# MACCS and the licensing process of nuclear facilities in Argentina

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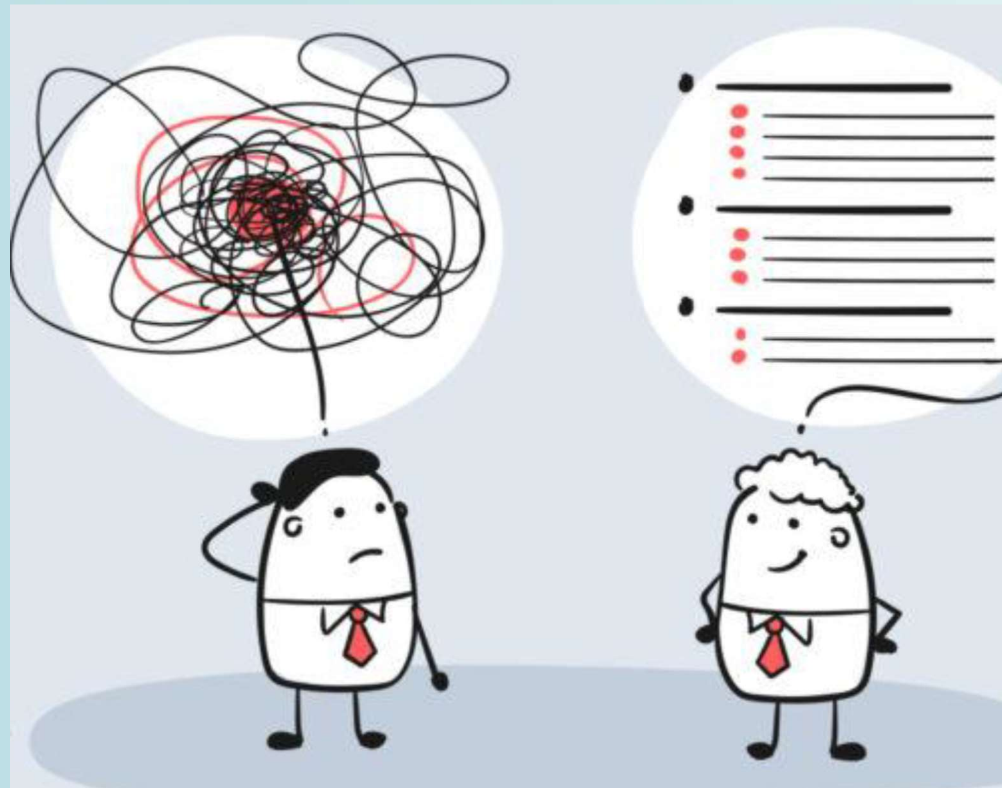
# Outline

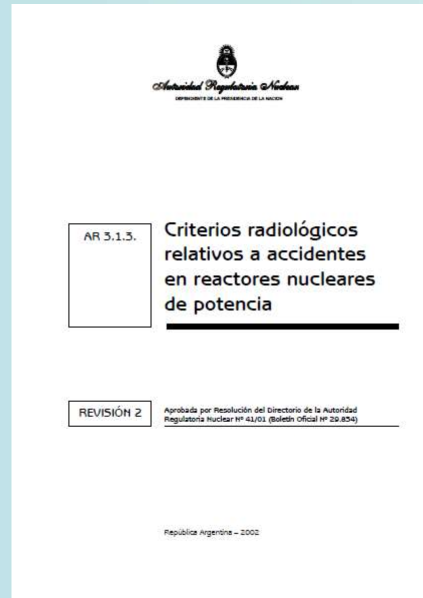
- gentine Acceptability Criterion for licensing
  - Individual Radiological Risk (IRR) definition
  - IRR calculation
  - Acceptability limit for IRR
- ACCS input
  - General properties
  - ATMOS
  - EARLY
- tional Experience
- her Applications



# Argentine Acceptability Criterion

**entine Regulatory Body:**

- ✓ Regulation focused on the NPP radiological impact.
- ✓ It must be verified before the facility construction and operation.



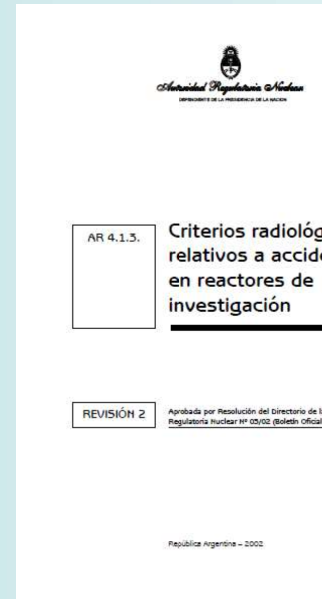
AR 3.1.3.

Criterios radiológicos relativos a accidentes en reactores nucleares de potencia

REVISIÓN 2

República Argentina – 2002

**AR 3.1.3 NPPs**



AR 4.1.3.

Criterios radiológ relativos a accid en reactores de investigación

REVISIÓN 2

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**AR 4.1.3 R**

**ective:**

**TO <u>LIMIT THE INDIVIDUAL RADIOLOGICAL RISK TO MEMBERS OF THE PUBLIC</u> ASSOCIATED WITH <u>POTENTIAL EXPOSURES</u> TO VALUES NOT GREATER THAN TH INDIVIDUAL RISK FROM <u>NORMAL EXPOSURES</u>**

# ndividual Radiological Risk (IRR) definition

dividual radiological risk is the **probability** of occurrence of the intersection of two events:

- accidental exposure to ionizing radiation of a member of the public (E)
- fatality due to such exposure (F) (This is the consequence, it is not activity I-131, It is no dose).

$$R = P\left(E \cap F\right) \Rightarrow R = P\left(E\right) \times P\left(F / E\right)$$

$P\left(E\right)$ Probability of Exposure

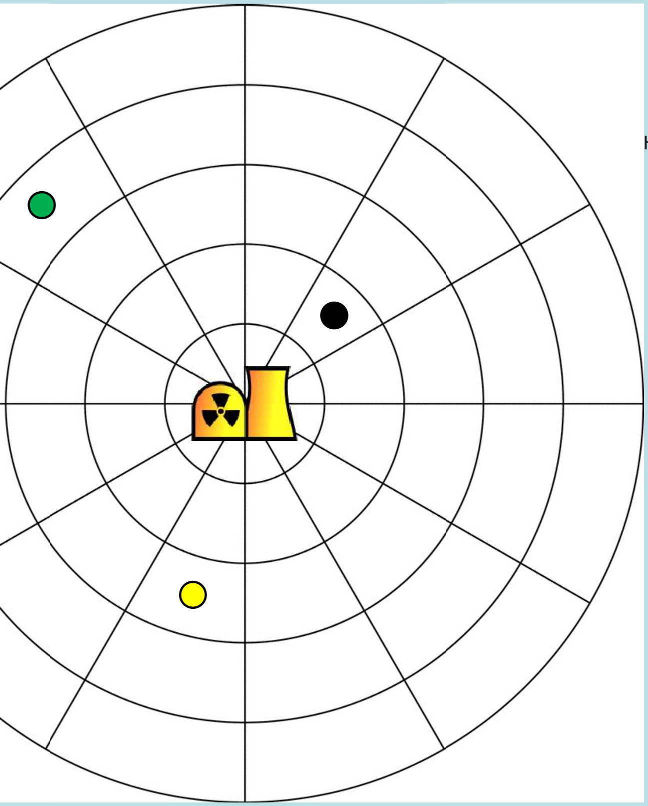
**Depends on:** plant characteristics, site, meteorological conditions, population distribution, etc.
**It is calculated by means of L1, L2 and L3 PSA.**

