# Probabilistic Safety Criteria for Nuclear Power Plants

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# Introduction

- **The project was initiated after recommendations from NPSAG (Nordic PSA Group)**
- **The project deals with Safety Goals for NPPs**
  - More general ”Probabilistic Safety Criteria”
- **These are discussed in the context of the Probabilistic Safety Assessment (PSA) of an NPP**

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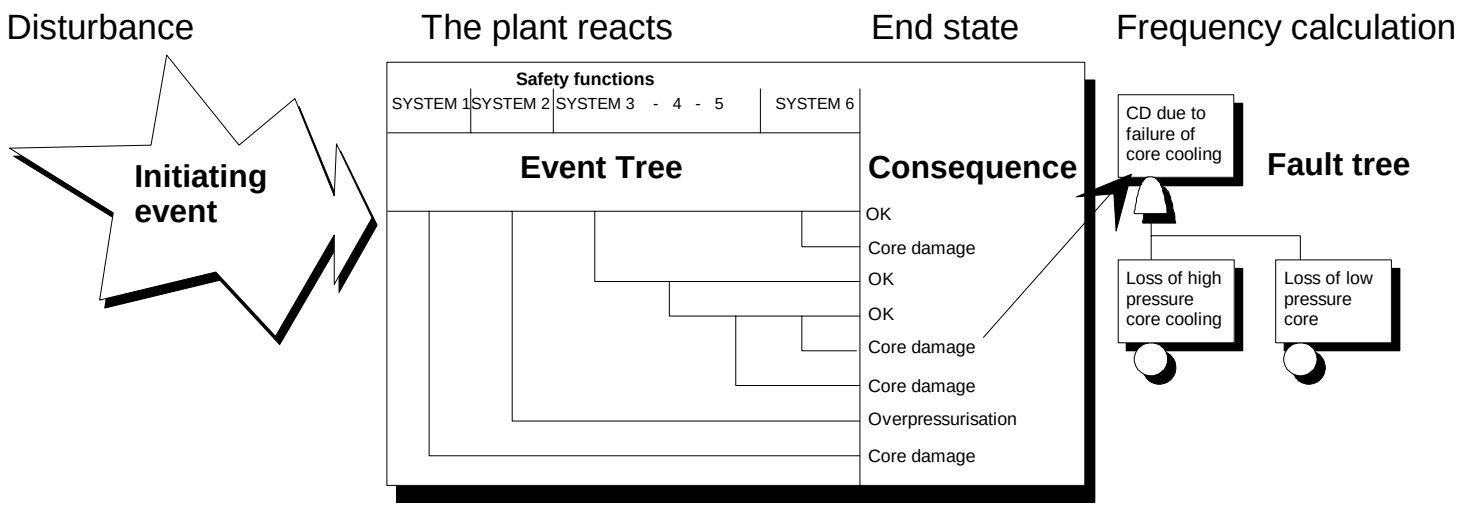


*PSA – qu'est-ce que c'est??*

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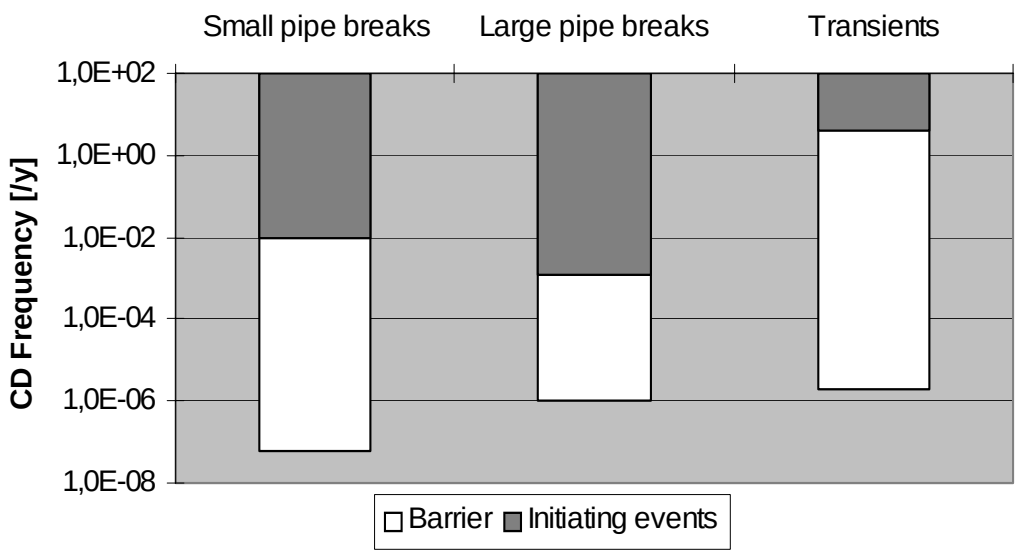
# Development of PSA

