IAEA 60 Years
Atoms for Peace and Development

Overview of the Concept of Risk and Risk Analysis

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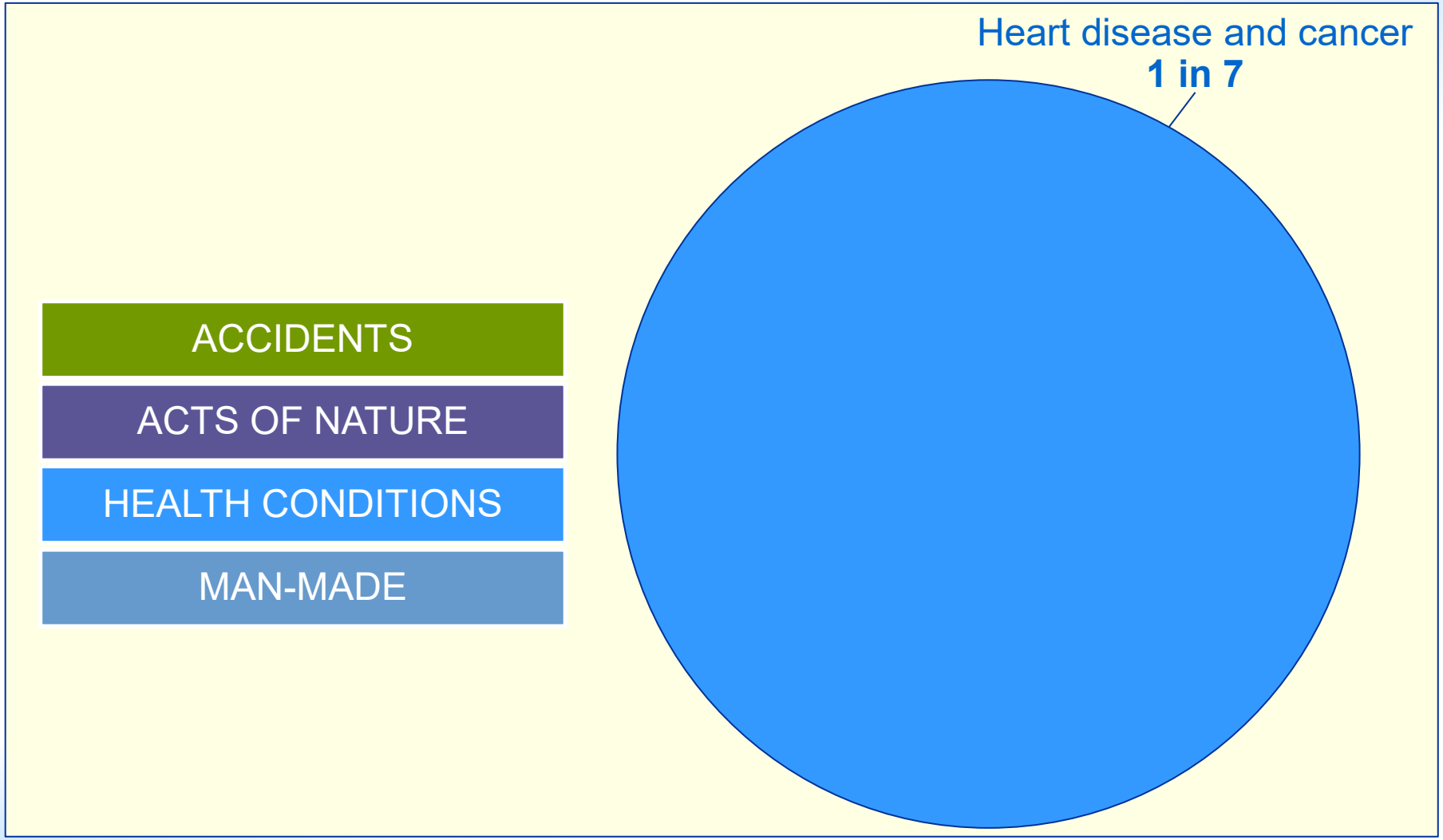
What Do We Mean By Risk?

