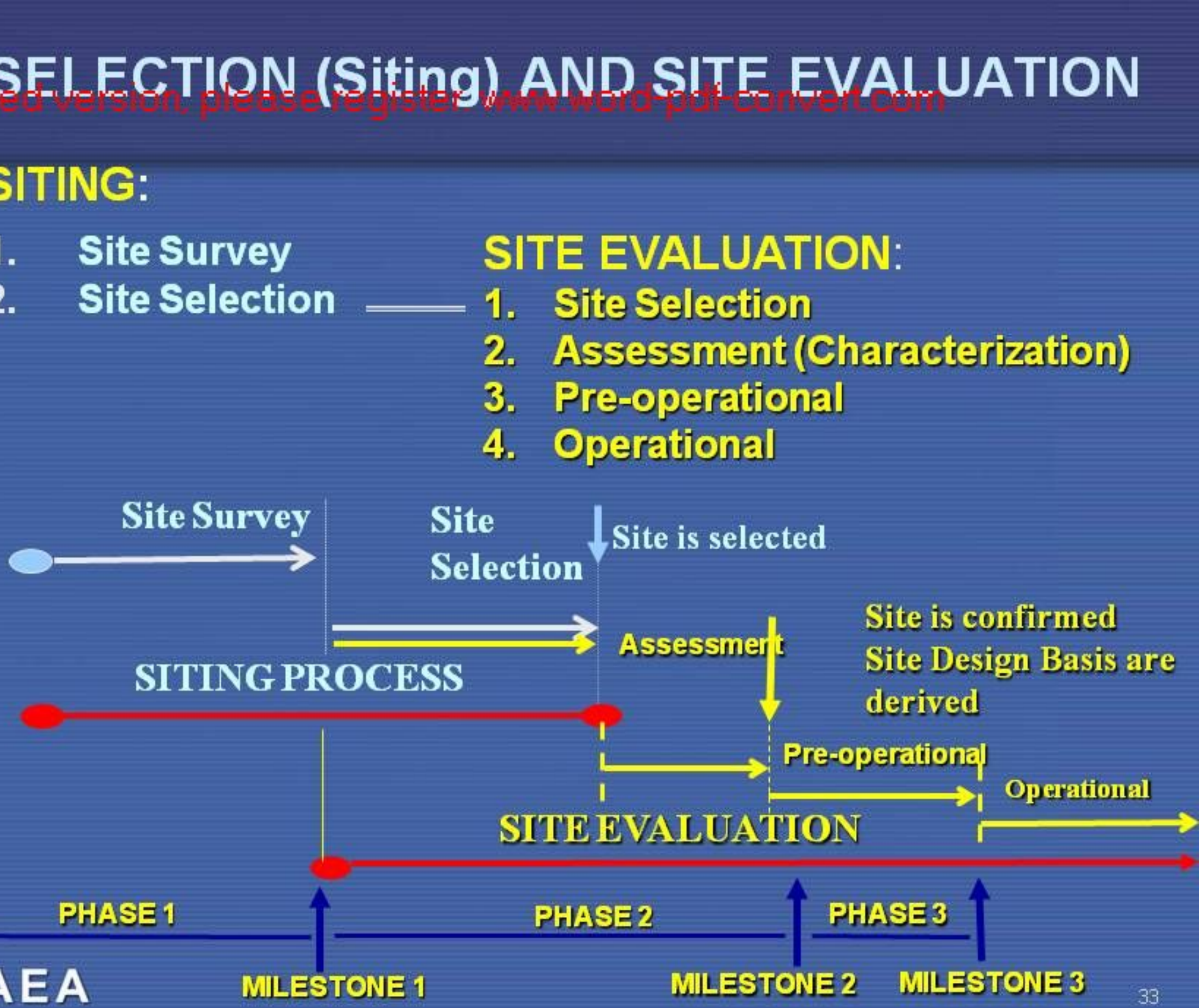
SITE SELECTION (Siting) AND SITE EVALUATION

SITING:

1. Site Survey
2. Site Selection

SITE EVALUATION:

1. Site Selection
2. Assessment (Characterization)
3. Pre-operational
4. Operational



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SITE SURVEY

Purpose: Identification of potential regions, potential sites and candidate sites through screening and comparison:

- consideration of both safety and non-safety aspects,
- regional scale,
- rejection of "unacceptable" sites,
- systematic screening, selection and comparison of the "acceptable" sites.
- use of available data

Result: the "*candidate sites*"

SITE SELECTION AND EVALUATION

Detailed and specific evaluation of the "*candidate sites*".

