IAEA
International Atomic Energy Agency
Atoms for Peace and Development

P5. Safety Goals

Workshop on Application of Level 1 Probabilistic Safety Assessment

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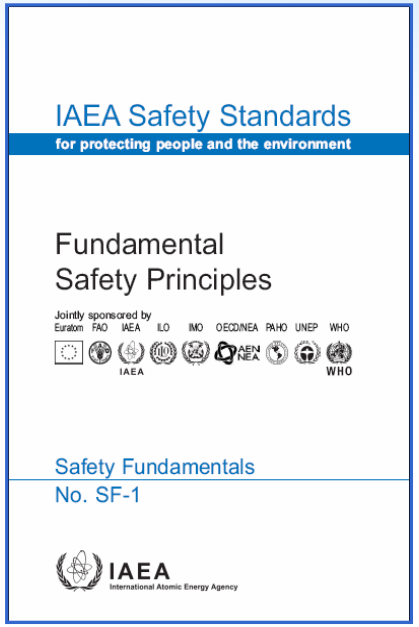
Relevant Statements from IAEA Safety Standards

The fundamental safety objective is

to protect people and the environment from harmful effects of ionizing radiation

Principle 6: Limitation of risks to individuals

"Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm"



Implications:

1) Risk associated with nuclear installations needs to be assessed

2) Guidance (criteria) for 'unacceptable risk' need to be established

3) Relevant measures (design features and procedures) provided

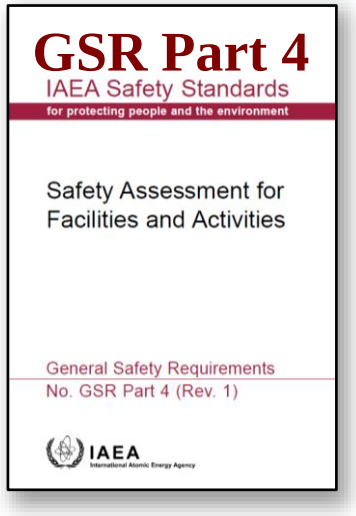
→ **SAFETY GOALS**

Relevant Statements from IAEA Safety Standards

GSR Part 4

Requirement 4: Purpose of the safety assessment

The primary purposes of the safety assessment shall be to determine whether an adequate level of safety has been achieved for a facility or activity and whether the basic **safety objectives** and **safety criteria** established by the designer, the operating organization and the regulatory body have been fulfilled.



