Addressing off-site consequence criteria using PSA Level 3 - Enhanced Scoping Study

NPSAG/NKS Level 3 PSA seminar

Lloyd's Register Consulting

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Background & Objective

- Currently Level 1 and 2 PSA/PRA methodologies are well established and the analysis are a natural part of many NPP's safety analysis.
- In light of the Fukushima, international standard/guideline development, possible new builds and development of new/updated regulation a need to explore the potential use Level 3 PSA has been identified.
- The project is defined as an enhanced scoping study with objective to explore questions such as:
  - What are the needs for Level 3 PSA?
  - For whom would a Level 3 PSA be beneficial and what kind of results (risk metrics) should then be used?
  - What is going on in the international community with respect to Level 3 PSA guideline & standards.
- The project is defined as a 3 year R&D project where the above questions have been of main interest during the 1st year and the ultimate objective of the project is to develop a Nordic **guidance document** on how to perform a Level 3 PSA.

- **Seminar objective is to present the work that has been performed during Phase 1 and to discuss with stakeholders and other seminar participants the continued work during Phase 2 (2014).**

Project funding and organisation

- Funding of the project during Phase 1 (2013) is provided by:
  - Nordic PSA Group (NPSAG, www.npsag.org)
    - Stakeholders: FKA, RAB, OKG & SSM
  - Nordic nuclear safety research (NKS, www.nks.org)
  - Finnish Research Programme on Nuclear Power Plant Safety (SAFIR, http://safir2014.vtt.fi)
    - Stakeholders: TVO, Fortum & STUK
  - Phase 2 (2014) has at this date received funding by NKS.

- Project working group consists of:

Organisation	Funded by
Lloyd's Register Consulting	NPSAG & NKS
Risk Pilot	
ES-Konsult	
VTT	SAFIR & NKS

Project Overview
3 year plan – Planned work distribution

Task	2013	2014	2015
Task 0 – Survey	100%	-	-
Task 1 – Risk Metrics	75%	25%	-
Task 2 – Regulation & Standards	75%	25%	-
Task 3 – Guidance document	-	50%	50%
Task 4 – Pilot Application	-	33%	67%
Project Management & other costs	33%	33%	33%

Phase 1 – Phase 1 Project Overview

- During Phase 1 the project has been divided in following sub-tasks:

Subtask	Task Leader 2013
Task 0 – Industry Survey	ES-Konsult
Task 1 – Appropriate Risk Metrics	Risk Pilot
Task 2 - Regulation, guides and standards	Lloyd's Register Consulting
Task 3 – PSA Level 3 Guidance Document	-
Task 4 – Pilot Application	VTT

Seminar participants

- The seminar has attracted 21 people
- Let us introduce ourselves to each other before we look at the agenda

Agenda

Time	Subject
09:00	Coffee/Tea, Registration
09:30	Opening of seminar
10:00	Task 0: Industrial survey
11:30	Lunch
12:30	Task 1: Risk metrics
13:15	Task 2: International regulations and standards
14:00	Task 4: Pilot study
14:45	First year project summary
15:00	Level 3 PSA workshop & group discussion
16:30	Adjourn

Anders Olsson
Deputy Managing Director / Principal Consultant
Lloyd's Register Consulting – Energy AB
T +46 (0)40 680 64 05 E anders.olsson@lr.org

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www.lr.org/consulting

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Task 0

Questionnaire results

Purpose of questionnaire

- collect base information about current international practices and motivations for utilities and regulators for Level 3 PSA
- provide with better understanding and characterization of off-site consequences

Objective with questionnaire

- The results from the questionnaire shall contribute to the ultimate objective and outcome of the project in total.

- ***Project objective****; A guiding document to provide clear and applied guidance towards regulators, utilities and Level 3 practitioners.*

Scope of work for task 0

– Development of the questionnaire

– Literature study

– Implementation of the questionnaire

– Compilation of results

– Workshop

– Final report

Layout; questionnaire

1.1.1 ENVIRONMENTAL IMPACT (1-5)

The impacts on the environment after a release of radioactive substances can last for a long period of time. Land contamination can result to restrictions for land use in many years. Elevated levels of cesium could be measured many years in meat from reindeers, mushrooms and berries after the Chernobyl accident.

How would you define unacceptable environmental impact?

Examples for discussion:

- Contamination of land, large areas
- Restrictions in land use
- Damage to biosphere (for example impacts on animals and plants)

Layout; final report

- *Final conclusion (This presentation)*

- *Expert's opinion*

- *Opinion from insurance companies*

Respondents to the questionnaire: Nuclear experts and insurance company's

Name of organization	Category of identification
FKA	Experts
RAB	Experts
ES-konsult	Experts
SSM	Experts
RiskPilot	Experts
STUK	Experts
UJV Rez	Experts
VUJE	Experts
Fortum	Experts
OKG	Experts
AON	Insurance company
Elini	Insurance company

Headlines – Level 3 PSA - Questionnaire

- Risk comparison
- Needs
- Advantages
- Challenges

Risk comparison

For the development of Level 3 PSA it is of main concern to be able to compare risks.

Is it possible to compare risks for activities that are society-made? For example comparison between annual risks for automobile accidents, societal risks from nuclear power plants. If so, how?

How can the risk involving a release from a nuclear power plant accident be compared to risks from other types of energy sources?

What are reasonable risk comparisons to the risk of a release from a nuclear accident (such as Fukushima)?

Risk comparison

Risk comparisons for society made risks are possible to do in theory; however, this might not be possible in practice.

- Difficulty in finding comparable units
- Risk perception and risk perspective

When comparing the risk with a nuclear power plant to other types of society made risks the whole life cycle must be taken in to account, making a life cycle analysis (LCA)

One possible comparable unit (risk metrics) for comparing the risk with a nuclear power plant to the risks from other types of energy sources is number of deaths (e.g. per produced TWh or per operating year).

The issue whether or not comparisons to the risks with a nuclear power plant are needed still needs to be decided.

Needs for Level 3 PSA

Level 3 PSA provides an assessment of off-site consequences from a radioactive release, not limited to nuclear reactor sites. Outputs from Level 3 PSA can vary; often the outputs include collective radioactive doses, different health effects, economic impacts and agricultural effects.

What is the main purpose of Level 3 PSA in your opinion?

Have you or your organization used Level 3 PSA for this purpose? If so, how?

How would you define unacceptable health effects in short- and long term?

How would you define unacceptable environmental impact?

How would you define unacceptable economic impact?

Needs for Level 3 PSA

The scope for Level 3 PSA and the use of results from this type of analysis needs to be established before the need for Level 3 PSA can be defined.

Expected purposes is to use Level 3 PSA:

- As an objective guidance tool for decision making
- Verify good emergency preparedness
- Improve insurance possibilities
- Creating acceptance for nuclear power in the society

Needs for Level 3 PSA

The view on effects after a release of radioactive substances differ.

Unacceptable effects from a nuclear expert point of view:

Can be graded as a principle in terms of risk metrics

Unacceptable effects from a insurance company point of view:

Any effect on health, environment or economics (on third party) is unacceptable

Advantages with Level 3 PSA

Communication

Using Level 3 PSA might enable different stakeholders to communicate about risks.

Are there any advantages of using Level 3 PSA for communication with or between different stakeholders regarding the societal risks of commercial nuclear power?

Advantages with Level 3 PSA

Communication

If Level 3 PSA could lead to defining the risk with nuclear power off-site and expressing the risks in terms that are possible to compare, discuss and calculate (e.g. in monetary values) with other societal risks then the results would be communicable.

Making the risks communicable could help to improve the communication between the nuclear industry, authorities, insurance companies and the community.

Advantages with Level 3 PSA

Important communication paths

- From experts to authorities
- From authorities (e.g. STUK and SSM) to the community (e.g. private persons, non-governmental organizations, and media)

The importance of different communication paths may differ between different stages, for example after an accident

Advantages with Level 3 PSA

For the nuclear community

One of the aims with Level 3 PSA is to better understand societal risks.

How can nuclear community in general benefit from a Level 3 PSA?

How can Level 3 PSA improve the benefit of PSA Level 1 and 2?

Advantages with Level 3 PSA

For the nuclear community

Expected advantages from Level 3 PSA is to provide help to:

- Communicate with insurance companies and thereby lead to better insurance possibilities
- Communicate with the society in large and thereby create higher acceptance for nuclear power in society
- Better understand societal risks of commercial nuclear power and thereby improve preparedness work
- Provide better design and siting considerations for new construction projects
- Improve and extend earlier levels of PSA, Level 1 and 2, in creating a more holistic point of view (this was not a unified opinion)

Challenges with Level 3 PSA

Using Level 3 PSA might be misleading depending on how we look at risk and how the risk is perceived.

What are the obstacles in using Level 3 PSA in your opinion?

What kind of risk metric is suitable in a Level 3 PSA?

Are there any needs for Level 3 PSA safety criteria?

How would you define an unacceptable release?

How can the results be used and to what purposes?

Are there any needs for Level 3 PSA guidelines?

Challenges with Level 3 PSA

Examples of discussed obstacles with Level 3 PSA:

- Uncertainties in the analyses
- Uncertainties from ingoing parameters
- Difficulty to make comparisons between different reactors
- The method might be expensive and require a lot of work
- The risk for a large gap in time between preforming Level 3 PSA studies which leads to problems with knowledge transfer
- As earlier discussed, difficult to communicate risks based on different risk perceptions and perspectives

Risk metrics

What kind of risk metric is suitable in a Level 3 PSA?

Appropriate risk metrics is one of the main questions when developing Level 3 PSA.

Suitable risk metrics can be divided three groups in terms of;

- Health
- Environment
- Economic

Both in long- and short terms

Risk metrics

What kind of risk metric is suitable in a Level 3 PSA?

The complete risk metric could be economic risk metric but this would require a lot of work to get it realistic due to difficulties to determine the economic value for different consequences.

Other possible risk metrics are doses and contamination of land. It is relatively easy to calculate fatalities from these metrics.

Different risk metrics are suitable for different parts of the society depending on the target group. For an insurance provider the economic analysis would be important, and relevant economic metrics would be of interest, while for authorities some other risk metric could be of greater interest.

To be continued…

Safety criteria

Are there any needs for Level 3 PSA safety criteria?

Yes and no;

Some of the respondents felt that Level 3 PSA has not been performed or applied enough to define such criteria, or even to see the needs for such criteria. Those that felt criteria should exist were interested in using them as a means of defining the scope of the analysis.

The outcome from the discussions during the workshop was that safety criteria must be defined in order to understand the results of a PSA. We need such criteria to understand if the results are good/bad or acceptable or unacceptable, this provides focus to an analysis.

The need for and definition of Level 3 PSA safety criteria's need to be further studied.

Unacceptable release

How would you define an unacceptable release?

Example from the responding nuclear experts:

- Based on defined acceptance criteria's, like e.g. ALARA principle and dose criteria's, determined from regulations by the authorities
- Based on reference values, e.g. define a limitation based on background radiation from normal operation of a NPP

Example from the responding insurance company's;

"any release which will have an adverse effect should be deemed unacceptable"

Use of results

How can the results be used and to what purposes?

Level 3 PSA can allow for better communication between stakeholders and give a general benefit to the nuclear community.

Examples of expected use of results from Level 3 PSA:

- Use for communication to the public (if this is done carefully)
- Use in planning (e.g. emergency planning, accident management)
- Use for increasing the knowledge for possible effects off-site from a nuclear accident to be used for new built (e.g. site location) or rebuilt

Guidelines

Are there any needs for Level 3 PSA guidelines?

There is an ongoing work regarding the peer review standards (ANS/ASME 58.24 (PSA Level 2) and ANS/ASME 58.25 (Level 3 PSA) that are currently being developed. This project will have the possibility to influence of the progress of these standards.

Guidelines

Are there any needs for Level 3 PSA guidelines?

The answer was yes.

Since there are so many ways to perform the analyses and evaluate the results guidelines are needed to ensure that scenarios from one plant can be compared with scenarios from another plant.

Written as suggestions rather than a strict guideline to give input on different ways to perform Level 3 PSA depending on the objectives.

To be continued…

Overall challenges

Challenges with the further work of Level 3 PSA

- Defining the scope for the analysis method
- Finding the appropriate risk metrics
- Finding comparable units

- Making necessary assumptions and dealing with uncertainties
- Expensive and complex analysis method to perform
- Making right comparisons between different reactors

- Communicating the results from a Level 3 PSA study

Overall challenges

"The challenges of Level 3 PSA might also be the reasons for performing Level 3 PSA"

To be continued …

- Risk comparison
- Needs
- Advantages
- Challenges

Addressing off-site consequence criteria using Level 3 PSA — Task 1: Risk Metrics

Jan-Erik Holmberg

Level 3 PSA seminar, January 21, 2014, Solna

Contents

- Concepts
- Summary of the Safety goal –project (2007-10)
- Conclusions from the questionnaire (Task 0)
- Risk metrics for level 3 PSA
- Conclusions

Risk

- Risk is defined relative to hazards or accidental events
- A hazard is something that present a potential for health, economical or environmental harm
- Risk is a combination of the probability (or frequency) of the hazardous event and the magnitude of the consequences

- An engineering definition of risk associated with an event X_i
  $Risk(X_i) = P(X_i) * C(X_i)$

- The risk of a system is derived by an integration over all accidental events associated with the system

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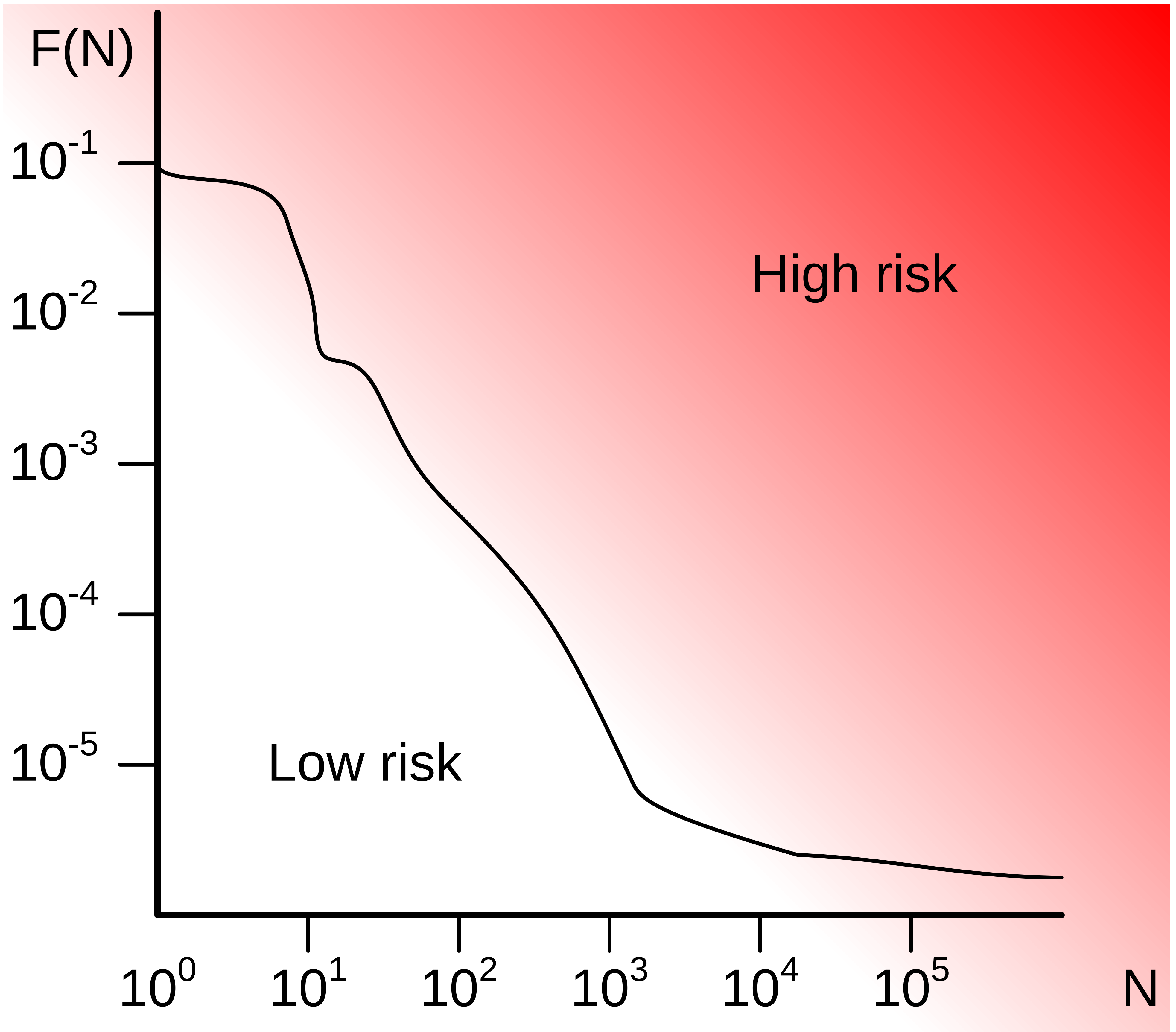
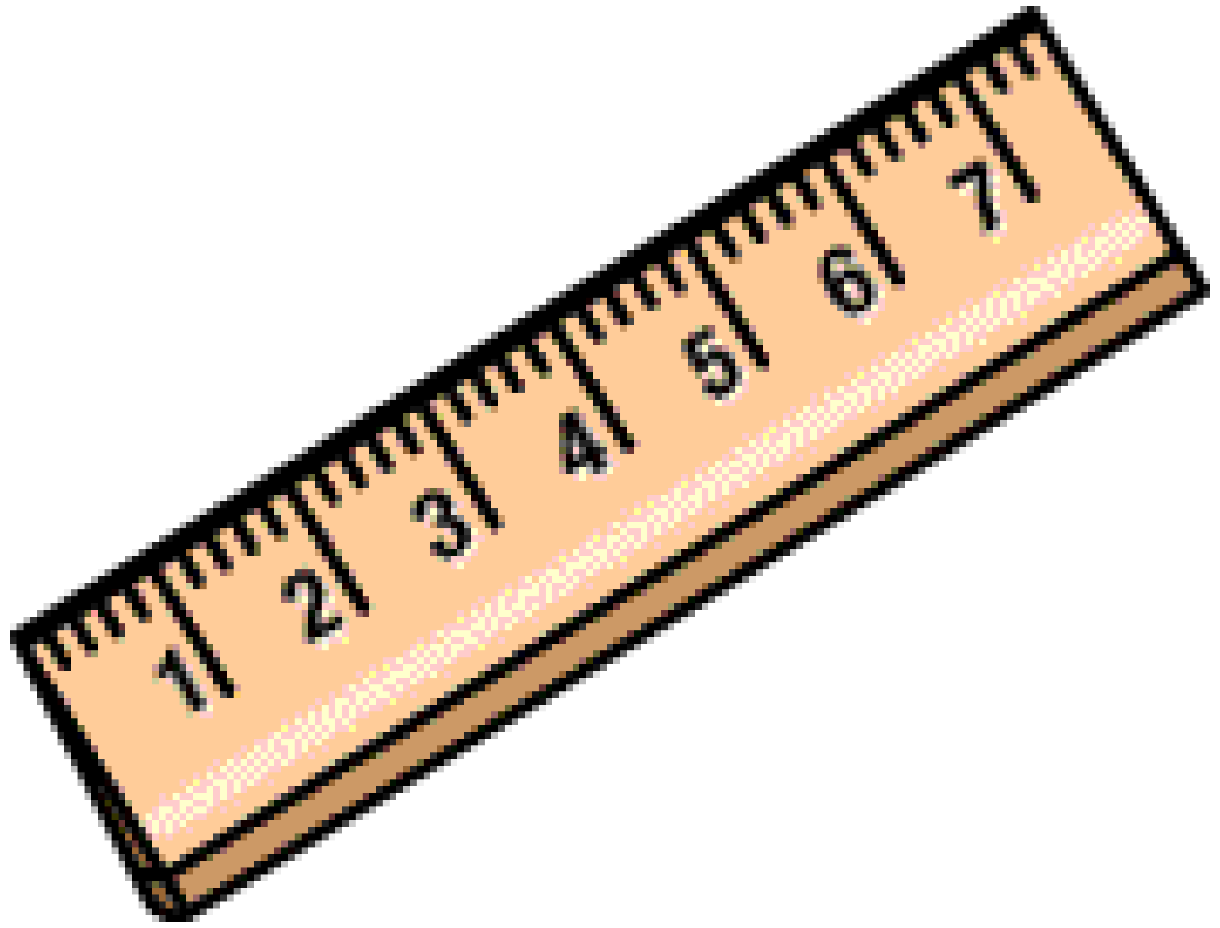
Individual and collective risk