Selection of *the site*.

For the selected site, detailed and specific investigations and studies result in the:

- demonstration of the acceptability of the site on the basis of established criteria,
- derivation of the site related design bases for the facility.

SITE EVALUATION – Aspects to be considered

- **Effects of the region on the plant** – i.e. external events occurring in the region, which could be of natural or man induced origin,
- **Effects of the plant on the region** – i.e. characteristics of the site and its environment which could influence the transfer of released radioactive material to persons and to the environment,
- **Population characteristics** of the region (i.e. density and distribution and others) in relation to the possibility of implementing emergency measures

IAEA STRUCTURE OF DOCUMENTS on SITE SELECTION and SITE EVALUATION for a NUCLEAR POWER PLANT

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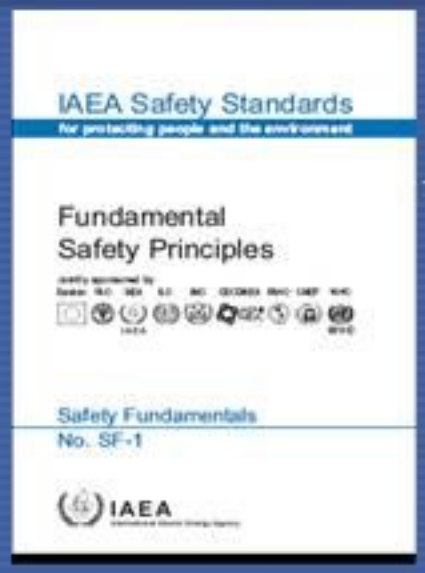
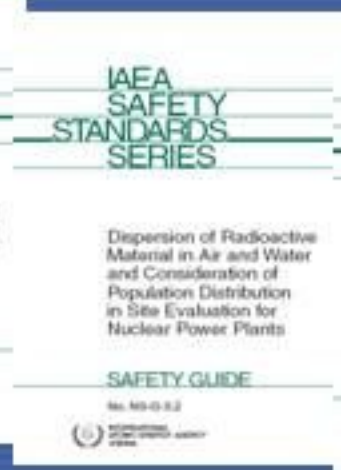
IAEA SAFETY STANDARDS ON SITE EVALUATION



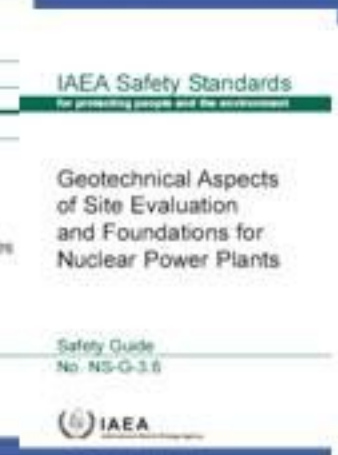
SITE EVALUATION

REQUIREMENTS

SAFETY GUIDES

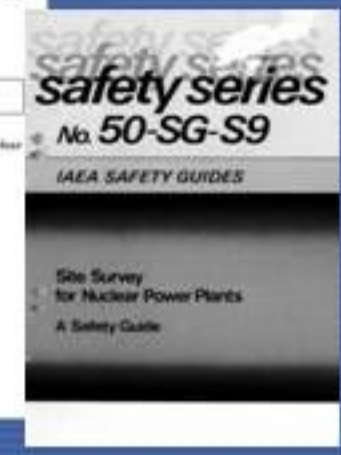


SSG-9
Replaced NS-G-3.3



New SG-DS417

DS405



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SITE SELECTION AND EVALUATION DOCUMENTS

