HISTORICAL PERSPECTIVE ON SAFETY MARGINS

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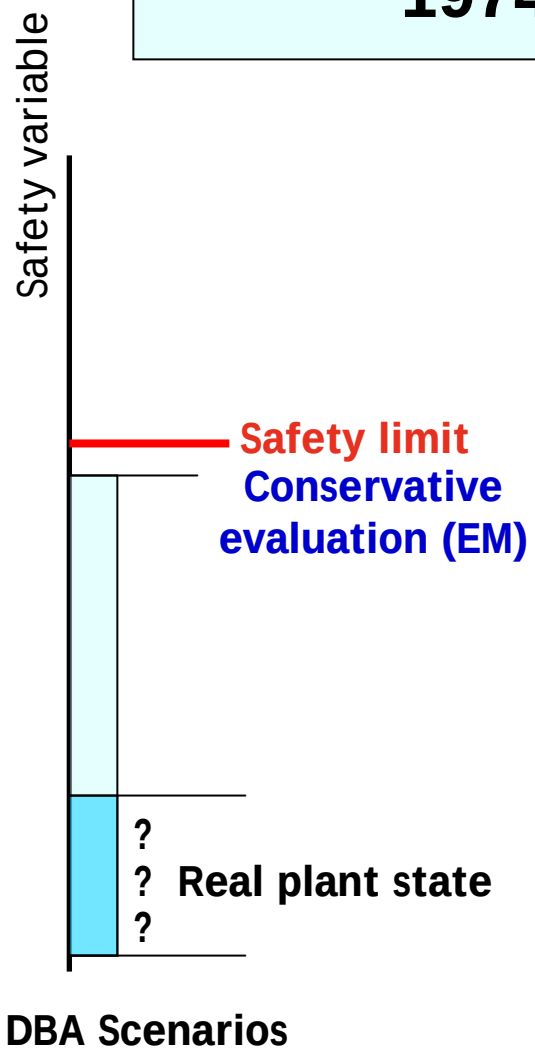
1974 ECCS RULES AND APPENDIX K



- Common question in 1974 to nuclear industry and regulator :

  How plants should be designed and built with the assurance that they will be safe ?

- Two main directions :
  - Definition of Design Basis Accidents (DBA) based on physical considerations
  - Establishment of rules and criteria
- Conservatisms introduced at every steps due to lack of physical knowledge :
  - Definition of criteria → safety limit under which nothing reprehensible shall occur
  - Definition of rules on boundary conditions, system availabilities and system failures in order to maximize consequences
  - Physical modelling highly conservative in order to get an increased evaluation of the consequences
- Prescriptive rules of Appendix K were edited.