- The *individual risk* is that faced by any specific individual as a result of an accidental event
  - Typically calculated for an anonymous person in the most exposed position

- The *collective* or *societal risk* is the expected number of casualties per unit time in the population exposed to risk
  - can be expressed by a *F-N curve*



Risk measure and risk metrics



- (Risk) measure is an operation for assigning a number to something

- (Risk) metric is our interpretation of the assigned number

- In PSA context, various numeric results obtained from the quantification of the model are **risk measures**
- The interpretations of these numbers as core damage risk, plant risk profile, safety margin, etc., are **risk metrics**

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Risk criteria

- Refer to any quantitative decision making criterion used when results of risk assessment are applied to support decision making

- Various type of criteria [NKA/RAS-450, 1990]
  - absolute criteria (= safety goal approach)
  - relative criteria
    - relative change is controlled
  - differential criteria
    - absolute size of change is controlled
  - trade-off criteria
    - any change resulting in risk increase must be compensated by changes reducing the risk

- Lifetime risk vs. Average risk vs. Instantaneous risk

Acceptable risk

- Risk is acceptable if it is tolerated by a person or group
- Whether a risk is "acceptable" will depend upon the advantages that the person or group perceives to be obtainable in return for taking the risk, whether they accept whatever scientific and other advice is offered about the magnitude of the risk, and numerous other factors, both political and social
- Risk acceptance is usually presented using the ALARP (As Low As Reasonably Practicable) framework
  - ALARP = ALARA

		Impact				
Probability		Very Low 1	Low 2	Medium 4	High 8	Very High 16
Very High	5	5	10	20	40	80
High	4	4	8	16	32	64
Medium	3	3	6	12	24	48
Low	2	2	4	8	16	32
Very Low	1	1	2	4	8	16

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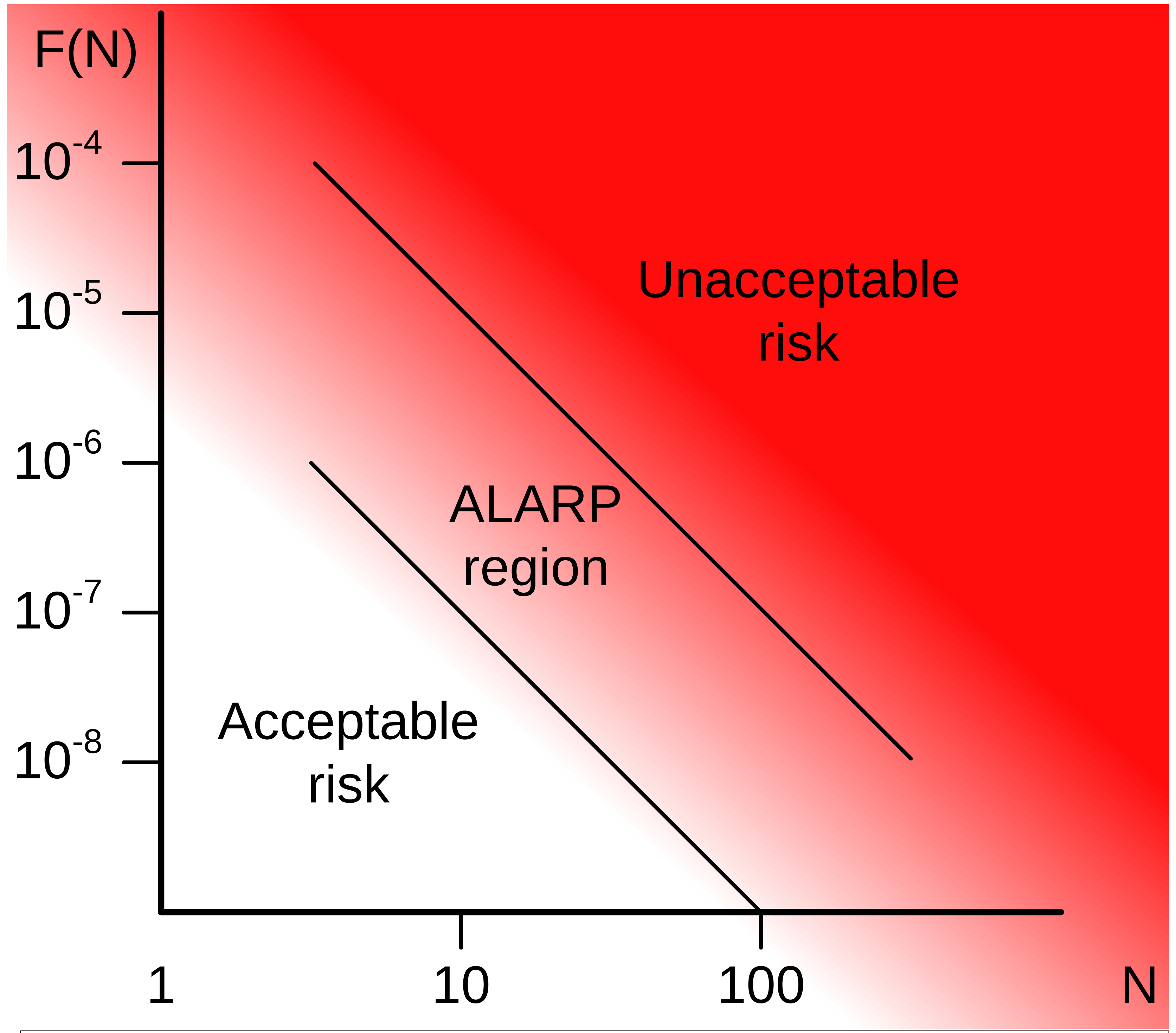
ALARP framework

1. Unacceptable (intolerable) region. Risk cannot be justified on any grounds

2. The ALARP or tolerability region. Risk is tolerable if benefit is desired. Trade-off analysis is made to evaluate the need for risk reductions

3. Broadly acceptable region. Risk is negligible. No need for further risk reduction



[Dutch VROM criteria] $F(N) = 10^{-3} \cdot N^{-2}$

The slope -2 on log-log-scale reflects *risk aversion*

Residual risk

- The remaining risk which cannot be defined in more detail after elimination or inclusion of all conceivable quantified risks in a risk consideration

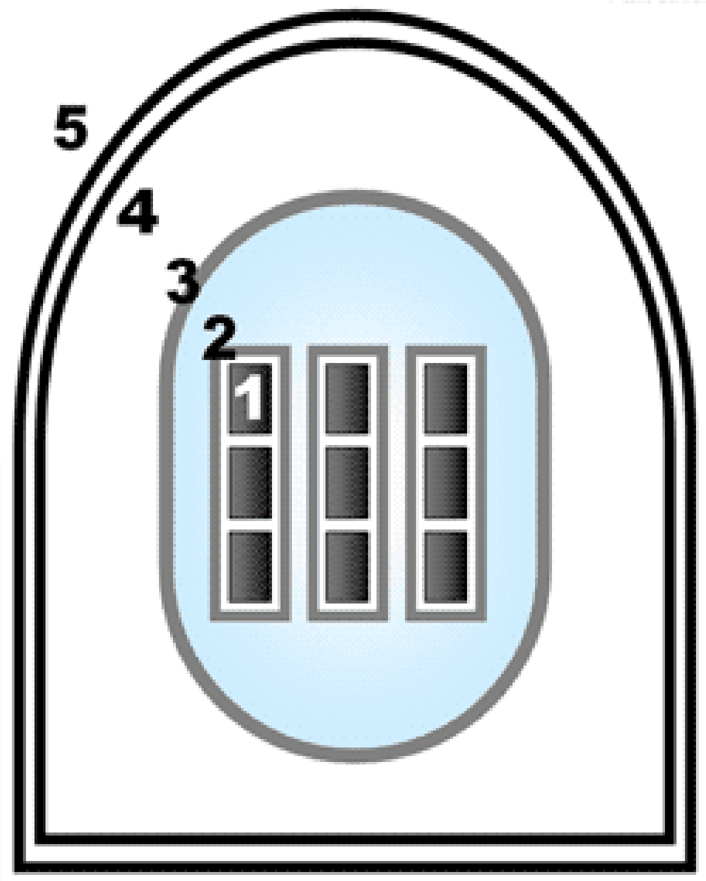
- Reactor vessel rupture is often given as an example of a residual risk
  - Based on WASH-1400, this has been interpreted to correspond of an event with a frequency of about 10^{-7}/year (median value)

- In SKIFS 2004:2, the definition is given as “Extremely improbable events (residual risks): Events that are so improbable that they do not need to be taken into account as initiating events in connection with safety analysis”

Surrogate risk criteria

- A risk criterion on a lower technical level to assess in a simplified way the consequences on a higher level
- Also called subsidiary risk criteria

- CDF and LRF/LERF are surrogate criteria for risk of offsite consequences if level 3 PSA is not required
- Surrogate criteria may be defined at lower level too, e.g., for the reliability of safety functions and systems
- The whole range of criteria related to levels of defence-in-depth (DID) could be defined



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Safety objectives, goals, targets, limits

- **Safety objectives** are the objectives to be achieved e.g. for safe operation of a nuclear power plants [INSAG-12]
- In the implementation of safety objectives, quantitative targets called (quantitative) safety goals or **numerical safety objectives** need to be defined [INSAG-12]
- EUR use concept "**safety targets**" and "**probabilistic design targets**"
  - "targets" are values established by the utilities which are more demanding than current regulatory limits, but that are considered reasonably achievable by modern, well designed plants
- NII translates the **risk acceptance criteria** (limit of tolerability) into a Basic Safety Limit (BSL). The lower bound of the ALARP region is called Basic Safety Objective (BSO).

Safety goal – project

Nordic NKS/NPSAG project
see reports
- NKS-153 (SKI 2007:06)
- NKS-172
- NKS-195
- NKS-226
- NKS-227 (SSM 2010:35)

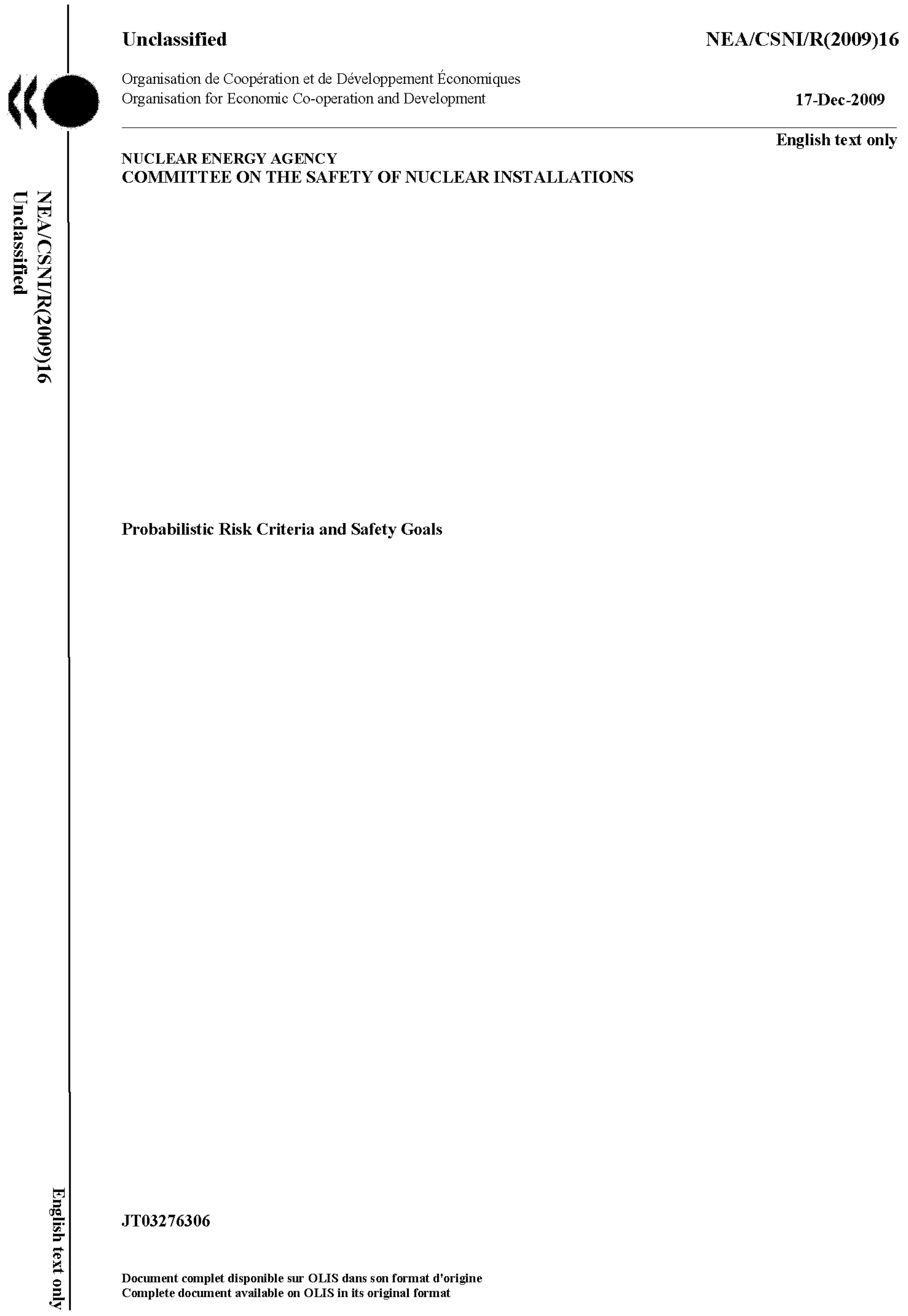
OECD/NEA WGRISK task
see next slides

Scope and purpose of the WGRISK task

- The objective was to review the rationales for setting Probabilistic Risk Criteria, their current status, and actual experience in the member states

- The scope included the whole range of criteria from individual and societal risk, off-site release, core damage and lower level goals to numerical criteria used in various risk-informed applications