SAFETY  **+** **NON-SAFETY**

1. **NS-R-3** **Site Evaluation Requirements**
2. **NS-G-3.1** **Human Induced Hazards**
3. **NS-G-3.2** **Dispersion air and water**
4. **SSG-9** **Seismic Hazards**
5. **NS-G-3.4** **Meteorological Hazards** **(NSG-3.4 +NSG-3.5**
6. **NS-G-3.5** **Flooding Hazards** **merged in DS417)**
7. **NS-G-3.6** **Geotechnical Aspects**
8. **DS-405** **Volcanic Hazards**
9. **DS433** **Site Survey and Site Selection for Nuclear Installation**

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MILESTONES NUCLEAR INFRASTRUCTURE DEVELOPMENT

PHASE 1 - Milestone 1: ready to make decision on introducing a nuclear power programme

- General survey to identify potential sites
- Selection of potential "candidate" sites

PHASE 2 - Milestone 2: ready for inviting bids

- Evaluation of "candidate" sites
- A suitable site is selected
- Full characterization of the selected site: confirmation of acceptability and derivation of Site related Design Bases.

PHASE 3 - Milestone 3: ready for commissioning and operation

- All site services and provisions in place and functional

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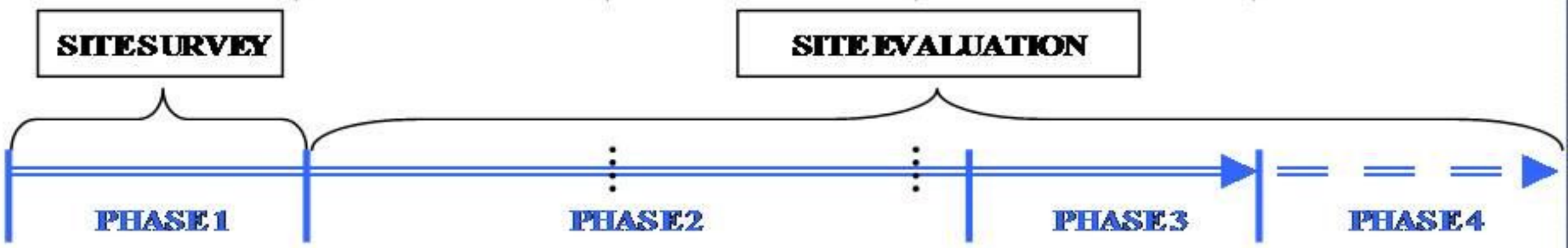
DS424–SITE SELECTION AND EVALUATION STAGES

SITE SURVEY STAGE:	*SITE SELECTION STAGE:*	*SITE ASSESSMENT STAGE:*	*PRE-OPERATIONAL STAGE:*	*OPERATIONAL STAGE:*
Identification of potential regions, potential sites and candidate sites through screening and comparison.	Evaluation aiming at selecting the final site through the ranking of candidate sites.	Confirmation of acceptability and complete site characterization; Derivation of site related design basis.	Confirmatory and monitoring work.	Confirmatory, monitoring and re-evaluation as per Periodic Safety Reviews.



DS424 – Road map: PHASE 1

The progressive implementation of the following Safety Requirements:

- 2.1 to 2.29, 3.1 to 3.55, and 4.1 to 4.15, 6.1 to 6.9 of NS-R-3;
- 3.126 of GSR Part 3 (revision of BSS 115);

necessitates that:

IN PHASE 1:

ACTION 1: The Government should ensure that potential sites are identified and candidate sites are selected on the basis of a set of defined criteria, at a regional scale and using available data.

