Nuclear Power Plant Safety Margins

Increasing the risks after 40 years of operation

Yves Marignac

International Consultant on Nuclear and Energy Issues, Director of **WISE-*Paris***

yves.marignac@wise-paris.org

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SES

"We all desire to reach
an old age,
but we all refuse that we've
actually succeeded"

Francisco de Quevedo,
Politica de Dios y Gobierno de Cristo, **1619**

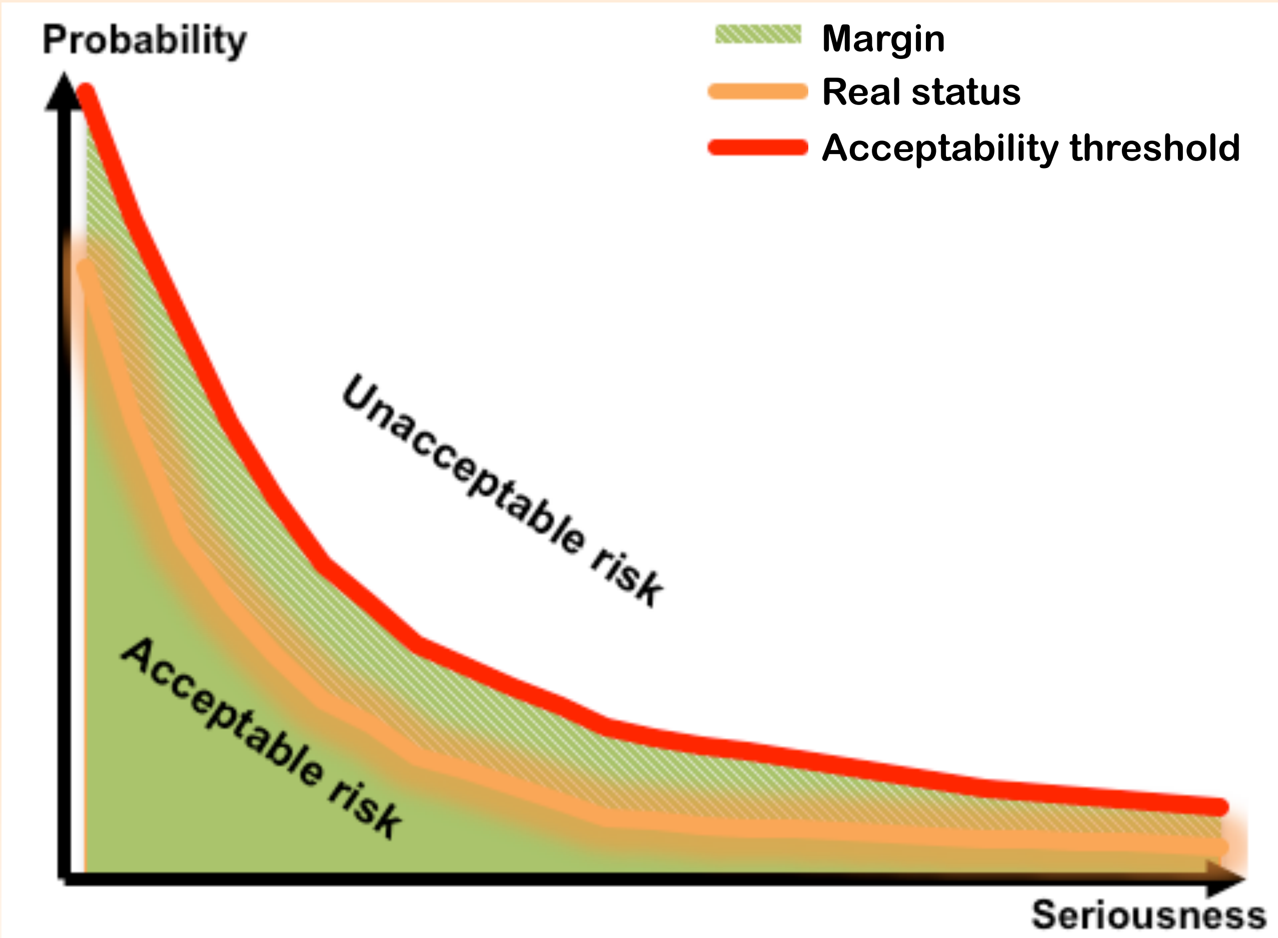
Principles
- **Safety margins**
- **The aging factor**

The case of Beznau
- **Irreplacable equipments**
- **Other issues**
- **Increased consequences**

Economic issues
- **The case of France**

Conclusions
- **Shut-down criteria**

The importance of safety margins and their sentitivity to different factors



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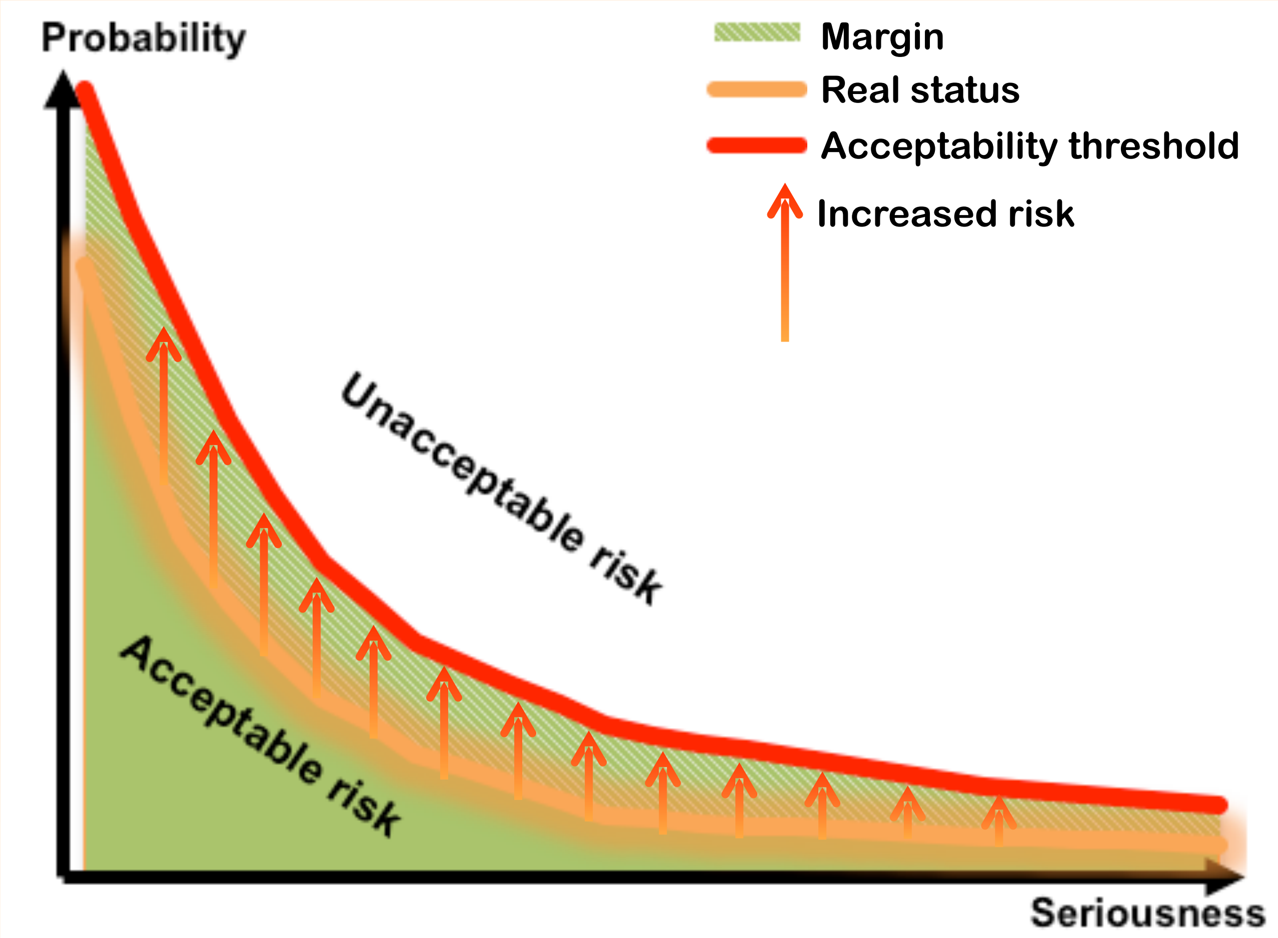