- Reported in NEA/CSNI/R(2009)16
  http://www.nea.fr/html/nsd/docs/2009/csni-r2009-16.pdf



NEA/CSNI/R(2009)16
Unclassified

Unclassified **NEA/CSNI/R(2009)16**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development

17-Dec-2009

English text only

NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

Probabilistic Risk Criteria and Safety Goals

JT03276306

Document complet disponible sur OLIS dans son format d'origine
Complete document available on OLIS in its original format

English text only

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Respondents to the WGRISK questionnaire

- 13 nuclear safety organizations (Canada, Belgium, Chinese Taipei, Finland, France, Hungary, Japan, Korea, Slovakia, Sweden, Switzerland, UK and USA)

- 6 utilities (Hydro-Québec, Fortum, OKG, Ontario-Power-Generation, Ringhals and TVO)

- Two of the regulatory bodies (Belgium and Chinese Taipei) declared they have not set (and do not intend to set) any Probabilistic Safety Criterion

- Some supplementary information (three countries) taken from a questionnaire on Safety Goals during the 20-24 November 2006 IAEA Technical Meeting on the development of draft DS-394

Status of risk criteria

Alternative statuses:

- A legally strict value to be fulfilled
- A strict value but not legally bounding
- Target value, orientation value, expectation, or safety indicator
- No risk criteria declared

- For most respondents probabilistic risk criteria are target values, orientation values or safety indicators

Differences in criteria for existing plants, life extension, new builds, new design

- Probabilistic risk criteria are the same for existing and future plants
- Probabilistic risk criteria use a similar metric for existing and future plants. The numerical values for the frequencies are a factor (typically 10) lower for future plants.
- Probabilistic risk criteria involve the same numerical values for the frequencies, considered as limits for future plants and targets for existing plants
- Probabilistic risk criteria are defined only for existing plants
- No numerical risk criteria have been defined for new plants. However, there is a general requirement that the level of risk should be comparable to (or lower than) the risk from existing plants

- For modernization and life extension, generally same criteria are applied as for operating plants

Types of risk criteria

Society level criteria

- not probabilistic, but are basis for the probabilistic criteria
- generally set in the mandate of the regulatory body
- "Prevent unreasonable risk to the public and the environment"

Intermediate Level Criteria

- "The risk from use of Nuclear Energy shall/should be low compared to other risks to which the public is normally exposed"
- These "other risks", when defined, are characterized as one or several criteria:
  - the background risk of cancer
  - the risk from other sources of energy production
  - the risk of fatality for all other sources (early or late)
- The separation between society level and intermediate level is not always clear

Technical Level Criteria

- Numerical risk criteria

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Technical Level Criteria

- The reported Probabilistic Safety Criteria can be grouped into 4 categories:
  - Core Damage Frequency (CDF) – Level 1 PSA – 16 respondents
  - Releases Frequency (LERF, LRF, SRF) – Level 2 PSA – 14 respondents
  - Frequency of Doses – Level 3 PSA – 4 respondents
  - Criteria on Containment Failure – System level – 2 respondents

- Several respondents use more than one criterion (e.g., CDF and LERF) while some others use a range of values for a given criterion (e.g., frequency of doses to the public, to the workers, during accidents, during normal operations)

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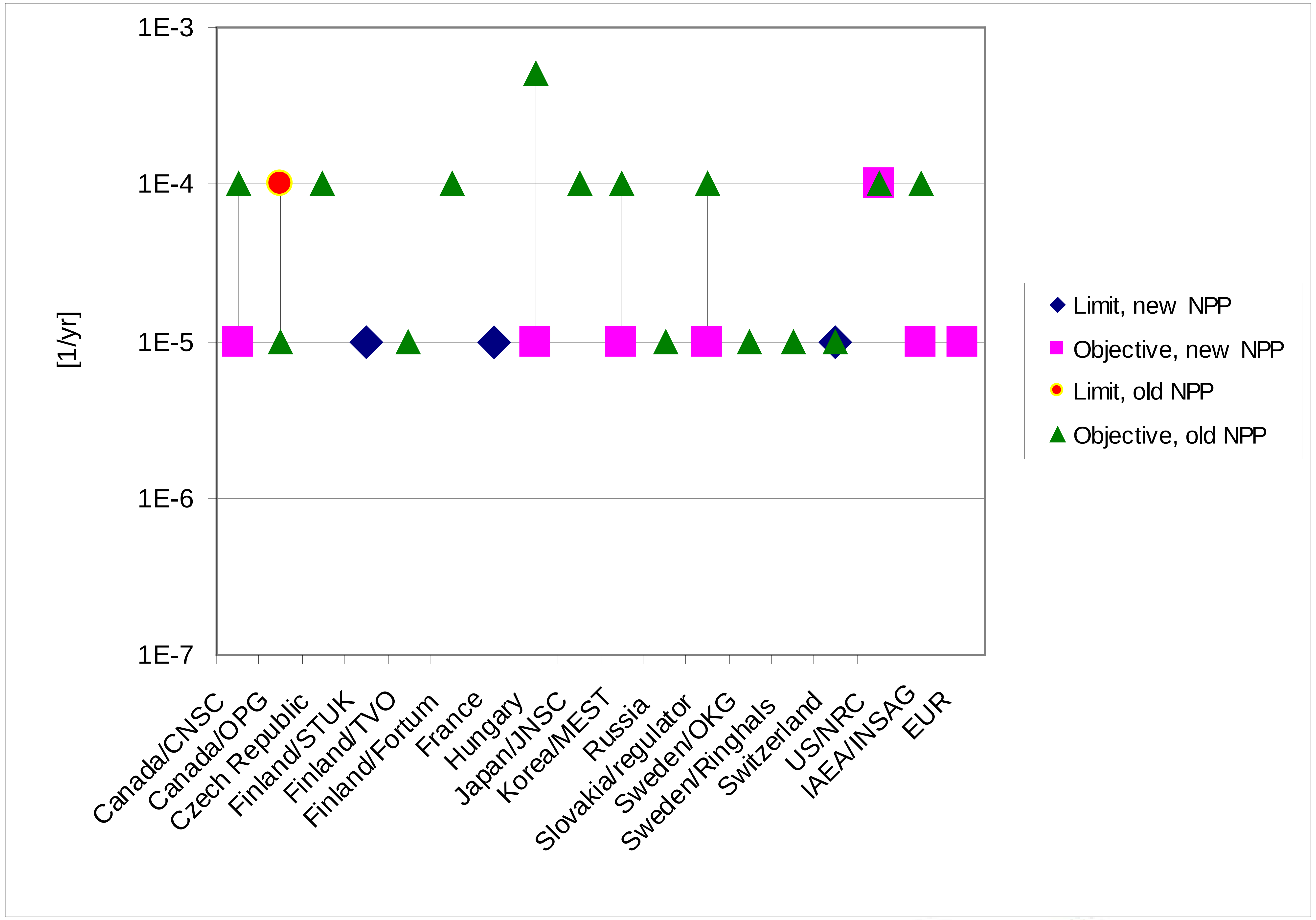
Core Damage Frequency Criterion

- Reactor level
- Full scope PSA
- Aim to control defence-in-depth of the design
- Well-known, allows comparison of results
- Frequently used for decision making regarding plant modifications



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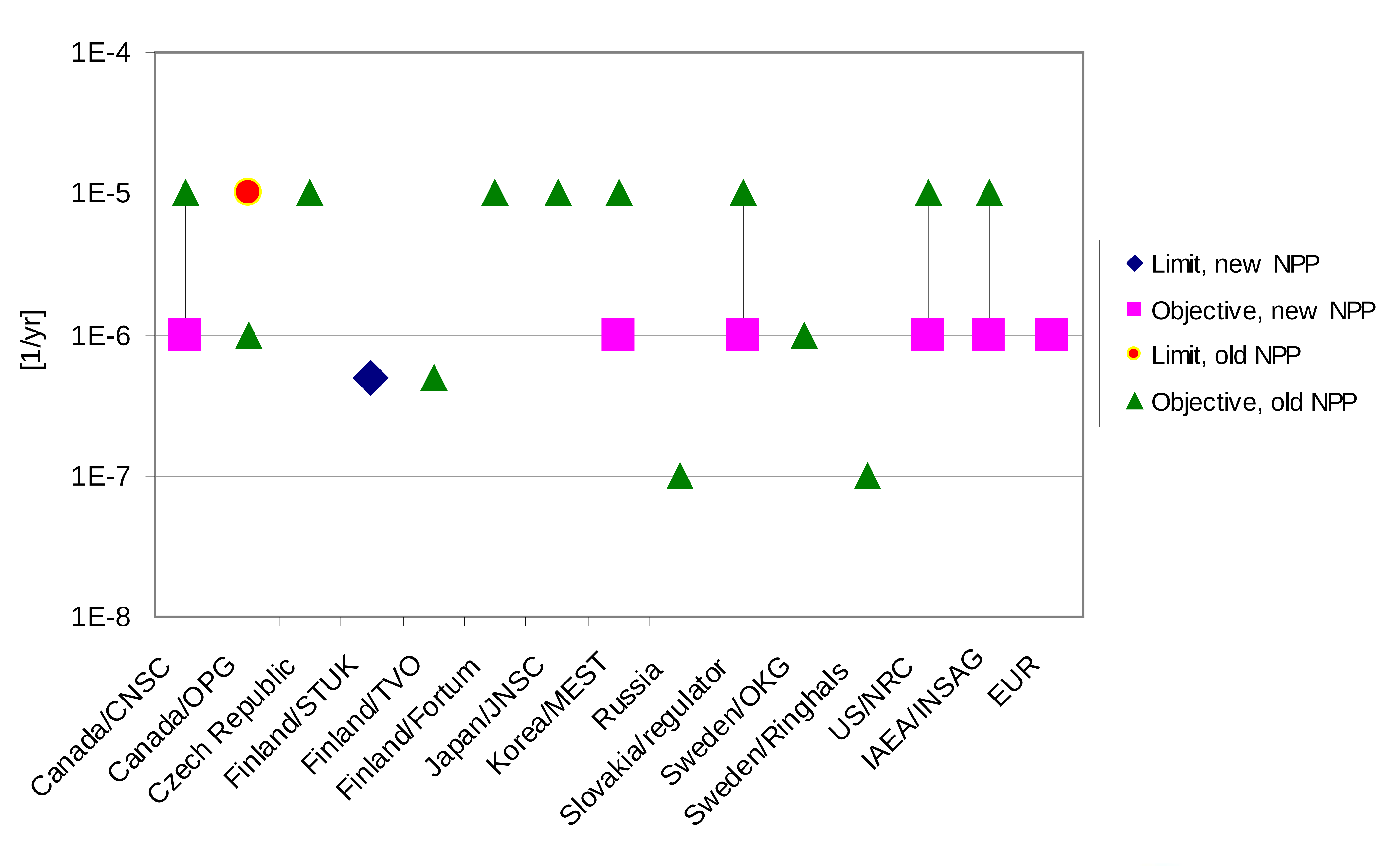
Release Frequency Criterion

- Large variation in the definition of what constitutes an unacceptable release
- Aim to protect the public against prompt fatalities and radiological-induced cancers
- The LERF criterion is based on the time being sufficient for public evacuation before a significant release occur
- Some countries do not consider the releases timing and base their criteria on land contamination



Criteria on Containment Failure

- A performance goal defined by the Japanese Nuclear Safety Commission (NSC)
  - For LWRs, the containment failure criterion 1E-5/year was derived from the quantitative health objective value, and the conditional average probabilities of acute fatality or cancer fatality of the individuals in the surrounding area determined for a hypothetical large release (< 0.1)
  - CFF criterion is a way to cope with the uncertainties in the quantification of source terms and the effectiveness of emergency protective measures, etc.
- U.S.NRC's Severe Accident Policy Statement

	CDF	**LERF**	**Conditional Containment Failure Probability**
Operating plants & License renewal	<1E-04	<1E-05	n/a
New plants	<1E-04	<1E-06	< 0.1

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Frequency of Doses Criterion

- Only used by two respondents (Canada-OPG and UK HSE)
- Fatal acute health risks, fatal late health risks
- Rate of exposure in Sv/yr to the individual and/or probability of latent health effects
- Can be calculated for an individual or a group
- The risk to the member of a critical group that receives maximum exposure from an accident
- Station/site level criterion
- Generally considered as meeting directly the high level goal of “no added significant risk to the public”

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Experience from the implementation, interpretation and communication of risk criteria

- The general experience from the implementation of risk criteria is positive
  - Increased the focus on the correctness and quality of PSA models
  - Importance of using PSA as an integrated part of the total safety analysis concept
- A general concern about using probabilistic risk criteria as absolute limits, as this might indirectly have an negative impact on the quality of PSA
- More work is needed in the definition of the various criteria, e.g., definitions for severe core damage and large release
- Responses regarding communication of probabilistic risk criteria to the public vary widely between the respondents
  - Concern about the complexity of the risk assessment process itself, and the ability of the general public to interpret results correctly
  - In those cases where probabilistic risk criteria are met, the results are useful when communicating the level of safety to the public

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Conclusions from the Safety goal project (WGRISK)

- Probabilistic safety criteria have been progressively introduced by regulatory bodies and utilities
- For most respondents probabilistic risk criteria are target values
- Introduction of probabilistic risk criteria had resulted in safety improvements
- A considerable spread in opinions on the benefits of using probabilistic risk criteria for communication with the public
- More work should be considered in the definition of releases frequencies

L3PSA project Questionnaire/question 4.4.2 and December 2013 workshop conclusions

- Multiple risk metrics should be used
- Different risk metrics is to be used when presenting the Level 3 PSA results for different kind of stakeholders
- However it is not possible based on today's knowledge decide on which risk metric to use or the priorities amongst the different risk metrics
- Rather a comparison between the different risk metrics should be done

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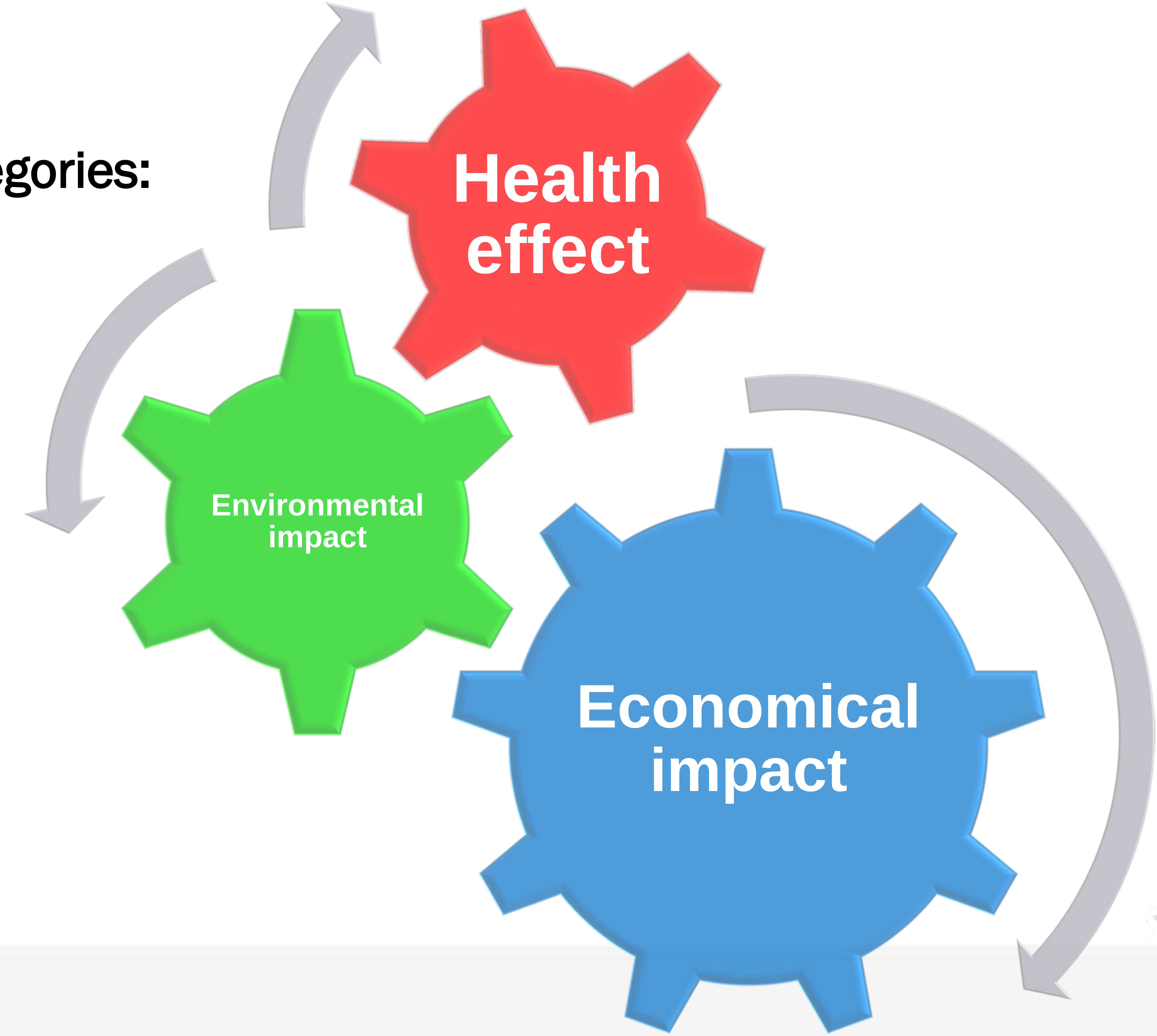
Risk metrics considered in L3PSA project