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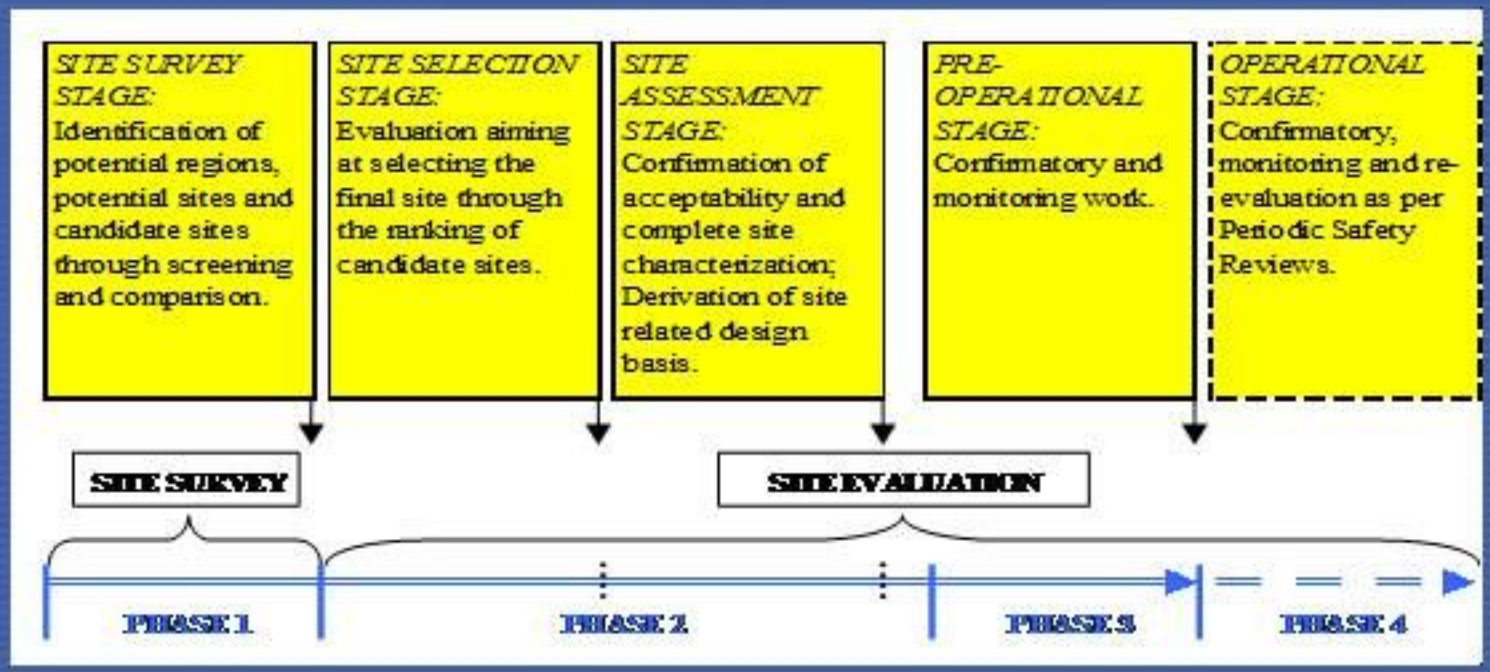
DS424 – Road map: PHASE 1

A set of criteria needs to be identified from the beginning of Phase 1, related to acceptability and comparison of sites, taking into account safety-related and non safety-related aspects. It is important to properly address both due to the interface between them. This will provide for a smooth development of the site selection and evaluation process during the following phases, with no need for coming back to earlier steps due to the lack of suitable available sites.