- The notion of risk is widely used in everyday life
- Colloquially, risk is associated with danger, hazard, exposure-to-death, injury, loss, or other *negative* consequences:
  - Risk implies a *potential* for harm
  - If the danger is actually realized, then it is no longer risk but actual death, injury, loss or other harmful consequence
- Risk is inescapable - it is inseparably associated with human existence

EXAMPLE: General Context of Risk Numbers (Lifetime Odds)



*Adapted from National Safety Council: Injury Facts, 2017 Edition

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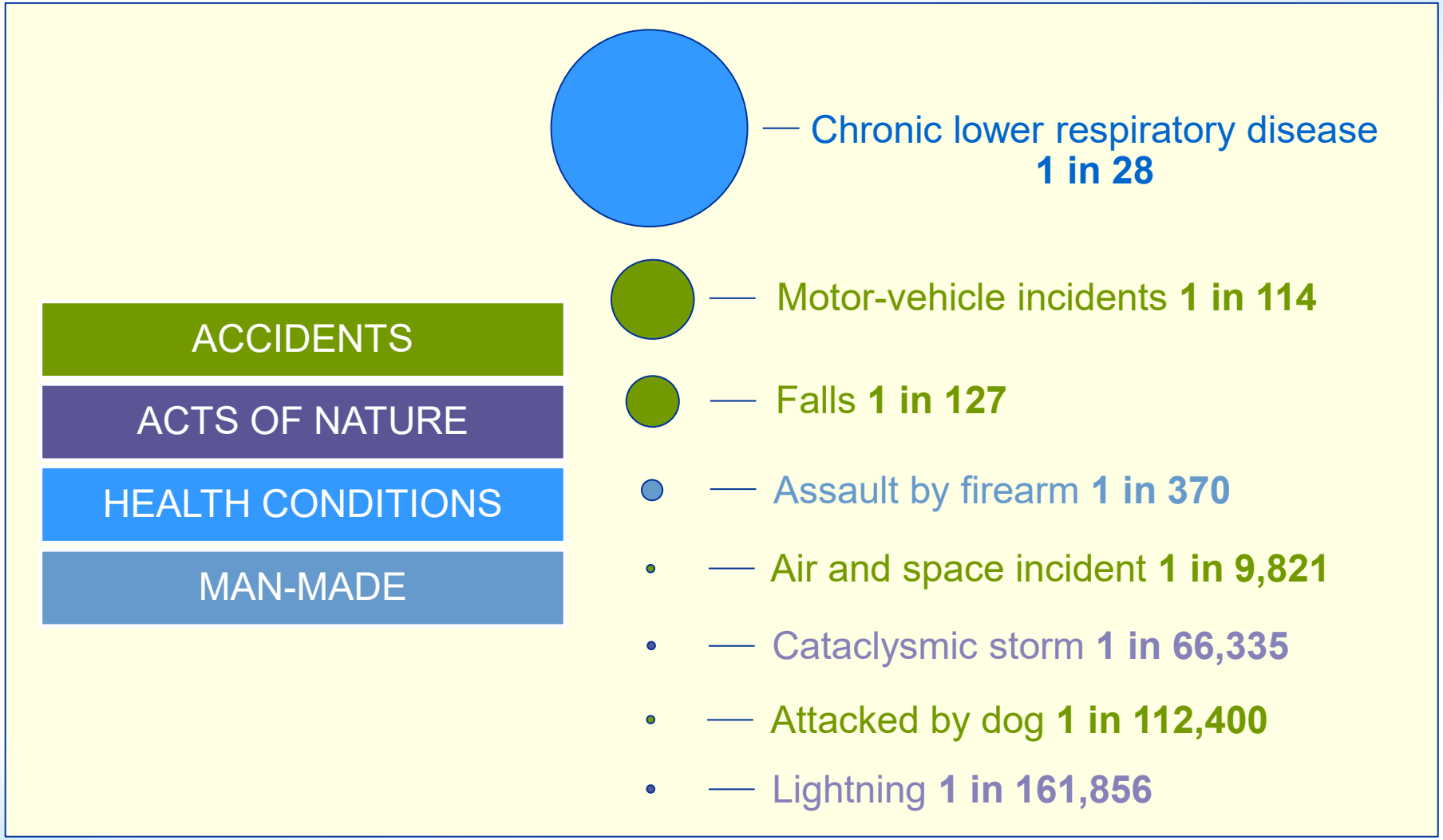