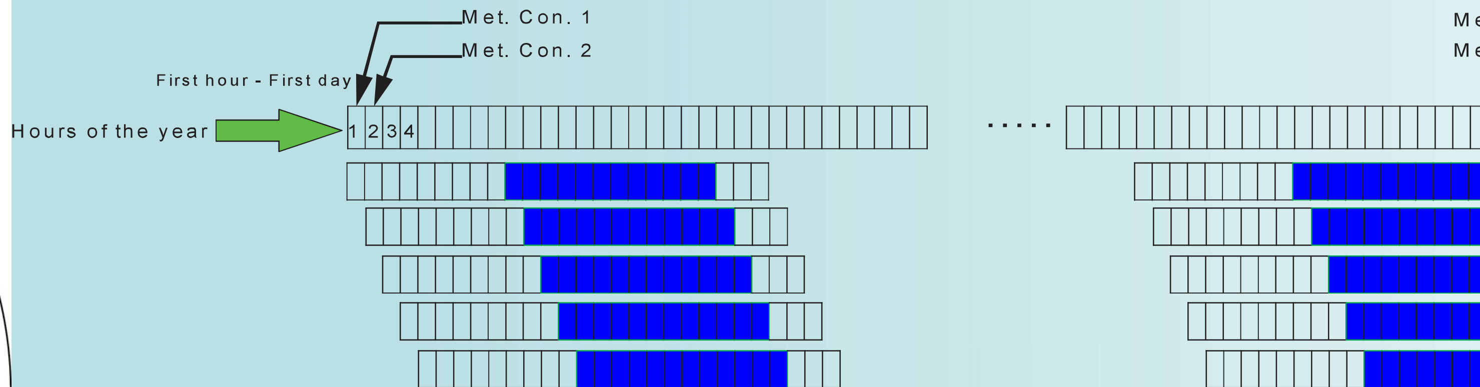
$P\left(F / E\right)$ Probability of Fatality due to the Exposure

From ICRP.

**IRR should be calculated in NPP surroundings!**

# ndividual Radiological Risk (IRR) calculation





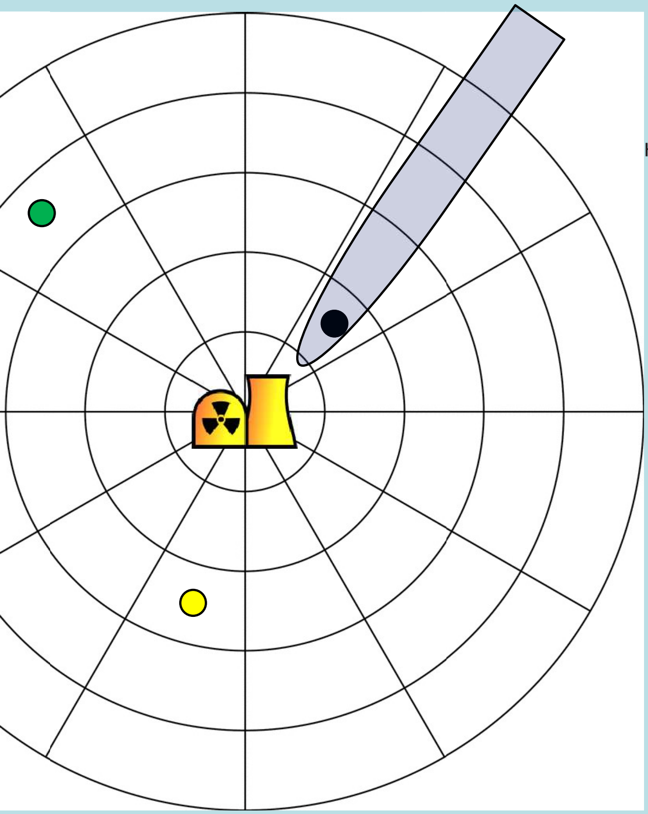

- The accident ($ST^n$) can occur at any time during the evaluation per
  uniform probability for the moment of occurrence is assumed.
- We can associate to each of the times intervals a set of weather cond
- Then the dose that an individual will receive at a specific position (*j*) a
  the NPP will depend on weather conditions (*i*).