Consequence categories:



Probability units:

- per year, per lifetime
- per reactor-unit, per site
- per MWh_e

Probability units

- [1/year per reactor] is the usual unit and probably the one that must be used in regulation
  - operating licenses are per reactor
  - risk criteria have been historically expressed [1/year]

- [1/MWh_e] may be used in risk comparisons

- Lifetime risk is theoretically the ”correct” unit in the investment decision making
  - per lifetime in years
  - per lifetime in produced energy

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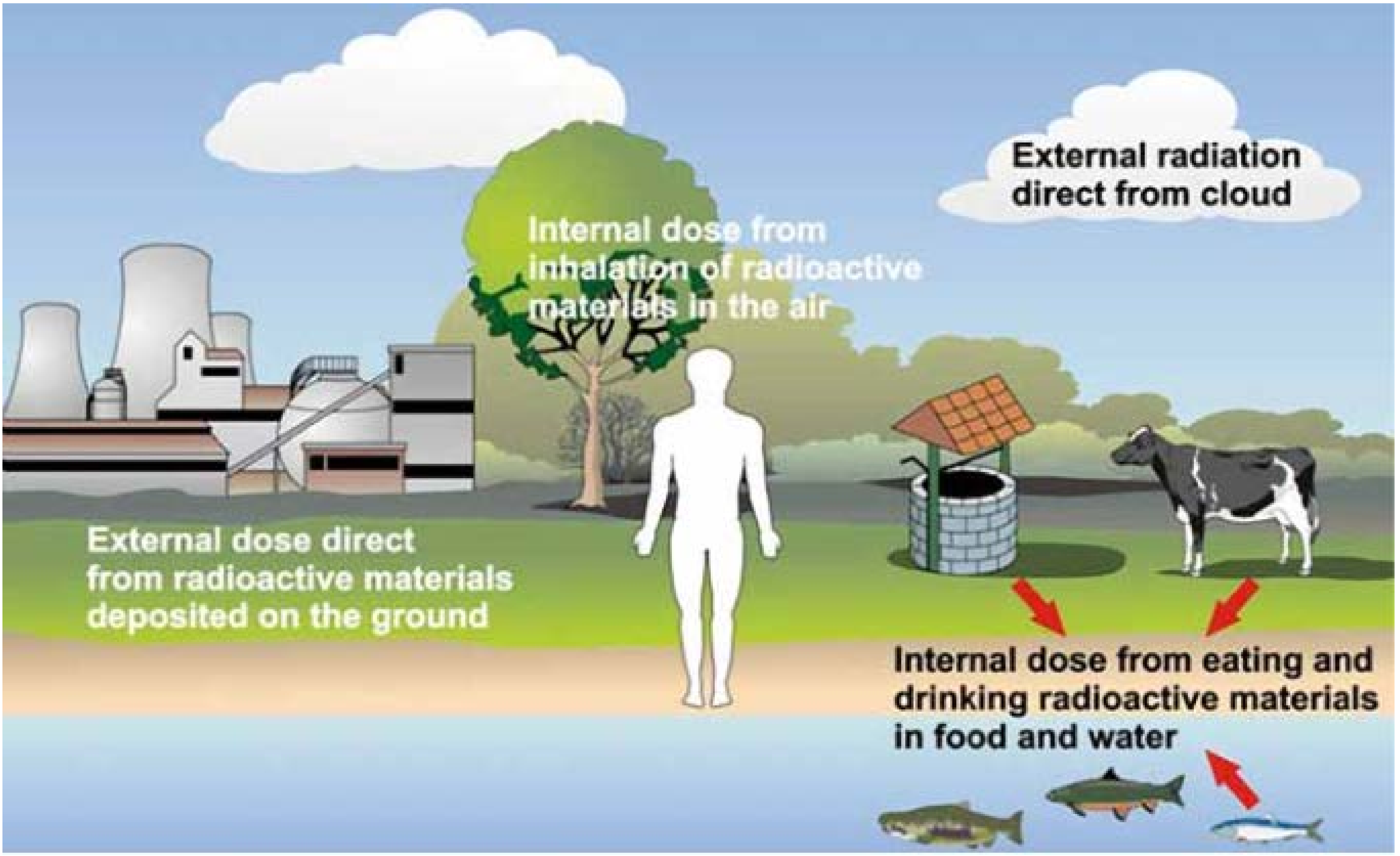
Health effect risk metric



Source: IAEA report on Environmental consequences of the Chernobyl accident and their remediation: twenty years of experience (2006)

- Dose/release based assessment
- Usually associated with the radiological impact on human beings
  - based on collective dose [manSv] and maximal individual dose estimates [mSv]
- Short term (prompt) and long term cancer fatalities are derived from dose estimates

- Used as a risk criteria in several countries (see e.g. safety goal –project)

Health effect risk metric
Advantages, disadvantages and uncertainties

Straightforward to calculate
Well known, often used risk criteria
Calculation codes exist

Does not cover all negative consequences of a nuclear accidents
E.g. no health impact at TMI, some health impact at Chernobyl and Fukushima

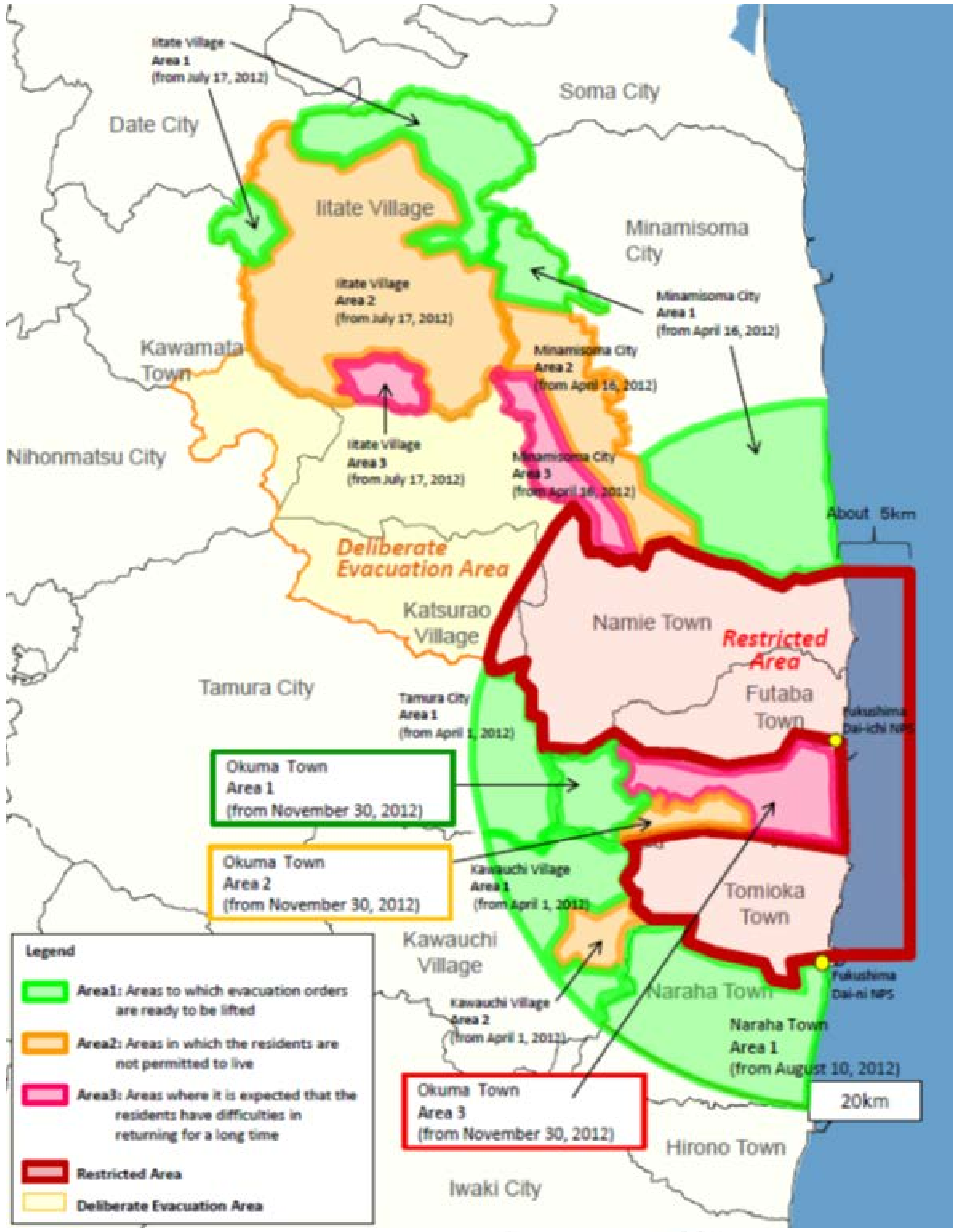
?

Uncertainties are related to

- release estimate
- dispersion estimate
- exposure estimate (groundshine, ingestion dose pathway, inhalation, cloudshine)
- how far in distance and time the estimates should be made (long term population impact)

Environmental impact risk metric

- Dose/release based assessment
- Used as a safety goal
  - “accidents requiring evacuation, long term restrictions in food consumption, etc., must be practically eliminated”
- Several metrics
  - contaminated area, contamination level
  - land use restrictions
  - lost food production
  - evacuated people
  - other biosphere effect



Environmental impact risk metric
Advantages, disadvantages and uncertainties

Well known, often used safety goal (but not as a numerical criterion)
Complements health criteria, same evaluation basis
Calculation codes exist

Does not cover all negative consequences of a nuclear accidents
Requires weighting between different environmental impacts => economic assessment

?

Uncertainties are similar to health effect estimates
AND

- biosphere model uncertainties
- weighting between different environmental impacts

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YOUR RISK NAVIGATOR

Economical impact

- Aim is to estimate the total cost of an accident
  - the sum of individual benefits foregone, summed over all affected individuals, businesses and public bodies
  - measured by the need for compensation
  - however, does not assume that this compensation is actually paid, either in full or in part

  - The evaluation of economic impact is subject to a number of limiting conditions, in space and time, as well as to other limitations due to the nature of the specific items being evaluated

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Direct vs. indirect costs

- Direct costs
  - normally described in terms of cost of the implementation of countermeasures
    - e.g., countermeasures to reduce doses, radiation-induced health effects

- Indirect costs
  - cover the effects which are produced out of the areas directly impacted by the contamination, as for instance the impact on non-contaminated food marketing, on tourism, or on the nation's nuclear programme
  - normally difficult to quantify a priori, but they are amenable to an a posteriori evaluation

Cost categories of nuclear reactor accidents [OECD/NEA 2000]

On-site Costs	Cost of decommissioning and decontamination Loss of capital (e.g. installed capacity)
Cost of countermeasures to reduce doses	Population movement - Transport away from the affected area - Temporary accommodation and food - Supervision of the evacuated area and monitoring of people - Loss of income for people unable to reach the workplace - Lost capital value and investment on land and property - Psychological effects of worry and upheaval Agricultural restrictions and countermeasures Decontamination - Cost of cleaning process, including the necessary equipment and materials, and the disposal and transportation of generated waste - Cost of labour - Cost of health effects induced in the workforce
Radiation-induced health effects in the exposed population	Cost of radiation-induced health effects : (1) early effects, (2) latent effects, (3) hereditary effects - Direct health care costs - Indirect costs, due to the loss of earnings during treatment and convalescence or of the total - Non-monetary costs, such as pain, grief and suffering associated with each effect
Psychological effects	
Impact on the activity with which the installation is associated	For example the nuclear power programme
Impact on economic factors	Employment, revenues, losses of capital, etc.
Long-term social and political impact	
Environmental and ecological impact	

IRSN study on cost of a nuclear accident (Momal et al 2013)

- Hypothetical case 900 MWe French PWR
  - “severe” accident, controlled release
  - “major” accidents, such as Fukushima or Chernobyl

	Severe accident		Major accident	
	b€	%	b€	%
On-site costs	6	5%	8	2%
Offsite radiological costs	9	8%	53	13%
Contaminated territories	11	10%	110	26%
Costs related to power production	44	37%	90	21%
Image costs	47	40%	166	39%
Total (rounded)	**120**	**100%**	**430**	**100%**

IRSN study cost categories

On-site costs	
Decontamination and decommissioning	Based on lessons learned from TMI
Electricity replacement	Corresponds to the value of the lost reactor and outages experienced by other on-site reactors
Other on-site costs	Marginal in comparison to the above
Offsite radiological costs	
Emergency countermeasures	Marginal compared to other costs
Health costs (radiological)	Strongly depend on the amount of contaminated foodstuffs ingested by the population. Boycott by consumers and retailers is considered possible.
Psychological costs	Mainly lost workdays and long-term treatment costs. No allowance for patient suffering (or social willingness to pay beyond hard costs).
Agricultural losses	Strongly depend on standards or boycott by consumers/retailers
Image costs	
Impact on Agricultural and Foodstuffs exports	Relates to perfectly clean produce; based on experience from such episodes as the Mad Cow Crisis, the Bird Flu or the Spanish Cucumber crisis in 2011 in Europe
Impact on Tourism	Based on crises in Tourism worldwide during the past 10 years
Reduction in other exports	Past experience is largely lacking in this area
Costs related to power production	The most plausible scenario given French procedures is a 10-year reduction in reactor lifetime
Contaminated territories	
Exclusion zones	Cost of radiological refugees (population of exclusion zones); cost of land considered as a capital (no additional willingness to pay or “value of motherland”)
Other contaminated territories	Based on feedback from Belarus; considers actual costs of contamination and tranfers, the latter providing a measure of the detriment to affected populations.

Economical impact
Advantages, disadvantages and uncertainties

✓ Ideal risk metric for decision making
Other risk metrics are surrogates

✗ Difficult agree on what to be accounted – general problem of risk decision making
Difficult to estimate indirect costs
How to avoid double counting the same effect when combining different assessments?

? Uncertainties are same as for health effects and environmental impacts
AND

- those related to the assessment difficultness's (see above)

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YOUR RISK NAVIGATOR

Level 1 and 2 PSA risk metrics as surrogates

1 Level 1 risk metrics not sufficient to health and environmental impacts

- Level 1 PSA could include an assessment economic impacts

2 Level 2 risk metrics could be a surrogate

- health, environmental and economic impacts are proportional to release categories (source term and timing)
- in order to compare with level 3 risk criteria, some site-specific level 3 PSA must be done to define the relationships between release categories and off-site consequences

Conclusions

- Health effects and environmental impacts are obvious risk metrics — even if we do not do level 3 PSA
  - Level 2 risk metrics may be used as surrogates but need site-specific validation
  - Risk criteria exist for health effects risk metric
  - Need for an environmental risk criterion?

- Economic impact is an ideal risk metric but cannot be defined unanimously and cannot be estimated comprehensively
  - needed for cost-benefit studies
  - different stakeholders may choose different weights for cost categories
  - may be sufficient to estimate the order of magnitude

Recommendations for the pilot applications (Task 4)

- preferably more than one site is studied
  - the effect of site-specific features
  - comparison of consequence assessment codes
  - effect of quality of input data

- consider all risk metrics
  - in order to find out our capabilities and limitations to estimate different impacts
  - try weight factor approach for combining different environmental and economic impacts

Jan-Erik Holmberg

jan-erik.holmberg@riskpilot.se
+358(0)40 827 6656

Level 3 PSA – Task 2: Regulations, guides and standards

First year seminar
January 21st, 2014

Lloyd's Register Consulting

Working together for a safer world

Task 2 - Presentation overview

- Purpose and objectives
- ANS/ASME Level 3 PSA standard (58.25)
- IAEA activities
- International activities

Purpose & objectives

- The purpose of Task 2 is to provide the ability to observe and influence the development of Level 3 PSA regulations, guides, and standards
  - Task 2 will provide input to the Task 0 and Task 1 activities
  - Provide feedback to external organizations based on the findings of the working group's activities.