Safety Requirements and Goals

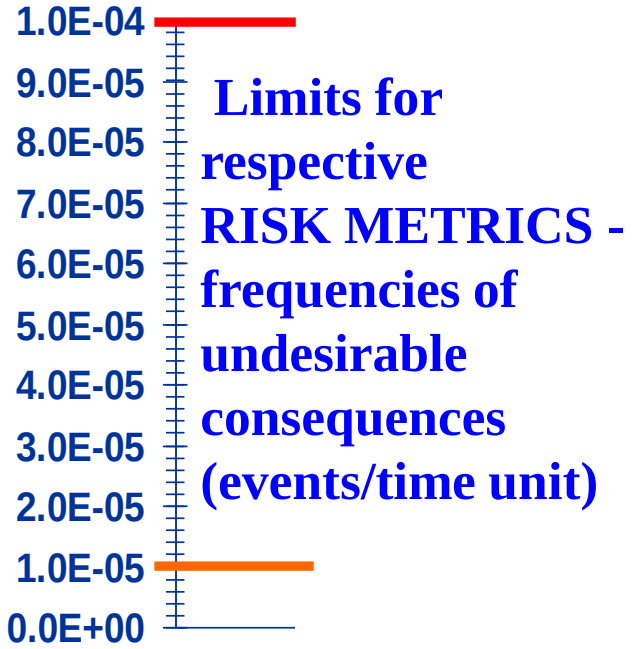
QUALITATIVE

Safety Margins

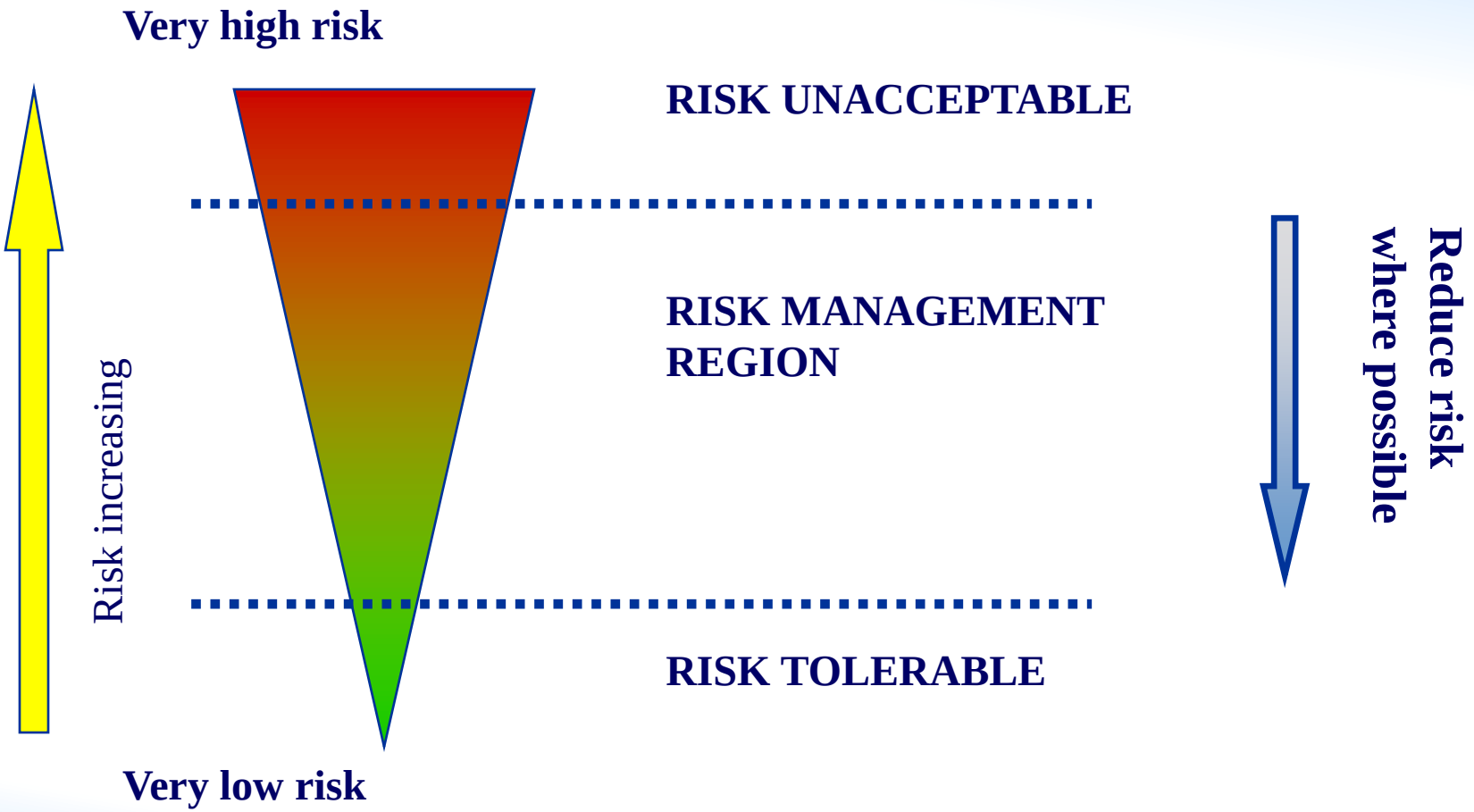
Defense-in-Depth

- Multiple barriers and levels of protection
- Diversity and redundancy within and between safety systems
- Single failure criterion
- Postulated initiating events, etc.

QUANTITATIVE



General Framework for Defining Risk Metrics
(Acceptance Criteria)