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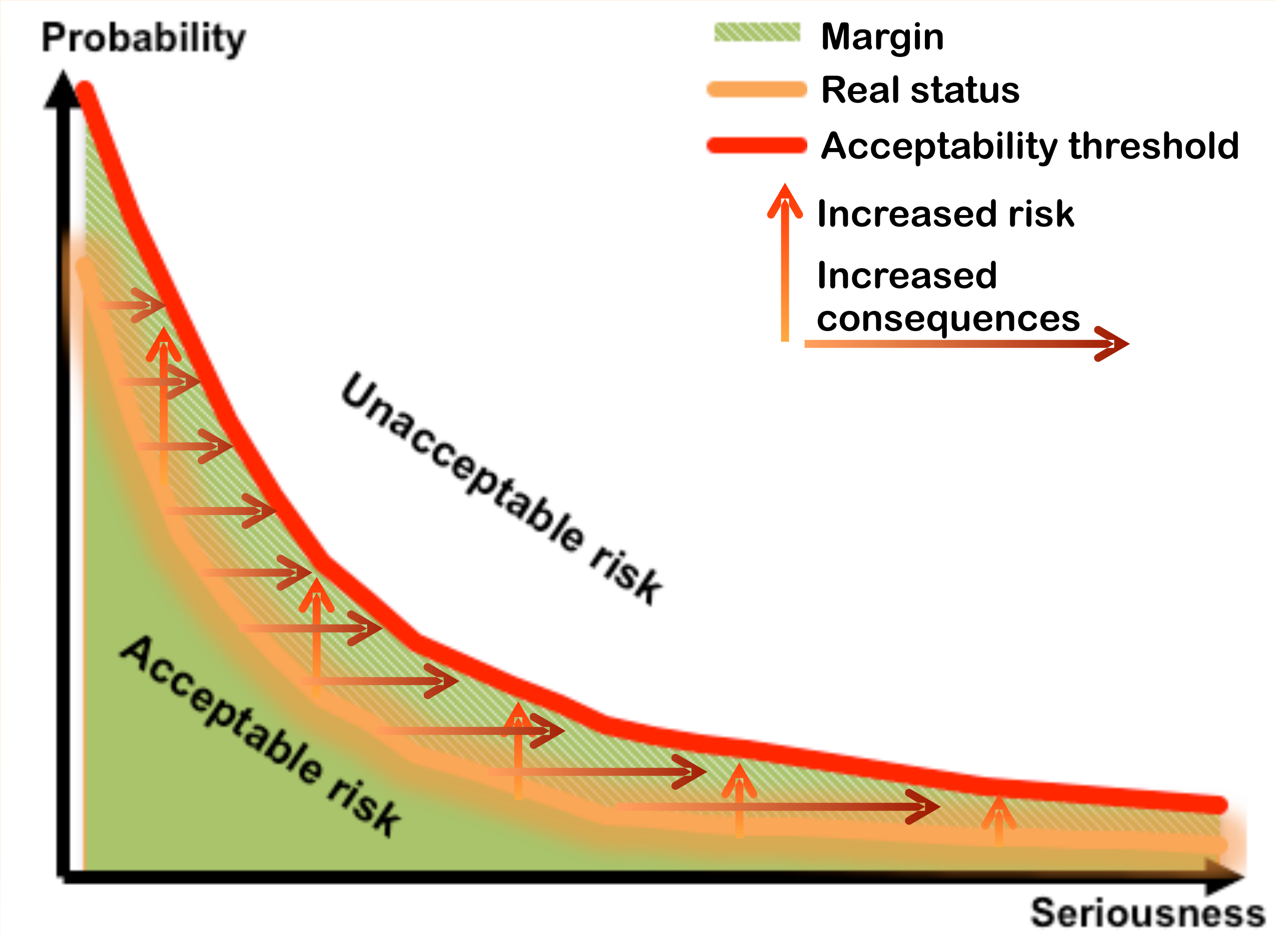