- **PSA.s started being performed in late 70s**
- **1st generation PSA:s i Sweden and Finland in mid-80s**
  - Now part of plant SAR:s with update requirements
- **Safety goals first defined in the beginning of the 90s**
- **Gradual scope extension of PSA:s**
  - Scope of PSA (internal events, area events, external events)
  - Coverage of PSA (power operation, start-up/shutdown, cold/refuelling shutdown)
  - Level of detail of modelling (functional dependencies, non-safety systems, …)
- **Extensive R&D in parallel**
  - CCF/Common cause failures, HRA/Human reliability analysis, event data, modelling of complex initiators (fire, external events…), etc. etc.
- **PSA:s are slowly becoming ”complete”…**
- **Current trends**
  - Increased formal requirements on PSA use (and acceptance of use)
  - Risk-informed / risk-based applications
  - Risk monitors, risk follow-up, preventive maintenance planning

# PSA results

- **Depending on the aims, the results of a PSA can be presented in different ways.**
- **Usually presented as frequency of**
  - Core damage (PSA level 1)
  - Unacceptable release (PSA level 2)
  - Off-site consequences (PSA level 3)

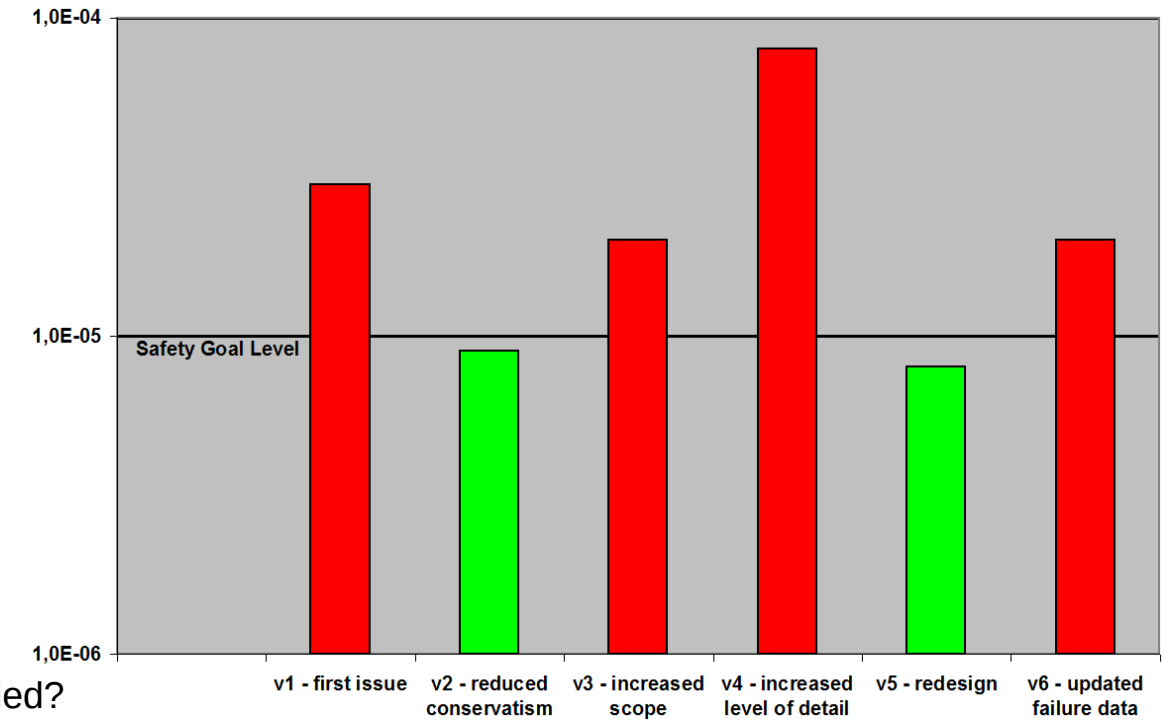


# Starting point of NKS project

- **Long experience with PSA**
  - Gradual increase of scope and level of detail since early 1980:s
  - Today's PSA:s are more or less complete

- **Safety goals not possible to fulfill?**
  - Safety goals outlined in the 1980s hard to achieve for operating plants.
    - NRC/IAEA - $10^{-4}$ per year for CDF (Core damage frequency)
    - Swedish utilities - $10^{-5}$ per year for CDF

- **This has aroused confusion!**
  - What safety goals should be applied?
  - Is the risk level of the plants too high?
  - Are PSA:s too conservative?
  - Are safety goals applied in an incorrect way?