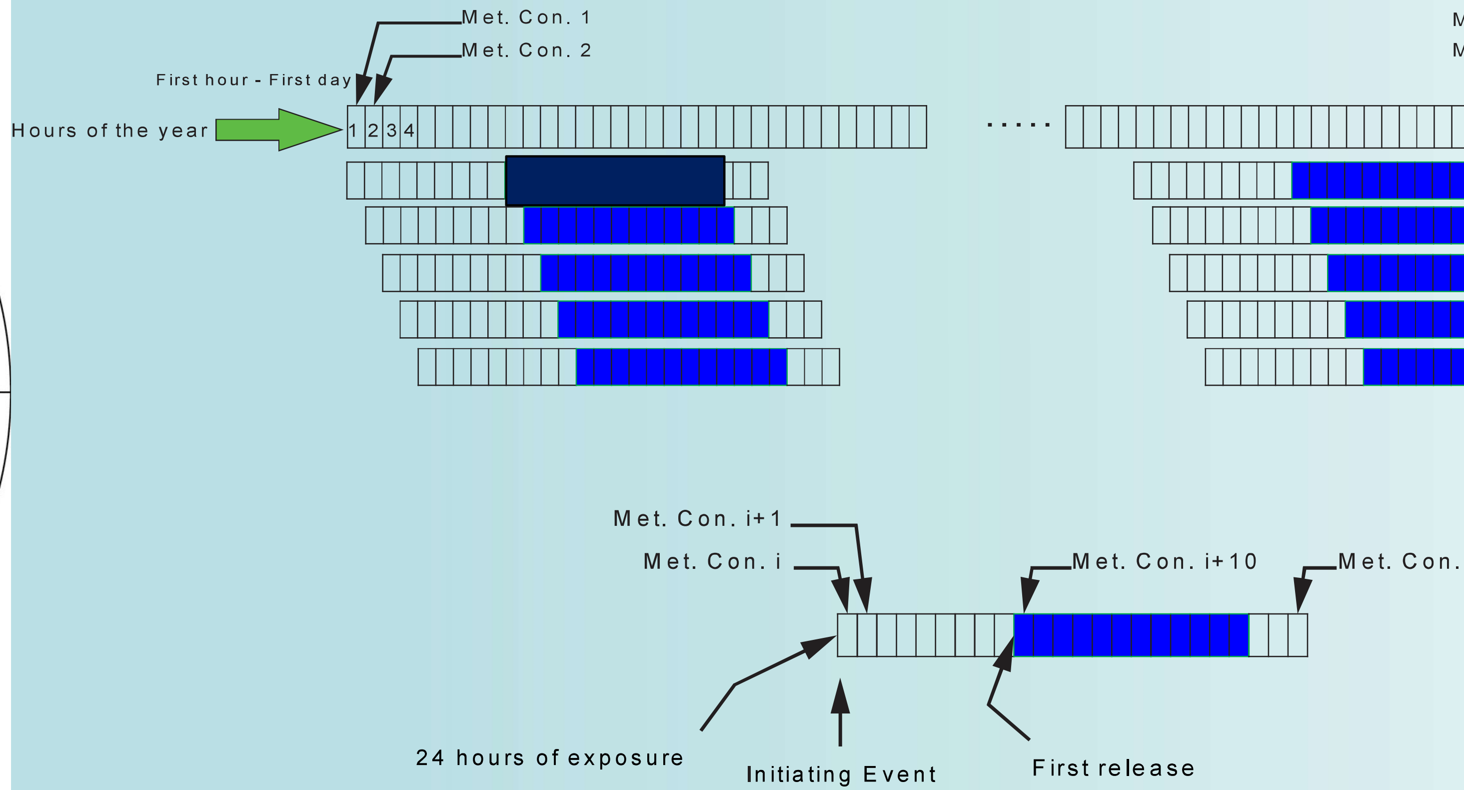
**ition**

**ather condition**

**urce Term**

# ndividual Radiological Risk (IRR) calculation






*Interval of Dose integration: 24 hs

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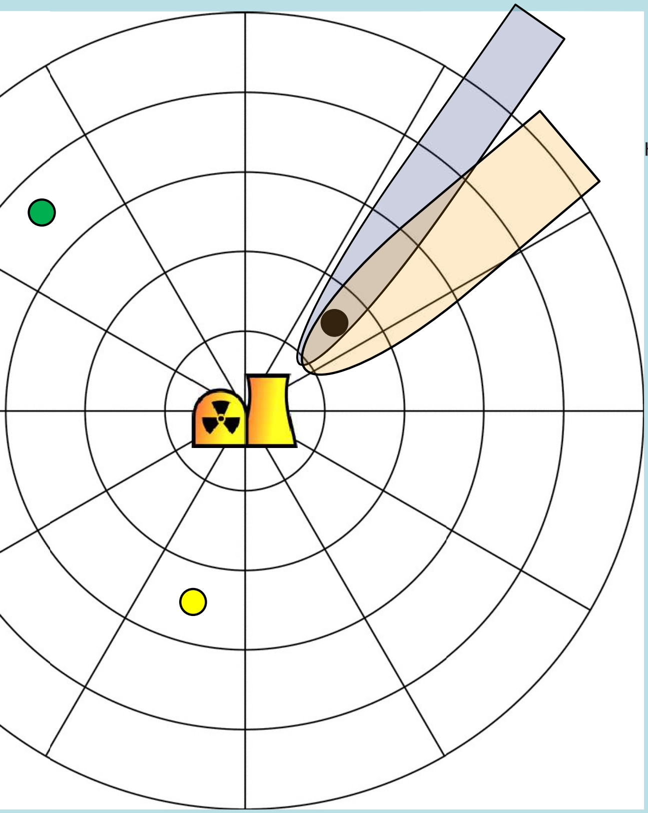

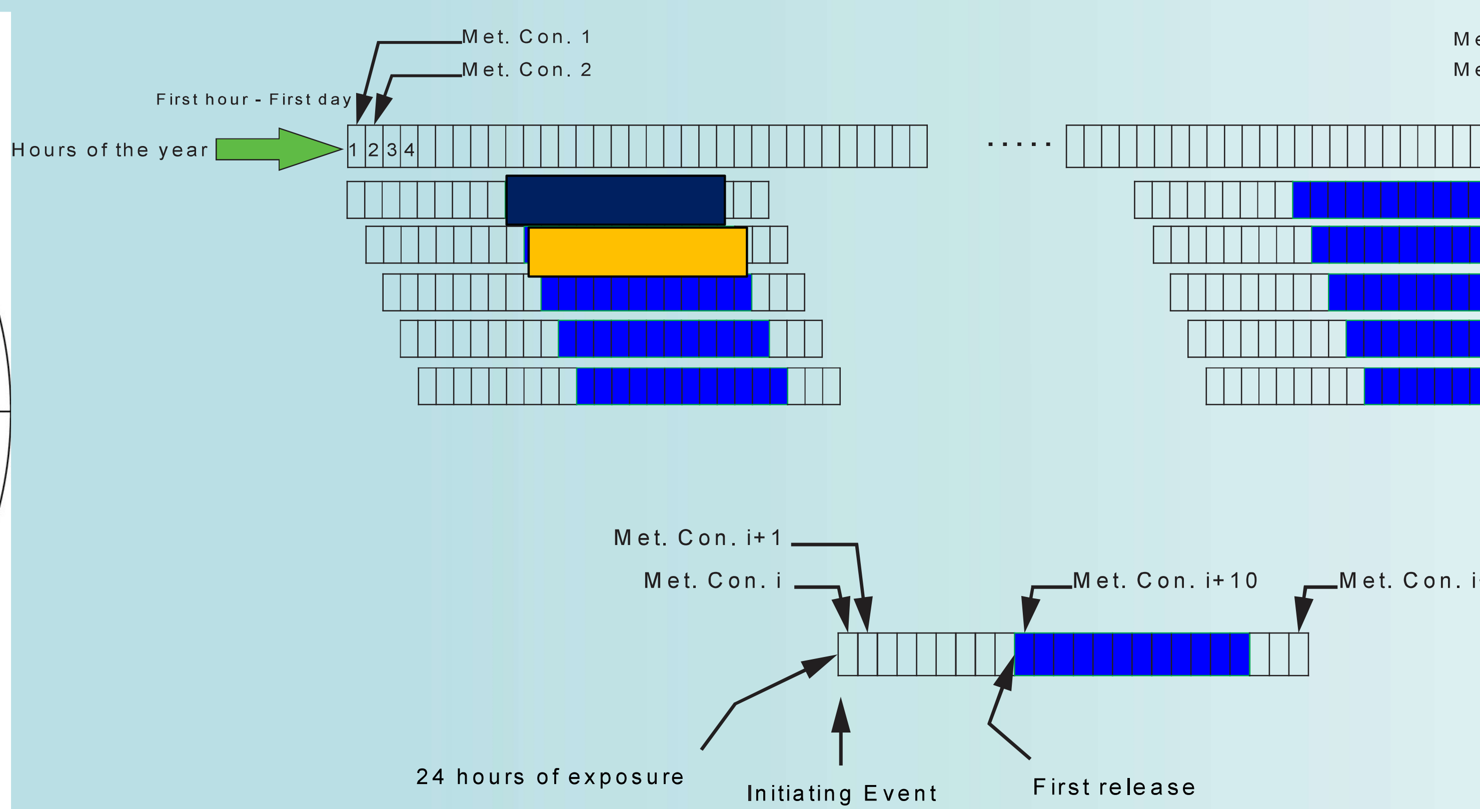


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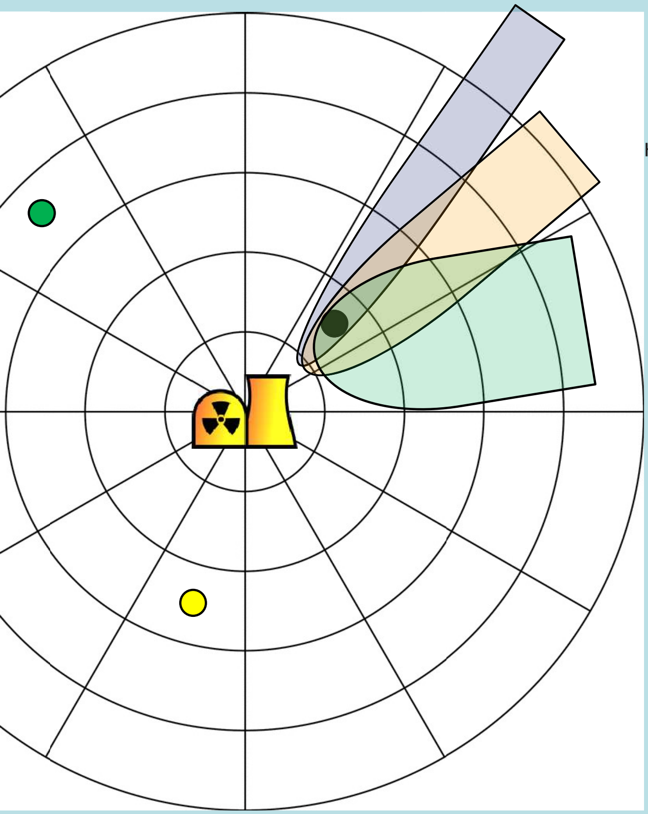