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EXAMPLE: General Context of Risk Numbers (Lifetime Odds)

ACCIDENTS

ACTS OF NATURE

HEALTH CONDITIONS

MAN-MADE

CONDITIONS THAT INCREASE HEART DISEASE ODDS

- High Blood Pressure
- High Cholesterol
- Diabetes

MAY BE ABLE TO DO SOMETHING ABOUT THIS

BEHAVIOURS THAT INCREASE HEART DISEASE ODDS

- Unhealthy Diet
- Physical Inactivity
- Excess Body Fat
- Tobacco Use

CAN DO SOMETHING ABOUT THIS

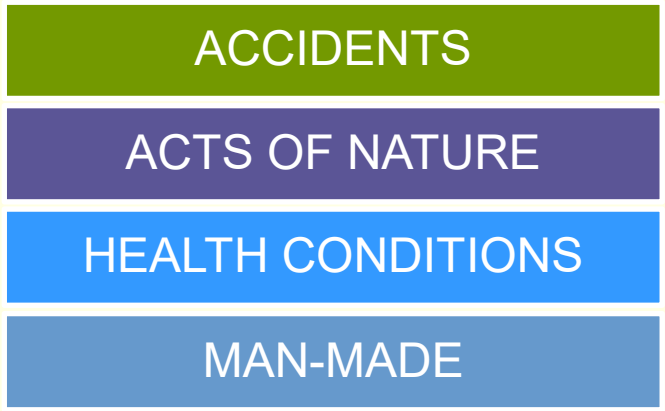
TRAITS THAT INCREASE HEART DISEASE ODDS

- Genetics and Family History
- Age
- Gender
- Race

NOTHING YOU CAN DO ABOUT THIS

*Adapted from Center for Disease and Control, Heart Disease Risk Factors

EXAMPLE: General Context of Risk Numbers (Lifetime Odds)