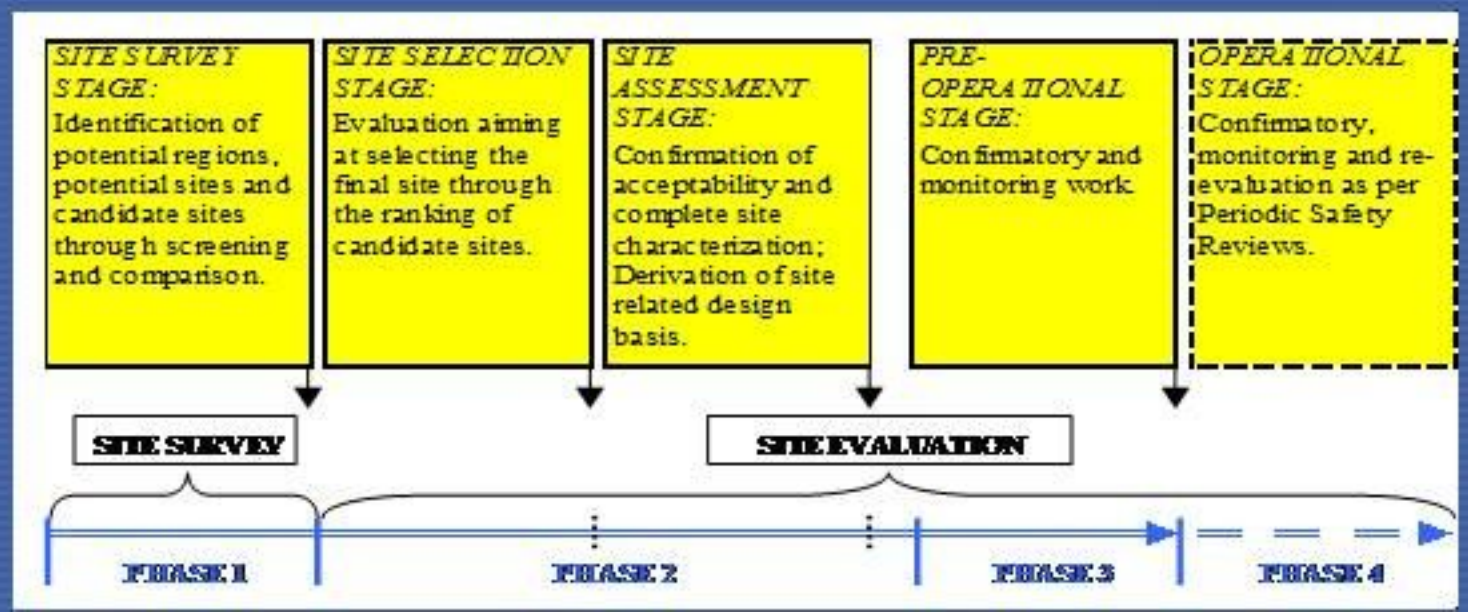
DS424 – Road map: PHASE 2

ACTION 2: The regulatory body should establish specific safety requirements for site evaluation, including the process for authorizing the selected site, in compliance with applicable IAEA Safety Standards