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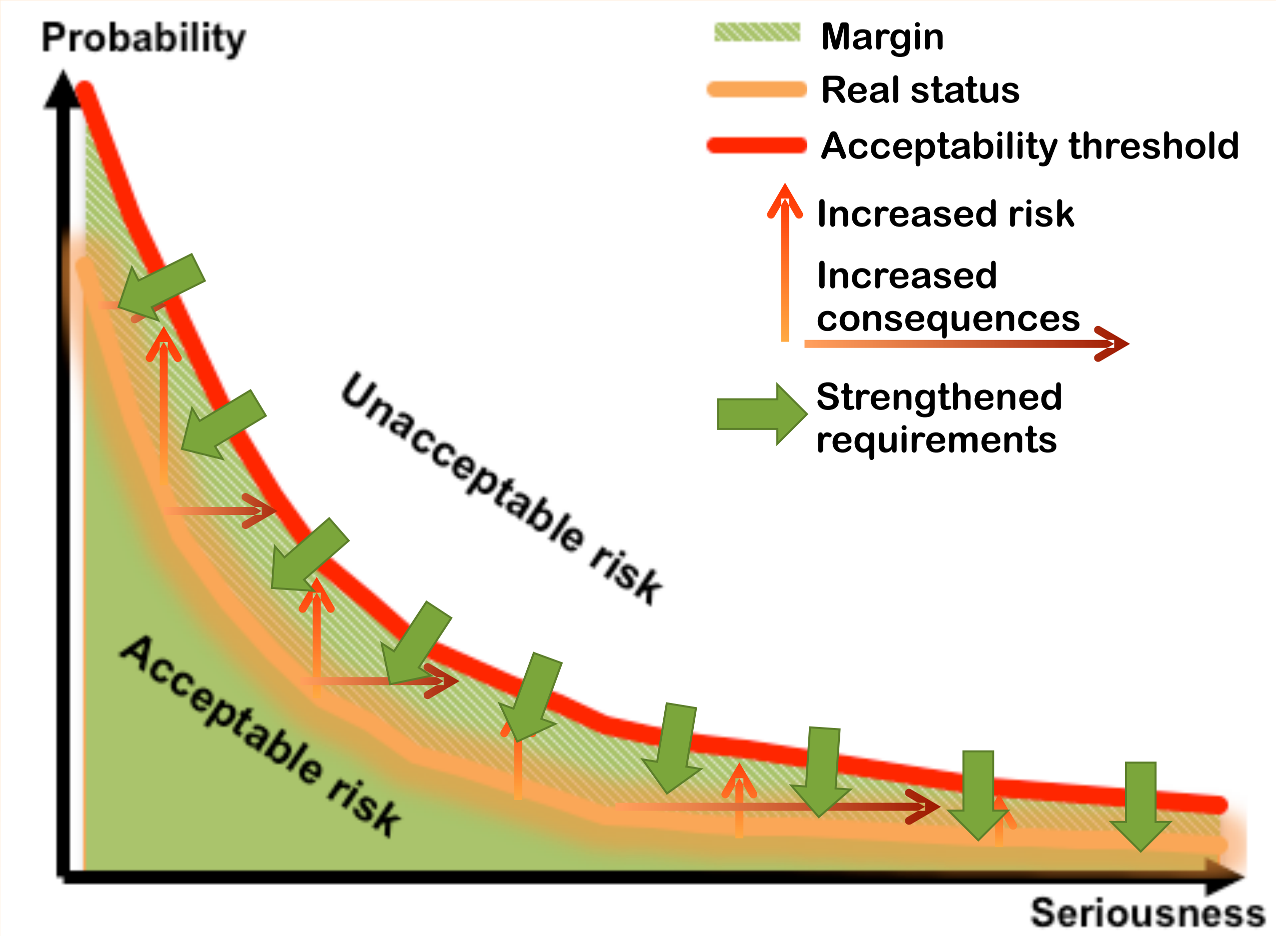

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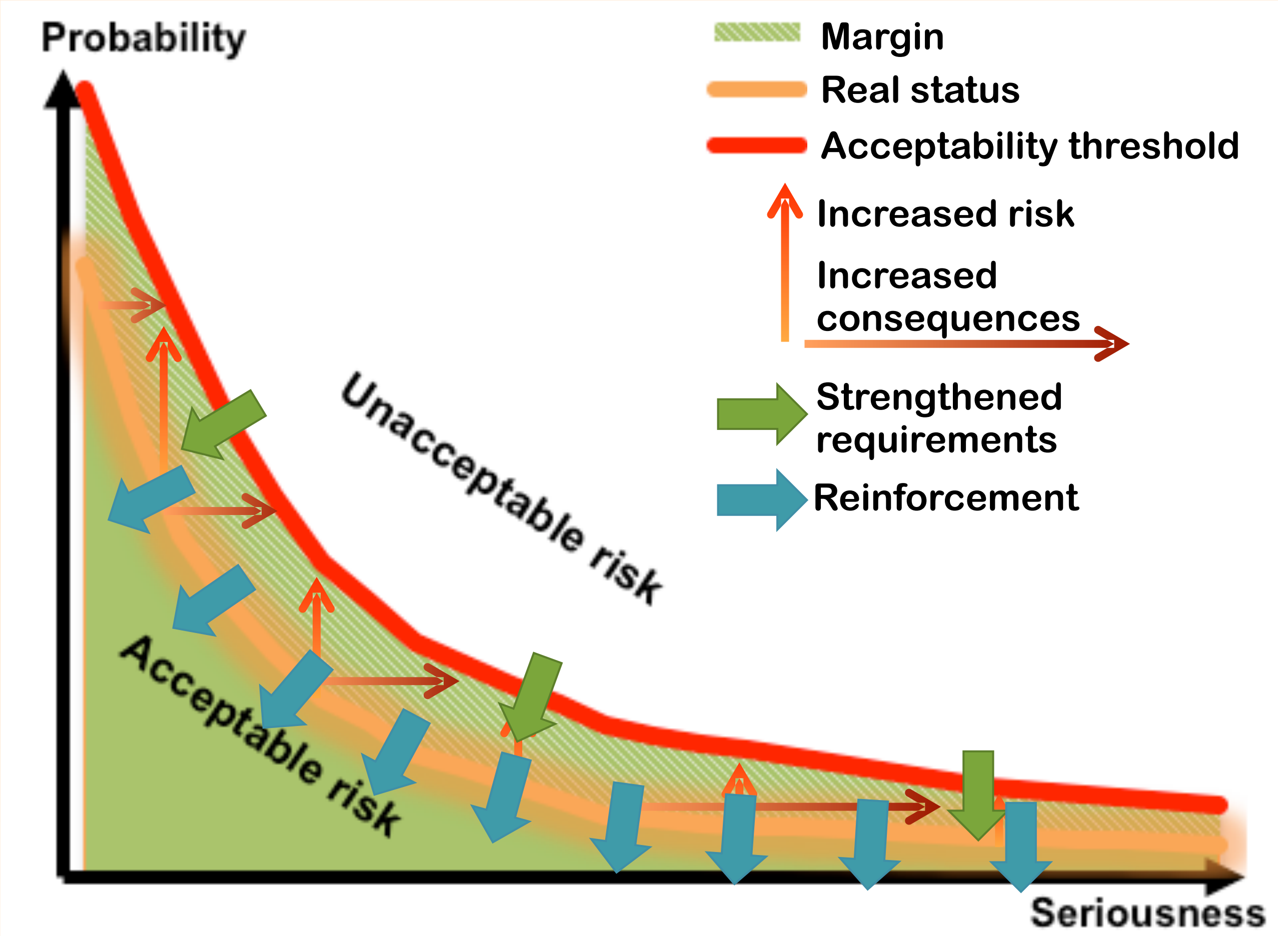