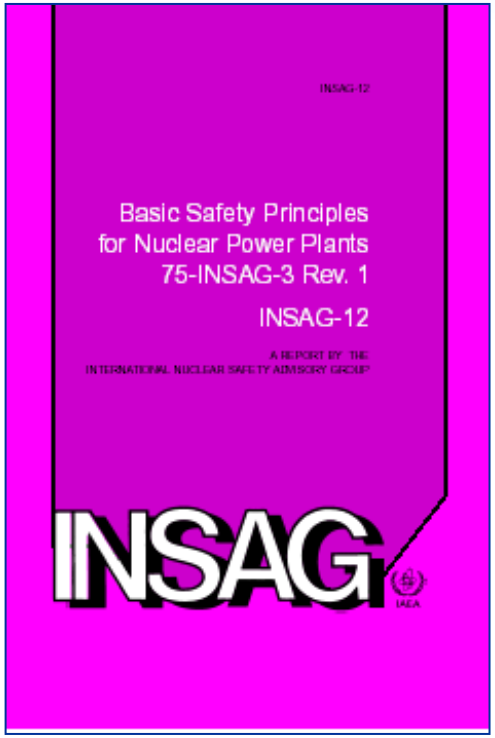
Reactor Safety Goal Policy Statement

- **Originally issued in 1986** **[Fed Reg. 51, No. 149]**
- **Expressed Commission's policy as:**
  - **"***… consequences of nuclear power operations such that individual bear no significant additional risk to life and health***"**
  - **Societal risks from NPP …** ***"should be comparable or less than the risks of generating electricity by viable competing technologies and should not be a significant addition to other societal risk"***
- **Established *Quantitative Health Objectives (QHOs)***
  - **Early fatality risk (0.1% of total accident risk) and latent cancer risk (0.1% from all causes)**
    - For an individual living in the vicinity of a NPP
  - **Based on the risk of accidental death in the U.S., this implies a prompt fatality QHO of $5 \cdot 10^{-7}$ per year**
  - **Based on the occurrence of cancer fatalities, this implies a latent cancer fatality QHO of $2 \cdot 10^{-6}$ per year**

Safety Goal Policy (concluded)

- **Interpretation by RB staff**
  - **Reg Guide 1.174 suggests surrogates for QHOs, including:**
    - Latent Cancer:
      - **Core Damage Frequency (CDF) < 10^{-4} per reactor-year**
    - Prompt Fatality:
      - **Large Early Release Frequency (LERF) < 10^{-5} per reactor-year**

INSAG-12



Basic Safety Principles for Nuclear Power Plants, 75-INSAG-3 Rev. 1, INSAG-12, A report by the International Nuclear Safety Advisory Group, IAEA, Vienna, 1999

– Revision of the original 75-INSAG-3 (1988)

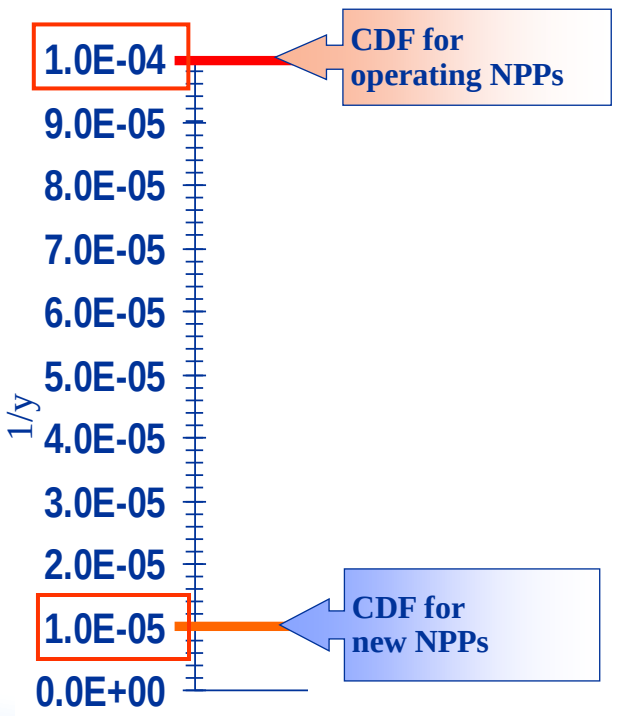
INSAG

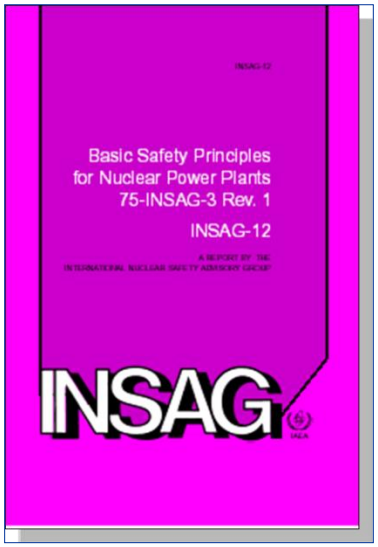
International Nuclear Safety Group

- A group of experts with high professional competence in the field of safety working in regulatory organizations, research and academic institutions and the nuclear industry
- Objective: to provide authoritative advice and guidance on nuclear safety approaches, policies and principles
- INSAG provides recommendations and opinions on current and emerging nuclear safety issues to the IAEA, the nuclear community and the public