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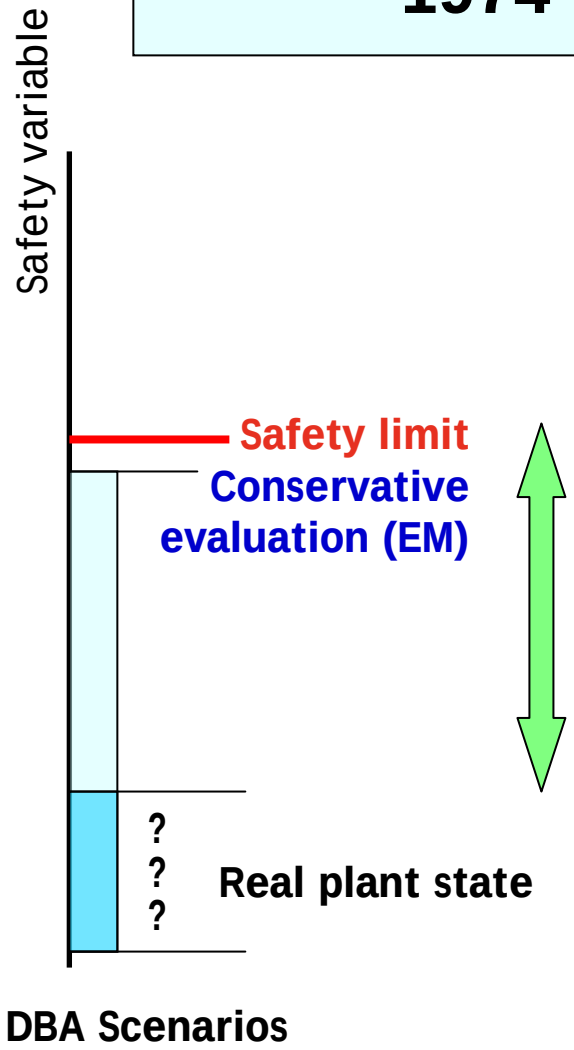
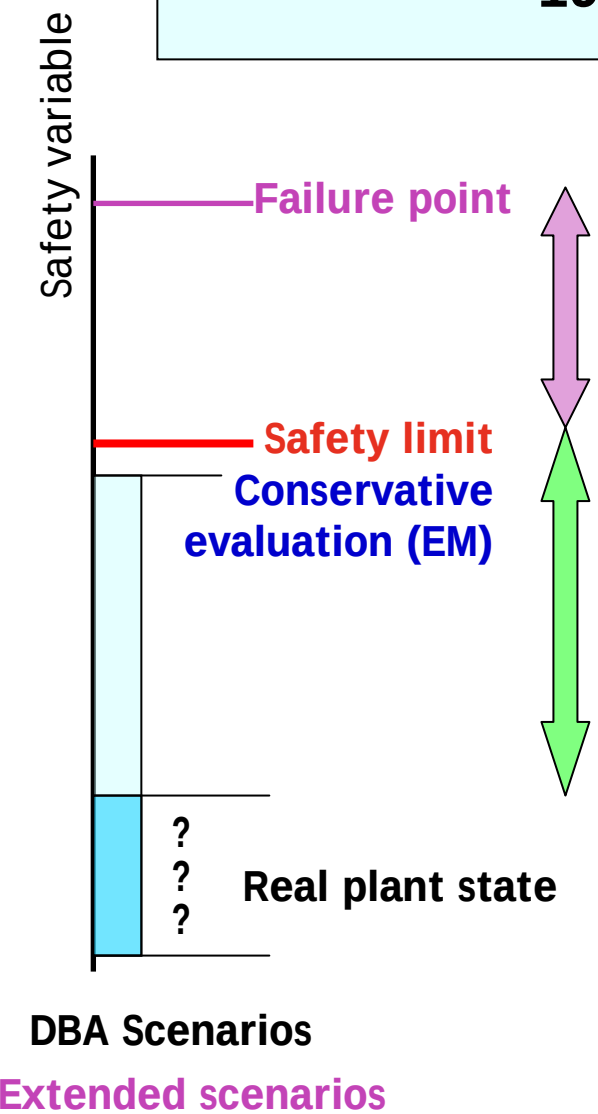


- Safety limit ensuring safe situation
- Conservative evaluation ensuring that plant behavior is well under the safety limit (on the right side)