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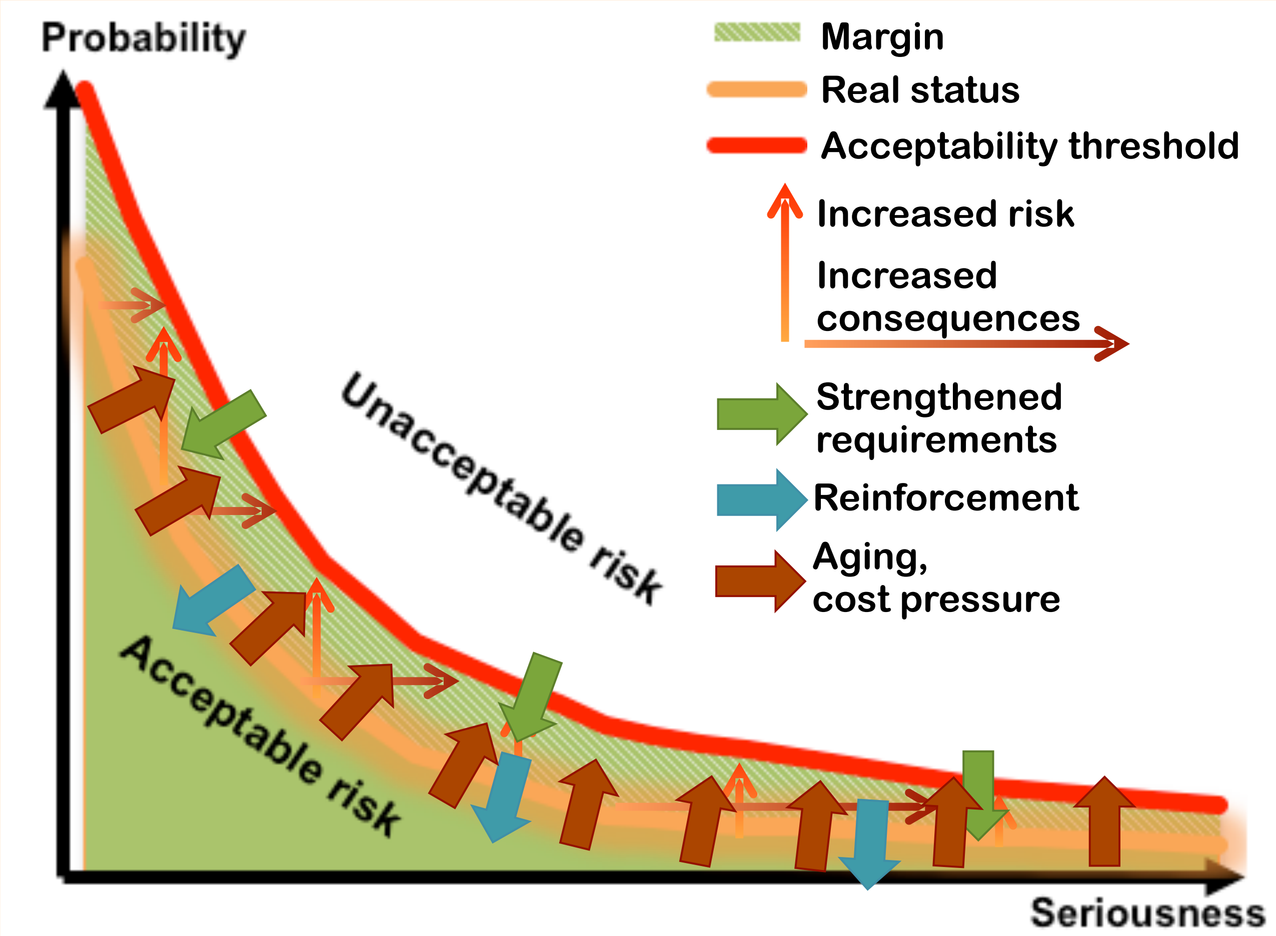
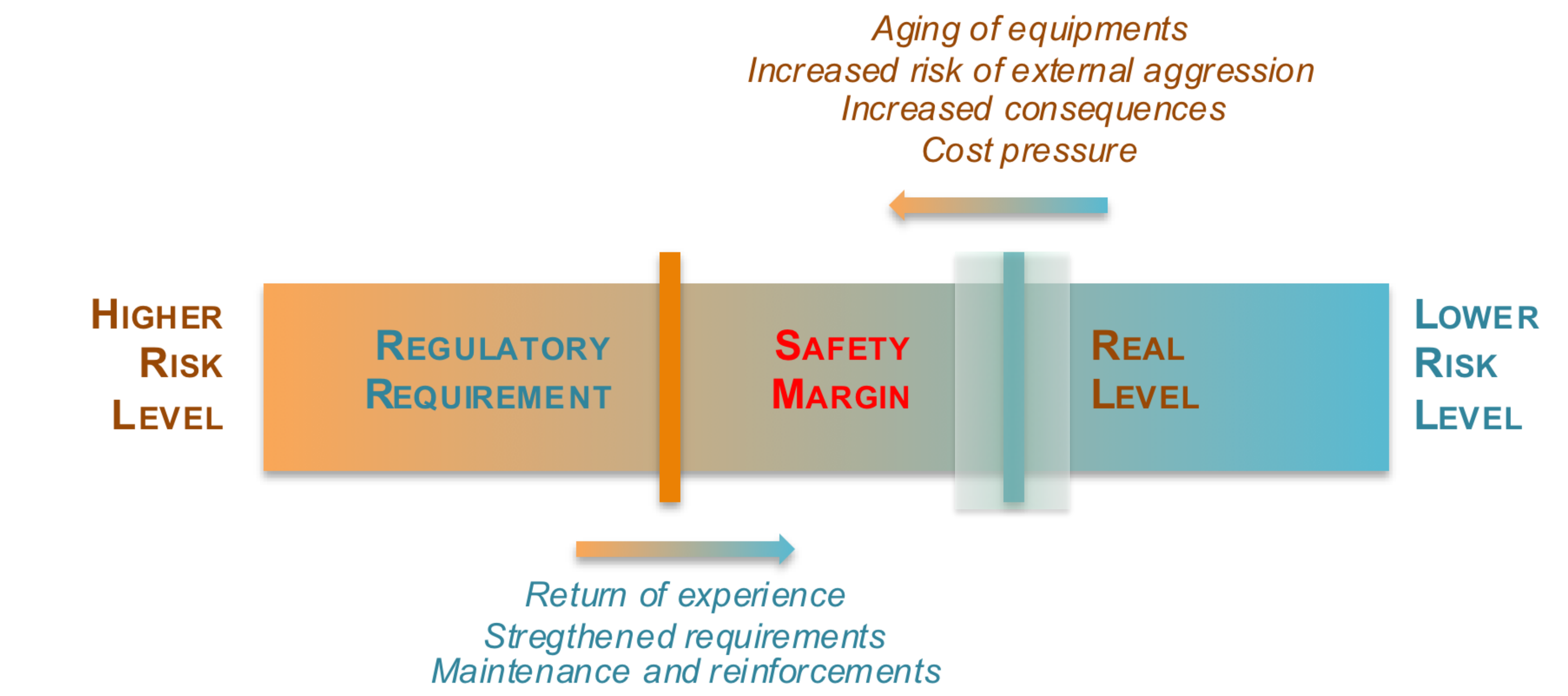


Maintaining safety margins

- **Margins were integrated during desing and construction**
- **Permanent need to compensate for ageing effects**
- **A balance between safety requirements and economic pressure**