ANS/ASME Standard

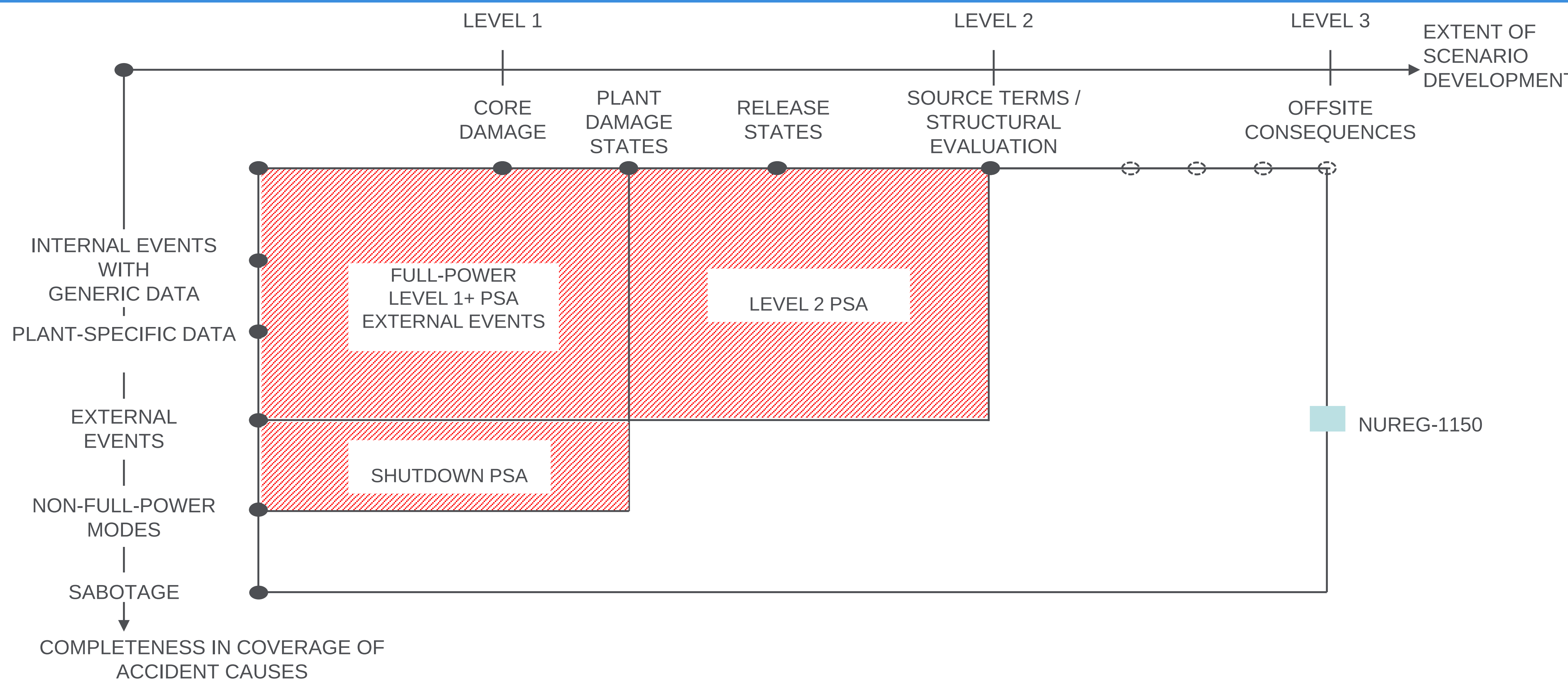
ANS/ASME Level 3 PSA standard 58.25

- The ANS/ASME Standard was intended to be the focus of Task 2,
  - no in-person meeting took place during 2013
  - modest progress over the past year
- Focus of Task 2 shifted toward the IAEA work
- What will be presented comes mostly from participation in the Level 3 PSA writing committee during the course of my thesis work (2011-2012)

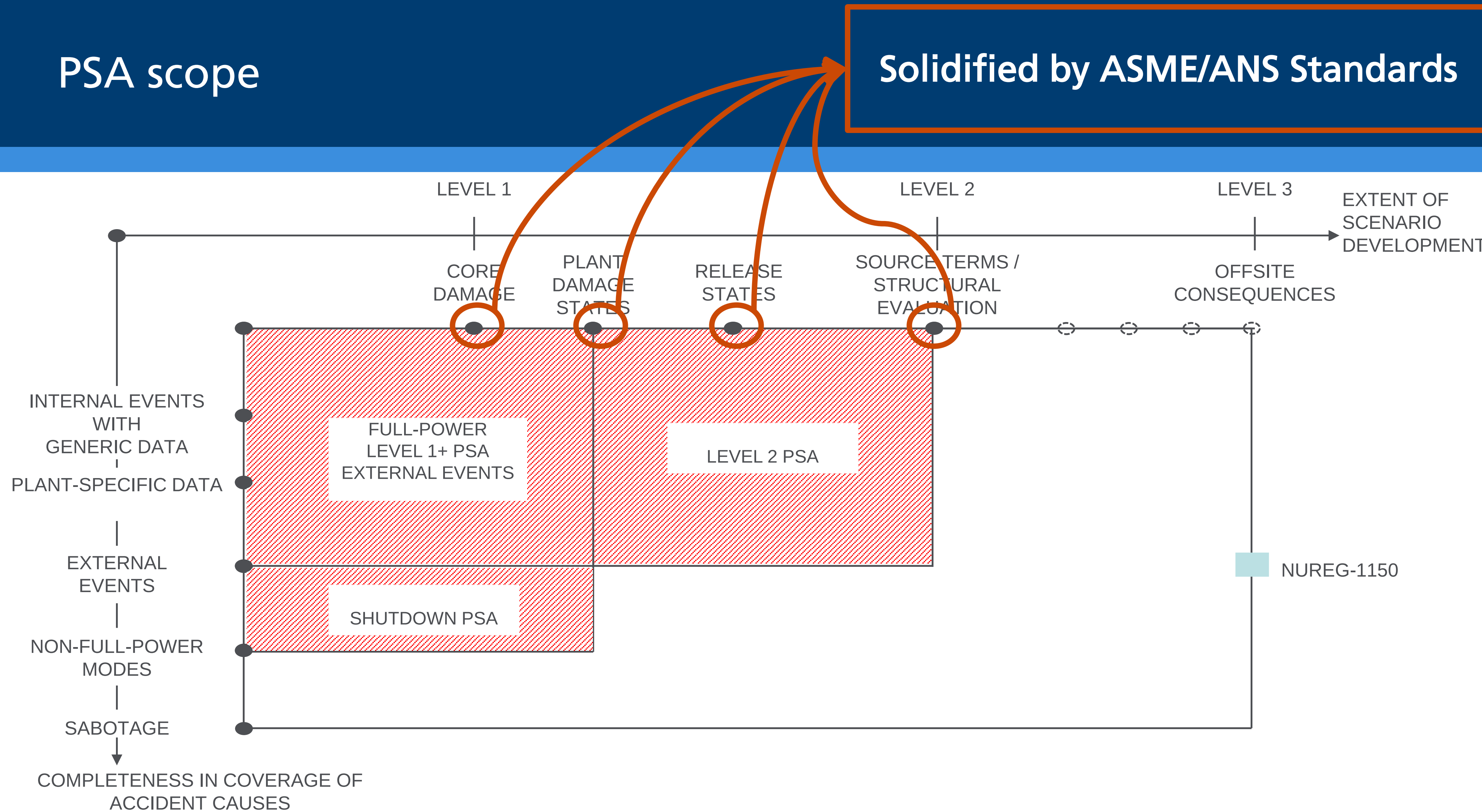
ASME/ANS PSA Standards

- Parallel development of Level 2 & Level 3 PSA standards
- Scope & purpose
  - Facilitate peer reviews for nuclear facilities
  - Establish anchor points for PSA analysis
- Structure
  - Technical elements of Level 3 PSA
  - Set of ~3 High Level Requirements (HLR) for each Technical Element
  - Set of Supporting Requirements (SR) for each HLR
    - Specific actions in implementing HLRs
    - Three levels of Capability Categories (CC) for each SR
    - Each CC is ascending in “Realism” & “Site-Specificity”

PSA scope


LEVEL 1
LEVEL 2
LEVEL 3
EXTENT OF SCENARIO DEVELOPMENT
CORE DAMAGE
PLANT DAMAGE STATES
RELEASE STATES
SOURCE TERMS / STRUCTURAL EVALUATION
OFFSITE CONSEQUENCES
INTERNAL EVENTS WITH GENERIC DATA
PLANT-SPECIFIC DATA
EXTERNAL EVENTS
NON-FULL-POWER MODES
SABOTAGE
COMPLETENESS IN COVERAGE OF ACCIDENT CAUSES
FULL-POWER LEVEL 1+ PSA EXTERNAL EVENTS
LEVEL 2 PSA
SHUTDOWN PSA
NUREG-1150

PSA scope


Solidified by ASME/ANS Standards
LEVEL 1
LEVEL 2
LEVEL 3
EXTENT OF SCENARIO DEVELOPMENT
CORE DAMAGE
PLANT DAMAGE STATES
RELEASE STATES
SOURCE TERMS / STRUCTURAL EVALUATION
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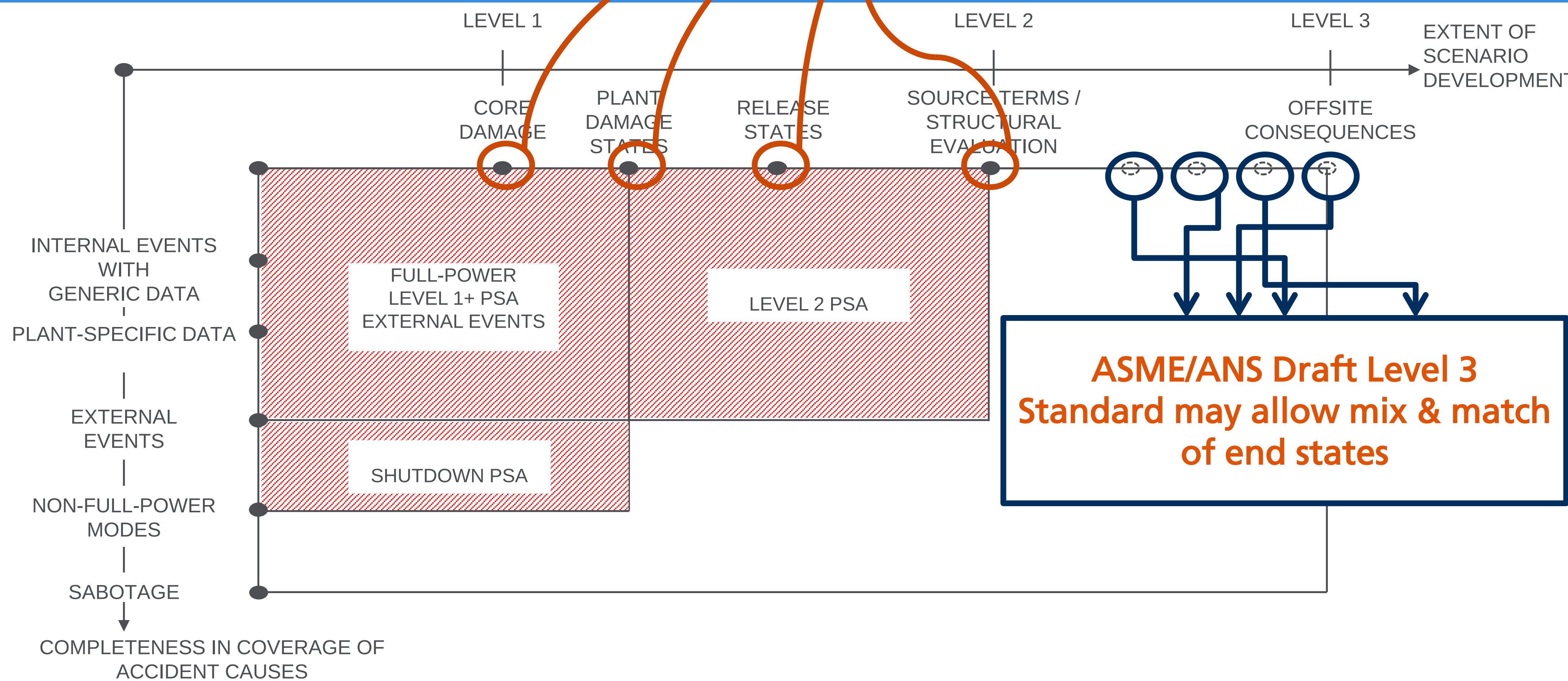
NUREG-1150

PSA scope

Solidified by ASME/ANS Standards



ASME/ANS Draft Level 3 Standard may allow mix & match of end states

ASME/ANS Level 3 PSA Standard

- Scope
  - Facilitate peer reviews on Level 3 PSA for nuclear
- Structure
  - Technical elements of Level 3 PSA
    - e.g. meteorological data, diffusion model, economic considerations
  - High Level Requirements (HLR)
    - e.g. data, modeling, documentation
  - Supporting Requirements (SR)
    - Specific actions in implementing HLRs
- MACCS is experience basis

“Capability categories”

Attributes	Capability Category I	Capability Category II	Capability Category III
1. Site-specificity: The degree to which site/plant-specific information is incorporated such that the existing conditions are addressed.	Use of generic data/models are acceptable.	Use of site/release specific data/models for the features that may have a significant impact on the results, e.g., the features of the site/plant or other source of radioactive release, as well as local area and regional features.	Use of site/release-specific data/models for all features with significant or even moderate impact on the results.
2. Model Realism: The degree to which realism is incorporated in the inputs and model.	Departures from modeling realism will have moderate impact on the conclusions and risk insights as supported by good practices.	Departures from modeling realism will have small impact on the conclusions and risk insights as supported by good practices.	Departures from modeling realism will have negligible impact on the conclusions and risk insights as supported by good practices.

ANS/ASME standard (example HLR, SR, CC)

Technical Element: Atmospheric transport and dispersion

Designator	High Level Requirement
HLR-AD-A	The analysis shall properly model the atmospheric transport and dispersion conditions at the site.
HLR-AD-B	The analysis shall include sampling of meteorological scenarios from the data base to provide probabilistic results.

AD-B1 Sampling Methods	Capability Category I	Capability Category II	Capability Category III
Sampling Methods	USE a suitable statistical sampling technique with a sufficient number of samples to ensure precision from the hourly meteorological data base for each simulated release (Note: This is not necessary if the entire data base is to be used.)		USE all hourly or quarter-hourly sequences in the data base to reduce statistical error.

MACCS monopolizes US analysis -> MACCS = CC-II

ANS / ASME Standard 58.25

- Development has progressed slowly on the standard
  - Level 2 PSA standard has also been quite slow
  - NRC involvement has been inconsistent
- Team is attempting to make it independent of software/methods
- Will not prescribe certain consequences as “required”
  - e.g. health consequences will not be a advised as a requirement in a cost-benefit analysis

IAEA activities in Level 3 PSA

IAEA activities in Level 3 PSA

- 1990s
  - Safety Series No. 50-P-12: Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants
- Recent
  - Technical Meeting – Level 3 Probabilistic Safety Assessment, 2-6 July 2012
  - TC RER915 Regional Workshop – “Level 3 PSA development and related issues”, 16-18 October 2013
  - Consultants’ Meeting - CM on Level 3 PSA, 25-28 November, 2013

IAEA Technical Meeting

- Level 3 Probabilistic Safety Assessment, 2-6 July 2012
- The purpose of the meeting was to inform the IAEA of:
  - current practices
  - recommendations for future agency activities in Level 3 PSA.
- Observations
  - During the course of the meeting it was apparent how widely varying the approaches to performance and regulation of Level 3 PSA are among the participating nations.
- IAEA actions
  - Development of TECDOC
    - Provide current guidance on Level 3 PSA
    - Series of Consultant Meetings to define Scope

IAEA Consultants Meeting – Level 3 PSA TECDOC

- An IAEA consultants meeting on Level 3 PSA took place in Vienna Austria from November 25-28, 2013.
- The meeting included several individuals from countries with active Level 3 PSA projects.
  - Sweden
  - Switzerland
  - South Africa
  - United States
- Objective of meeting
  - TECDOC to form current basis for agency guidance on Level 3 PSA
  - Determine general scope of TECDOC
  - Develop a TECDOC outline
  - Cite where old IAEA report and guidance are relevant or no longer

IAEA Safety Series No. 50-P-12

- “Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 3 PSA) – Off-site Consequence and Estimation of Risks to the Public“
- Level 3 PSA is final in the Safety Series Publications on Level 1, 2 and 3 PSA
  - Level 1 PSA No. 50-P-4 (1992)
  - Level 2 PSA No. 50-P-8 (1995)
  - Level 3 PSA No. 50-P-12 (1996)
- All publications in this series are “superseded”
  - Significant updated guidance provided for Level 1 and Level 2 PSA
  - IAEA has not provided further guidance on Level 3 PSA

IAEA Safety Series No. 50-P-12 – scope and limitations

Scope

- The main emphasis in this Safety Practices document is on the procedural steps
  - Not on the details of corresponding methods.
- This document is primarily intended to assist technical personnel with responsibilities in managing or performing PSAs.
- A particular aim is to promote a standardized framework, terminology and form of documentation for PSAs so as to facilitate external review of the results of such studies.
- The report outlines the methodology and indicates the techniques most widely used to date.