  → **"Adequate safety margin" was claimed**

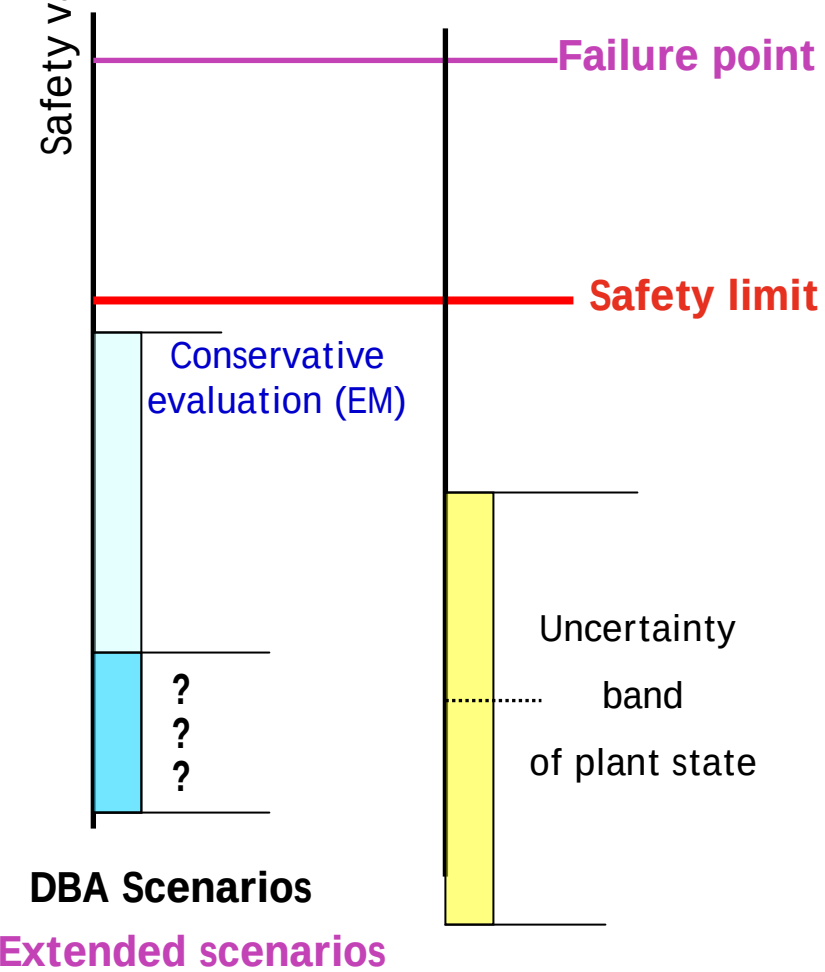
- Several difficulties in the justification
  - No way to determine how large the margin was
  - Additivity of conservatisms not possible to demonstrate
  - Prediction of the real plant state : the only way to get an evaluation of the safety margin
  - This was clearly stated by the American Physical Society in the review of ECCS rules.
- US AEC directs research to be conducted to establish the magnitude of safety margins
- Large international Th research programme launched in late 70's up to 90's

1980's TMI CONSEQUENCES



- DBA not the only safety concern
  - Other transients, operator actions, BDBA
  - Extended scenarios + probabilistic approach
- Severe accidents were considered
- Plant operation over the safety limits became of a greater interest
- Failure points were considered
- Attention was paid to the space between safety limit and failure point which appeared as an other margin introduced by setting up the safety limit in a conservative manner
- Safety margin concept was more and more used in the 80's and 90's but with different meanings
  - Maintain SM, increase SM,
  - Impact on SM required for launching safety research

1985 -2007 APPLICATION OF NEW METHODS FOR TRANSIENT PREDICTIONS



- 1985 : first versions of Best Estimate codes became available
- Best Estimate codes still based on assumptions and approximations
- Need to evaluate uncertainty band for plant prediction
- Several methods being developed and used : bounding approach, realistic conservative, best estimate plus uncertainties
- Open questions still remaining

PRACTICES POSSIBLY IMPACTING SAFETY MARGINS (1990s' →)

- Since mid 1990's modifications are implemented in order to maximize plant output (cycle length, higher burn up, power uprate,…)

- With those modifications
  - Safety limits are exceeded with traditional conservative methods
  - New methods had to be applied to demonstrate that plant still stays under safety limit

- Modifications resulting sometimes from addition of several small design changes. Accumulation of changes may lead to exceedance of safety limit.

- After modifications, in some operational conditions, the safety limit appears not any more valid (ex RIA)