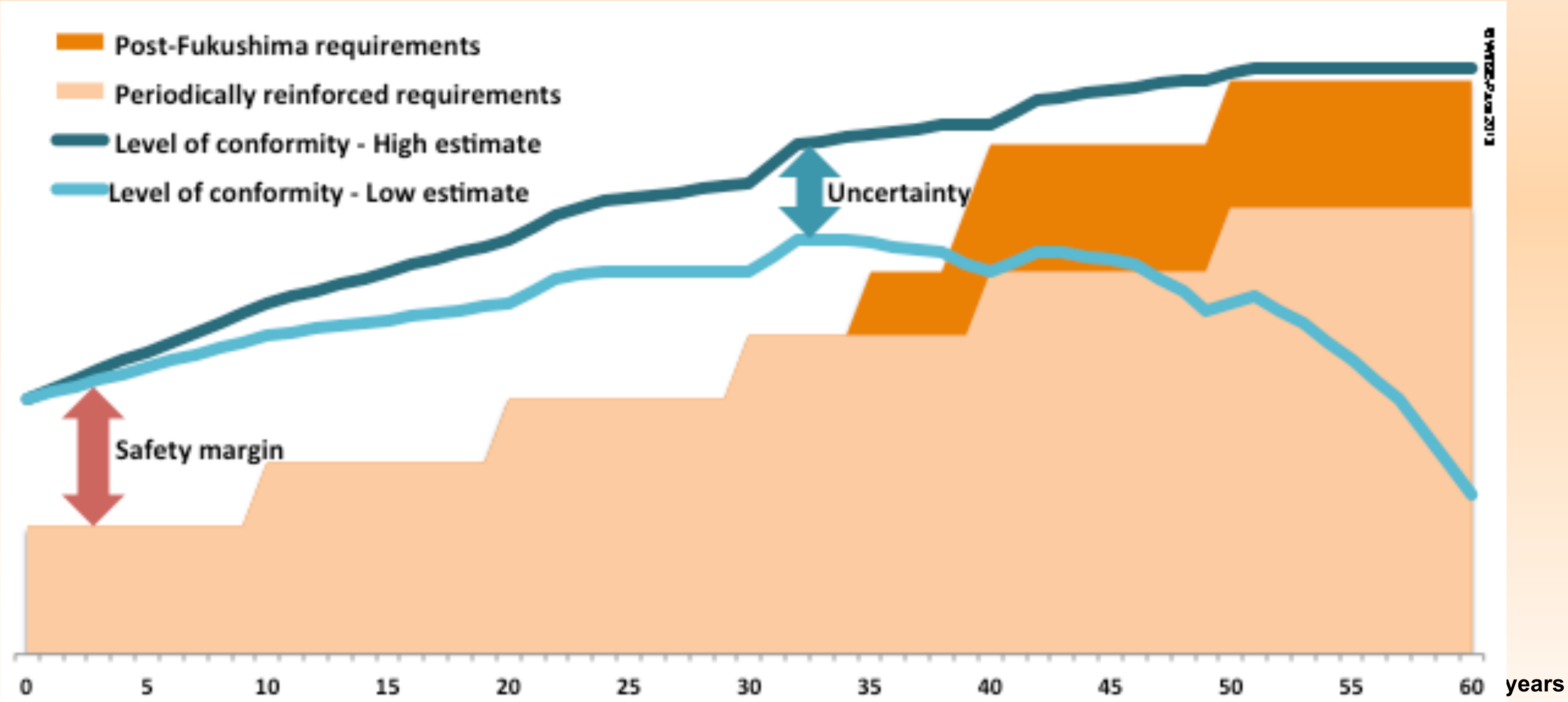
Safety issues

- **Intractable limits of the initial design**
  - **for 30 to 40 years of operation at most** (big / not replacable components)
  - **severe accidents discarded** (before Three Mile Island and Tchernobyl)
- **Unavoidable problems of ageing**
  - **concerning big and especially not replacable components** (vessel…)
  - **concerning diffuse equipement** (e.g. pipings, electric wires…)
- **Major failures of "in-depth defense" approach as demonstrated by the return of experience after Fukushima**
  - design against external events
  - reassessement of the risk of major accident on reactors
  - evidence of the risk of severe accident arising from spent fuel storage
- **Reinforcements introduced in some countries following the "stress tests" but still a long process with a lot of major question marks still open**

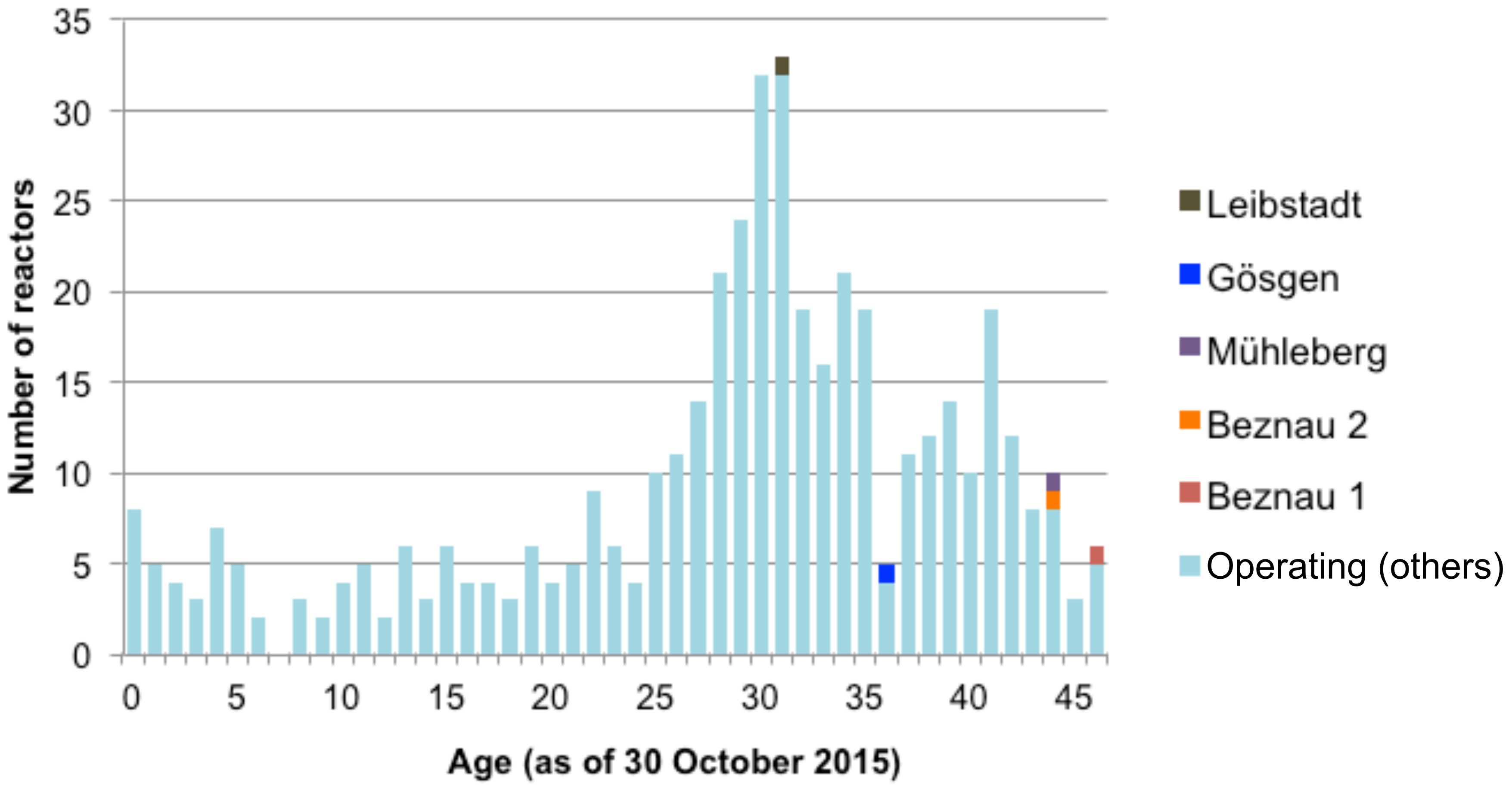
  In France, over 55 detailed instructions after Fukushima, only 8 are directly implementable