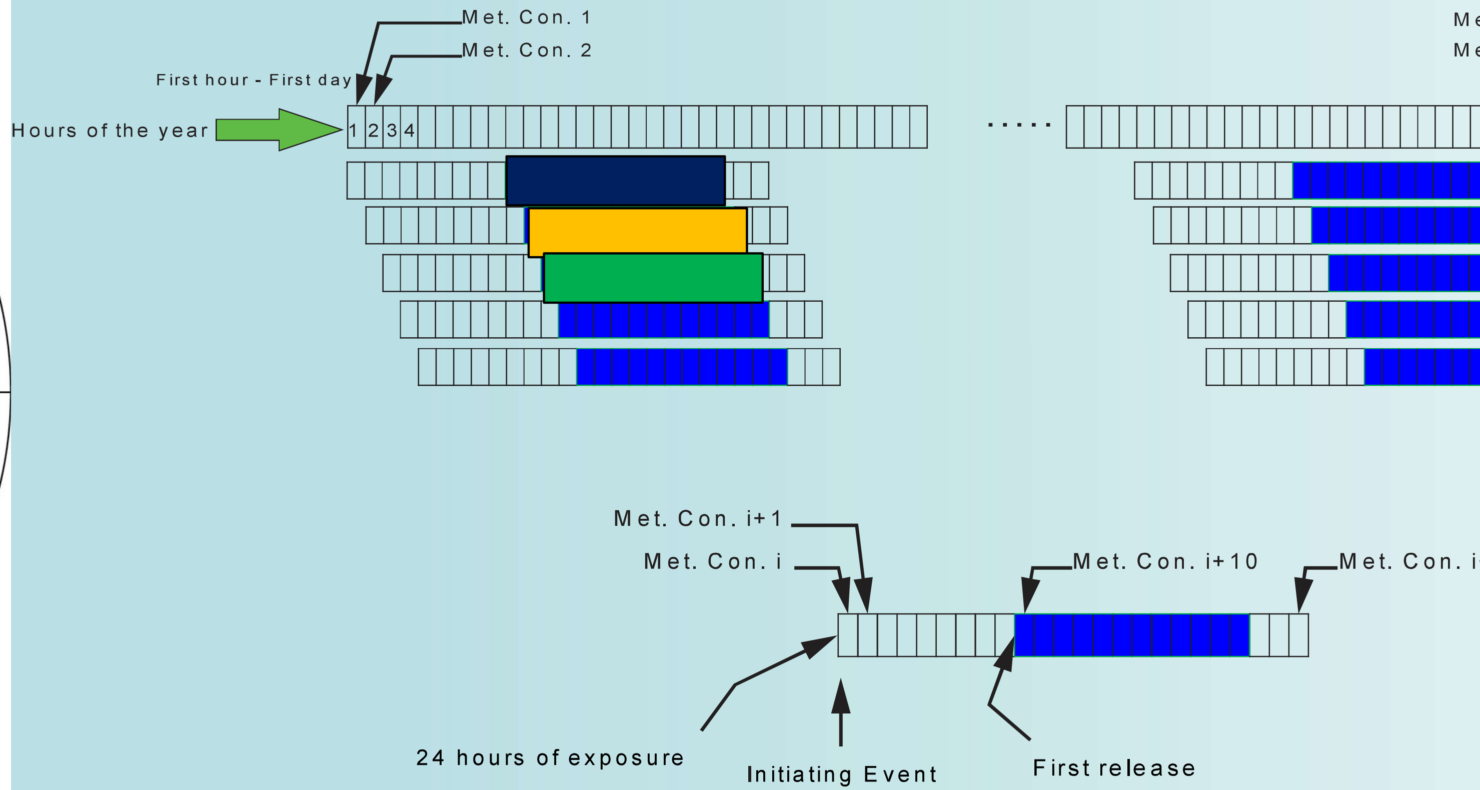


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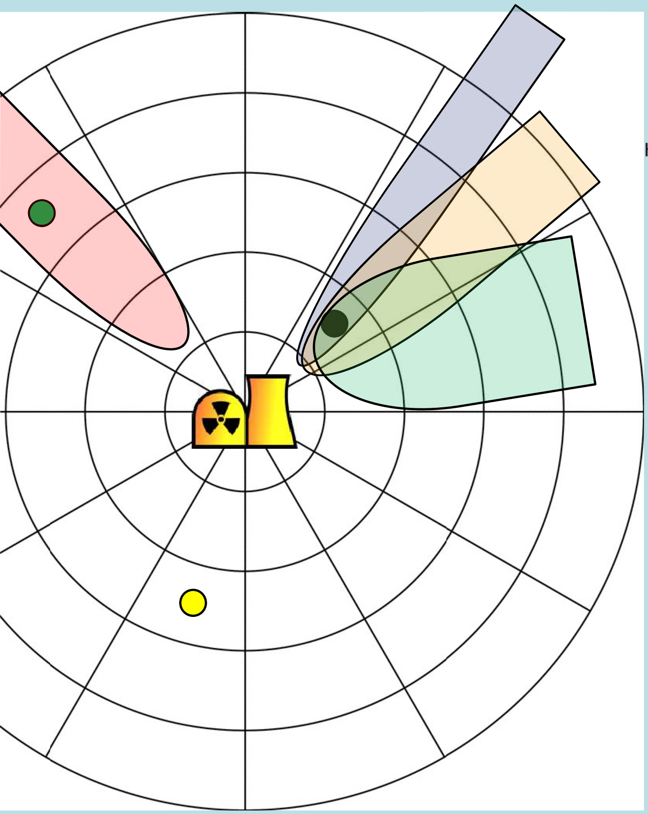