# Project overview

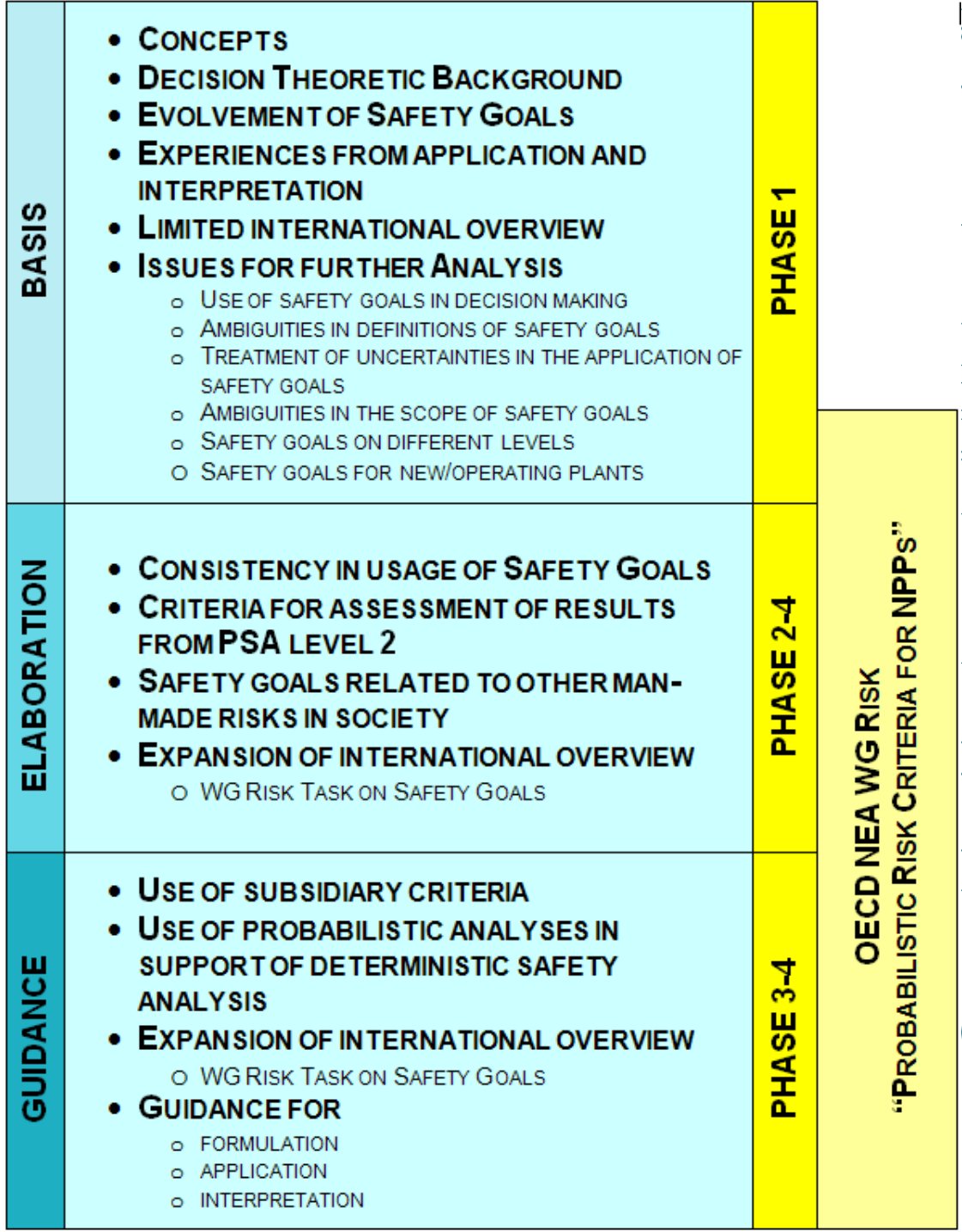
**Nordic project "The Validity of Safety Goals"** — **2006**

NKS (Nordic Nuclear Safety Research)

NPSAG (Nordic PSA Group)

SAFIR (Finnish NPP safety research programme) — **2007-2009**

Co-operation with OECD/NEA WGRisk task 2006(2) — **2009**

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# What is a probabilistic safety goal?

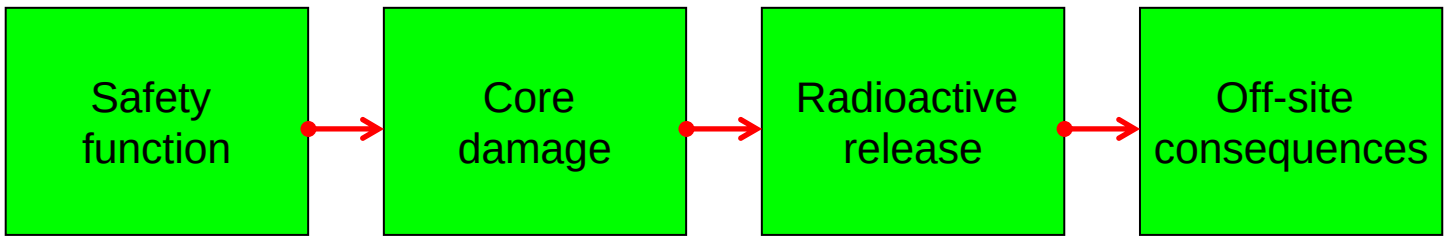
- **Lots of alternative formulations**
  - Risk/Safety limit/criteria/target/objective
  - … sometimes (but not always) synonyms

- **Main elements**
  - **Probabilistic**
    - The frequency or probability to be achieved/demonstrated/aimed for
  - **Safety**
    - The risk metric (fatalities, core melts, system failures, etc.)
  - **Goal**
    - ... vague... (voluntary/mandatory; limit/objective, etc.)