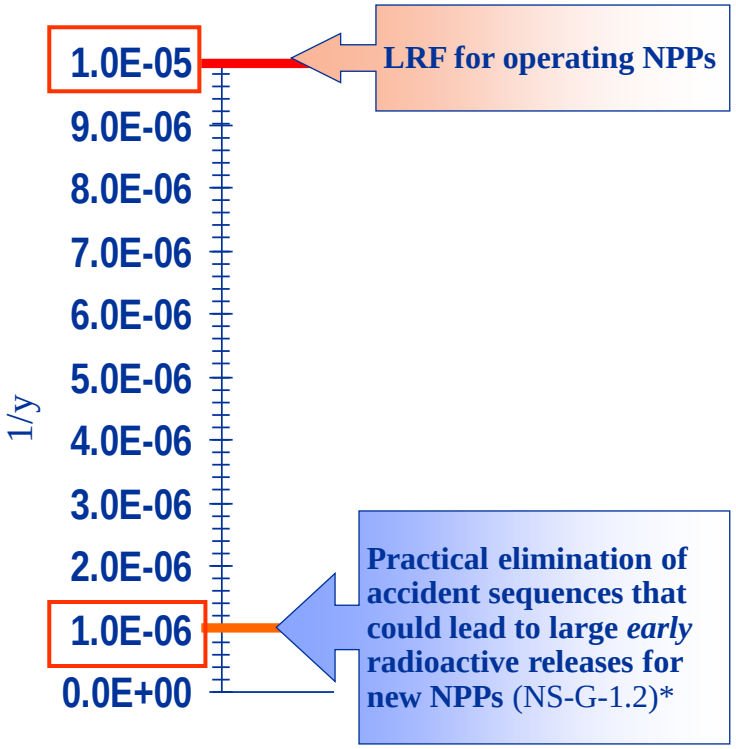
Concept of Numerical Safety Goals Considered in INSAG-12

Core Damage Frequency (CDF)





Large Release Frequency (LRF)



Examples of National Risk Criteria

Definition of Core Damage

- Core Damage can be defined differently in different countries and for different reactors
  - Highest node temperature, core collapsed liquid level
  - Cladding temperature limit, percentage of cladding thickness oxidized, etc.
- Parameters and associated acceptance criteria for core damage in PSAs
  - ***BWR:***
    - Collapsed liquid level less than 1/3 core height or code-predicted peak core temperature > 2500°F (1370°C)
  - ***PWR:***
    - Collapsed liquid level below top of active fuel for a prolonged period or
    - Code-predicted core peak node temperature > 2200°F (1204°C) using a code with detailed core modelling or
    - Code-predicted core exit temperature > 1200°F (650°C) for 30 min using a code with simplified core modelling
    - Core uncover of any duration, etc.
  - ***RMBK, CANDU***
    - Different levels of core or fuel damage are used to reflect scenarios with damage limited to
      - only one channel; a group of channels
      - a portion of the core; the entire core
- Core Damage Frequency may be incomparable between different type of plants and in different countries

Examples of National Risk Criteria Based on CDF

- **Some countries accept INSAG-12 suggestions**
  - CDF $\leq$ **10^{-4}** per reactor-year for existing plants
  - CDF $\leq$ **10^{-5}** per reactor-year for new plants
- **European Utility Requirements**
  - CDF $\leq$ **10^{-5}** per reactor-year
- **Russia**
  - CDF $\leq$ **10^{-5}** per reactor-year
- **Finland**
  - CDF $\leq$ **10^{-5}** per reactor-year

Definition of Level-2 PSA Risk Criteria

- A typical numerical safety criterion relates to the large (early) release frequency
  - ”**Large (early) release**” - a release of radioactive material that require a (short-term) off-site emergency arrangements to be implemented
    - The release can be specified in several ways
      - Absolute quantities (in Becquerels) of the most significant radionuclide's released
      - Fraction of the inventory of the core
      - Specified dose to the most exposed person off the site
      - Release resulting in ‘unacceptable consequences’, etc.
- Level-2 PSA results may be incomparable between different countries if different definitions for releases are used