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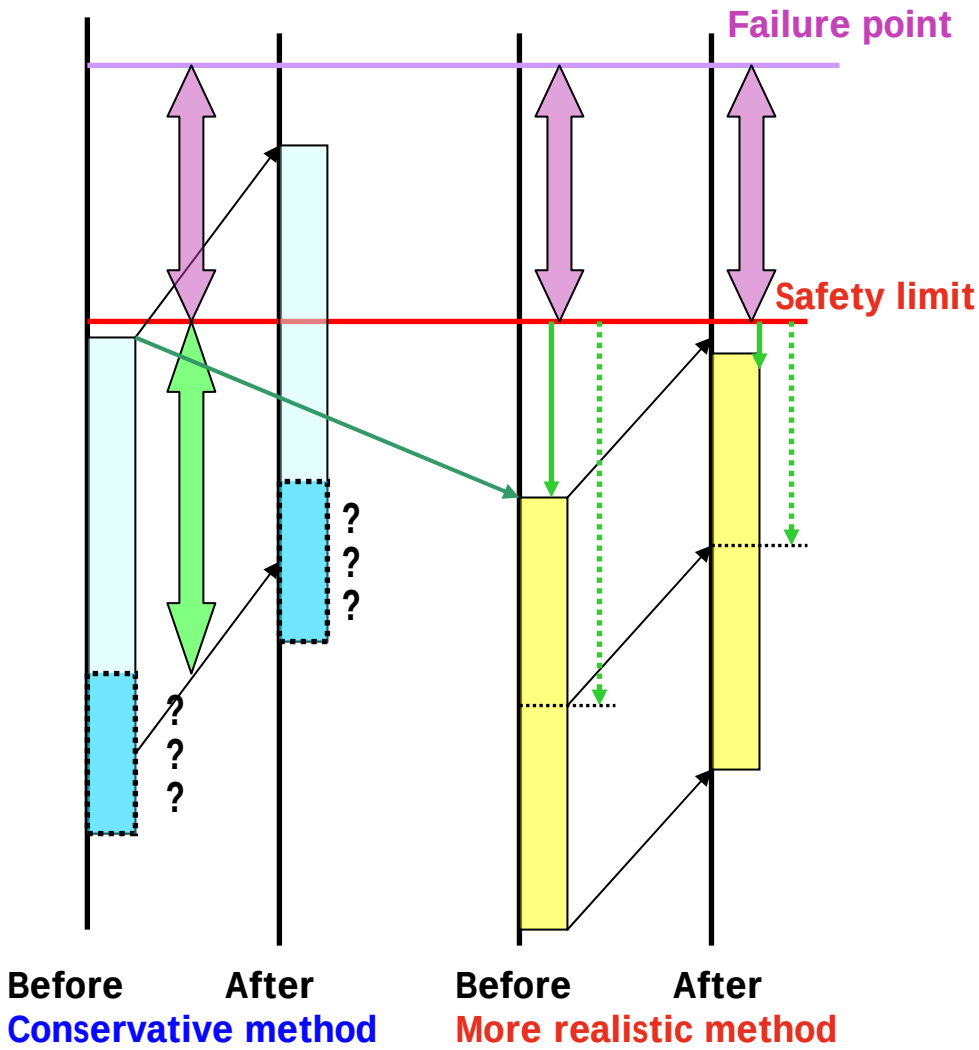