- **Also needed**
  - …but usually receiving less attention
  - Definition of **scope of plant model** and of procedure to calculate risk level to be compared (“Target PSA”)
  - **Procedure for applying** the goal and acting on the outcome of the comparison (goal met / goal violated)

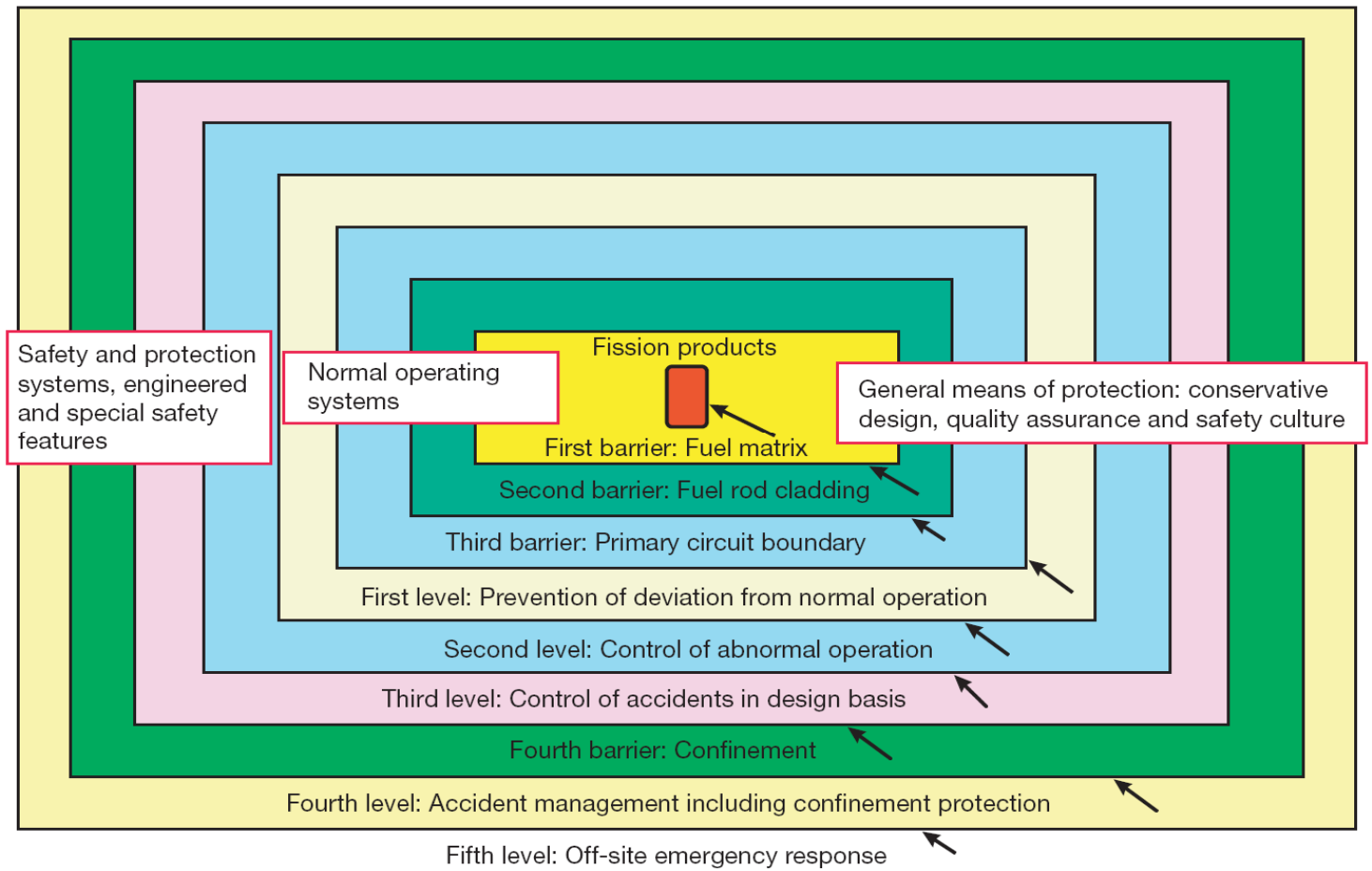
# Levels of Safety Goals

- **Important aspects of risks from nuclear power plants**
  - Health risk to people (individual/collective)
  - Risk of long-term contamination (evacuation, land use)
- **Accidents with significant off-site damage are extremely rare**
- **Levels of safety goals**
  - Off-site consequences (corresponds to PSA level 3)
  - Radioactive release from plant (corresponds to PSA level 2)
  - Core damage in plant (corresponds to PSA level 1)
  - Loss of important safety function (ECCS, RHR, scram, containment isolation)