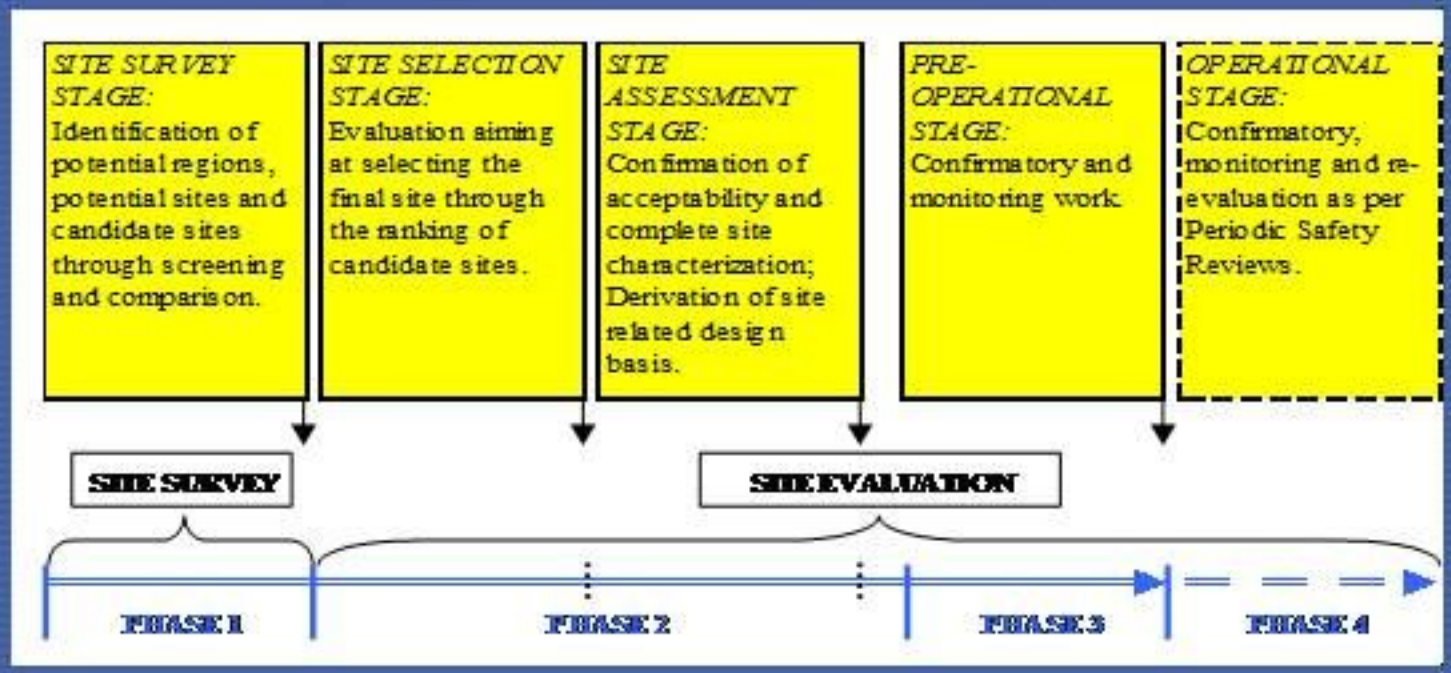
DS424 – Road map: PHASE 2

ACTION 3: The operating organization should complete the investigations related to the suitability of the candidate sites and select the preferred candidate site for the first NPP, using specific site data, information, studies and assessments conducted with the full temporal and spatial scales of investigations.



DS424 – Road map: PHASE 2

ACTION 4: The operating organization should prepare the Site Evaluation Report (SER) and submit it to the regulatory body, based on a full assessment of the selected site and including the confirmation of site acceptability and the characterization of the site for the definition of the site related design basis parameters.



IAEA Review Services on Seismic Safety of Nuciear Facilities

In the following slides, a brief overview of the sites/plants that have been reviewed (in the past several decades) is presented. Both new and existing sites and plants are considered. In total close to 370 site safety review missions (either complete or partial) have been conducted by the ISSC (and its predecessor ESS). A database has been established for all of these at the ISSC.

Current Status of Plants/Sites

• Zarnowiecz (Poland)	• Project abandoned
• Tirana RR (Albania)	• Project abandoned
• Gorki (USSR)	• Project abandoned
• Crimea NPP (USSR)	• Project abandoned
• Smolensk NPP (RF)	• Operating NPP
• Leningrad NPP (USSR)	• Operating NPP
• Temelin NPP (Czech)	• Project completed
• Mochovce NPP (Slovak)	• Project completed
• Bohunice NPP (Slovak)	• Operating NPP
• Paks NPP (Hungary)	• Operating NPP

Current Status of Plants/Sites

• Cernavoda NPP(Ro)	• Operating NPP
• Pitesti RR (Ro)	• Operating RR
• Kozloduy NPP (Bulgaria)	• Operating NPP
• Belene NPP (Bulgaria)	• Project restarted
• Krsko NPP (Slovenia)	• Operating NPP
• Medzamor NPP (Armenia)	• Operating NPP (new unit planned)
• Akkuyu (Turkey)	• No construction to date
• Sinop (Turkey)	• No construction to date
• Cekmece RR (Turkey)	• Operating RR

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Current Status of Plants/Sites

- Near Aqaba (Jordan)
- Iraq
- Bushehr NPP (Iran)
- Ulken (Kazakhstan)
- Alatau RR (Kazakhstan)
- Ulughbek RR (Uzbekistan)
- Rooppur (Bangladesh)
- Chashma (Pakistan)

- Site suitability and evaluation on-going
- Project abandoned
- Construction near complete
- Project abandoned
- Operating RR
- Operating RR
- Project frozen (?)
- Construction completed two units in operation

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Current Status of Plants/Sites