Limitations

- In general, this document seeks to provide sufficient detail to define unambiguously the methods to be used, while avoiding prescriptive detail
- The publication of this report is therefore not intended to pre-empt the use of new or alternative methods

IAEA Consultants Meeting – Level 3 PSA TECDOC

- Decision of scope
- Options
  - Update of Safety Series 50-P-12
  - Similar to TECDOC-1511 “Determining the quality of PSAfor applications in nuclear power plants”
  - Overview of current practices
- Decision
  - Develop general, non-prescriptive guidance similar to Safety Series 50-P-12
  - Extend to reflect on recommendation of 2012 Technical Meeting
  - Expand discussion on Level 2 & Level 3 PSA interface
  - Update examples and references
  - Not enough resources for TECDOC-1511 type document

TC RER915 Regional Workshop – "Level 3 PSA development and related issues", 16-18 October 2013

- Motivation
  - Region has expressed issue with inaccessibility in finding information on Level 3 PSA.
  - Many open questions in the eastern European region
  - A 3-day workshop could provide significant insight into the basic constituents, uses, and scope of a Level 3 PSA.
- Participants
  - Bulgaria
  - Belarus
  - Czech Republic
  - Lithuania
  - Russian Federation
  - Slovenia
  - Ukraine
  - Armenia
  - Croatia
  - Hungary
  - Netherlands (expert participant)
  - Slovakia
  - Sweden (expert participant)
  - United Kingdom (expert participant)

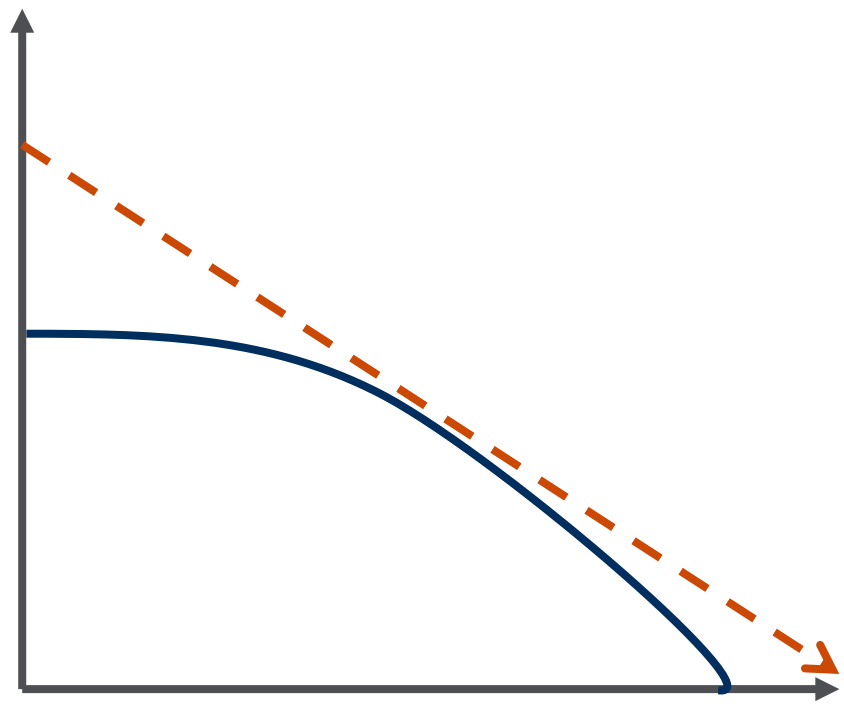
- In general relatively little Level 3 PSA has been performed or is currently in planning stages in eastern Europe. Two exceptions are:
  - Belarus (developing in-house Level 3 PSA software)
  - Czech Republic (starting study in 2014)
- Many good questions asked by group
  - Many questions of what input data is required to perform an analysis
    - Level 2 PSA source term data
  - Limitations of methods
  - Possible applications for Level 3 PSA

Interest and application of Level 3 PSA globally

- *Interest* in off-site consequence analysis is widespread
- The *applications* of these analyses are not widespread
- The criteria imposed upon off-site consequences vary greatly between national nuclear regulatory agencies
  - Some countries have update Level 3 PSA with updates to Level 1 and 2 PSA (South Africa & The Netherlands)
  - Simplified probabilistic off-site consequence studies (UK)
  - Cost-benefit analyses (USA)
- Many are waiting to see what happens with ANS/ASME Level 3 PSA Standard & IAEA recommendations

Netherlands
Off-site consequence criteria

- Level 3 PSA restrictions rather than Level 3 PSA
- Imposed on every plant (currently 1) in order to operate
- Consistent with other industrial regulations
- Analysis is performed using COYSMA program
- **Individual risk & Societal**
- **Societal risk** is defined on a logarithmically decreasing scale
- No surrogate Level 2 PSA requirement
- Noted in ENSREG Stress test report



United States & US Nuclear Regulatory Commission

- WASH 1400 ▶ NUREG 1150 ▶ *New Study*
- SOARCA (State Of the Art Reactor Consequence Analyses)
  - Study of MELCOR/MACCS2 code
  - **NOT** level 3 PSA
    - Methodology focused
    - *Felt to be less complete than Level 3 PSA*
- New Study, NUREG 1150 update
  - Discussions in ACRS (Advisory Committee on Reactor Safeguards)
  - In works since 2009
  - Renewed interest following Fukushima
- Severe Accident Mitigation Alternatives (SAMA)
  - Averted public exposure 2 USD per person-Sv.

New US Level 3 PSA study

- Objectives of Study
  - Demonstrate / determine value of Level 3 PSA
  - Train staff that have not been involved in full scope PSA previously
  - Develop 1-3 PSA for state of practice
- Schedule
  - Began and planning phase in 2012
  - Level 1 PSA nearly complete (at power)
  - Level 2 PSA will continue through the spring
  - Initial findings Fall 2014
- Technical issues
  - Applicable risk metrics (still undefined)
  - Tight budget and schedule constraints
  - Technical scope somewhat limited

Switzerland

- No regulatory requirement for Level 3 PSA
- Study for interest of Nuclear Power operator in case it is needed in the future
- Performed for specific (large release) accident sequences
  - 50 simultaneous U-tube rupture in steam generator
  - Air crash
  - Fast station blackout
  - Slow station blackout
- MACCS code for analysis
- Findings
  - “Surprising” low conditional probabilities numbers despite large scale sequences
  - Cross-border statistics and data acquisition was “biggest” challenge

Review of international perspectives toward Level 3 PSA

- Attitudes and applications of Level 3 PSA vary greatly internationally
- In Nordic countries Level 1 & 2 PSA proxy metrics often used in place of Level 3 PSA
- Criteria viewed as important varies
  - Stakeholders & special interests
  - Cultural sensitivity
- Contamination larger point of discussion following on-going Fukushima Daiichi issues
- Methods development is modest
  - MACCS
  - COYSMA -> PACE
  - ARANO / LENA
  - OSCAAR

Closing statements

- This work will continue through 2014
- Progress on the Level 3 PSA standard has been modest over the past year
  - Work began on the standard in 2004.
  - Still several years before completion
- IAEA work is poised to continue
  - Several CM will be required to continue on TECDOC
  - Possible further regional workshops
- Internationally there is significantly more work being done in Level 3 PSA
  - Large scale US NRC study
  - Some new methods work on “PACE”
- Significant interest in this NPSAG / NKS projects
  - Next Seminar to be planned at least 6 months in advance

Andrew Wallin Caldwell
Consultant
Lloyd's Register Consulting – Energy AB
T +46 (0)72 244 73 13 E andy.wallin-caldwell@lr.org

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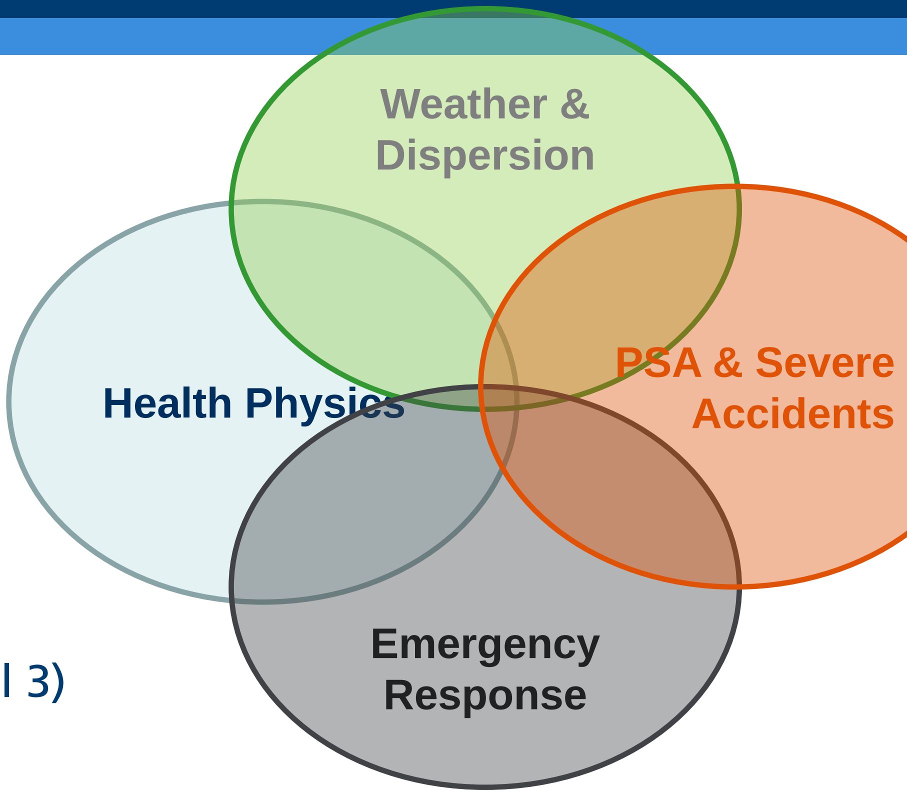
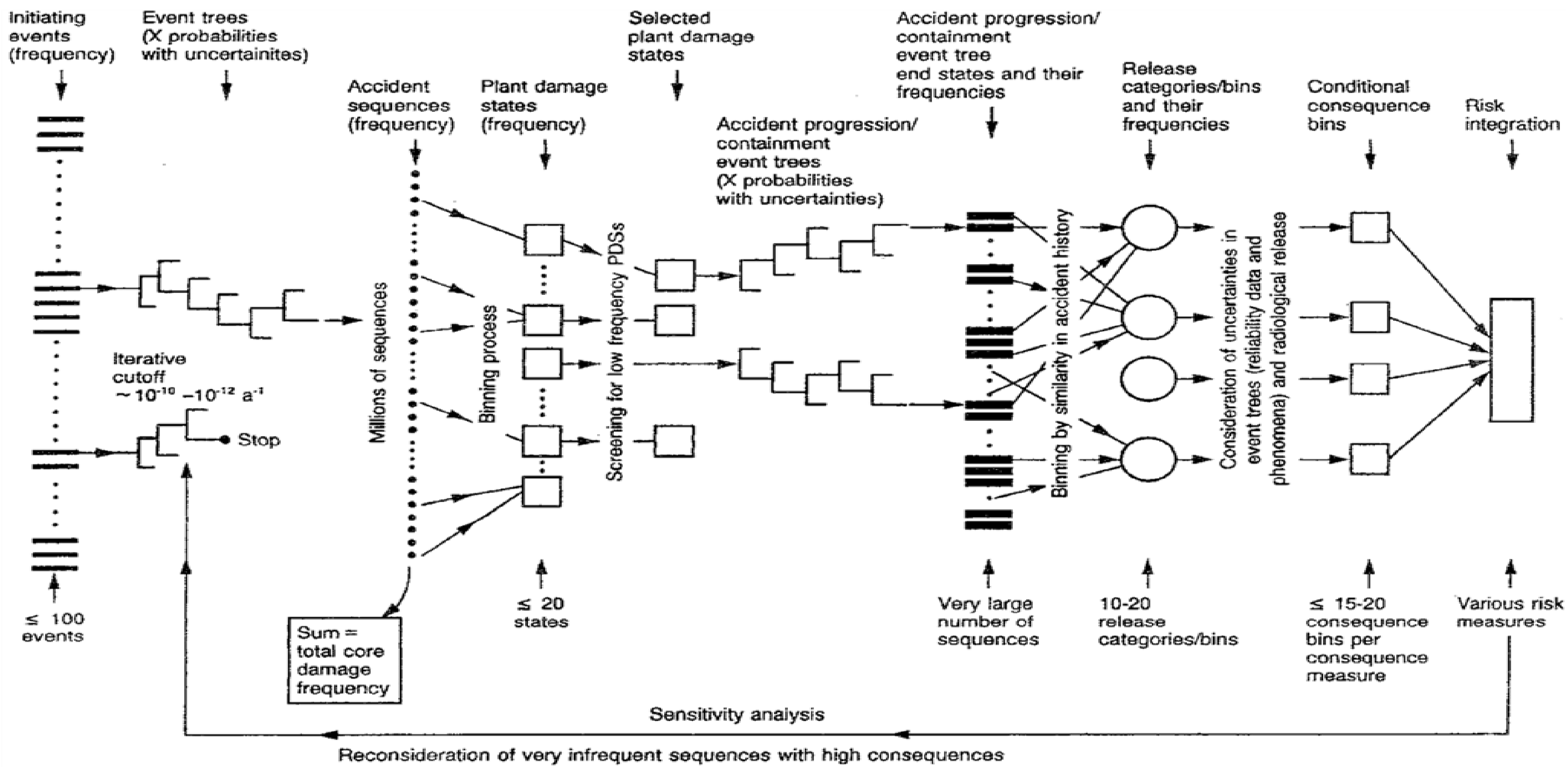
PSA level 3 – *Probabilistic Consequence Analysis (PCA)*

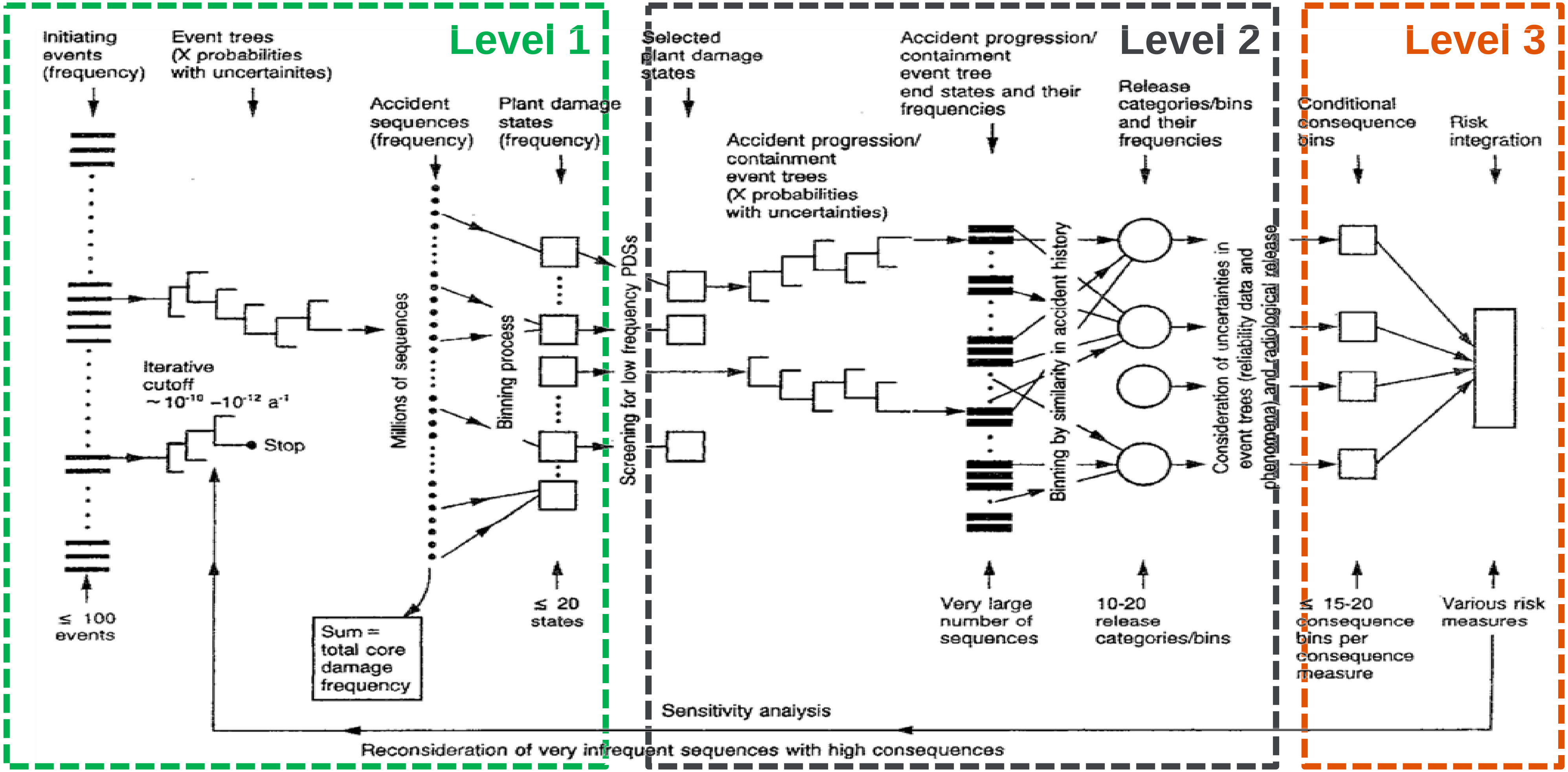


- History
  - USNRC WASH 1400 Report (1975)
  - NUREG 1150 (1991)
  - International PCA code comparison (1992)
  - IAEA Level 3 Safety Practices (1996)
- Not performed with frequency of other PSAs
  - Propagation of uncertainty (Level 1 ► Level 2 ► Level 3)
  - Direct discussions to value of human life
  - Resource intensive, diverse skills and expertise required
- Understanding impact and possibility and magnitude of a nuclear disaster, effect of reactor siting, effectiveness of contingencies