A triple problematic

- **Need to compensate ageing by reinforcements**
- **Introduction of new safety requirements after Fukushima-Daiichi**
- **Managing a growing uncertainty between theoretical and real status**



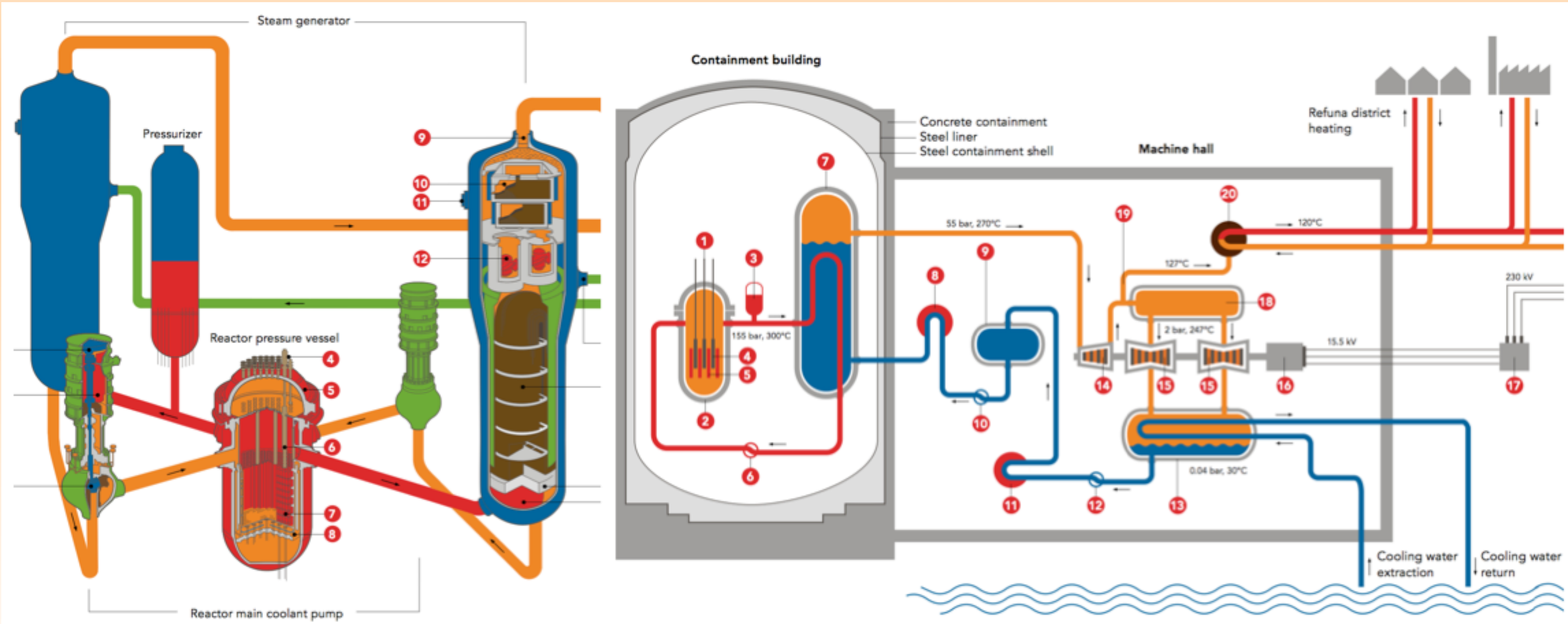
Age of operating reactors in the world



Source: WISE-Paris, based on WNISR 2015

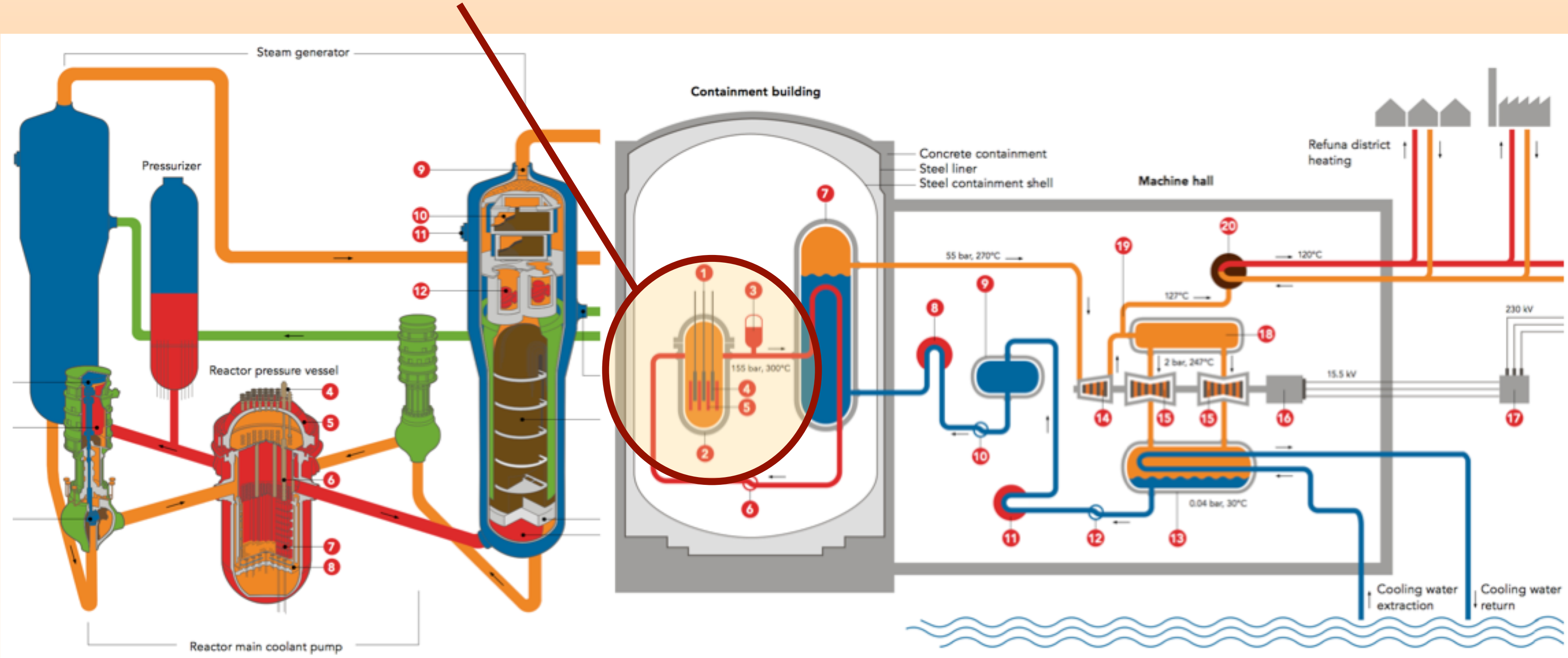
Beznau NPP

- Two units of 365 MWe, Pressurized Water Reactors (PWR)
- Started operation in 1969 and 1971
- Respectively 10 and 8 years before Three Mile Island
- The oldest operating nuclear power plant in the world



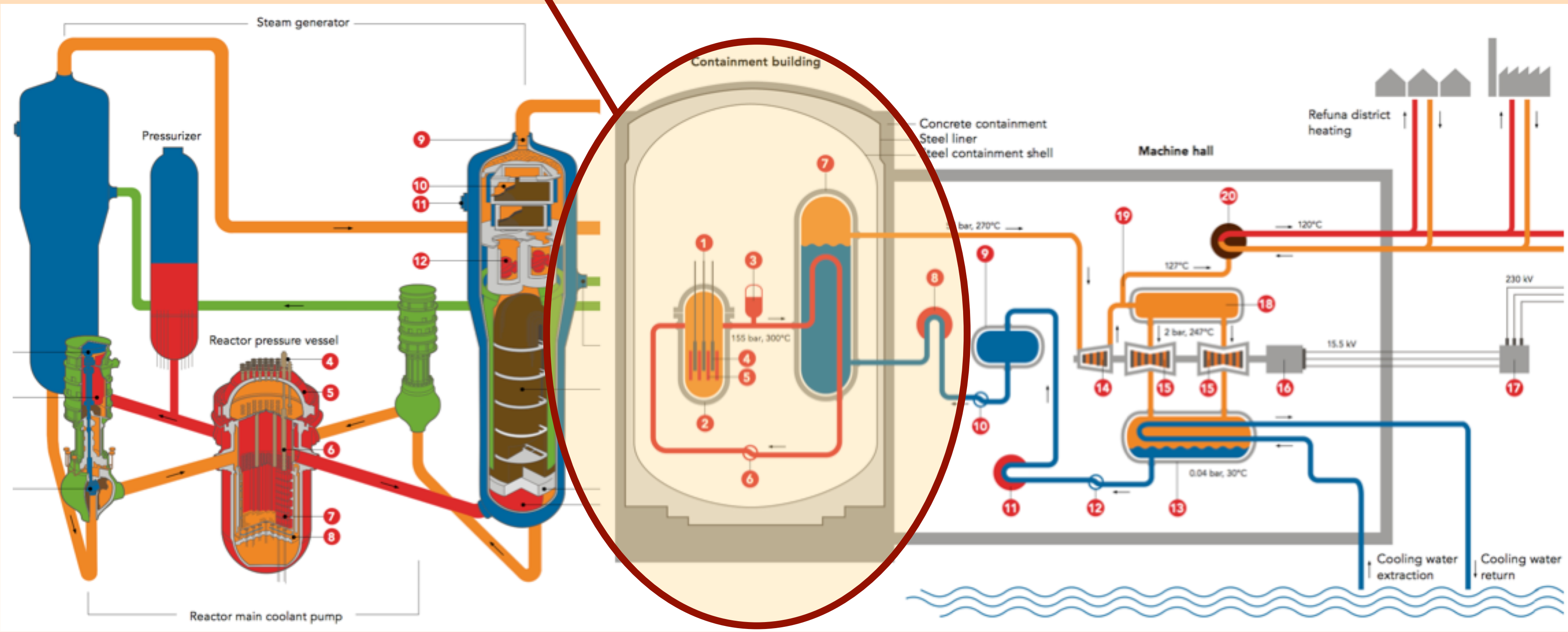
Reactor pressure vessel

- Loss of margin through routine operation (irradiation, etc.)
- Initial design up to 40 years
- Uncertainty of model, loss of monitoring capacity
- Aggraving factor of the late discovery of a large number of cracks



Reactor building

- Loss of margin through aging of concrete and steel structure
- Increased concern for the robustness in post-Fukushima scenarios
- Weaknesses introduced by the opening for changes of big components
- Aggraving factor of the recent discovery of corrosion of the steel liner



Diffuse Equipments

- Hydraulic systems (pumps, pipes…)
- Electric and electronic systems (cables, switchs…)
- Civil engineering structures (steel and concrete works…)

Reinforcement issues

- Concrete slab (againt melted core)
- Hydrogen recombining (prevention of hydrogen explosion)