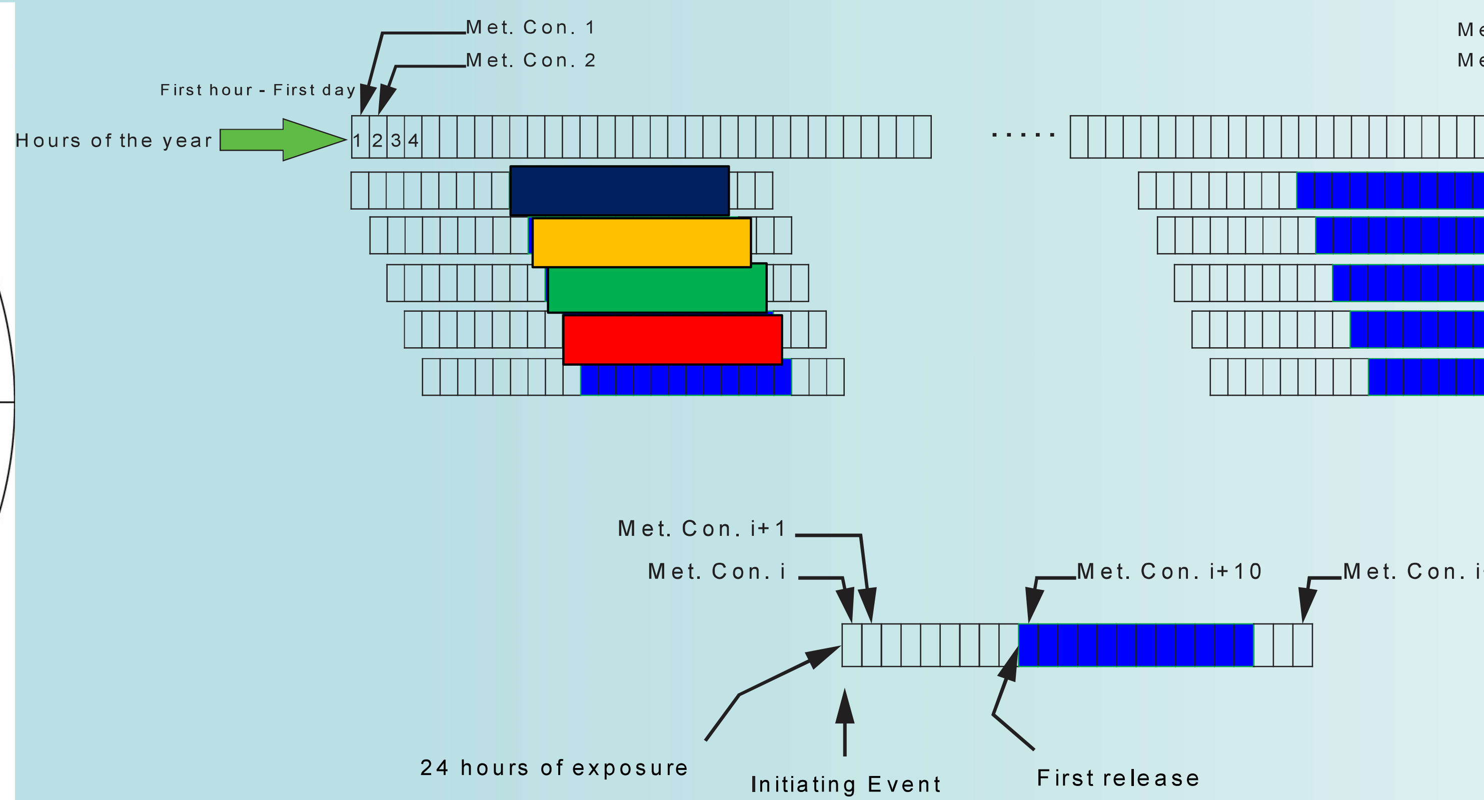


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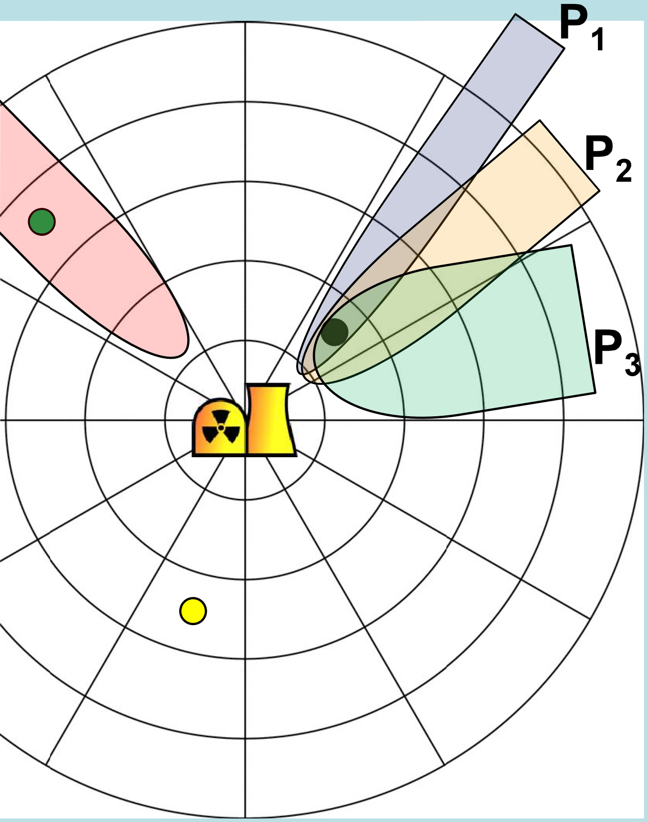
# ndividual Radiological Risk (IRR) calculation

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The individual at the black dot will be exposed (event of in

due to the release $ST^n$, when the meteorological co

generates plumes $P_1$ **OR** $P_2$ **OR** $P_3$, and it will **not** be exposed

The green dot will be exposed only to the plume $P_4$.

The effective doses at position *j* due to meteoro

condition *i*, $d_{ji}$, due to exposure to different $P_i$ are disjoints eve

**Therefore, for each $d_{ji}$ it is possible to calculate its asso**

**IRR ($R_{ji}^n$).**

# ndividual Radiological Risk (IRR) calculation

ce Term *n* probability.

Probability of exposure in *j* position due to the Source Term $ST^n$

Probability of $D_i$ given an exposure $A_j$ and a Source Term $ST^n$

Probability of fatality or dose function calculated according specification (based on ICRP)

$$R_{ji}^{n} = P(ST^{n}) \times P\left(A_j \,/\, ST^{n}\right) \times P(D_i/(ST^{n} \cap A_j)) \times f\left(d_{ji}\right)$$

ent $A_j$ is the logical union of all the exposure events with the different doses, greater than zero, at *j* p

disjoint events, if the accident (release) in the NPP happens at a given time (a given meteorolog ons) it will not in another.

# ndividual Radiological Risk (IRR) calculation

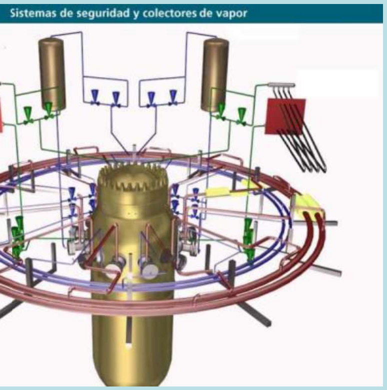
fore the total IRR –a probability- of an individual at *j* position, due to the event "exposure $A_j$", is the ks of having a dose greater than zero, and can be written as:

$$R_j^n = \sum_i R_{ji}^n$$

$$R_j^n = \underbrace{P(ST^n) \times P\left(A_j \;/\; ST^n\right)}_{\text{Term I (P(E))}} \times \underbrace{\sum_i P\left(D_i/(ST^n \cap A_j)\right) \times f\left(d_{ji}\right)}_{\text{Term II (P(F/E))}}$$

**Term I (P(E))** **Term II (P(F/E))**

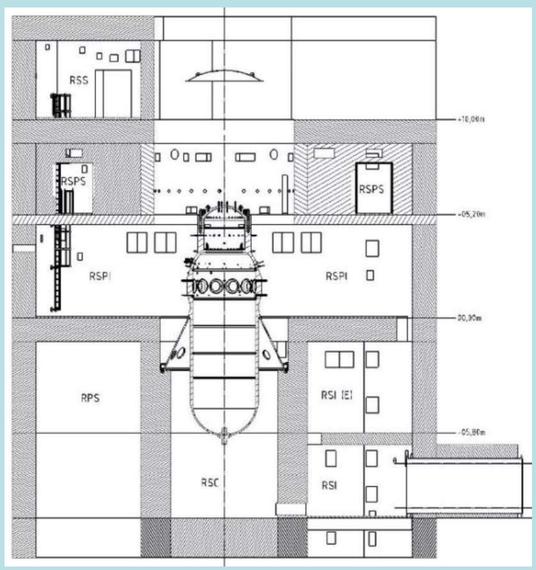
# P(E) calculation (Term I)