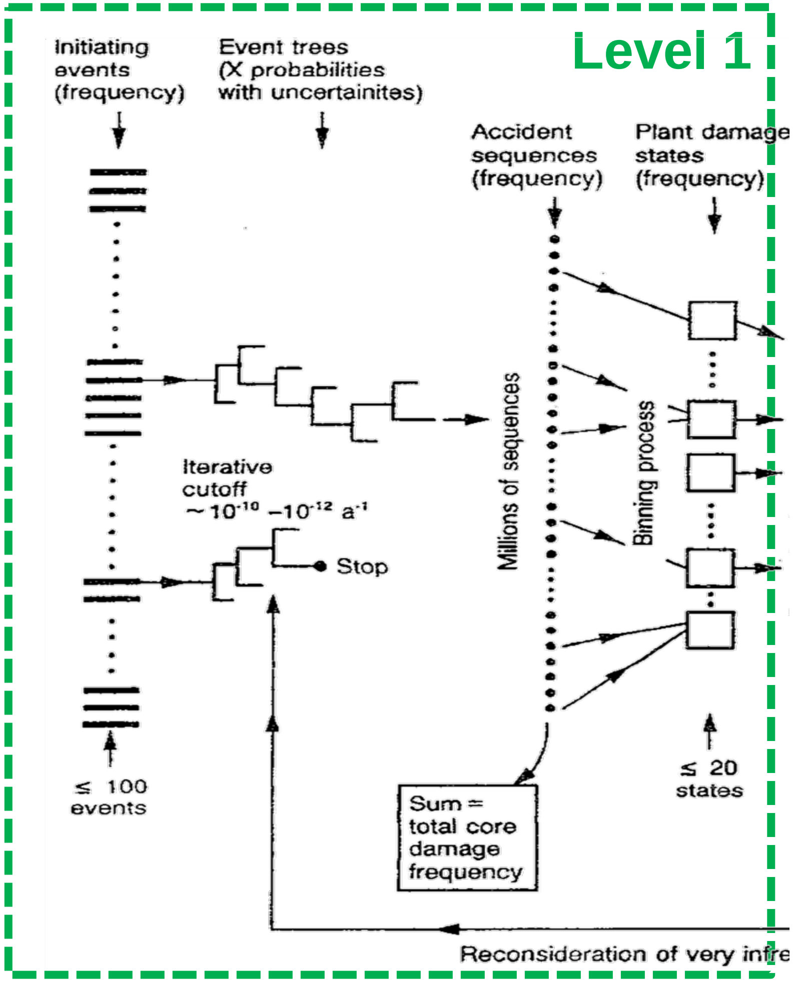
PSA overview



PSA overview



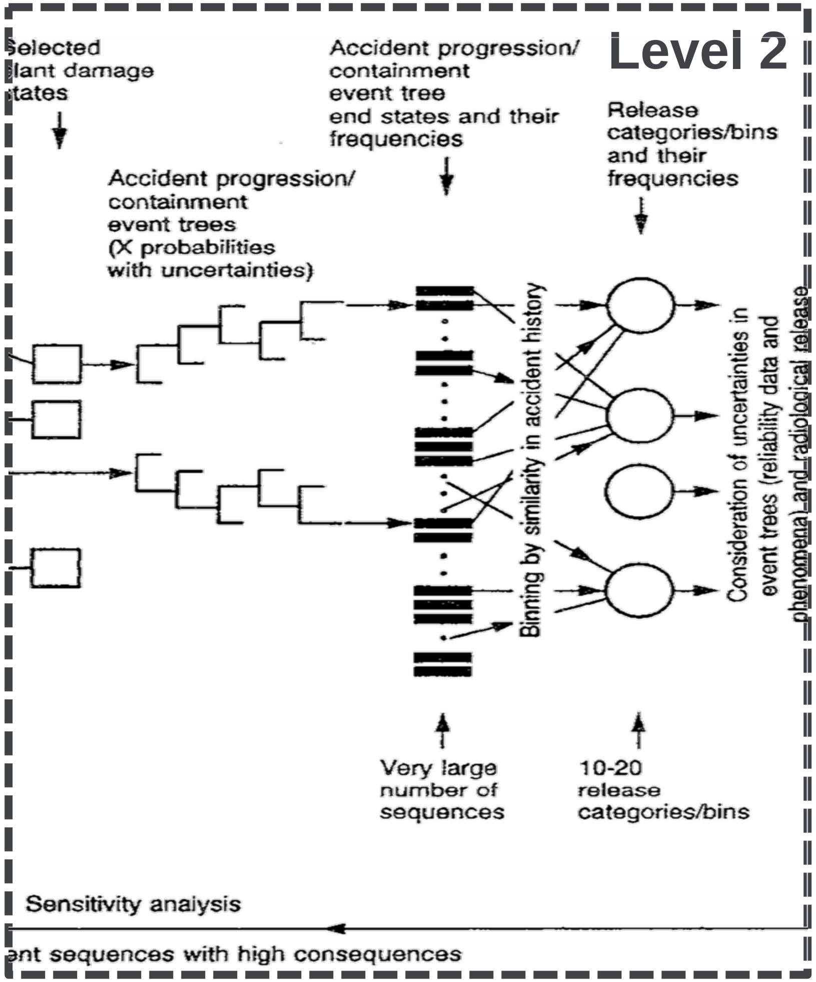
PSA overview



- Begins with initiating events
- Progresses through accident sequences
- Results in plant damage states

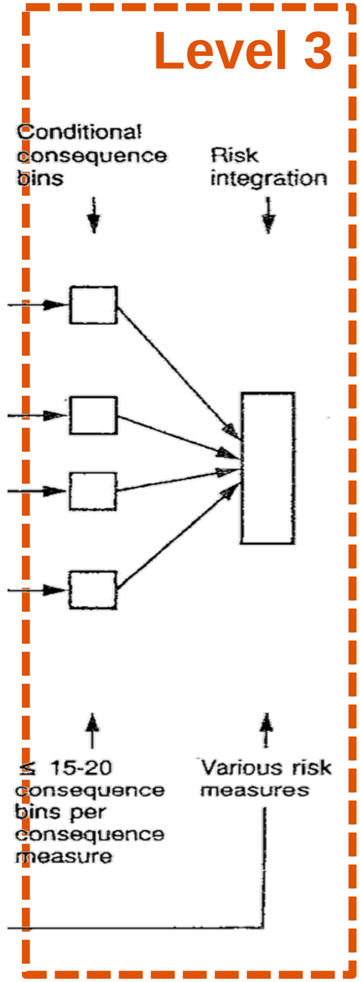
PSA overview

- Reduction of plant damage states into manageable subset
- Severe accident progression
- Release categories

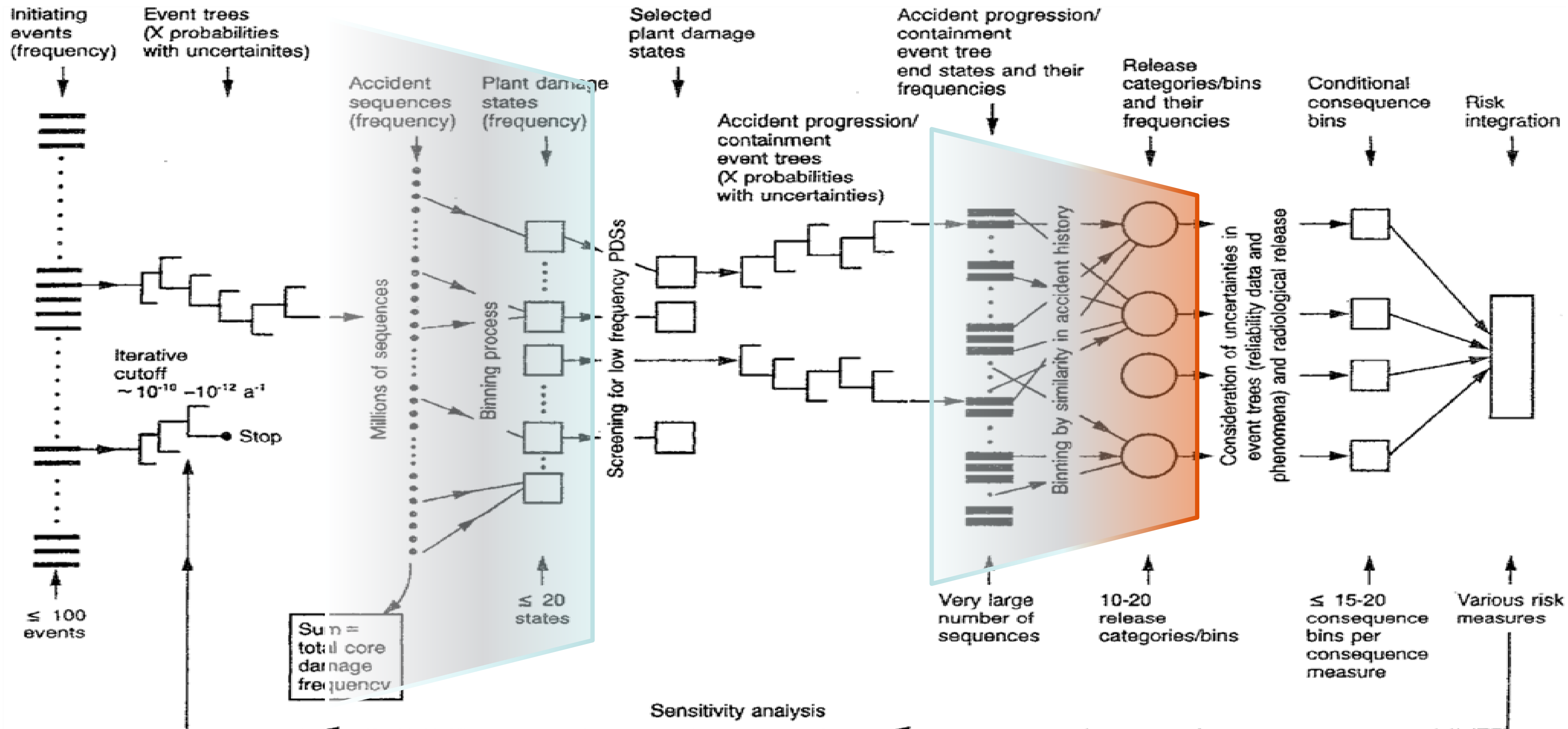


PSA overview

- Re-condense Level 2 PSA release categories into manageable subset
- Propagate release source terms
- "Risk Integration"
  - Determine *risks* based upon frequency and consequences of the Full Scope PSA.

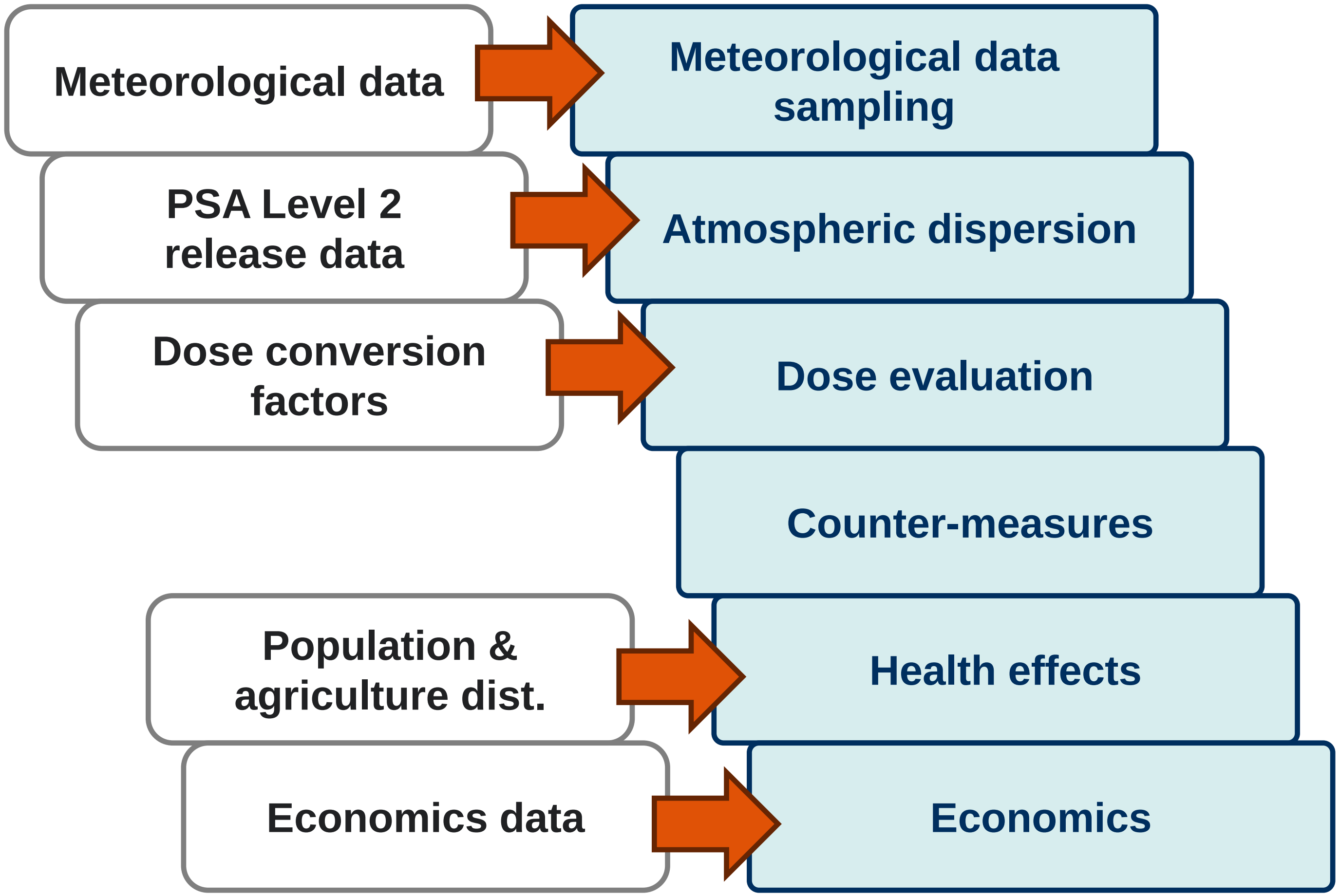


PSA overview



Event sequences propagate and are re-condensed after each level of PSA

Level 3 PSA methodology



Task 4 – VTT’s pilot

NPSAG/NKS Level 3 PSA seminar, 21.1.2014

Ilkka Karanta

VTT Technical Research Centre of Finland

Summary of the pilot plan

- IDPSA applied to level 3
- Scope
  - atmospheric dispersion of release(s)
  - their consequences on public health
  - Possibly also land area contamination
- Pilot case: the Fukushima Daiichi NPP disaster in March 2013

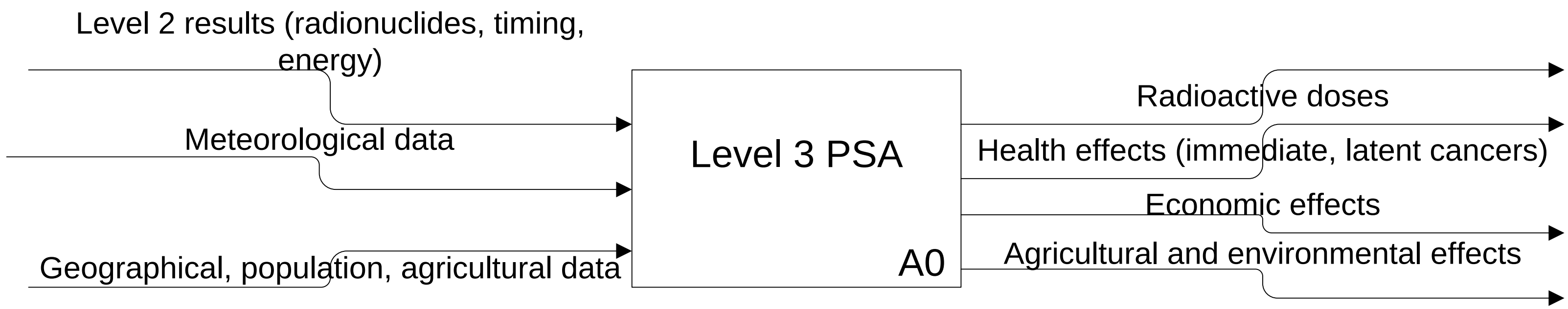
Background

- Level 3 analyses traditionally not required
- New YVL guide in Finland concerning severe accidents with release
  - there shall not be need for evacuation outside the protective zone (< 5 km)
  - no need for sheltering outside the preparedness zone (< 20 km)
- Task 4 of the ”Addressing off-site consequence criteria using Level 3 PSA” project