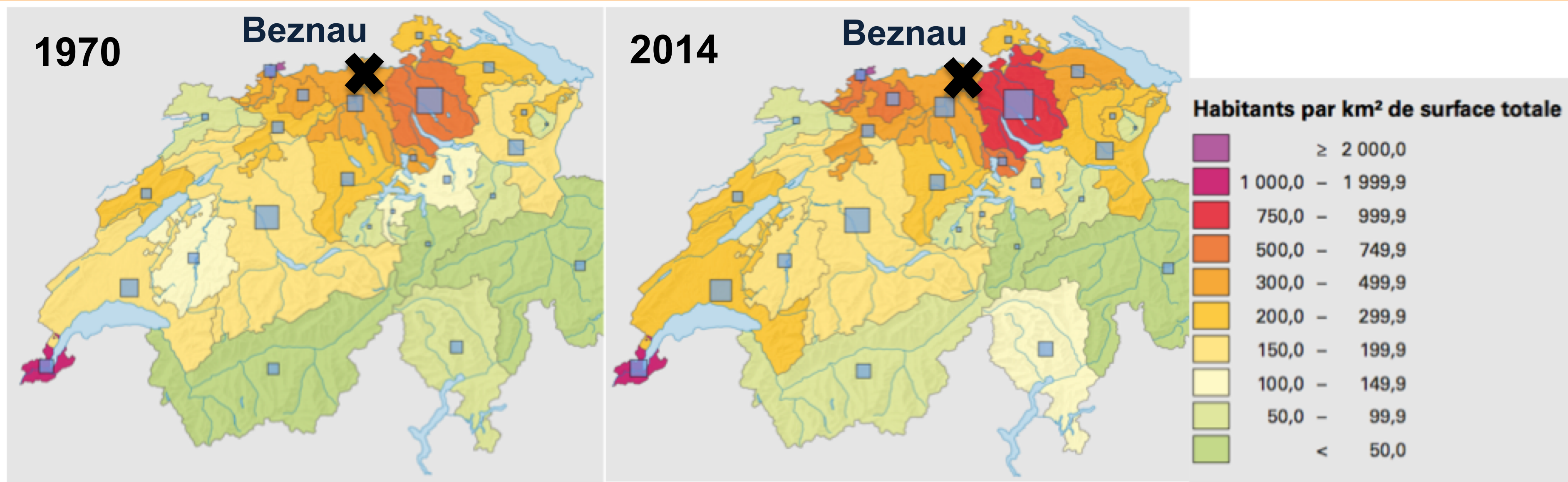
Robustness to plane crash

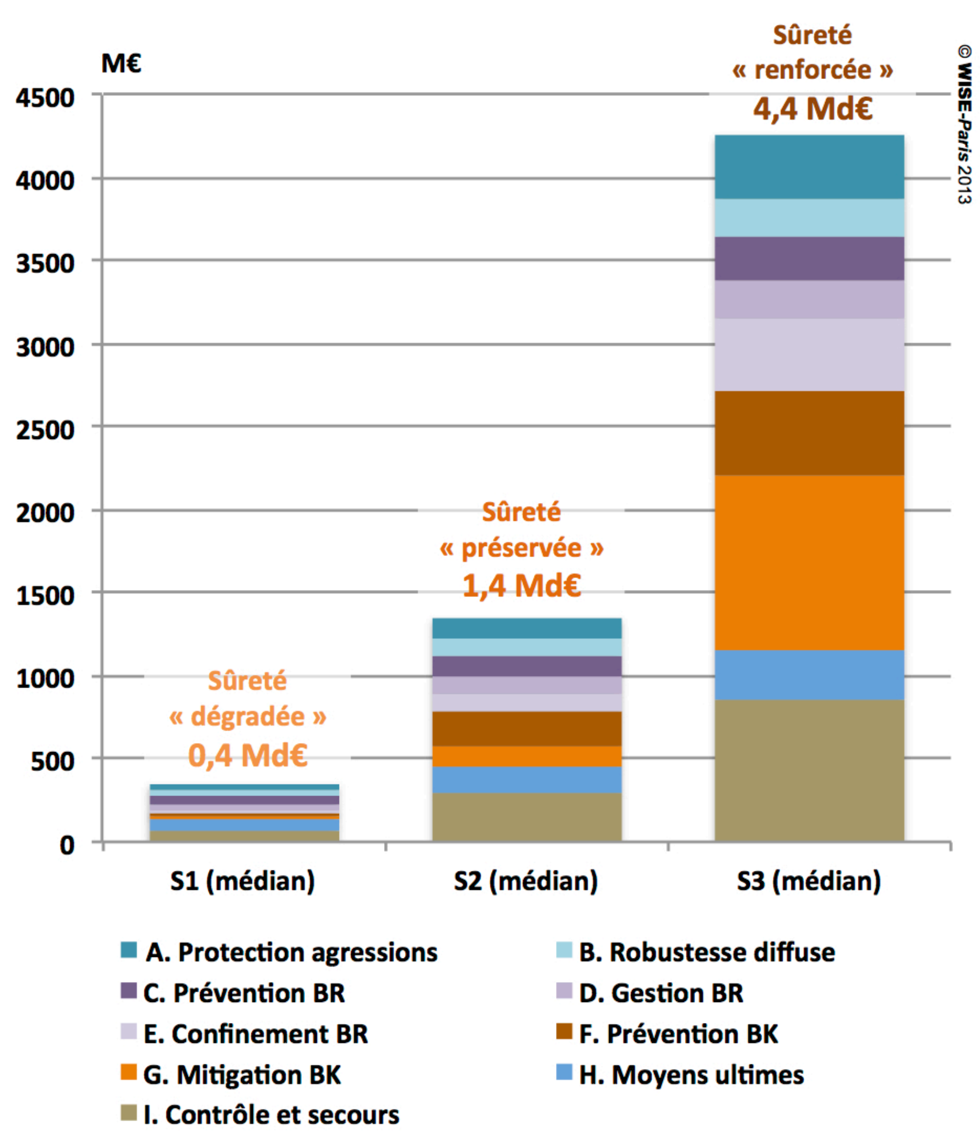
- No specific robustness to plane crash was introduced in the design phase
- Requirements to withstand light planes were introduced in regulations in 2009
- Analysis performed shows that damage from large plane is possible
- Concern with the risk at reactor buildings and spent fuel pools

Consequences of a possible accident

- Constructed from the start in a dense area
- Population of the Zurich canton, within 60 km of Beznau, has grown by 30% since the period when the plan was started
- More than 1 million people in 30 km radius and 5.8 million in 75 km radius, including in Germany

Density of population in Switzerland





Projections for one reactor (France)

- **High discrepancy of costs depending on the level of safety**

  Scenario S1 : ~ 350 M€ ± 150 M€

  Scenario S2 : ~ 1350 M€ ± 600 M€

  Scenario S3 : ~ 4350 M€ ± 1850 M€

- **A high profitability stake for the operator**
  (and a stake on prices for consumers)

- **A high stake of industrial capacity to manage heavy work on such a large scale**

Possible approach to define criteria

- **Deterministic criteria based on ageing mechanisms:**

  Principle: thresholds corresponding to the ageing of key components

  Example: vessel fragilization (ductile-fragile temperature)

  Application: key components and known and measurable mechanisms

- **Probabilistic criteria based on probabilistic safety assessment:**

  Principle: thresholds regarding the probability of severe or major accident

  Example: evolution of core damage frequency (CDF)

  Application: use of relative values (comparison) rather than absolute, problem with the acceptability and relevance of thresholds

- **Criteria based on the implementation of good practices:**

  Principle: thresholds on the gap between operator’s management and “good pratice”

  Example: failure to respect deadlines for major repairs

  Application: the field of planification, management and information where “good practices” can actually be defined and agreed upon

- **Criteria based on capacity (financial and human ressources...)**

Safety margins are crucial in safety assessment

- Safety margins are needed to guarantee that safety requirements are met with enough confidence, taking into account uncertainties of the models used and the uncertainties of the real status of the plant

Safety margins tend to be lost through aging

- Large components that can be replaced lose initial margins
- Diffuse equipments are also subject to fatigue
- The risk of undedected non conformity increases with time
- Reassessment of external risks is bound to happen

The loss of safety margins through aging is not properly assessed

- Safety assessment remains based on the assumption of conformity
- There is an illusion that safety can be maintained or even reinforced with time
- There is a need to define shutdown criteria

Thank you for your attention

More information :

Yves Marignac, Director of **WISE-*Paris***

E-mail: yves.marignac@wise-paris.org
Tel: +33 6 07 71 02 41
Twitter: @YvesMarignac