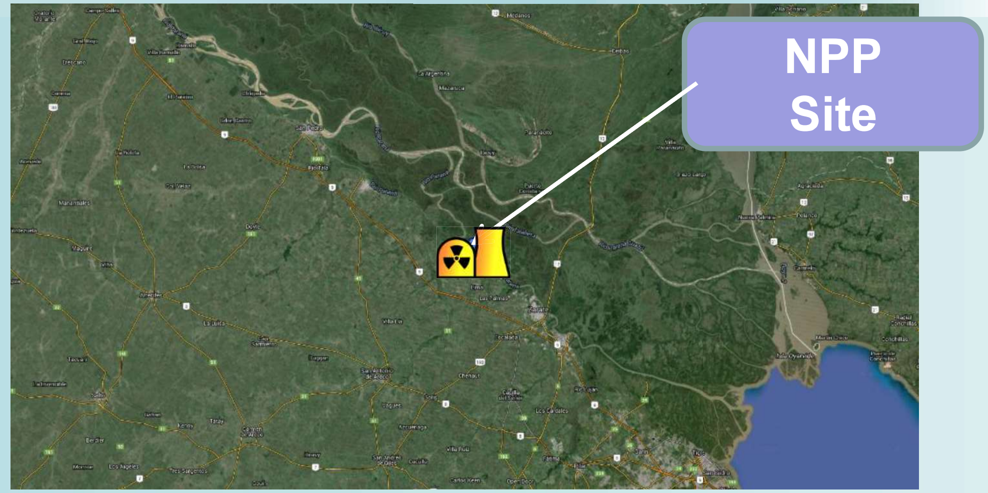



PSA Level 1

$P(RC^n)$

PSA Level 2



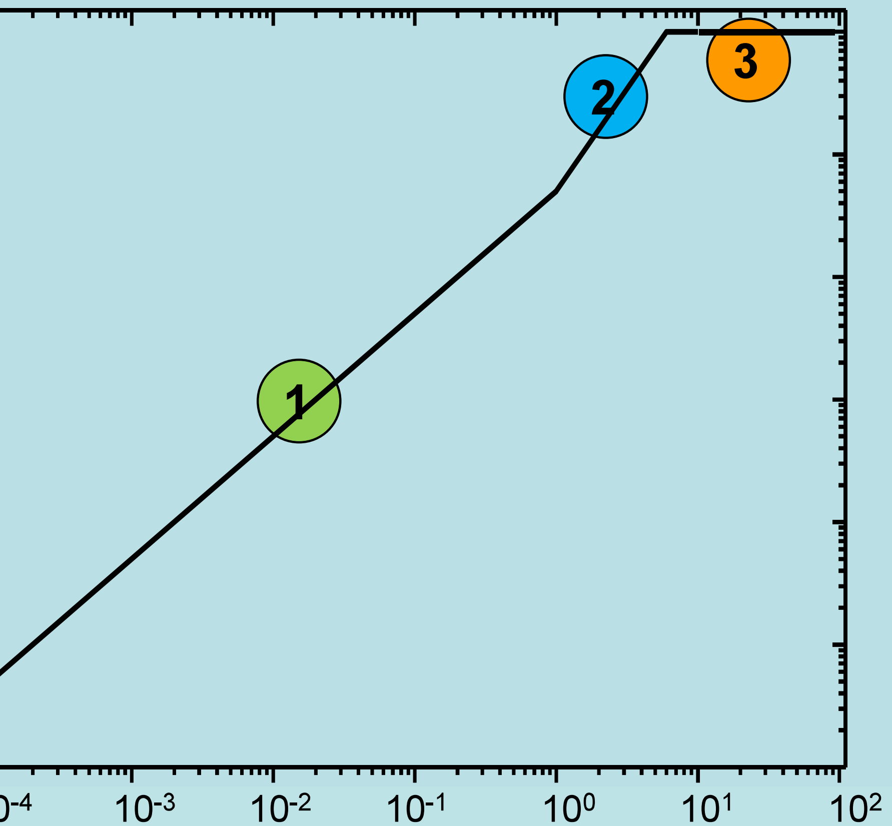

PSA Level 3

$P(A_j \,/\, ST^n)$

$$P(E) = P(ST^n) \times P(A_j \,/\, ST^n)$$

# P(F/E) calculation (Term II)

$$P(F/E) = f(D)$$




1. Stochastic region , D < 1Sv

$$f(D) = 0.05\,[Sv^{-1}] \times D\,[Sv]$$

2. 1Sv < D < 6Sv

$$f(D) = 0.05\,D^{1.6719}$$

3. Non-stochastic region, D > 6Sv

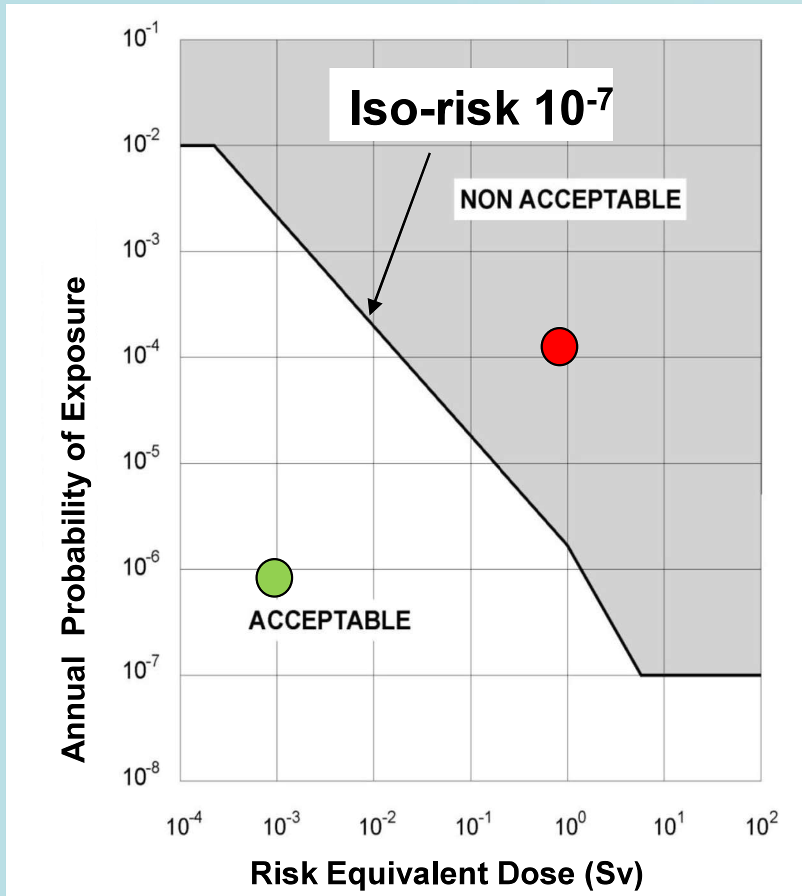
$$f(D) = 1$$

*Based on ICRP and ARN considerations.

Represents a conservative and precautionary approach only with regulatory purposes.

# Acceptability limit for IRR

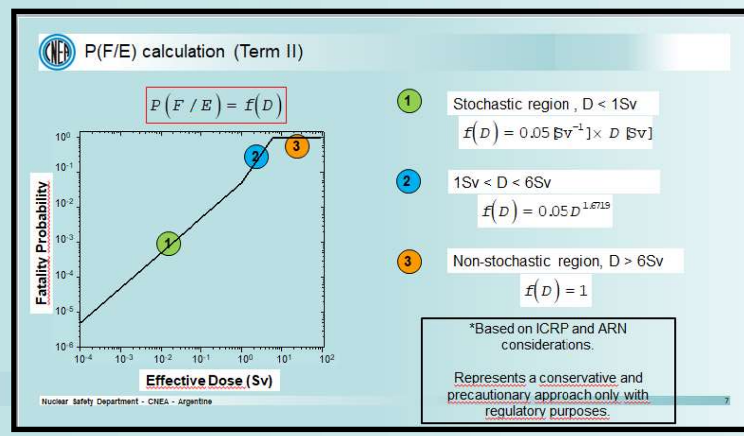
**LIMIT THE IRR ASSOCIATED WITH POTENTIAL EXPOSURES TO VALUES NOT GREATER THAN THE I NORMAL EXPOSURES**




**Criterion Curve** for members of the public

# MACCS input: General

- CCS versions: 3.6, 3.10 and 3.11.2
- ope: Dispersion calculations and Early Consequences assessment. (ATMOS & EARLY)
- t. Data: Hourly data.
- p. Parameters: Look Up Tables and Dispersion Functions. Depends on availability and Site features.
- e Data: Uniform/Real Population Distribution.
- se Factors: FGR-13.
- acuation: Radial & 1 Emergency Scenario.
- ndshift without Rotation. (IPLUME = 3)
- se Response Model: Health effects are calculated using Dose Response Model established by the Regulatory dy of Argentina based on ICRP publications.



## MACCS input: ATMOS module

atial Grid: 20 km max distance. Sectors:16 (depends on weather data).

dionuclides: 69 radionuclides and 9 chemicals groups: Xe, Cs, Ba, I, Te, Ru, Mo, Ce and La. Invento
nes from ORIGEN.

/Wet Deposition: Yes.

ease Description: Plume Parameters (PDELAY, PLHITE, PLUDUR), Particle Size Distribution and
ease Fractions. For NPPs this information comes from MELCOR runs and is post processed using
LMACCS. For Research Reactors these parameters are estimated based on accepted documentatio
iography and judge of expert.

ather Sampling: Stratified Random Sampling (METCOD = 5, NSMPLS = 24). All the Meteorological
nditions are considered for the calculations.