Examples of National Risk Criteria Based on L(E)RF

- **Some countries accept INSAG-12 suggestions**
  - LERF ≤ $\mathbf{10^{-5}}$ per reactor-year for existing plants
  - LERF ≤ $\mathbf{10^{-6}}$ per reactor-year for future plants
- **European Utility Requirements**
  - LRF ≤ $\mathbf{10^{-6}}$ per reactor-year
- **Russia**
  - LERF ≤ $\mathbf{10^{-7}}$ per reactor-year

LERF - release which leads to exceeding dose limit at Accident Planning Zone Boundary specified as **5 mZv** (body) or **50 mZv** (thyroid)

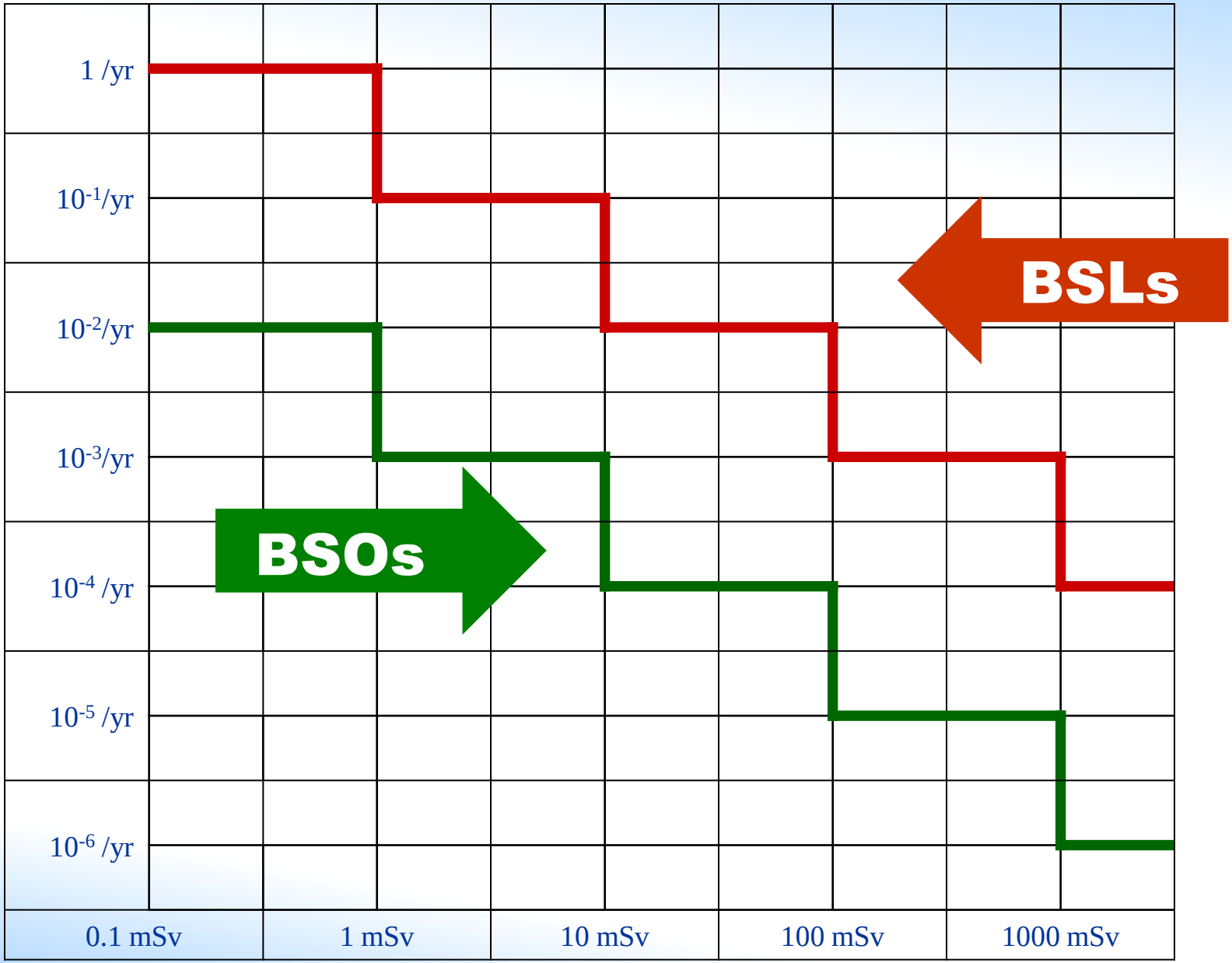
- **Finland**
  - LRF ≤ $\mathbf{5 \cdot 10^{-7}}$ per year