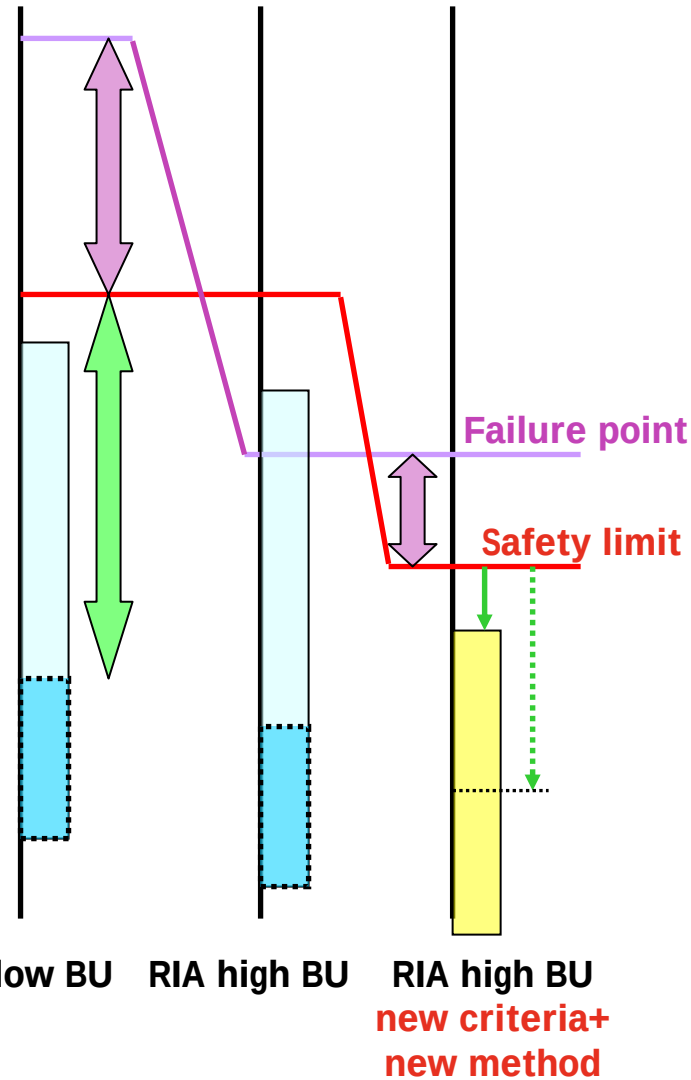
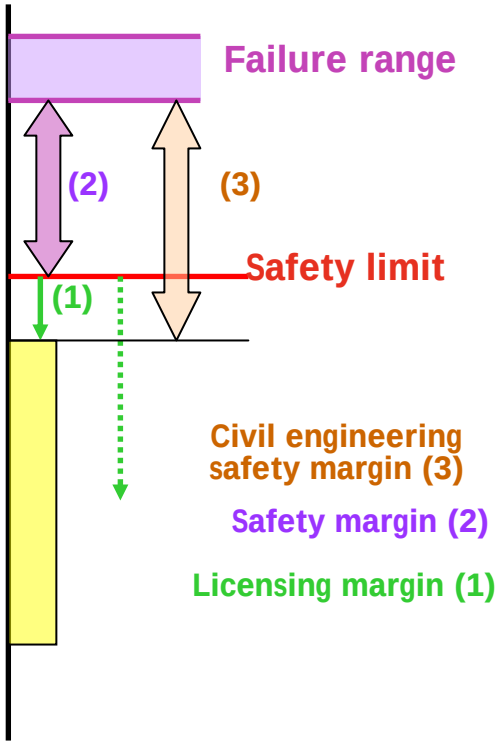
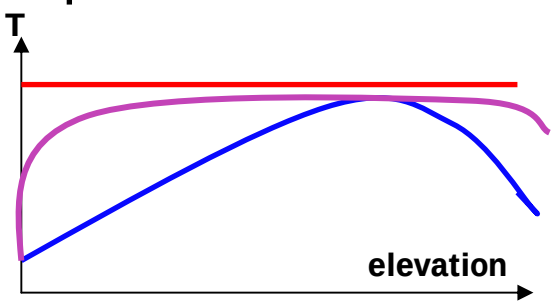