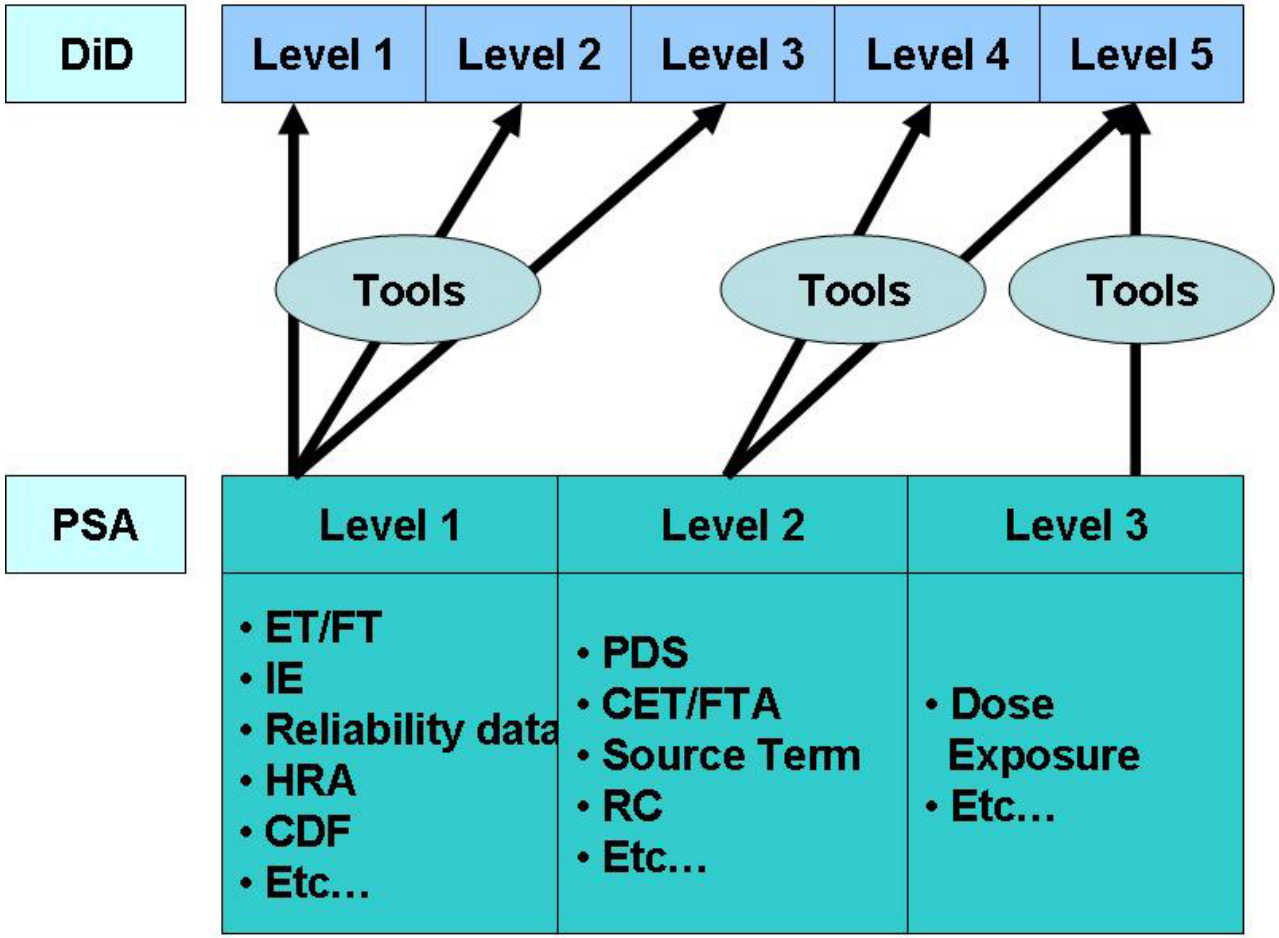



- **Important additional aspect: Defence in depth**

# Defence in Depth (INSAG 12) – Physical