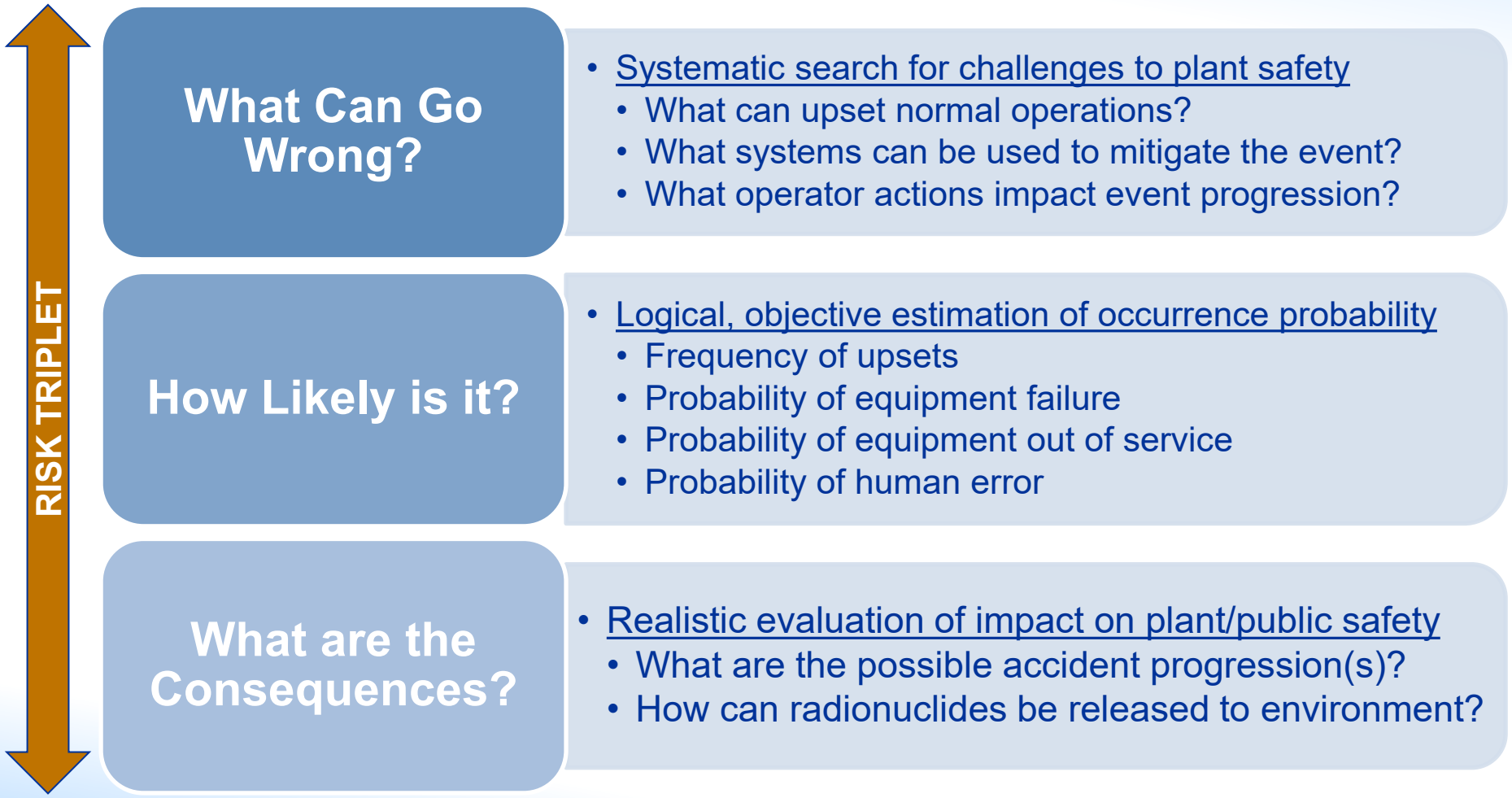
IMPORTANT

In general, benefit of doing risk assessment is to:

- ***Compare risk contributors***
- ***Assess what can be done to minimize risk when possible***
- ***Consider how to manage the contributors we don't control***
- ***Avoid risk "blind spots"***
- ***Focus on what's important!***

RISK TRIPLET

In practical terms, what do we mean when we ask "what is the risk" of a specific application?