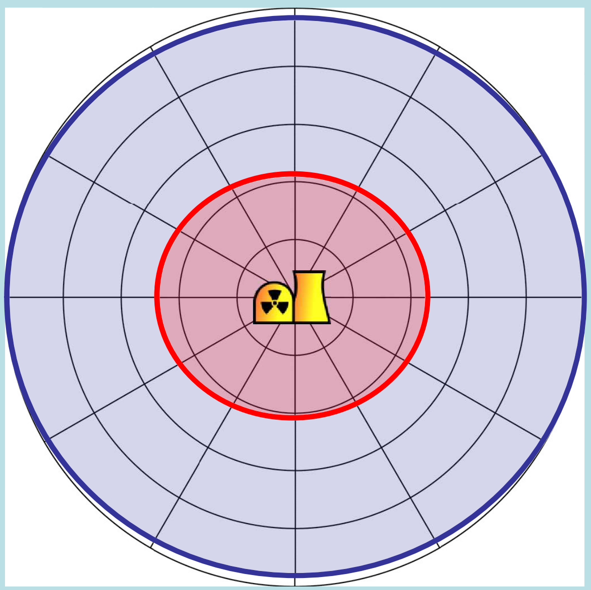
# MACCS input: EARLY module

posure Pathways: Cloudshine, Inhalation and Groundshine.

elding Factors: Yes.

get (tissue/organ): L-ICRP60ED

untermeasures: Emergency phase. Evacuation and early Relocation. NUMEVA = 10 km & LASMOV



**Evacuation:**

- RFPNT = ALARM, OALARM = 2 hours.
- Sheltering: Normal. DLTSHL = 24 hs
- Evacuation = Instantaneous. DLTEVA = 0.
- Evacuee travel speed = 1000 m/s

**Relocation:**

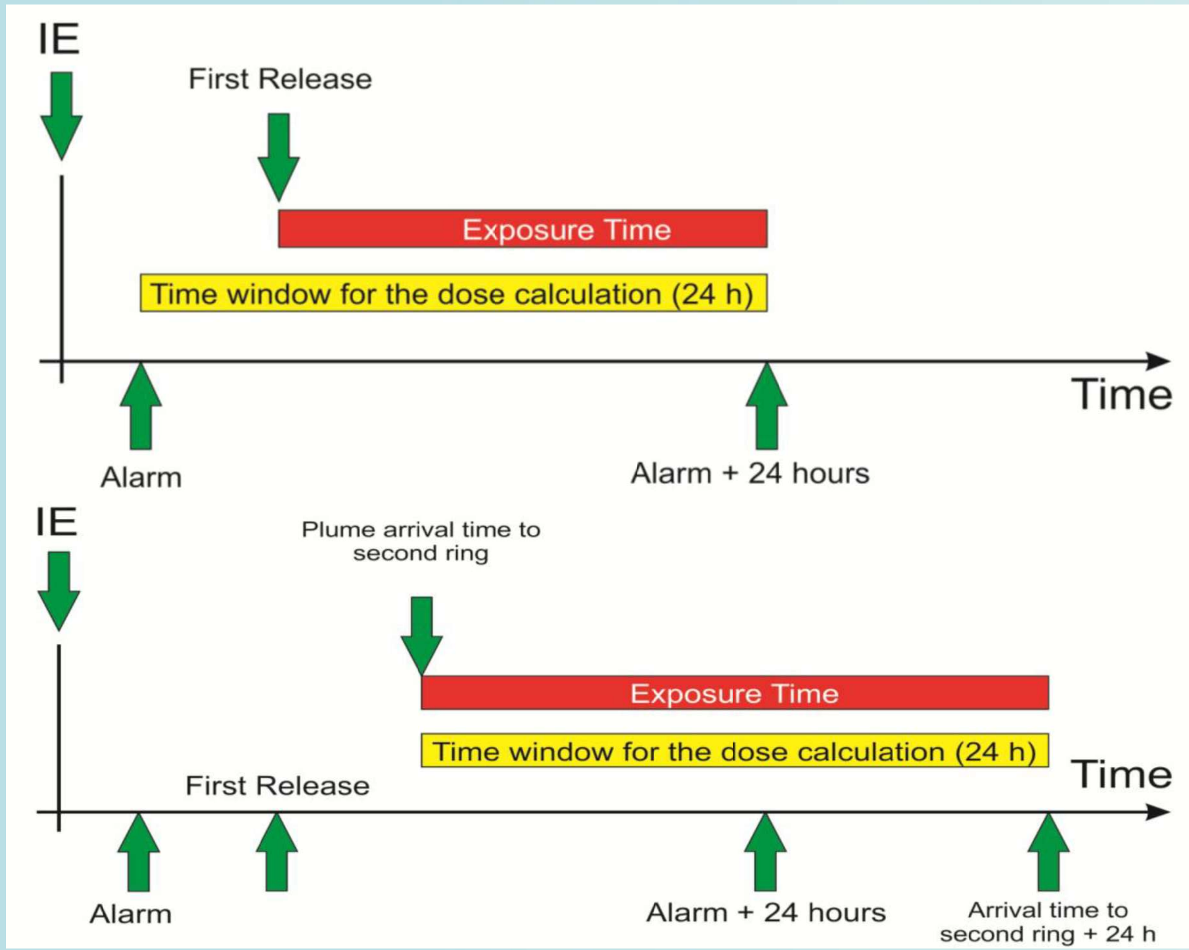
- RFPNT = Plume Arrival
- TIMNRM = TIMHOT = 24 hs
- DOSNRM = DOSHOT = 0 Sv

# MACCS input: EARLY module

line of the Emergency Scenario and the exposure periods:

**er Ring: 1 – 10 km**

**ltering & Evacuation**




**er Ring: 10 – 20 km**

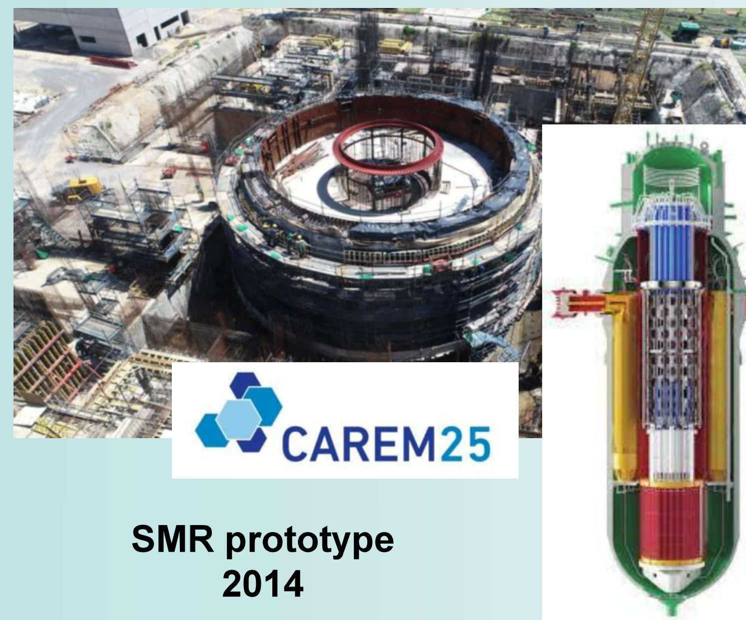
**y Relocation**

# National Experience

| | Status |
|---|---|
| II (NPP) | under Operation |
| M25 (SMR) | under development |
| (RR) | under development |