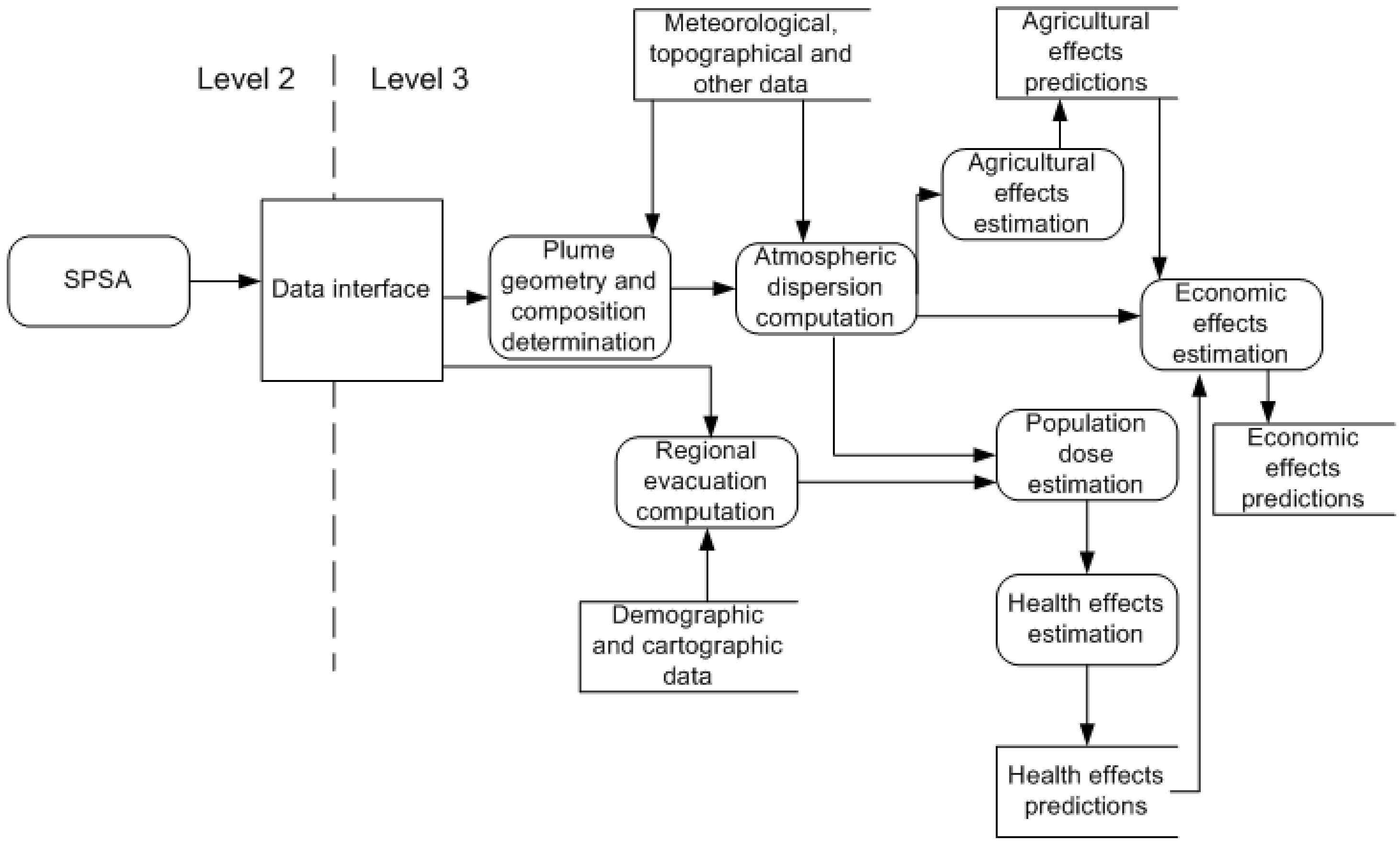
Motivation

- IDPSA methodology
  - Gain experience in applying it to level 3
  - Evaluate its usefulness on level 3
- Risk measures on level 3
  - Apply and evaluate
- Modeling and analysis
  - Develop methods for taking into account multiple source terms
- Software development
  - Gain experience in conducting level 3 analyses for SD purposes
- Other
  - Comparison with the Swedish approach
  - Issues related to shutdown conditions and fuel pool accidents

Level 3 inputs and outputs



Level 3 analyses



Integrated Deterministic and Probabilistic Safety Analysis

- Deterministic methods
  - Plant response
  - E.g. accident simulation codes (MELCOR, TEXAS-V etc.)
- Probabilistic methods
  - Stochastic disturbances
  - E.g. fault and event trees
- Integration
  - E.g. timing information from deterministic to stochastic
- Originally developed for level 2

Deterministic part on level 3

- Atmospheric dispersion
  - ARANO or a dedicated software (e.g. AERMOD)
- Dose calculations
- Health effects

Probabilistic part on level 3

- Source term
- Weather
- Countermeasures
    - Sheltering, evacuation, iodine tablets
- Human behavior

- Sources of probability estimates
    - Statistical analyses of e.g. weather data
    - Expert judgment
- Event tree

Uncertainty analysis on level 3

- Uncertainties
  - Input uncertainties
  - Parameter uncertainties
- Uncertainty propagation by Monte Carlo on the deterministic

Data requirements

- Source term
- Weather data
- Geographic data
- Population data
- Countermeasure data or plans

Source term

- Amount of each radioactive isotope (from inventory)
- Chemical composition
  - Not important for metals (Cs etc.)
  - Central for Iodine (organic or inorganic)
- Energy of the release (mainly temperature)
- Particle size distribution
  - If not available, must be postulated or inferred on level 3
- Height of the release
- Start time and end time of the release

Geometric and geographical data

- Geometry of the NPP
  - Geometric shape of the containment building (optional)
  - geometric shape and dimensions of the aperture in the containment, if available
  - From publicly available sources or officials
- Geographic data in the NPP surroundings and plume route
  - Ground elevation (topographic) data
  - Bodies of water
  - Vegetation (esp. tree coverage)
  - Locations of houses
  - Road network (for evacuation calculations)
  - Can be roughly estimated from e.g. Google maps

Weather data

- Coverage of the whole release and dispersion period
  - Longer periods if uncertainty analysis conducted
- Preferably hourly data
- Kinds of data
  - Air temperature optional
  - Wind speed and direction (airflow patterns)
  - Amount of atmospheric turbulence (stability class)
  - Precipitation (rainfall)
  - Mixing layer altitude
- From weather services

Demographic and countermeasures data

- Demographic data
  - Population distribution in the preparedness zone
  - E.g. can be roughly estimated from air photos (Google Maps) when the total population of the area is known
- Countermeasures data
  - Timing information most important
  - Sheltering
  - Evacuation
  - Iodine tablets
  - Relocation, food bans data etc. optional
  - From countermeasure plans or news accounts

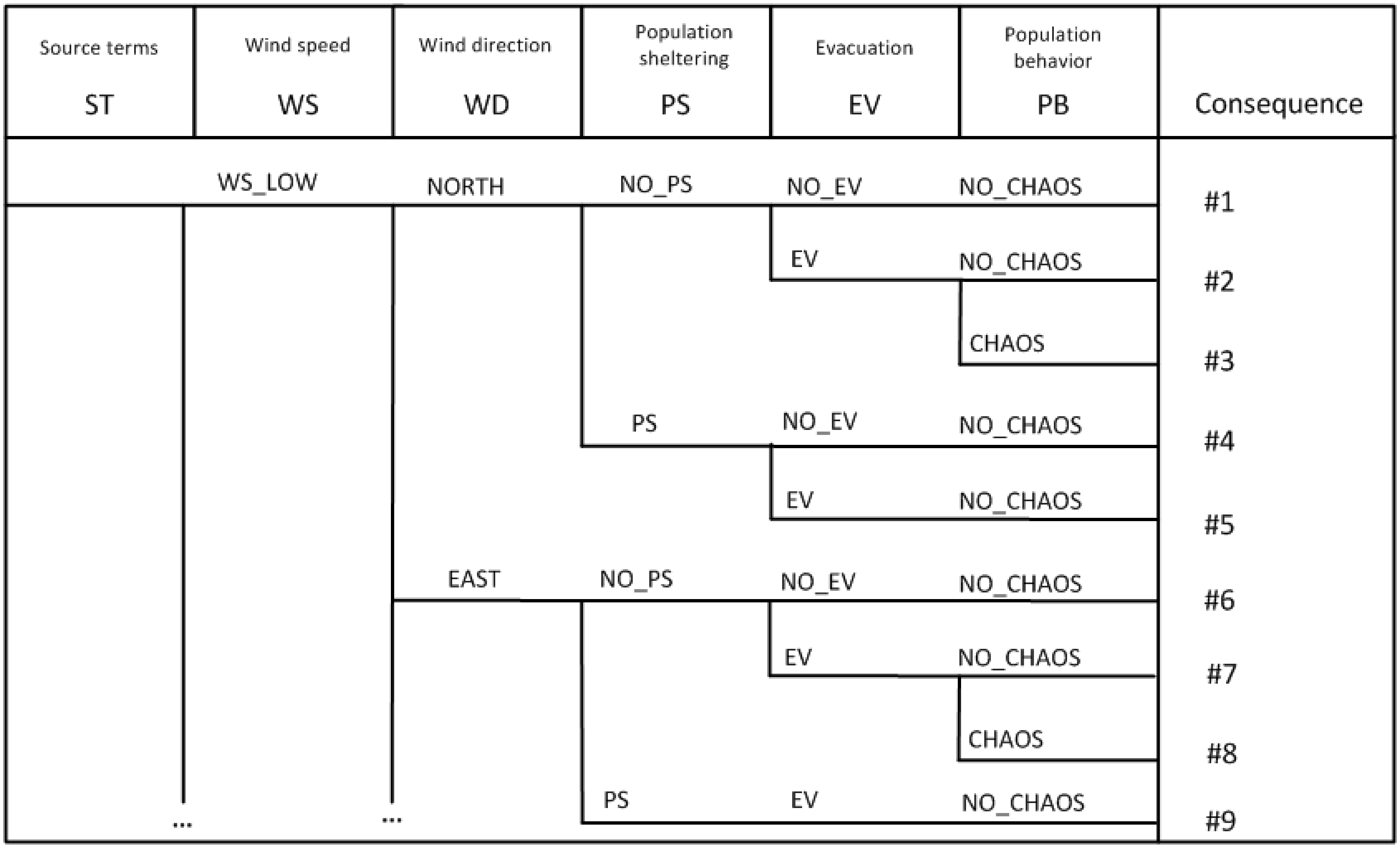
Atmospheric dispersion calculations

- ARANO
- free dispersion software (e.g. AERMOD)

Event tree analysis

- Event tree construction
  - Selection of variables
  - Discretization of continuous variables (e.g. wind direction)
- Analysis
  - With SPSA
    - Some aspects, such as timing, have to be modelled outside of the event tree → SPSA's CET language
- Problems
  - Some variables related to decisions (evacuation, its timing etc.)
    - How to find probabilities of decisions?

Sketch of an event tree (population dose)



Experimentation with risk metrics

- Goals
  - To gain experience with their practical implementation and its challenges
  - To evaluate uncertainty connected with them
- Means
  - Uncertainty analysis from input and parameter uncertainties
  - Monte Carlo
- Possible metrics
  - Collective dose
  - Cancer fatalities (long term)
  - Non-usable area of land

Kinds of analysis results

- Dispersion results
  - Fallout of radioactive metals
  - Spread of Iodine compounds
- Health effects
  - Doses
  - Health effects
- Economic consequences (not in the pilot)
  - Contaminated land area
  - Evacuation costs
  - Loss of production
  - Loss of produced electricity etc.

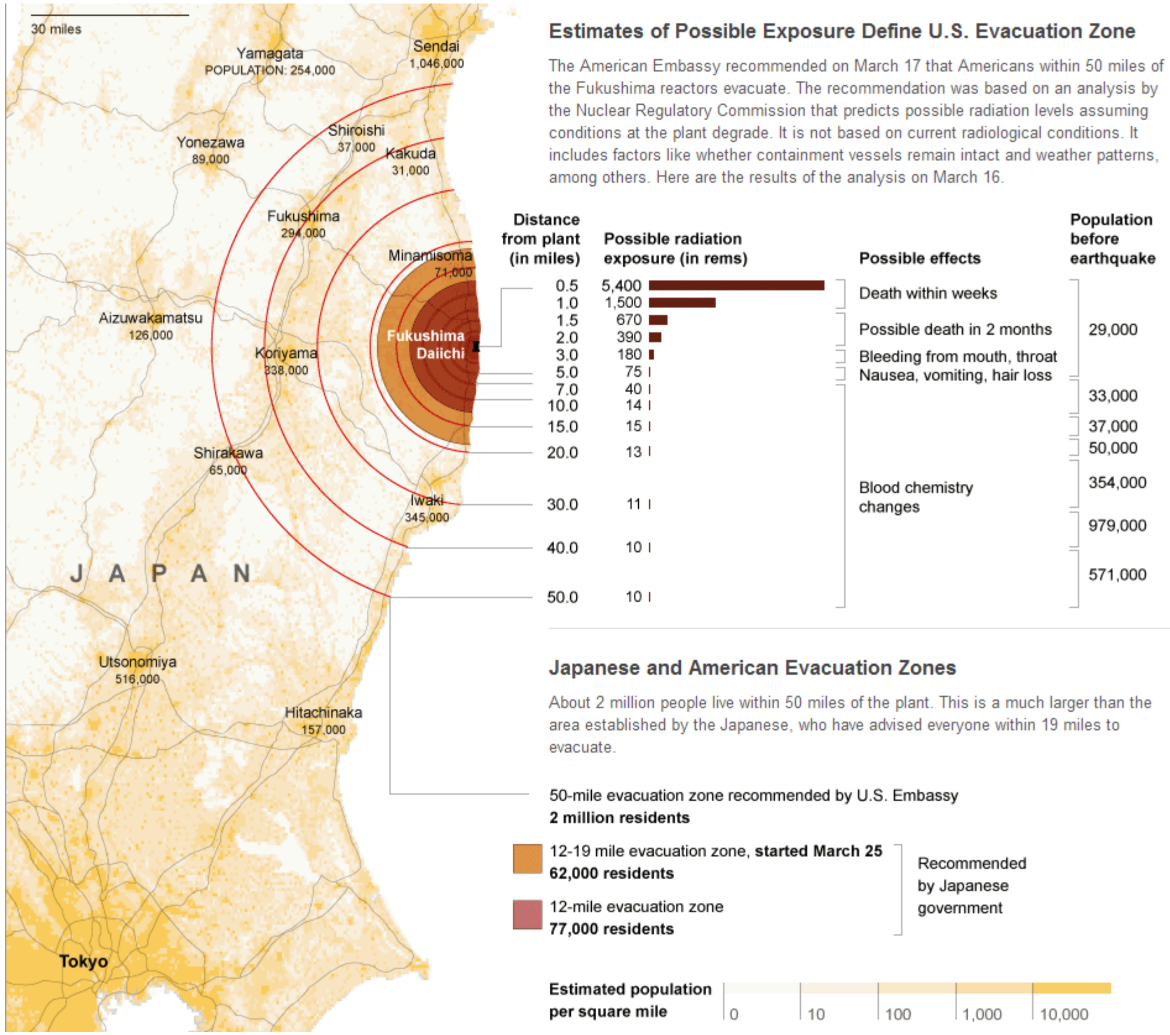
Probabilistic results

- Probability distributions for doses
  - From event tree
- Uncertainty analysis results
  - Probability distributions of probabilities

Case: Fukushima Daiichi disaster

- Data
  - Source terms from published papers
    - Problem: estimates vary widely
  - Weather data from the Finnish Meteorological Institute
  - Topographical data (coarse) from Google Maps
  - Demographic data (coarse) from NRC report
  - Countermeasures from published sources
- Analysis
  - Problem: several source terms from different sources at different times

Evacuation zones around Fukushima




TECHNOLOGY FOR BUSINESS

Addressing off-site consequence criteria using PSA Level 3 – First year project summary & Level 3 PSA Workshop

NPSAG/NKS Level 3 PSA seminar

Lloyd's Register Consulting

Working together for a safer world

Project Overview
3 year plan – Planned work distribution

Task	2013	2014	2015
Task 0 – Survey	100%	-	-
Task 1 – Risk Metrics	75%	25%	-
Task 2 – Regulation & Standards	75%	25%	-
Task 3 – Guidance document	-	50%	50%
Task 4 – Pilot Application	-	33%	67%
Project Management & other costs	33%	33%	33%

Phase 1 – Project Overview and Seminar Objective

- During Phase 1 the project has been divided into the following sub-tasks:

Subtask	Task Leader 2013
Task 0 – Industry Survey	ES-Konsult
Task 1 – Appropriate Risk Metrics	Risk Pilot
Task 2 - Regulation, guides and standards	Lloyd's Register Consulting
Task 3 – PSA Level 3 Guidance Document	-
Task 4 – Pilot Application	VTT

Phase 1 documents

- Phase 1 will result in the following documents:
  - Project Plan
  - Task 0 – Industry Survey
  - Task 1 – Risk Metrics
  - Task 2 – Regulation, guides and standards
  - Task 4 – "A plan for a case study of level 3 PSA using IDPSA"
  - NKS Summary Report which will summarize the above documents

? Question for stakeholders:

  - Would stakeholder like to be able to provide comments for each task report or only the Summary Report?

Workshop

- In order to get input that will aid in the planning of Phase 2 (2014), some questions have been identified that will be discussed within a workshop format.

- Group definitions and questions are provided in printed document.

- Time table to stick with:
  - 15:00 – 15:50 Group discussions & Coffee
  - 16:00 – 16:30 Each group present their conclusions, 10 min/group

  - All groups are to hand in their notes from the discussions in the form provided

? Question for stakeholders:
  - How would stakeholders like to participate in Phase 2?

Anders Olsson
Deputy Managing Director / Principal Consultant
Lloyd's Register Consulting – Energy AB
T +46 (0)40 680 64 05 E anders.olsson@lr.org

Lloyd's Register Consulting
www.lr.org/consulting

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