Risk Terminology

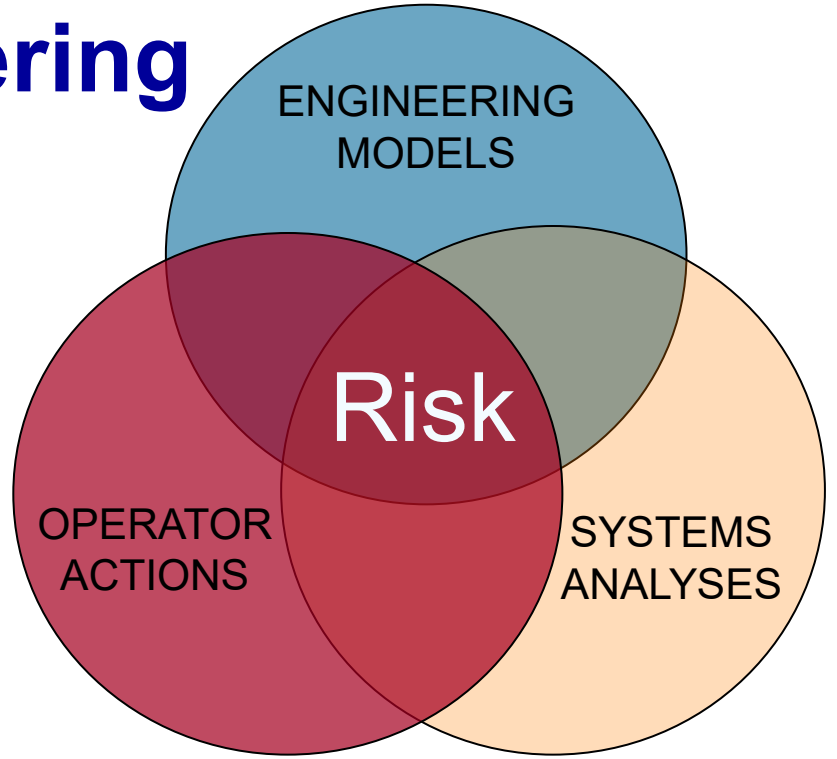
- A *hazard* is a potential condition that causes:
  - injury or death to people,
  - loss of or damage to equipment, property, etc.
- Hazard is characterized by
  - magnitude (severity) and
  - frequency of occurrence of the hazard with specified magnitude
- Risk is a measure of a consequences from the hazards
- Risk is characterized by :