Atucha II NPP – 745 MWe PHWR
2012

MW
2



SMR prototype
2014

# Other Applications: EPR

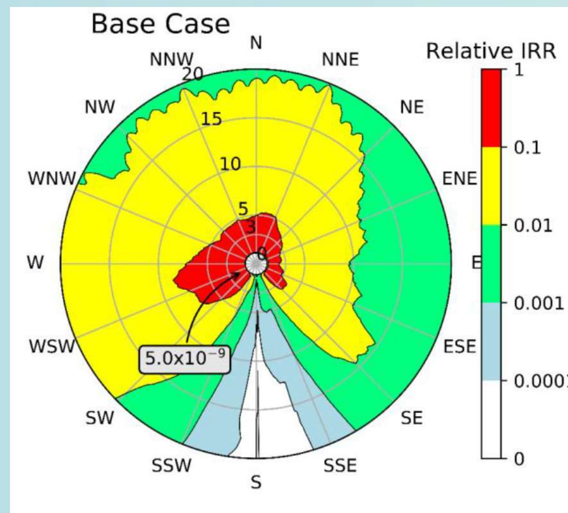
**e working on the suitability of the IRR concept for two topics of t interest:**

**ergency Preparedness and Response**

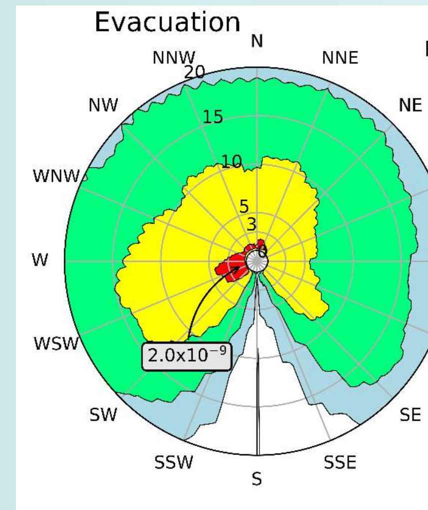
e are aware of the close relationship tween L3 PSA and EPR. We believe that **e IRR concept and our L3 PSA approach** n give support to EPR tasks.

**e consider that the IRR concept could be ed to assess the EPZ boundary.**

Iso-IRR curves around NPP




NO Countermeasures



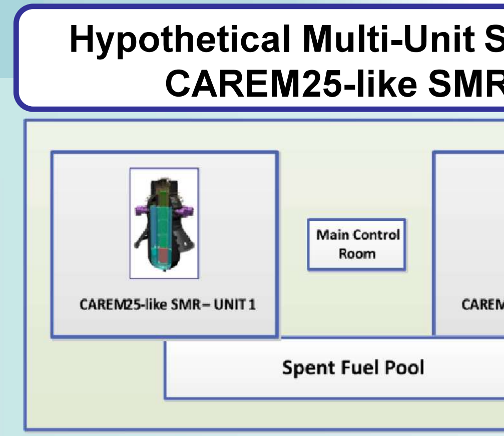

Evacuation

***RP I31029: Development of Approaches, Methodologies and Criteria for Determining the Technical Basis rgency Planning Zone for Small Modular Reactor Deployment (2018-2021).***

# Other Applications: Multiunit Sites

**le Units-PSA (MUPSA)**

to adapt **the IRR concept** and **L3 PSA methodology as a Risk Metric**
site with several reactors and FFEE pool.




**Metric Proposal: Individual Radiological Risk**

$$IRR_{Total-Site} = \underbrace{\sum_{k=1}^{m} IRR_{PSA_k}}_{\text{sum over m single unit PSA}} + \underbrace{IRR_{MUPSA}}_{\text{MUPSA}}$$

**y Goal Proposal:**

$IRR_{\text{Total-site}} <$ Radiological Risk due to normal practice (based on public dose limit: 1mSv)

***RP I31031: Probabilistic Safety Assessment (PSA) Benchmark for Multi-Unit/Multi-Reactor Sites (2018-20***

# Other Applications: Research

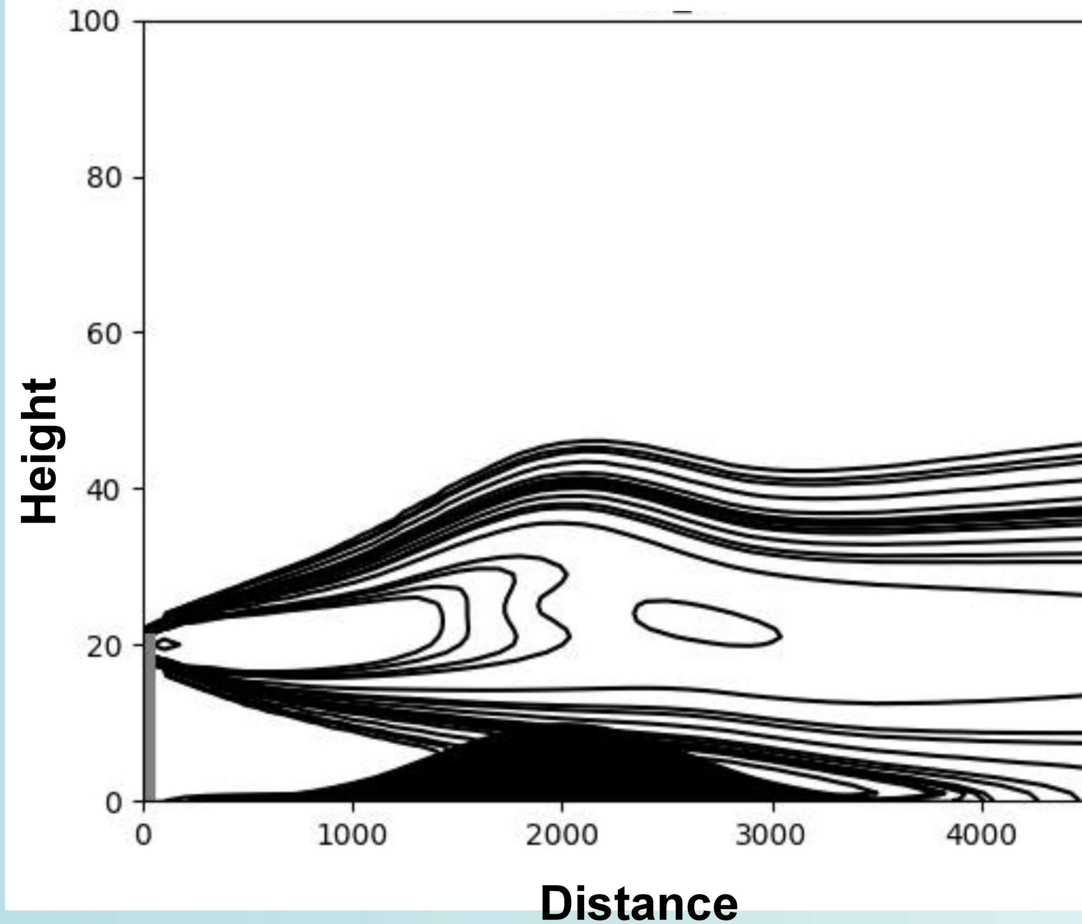
loring new ATD assessment tools:

- Complex terrain.
- Boundary layer meteorology.
- Plume Rise, Wake effects and near field dispersion features.
- Calm and Low wind conditions.

) codes development:

- An analytical non-stationary dispersion-deposition model. (Caputo et al, 2008)
- Simple Straight Gaussian Plume Model with capability of dose assessment.

Plume concentration distribution for a single hill



# Thank you for your attention!

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# Acceptability limit for IRR

**T THE IRR ASSOCIATED WITH POTENTIAL EXPOSURES TO**
**S NOT GREATER THAN THE IRR FROM NORMAL EXPOSURES**

ose annual limit for the public under routine exposures is 1mSv

atory Body assume that this annual limit can be reached after three
gical practices, so the dose limit for each planned exposure is
v.

$$P_e = \mathbf{1};\ \text{due to normal exposure} \qquad f(D)$$

$$R_{NE\,lim} = P_e \times f(D) = 1 \times 0.05Sv^{-1} \times 0.0003Sv = 15 \times 10^{-6}$$

$$R_{PE\,lim} = 10^{-6} < 15 \times 10^{-6} = R_{NE\,lim}$$

$$R_T \le R_{PE\,lim} = 10^{-6} \qquad R^n \le \begin{cases} 10^{-7} & N \le 10 \\ \frac{10^{-6}}{N} & N > 10 \end{cases}$$