LRF - of **100 TBq** of Cs-137

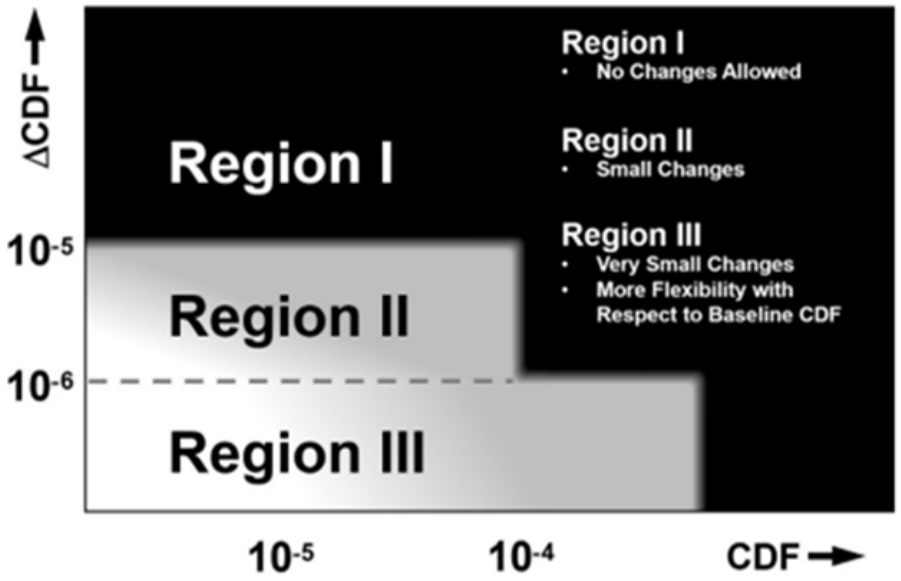
Definition of Level-3 PSA Risk Criteria

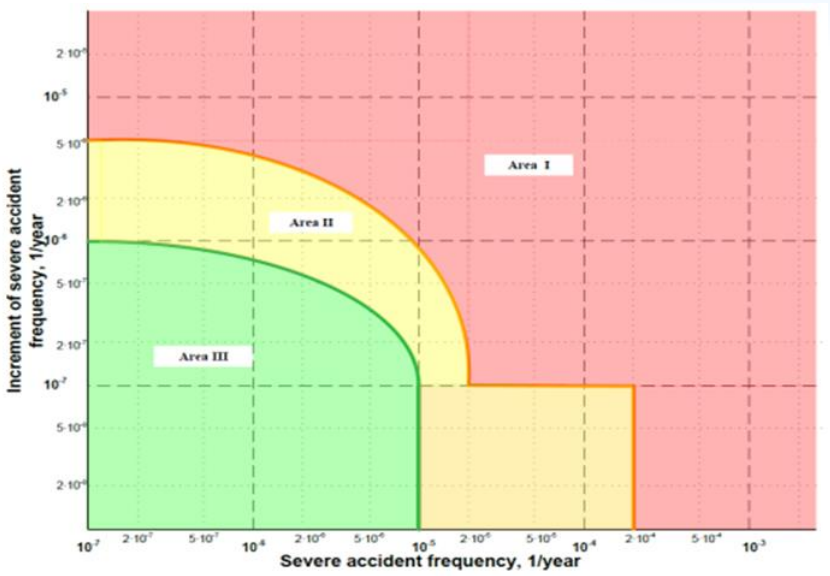
- Various numerical safety criteria are used:
  - Health effects
    - Dose rates over a short period of time occurs close to the point of release
    - Dose rates over an extended period of time occurs over a wide range
  - Societal risk measures
    - Individual death (early or late)
    - Number of deaths (early or late)
    - Non-fatal deterministic or stochastic effects
    - Number of hereditary effects
    - Collective dose
    - Area of ground contaminated
    - Number of individuals effected by countermeasures
    - Monetary costs of the accident

Examples of Risk Criteria Based on Level-3 PSA



National practice on risk ranking using safety goals





References

- Stanley Kaplan and B. John Garrick “On The Quantitative Definition of Risk”, Risk Analysis, Vol. I , No. I , 1981
- Development and Application of Level-1 PSA, IAEA Safety Standards Series, SSG-3, IAEA Vienna (2010)
- Development and Application of Level-2 PSA, IAEA Safety Standards Series, SSG-4, IAEA Vienna (2010)


Thank you for your attention
Questions?