  1) the *magnitude* (*severity*) of the adverse *consequence*(s) that can potentially result from the given hazard, and

  2) by the *probability (frequency)* of occurrence of the given adverse consequence(s)

Risk Assessment and Engineering

- An integrated, multidisciplinary engineering tool
- Models how accidents may progress and how systems, operators impact scenarios

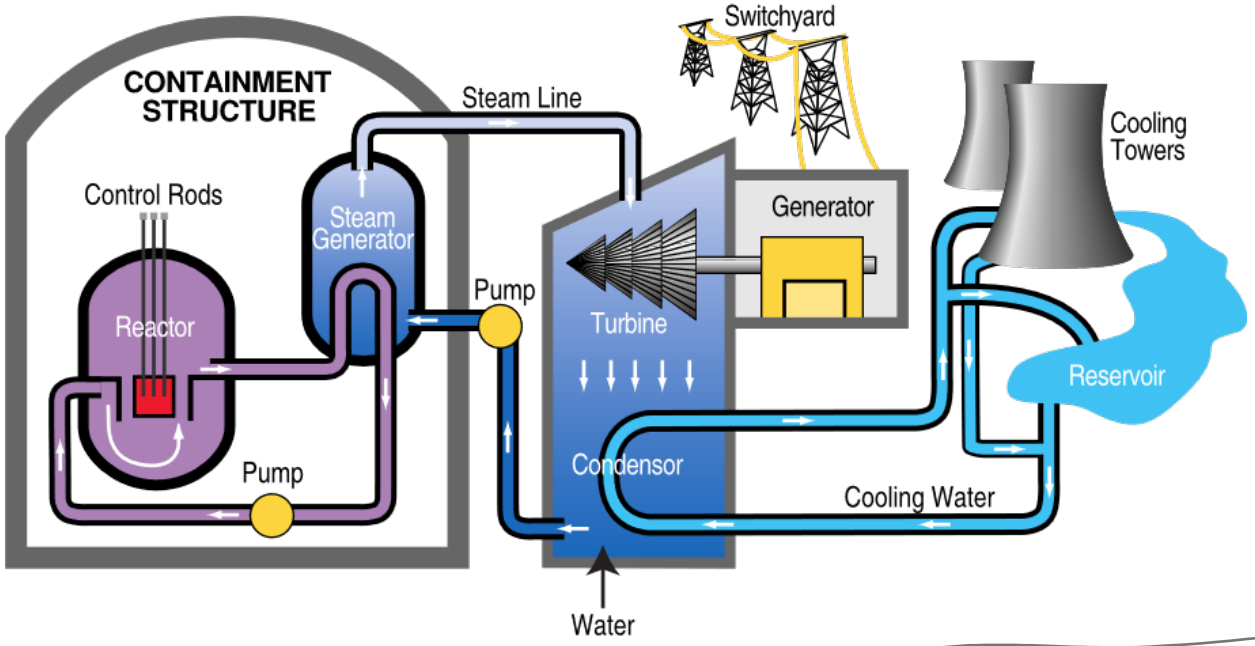


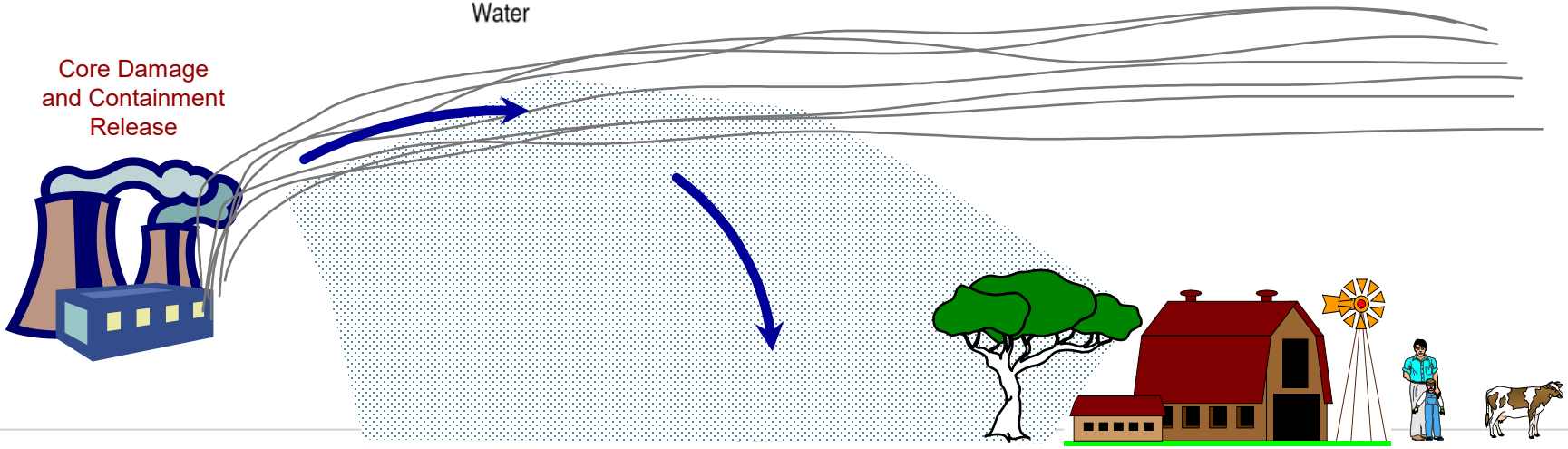
- Uses probabilistic and statistical approaches as a common language for assessing risk

***IMPORTANT:* risk assessment is intended to provide a systematic, comprehensive technical framework for evaluating risks associated with specific engineering applications**