ON GOING STUDIES ON SAFETY MARGINS



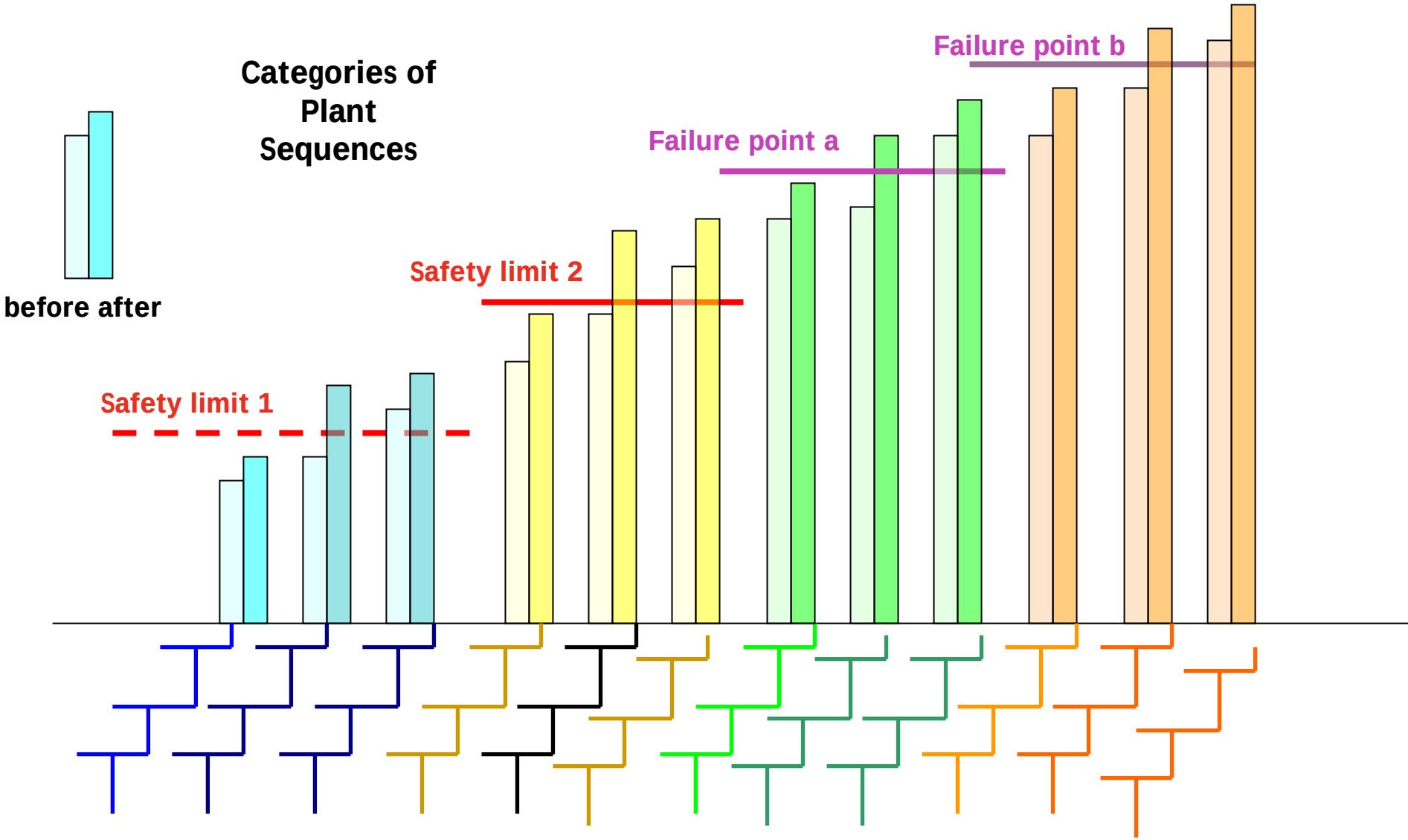


- Since end of 90's, safety margin concept is being investigated particularly at an international level (CSNI, IAEA)
- Plant optimization leads most often to more reactive plant behaviors getting closer to safety limits / failure points. Qualitatively, some margin seems to be lost.

- But " what is safety margin ? "
- Several approaches (OECD / IAEA) to this question but still re-discussed from time to time

- Distances between plant state/ safety limit/failure point not the only factor which may represent physically safety margin
- Static view of safety margin . In fact several DBA and BDBA transients, several safety limits and failure ranges → need for a more global view of the plant physical response.

SAFETY MARGINS PROBLEMATICS



SAFETY MARGINS CONCEPT EVOLUTION

- Objective of safety margins in the 1970s was to cover in the deterministic approach lacks of knowledge, unexpected events and unexpected errors in the design or in the operation
- Results of research have clearly improved scientific knowledge
- Accumulation of experience on plants has significantly confirmed design and operation practices
- But open questions still remain
- Those questions are presently formulated in terms of "unknown unknowns" and in terms of robustness.
- Safety margins concept is still relevant but has to be precised
- The safety margin issue has to be investigated using deterministic and probabilistic tools

PERSPECTIVES

- Several techniques and capabilities are available to investigate safety margins
  - Safety computer codes of second generation and code applications
  - Probabilistic techniques (PSAs)
  - Continuously increasing computer capabilities
- Lot of numerical investigation can be and should be performed

- Indicators and metrics for safety margins will have to be precised :
  - All results should be analysed physically
  - Prediction of uncertainties for every contributors to the results is a key issue
  - Safety significance should be established