• Kanupp (Pakistan)	• Operating NPP
• Muria (Indonesia)	• Site abandoned
• Madura (Indonesia)	• Site abandoned
• Near Bangkok (RR) (Thai)	• Project frozen (?)
• Batan (Ph)	• NPP – possible restart (?)
• Sidi Boulbra (Morocco)	• No construction to date
• Maamora RR (Morocco)	• Started operation
• Tantan (Morocco)	• Project abandoned
• Gulf of Sirt (Tunisia)	• No construction to date
• El Dabaa (Egypt)	• No construction to date

Current Status of Plants/Sites

- Inshas RR (Egypt) — Operating RR
- Koeberg NPP (SA) — Operating NPP
- Lucas Heights (Australia) — Started operation
- La Reina RR (Chile) — Operating RR
- Angra 1 (Brazil) — Operating NPP

Comparison of Design/Reevaluated Values for PGA

Name of Installation	Design Value of PGA	Re-evaluated value (Deterministic or corresponding to 10^{-4} annual frequency
Leningrad NPP	< 0.1g	0.1g
Temelin NPP	< 0.1g	0.1g
Mochovce NPP	< 0.1g	~ 0.16g
Bohunice NPP	< 0.1g	0.34g

Comparison of Design/Reevaluated Values for PGA

Name of Installation	Design Value of PGA	Re-evaluated value (Deterministic or corresponding to 10^{-4} annual frequency
Paks NPP	< 0.1g	0.35g → 0.28g
Cernavoda NPP	0.2g	0.34g
Kozloduy NPP	< 0.1g	0.1g → 0.2g
Belene NPP	0.1g	0.25g

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Comparison of Design/Reevaluated Values for PGA

Name of Installation	Design Value of PGA	Re-evaluated value (Deterministic or corresponding to 10^{-4} annual frequency
Krsko NPP	0.3g	0.4g
Medzamor NPP	0.1g	0.2g → 0.35g
Çekmece RR	0.1g	0.4g
Bushehr NPP	0.4g	0.4g

Comparison of Design/Reevaluated Values for PGA

Name of Installation	Design Value of PGA	Re-evaluated value (Deterministic or corresponding to 10^{-4} annual frequency
Alatau RR	0.3g	0.7g
Kanupp NPP	0.1g	~ 0.25g
Wolsung NPP	0.2g	> 0.3g
Lucas Heights RR	0.1g	0.35g

Lessons Learned

- Site selection and evaluation is a life long activity for a nuclear installation.
- While many projects were abandoned or interrupted due to political or financial reasons, a significant number of the projects also had technical issues related to site selection and evaluation.
- For a ‘new comer’ the general rule is that the competent nuclear organizations do not have ‘site’ expertise and site specialty institutions do not have ‘nuclear’ project experience (e.g. standards and QA)

Lessons Learned

- Design basis parameters had often been underestimated in earlier studies. This led to re-evaluation of hazard (especially seismic hazard) and the plant sometimes requiring plant upgrades involving significant costs.
- A good balance is needed between the local expertise and international consultants especially for the first NPP site selection and evaluation.
- IF YOU ARE IN A HURRY – TAKE YOUR TIME

CONCLUDING REMARKS

1. A global nuclear safety and security regime is in place for the safe use of nuclear energy.
2. Nuclear installations – complex systems- are sited, designed, constructed and operated taken into account the potential occurrence of extreme rare events.
3. No complacency, continuous improvement process is required.
4. Lessons learned (lessons forgotten) and lessons to be learned after the multi-unit nuclear accident induced by external hazards in Fukushima shall enhance safety measures in relation to Site Safety aspects and protection against External Hazards

CONCLUDING REMARKS

7. The selection of the site (siting) for a nuclear installation and, particularly, for a nuclear power plant, is one of the most critical initial stages in the programme for developing a nuclear energy programme.
8. Careful attention should be paid from the very beginning since mistakes, wrong approaches and simplistic criteria, may seriously impact safety and economic aspects of the programme.
9. Extensive use of the site safety review services available through ISSC should be used to get peer review feedback on siting issues.

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Thank you for your attention

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