barriers and levels of protection



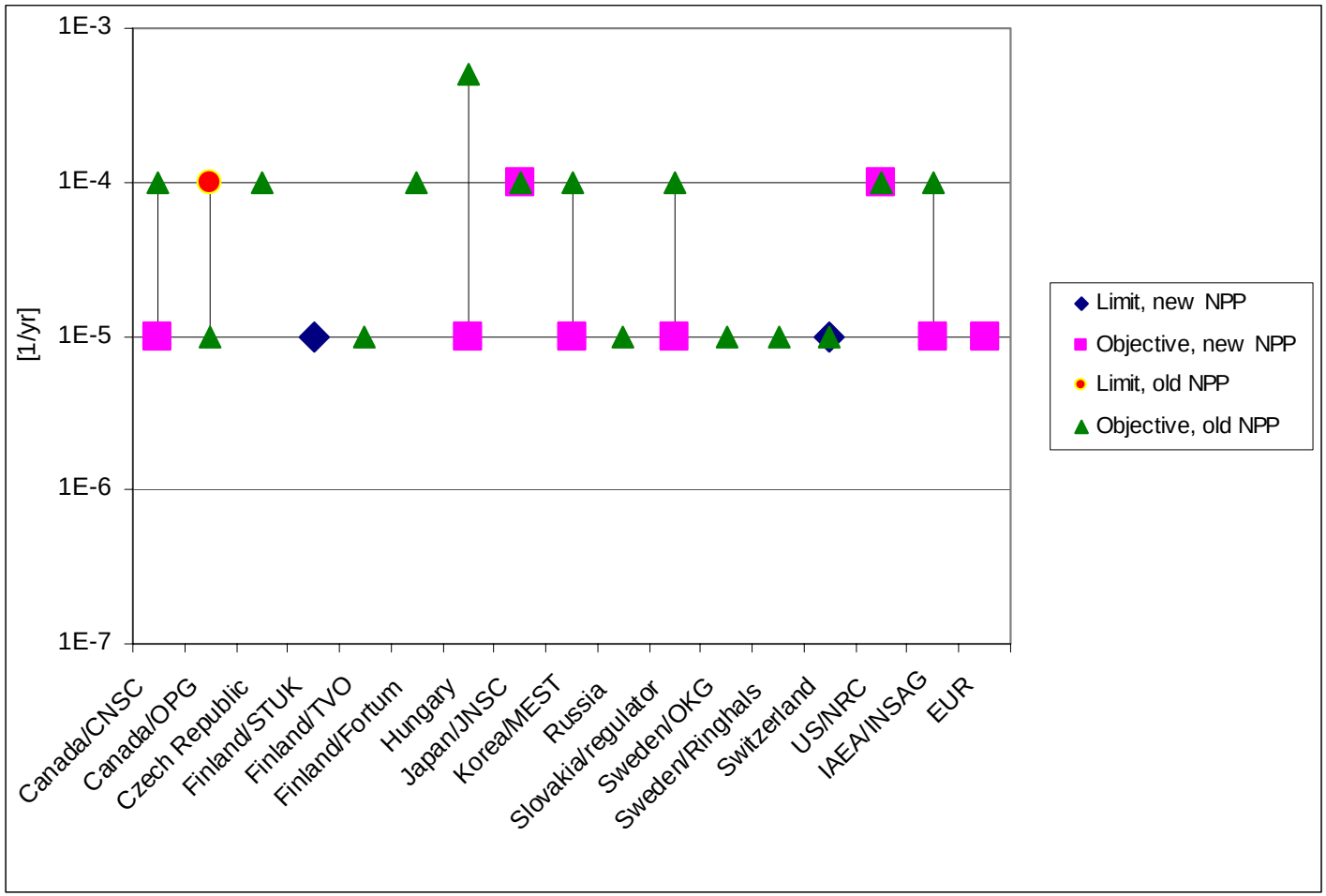
# Defense in depth and probabilistic analysis?



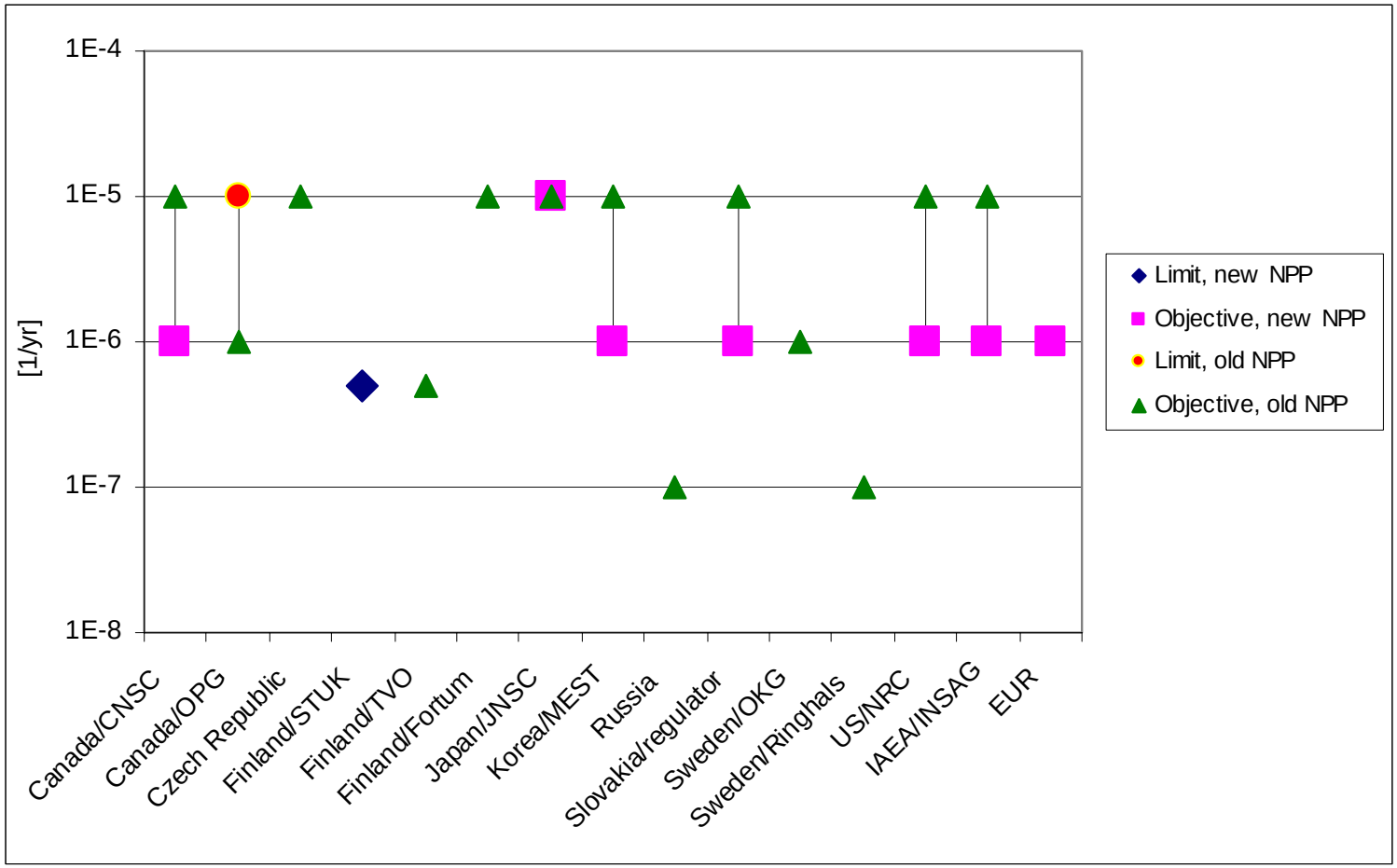
# Summary of Swedish safety goals

| Authorities | Vattenfall | Sydkraft / EON |
|---|---|---|
| 1985<br>Core damage<br>-<br>Release<br>”Extremely unlikely” release of more than 0,1 % of the inventory of the cesium isotopes $Cs_{134}$ and $Cs_{137}$ in a core of 1800 MWt,<br><br>(Interpreted as < $10^{-7}$/year?) | 1990<br>Core damage<br>$10^{-5}$/year with a high degree of confidence<br><br>Release<br>$10^{-7}$/year for a release involving more than 0,1% of the core inventory of substances causing ground contamination. | 1995<br>Core damage<br>$10^{-5}$/year<br><br>Release<br>$10^{-7}$/year for release involving more than 0,1% of the core inventory excluding noble gases. |
| | 2006<br>Core damage<br>$10^{-5}$/year for core damage<br><br>Release<br>$10^{-7}$/year for a release involving more than 0,1% of the core inventory of substances causing ground contamination | 2006<br>Core damage<br>$10^{-5}$/year for severe core damage<br><br>Release<br>Frequency of release involving more than 0,05-0,1% (depending on thermal effect) of the core inventory excluding noble gases shall be considerably lower than $10^{-5}$/year. |

# Numerical values defined for the core damage criterion



# Numerical values defined for the large release criterion

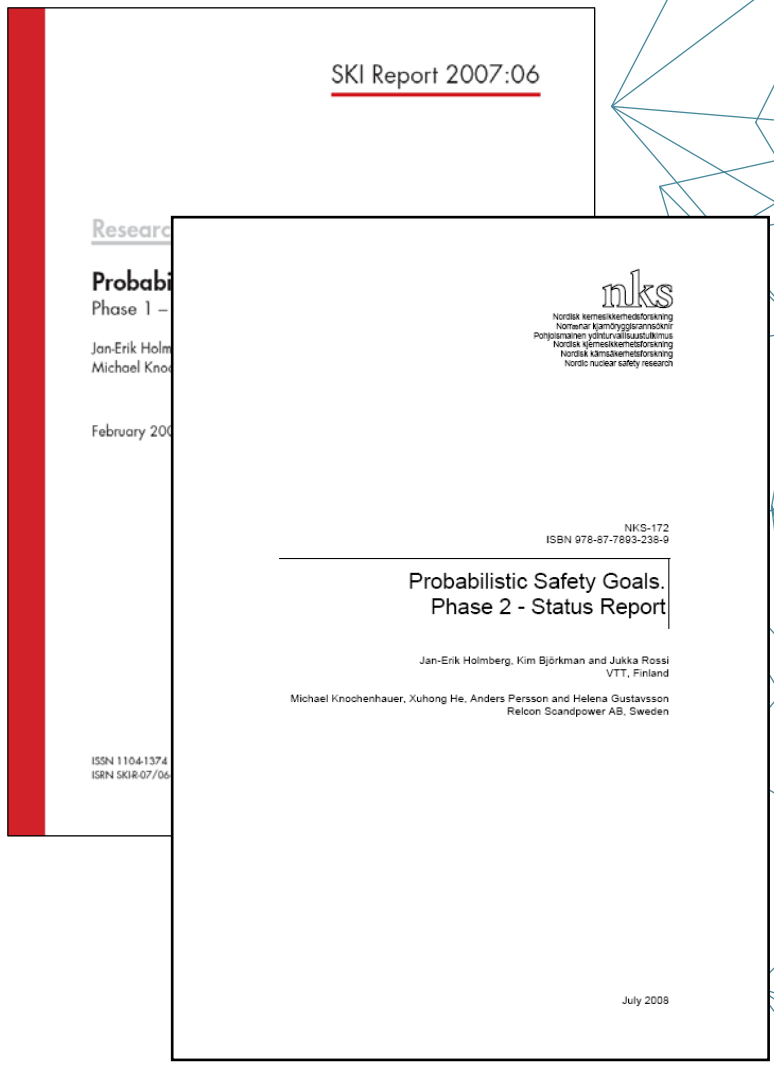


# Important final step - Guidance for the formulation, application and interpretation of probabilistic safety criteria

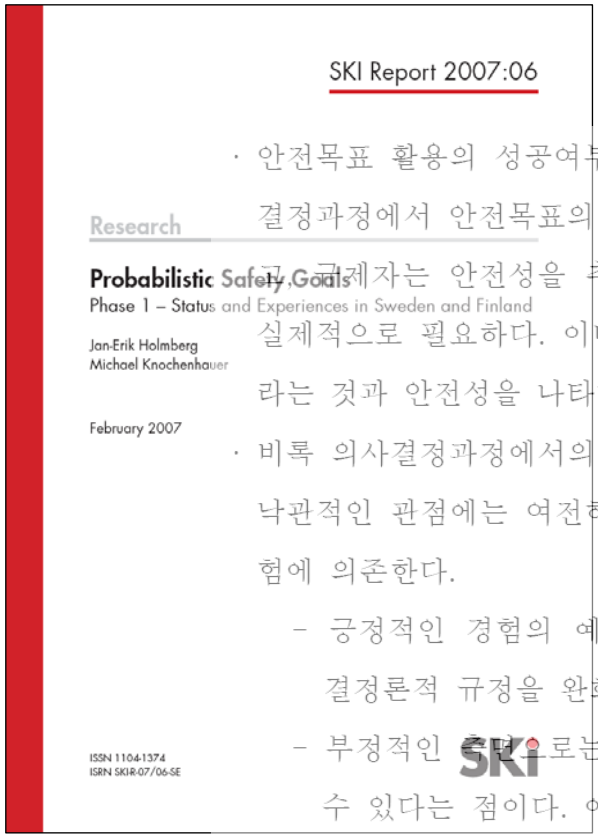
- **Aims at summing up, on the basis of the work performed throughout all project phases, issues to consider when formulating, applying and interpreting probabilistic safety criteria.**
- **This includes (but is not limited to) questions like:**
  - What should be considered?
  - What can be done with safety goal and what not?
  - Use of criteria as limits vs. objective
  - Treatment of uncertainties in the application of safety goals
  - The scope of safety goals
  - Problematic issues
- **This will be supported by a common workshop with utility and authority representatives.**

# Publication plan

- **Phase 1 / 2006**
  - NKS Report (NKS-153)
  - SKI Research Report (SKI 2007:06)
    - Project initiation – status in Sweden and Finland
- **Phase 2 / 2007**
  - NKS Report (NKS-172)
- **Phase 3 / 2008**
  - NKS Report (early 2009)
  - SSM Research Report (late 2009)
    - Specific issues covered in phase 2, 3 and 4
- **Phase 4 / 2009**
  - NKS Report (early 2010)
  - SSM Research Report (late 2009)
    - Guidance document



# Unexpected project report…




· 안전목표 활용의 성공여부는 관련 이해 당사자(규제기관, 사업자 등) 사이의 의사결정과정에서 안전목표의 임무에 달려있다. 기본적으로 사업자는 경제성을 추구하고 규제자는 안전성을 추구하기 때문에 공통된 목표를 추구하는 합의된 상황이 실제적으로 필요하다. 이때 제기되는 의문점은 '얼마나 충분히 안전하여야 하는가라는 것과 안전성을 나타내는 방법이 충분한가' 하는 것이다.

· 비록 의사결정과정에서의 PSA 개발과 활용이 계속 진전하고 있지만 PSA에 대해 낙관적인 관점에는 여전히 차이가 있다. 이것은 PSA 활용으로 부터 얻어지는 경험에 의존한다.

  - 긍정적인 경험의 예로는, PSA로 부터 제공되는 보완적인 관점과 보수적인 결정론적 규정을 완화할 수 있게 한다는 점이다.
  - 부정적인 경험으로는, PSA가 결정론적인 규정에 추가로 부과되는 부담이 될 수 있다는 점이다. 아울러 PSA방법의 신뢰성을 약하게 할 수 있는 요인으로 PSA 개정시 큰 변동사항이 발생하므로 PSA기술에 제한된 지식을 가진 의사결정자들로 하여금 회의를 갖게 한다.

· 안전목표에 대해 논란이 되는 현안은 결정론과 확률론적인 안전 요건 사이의 상