Risk Assessment and Engineering

A tool to focus on important safety aspects





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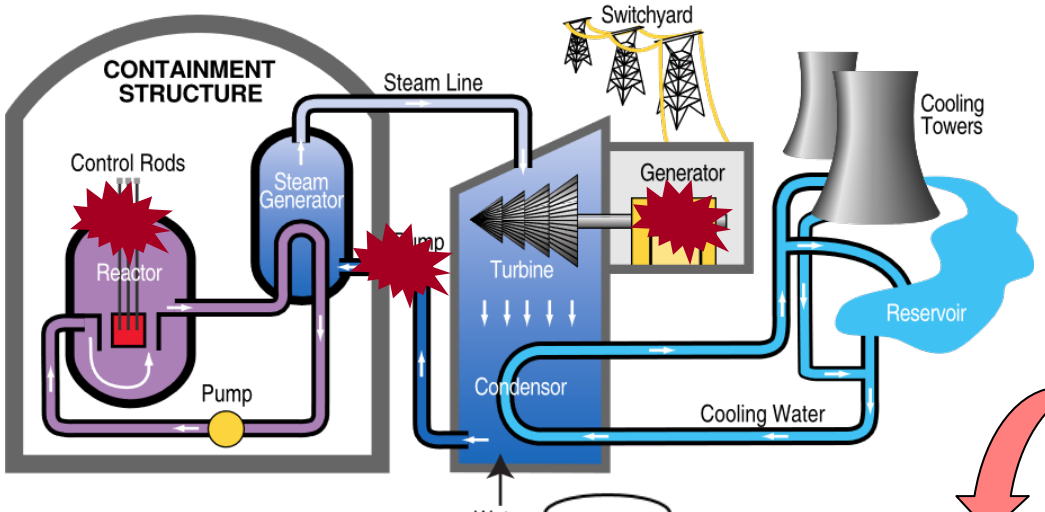
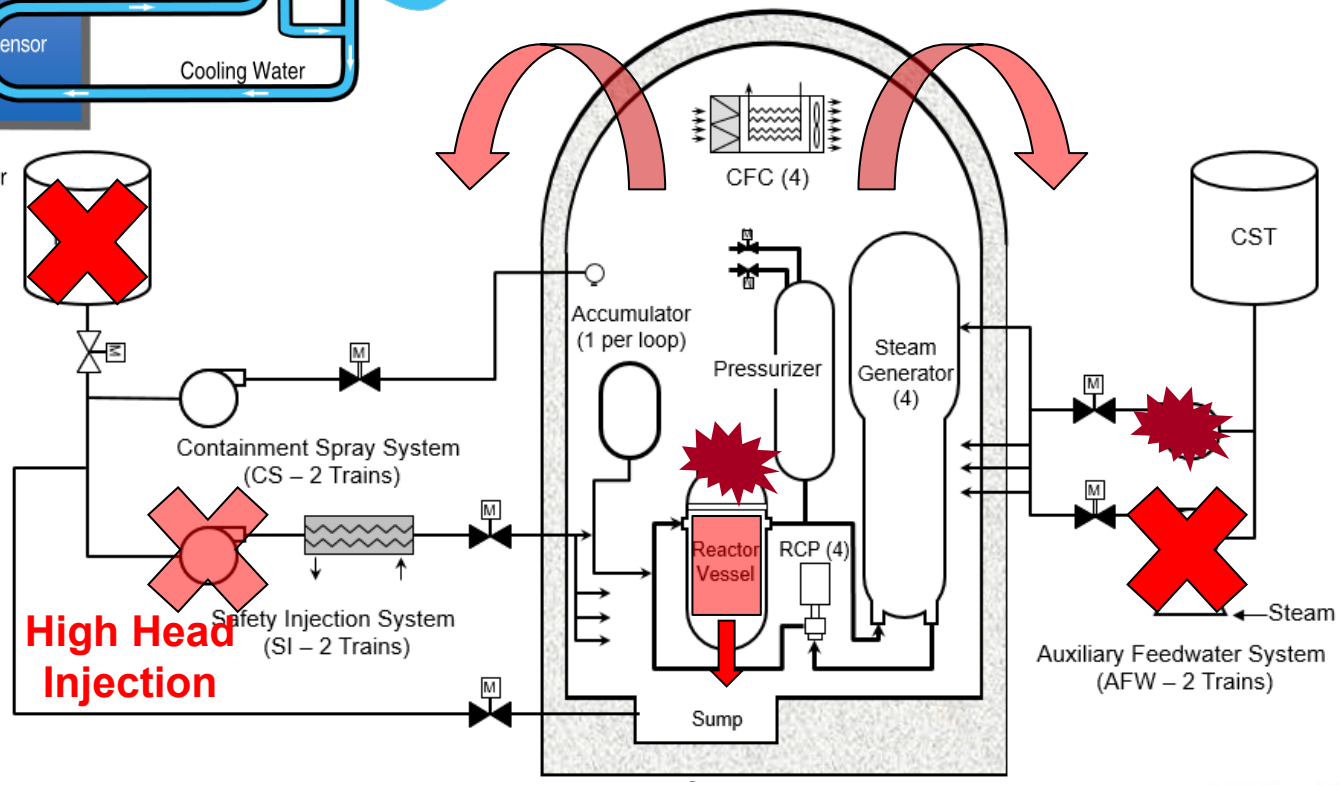
Risk Assessment and Engineering

A tool to focus on important safety aspects



- Assume NPP is operating at full power
- Assume a component fails



*Typically, risk models for NPPs estimate the risk of **core damage** and **large early releases** for accident scenarios*

Risk Assessment and Engineering

A tool to focus on important safety aspects

Type of detriment	Measuring unit
Human death	Number of deaths
Health effects	Number of affected (injured) persons
Regions uninhabitable	Surface area (km^2)
Material damage	Monetary units

ating at full power

t fails

Typically, risk models for
*estimate the risk of **core***
*and **large early releases** for*
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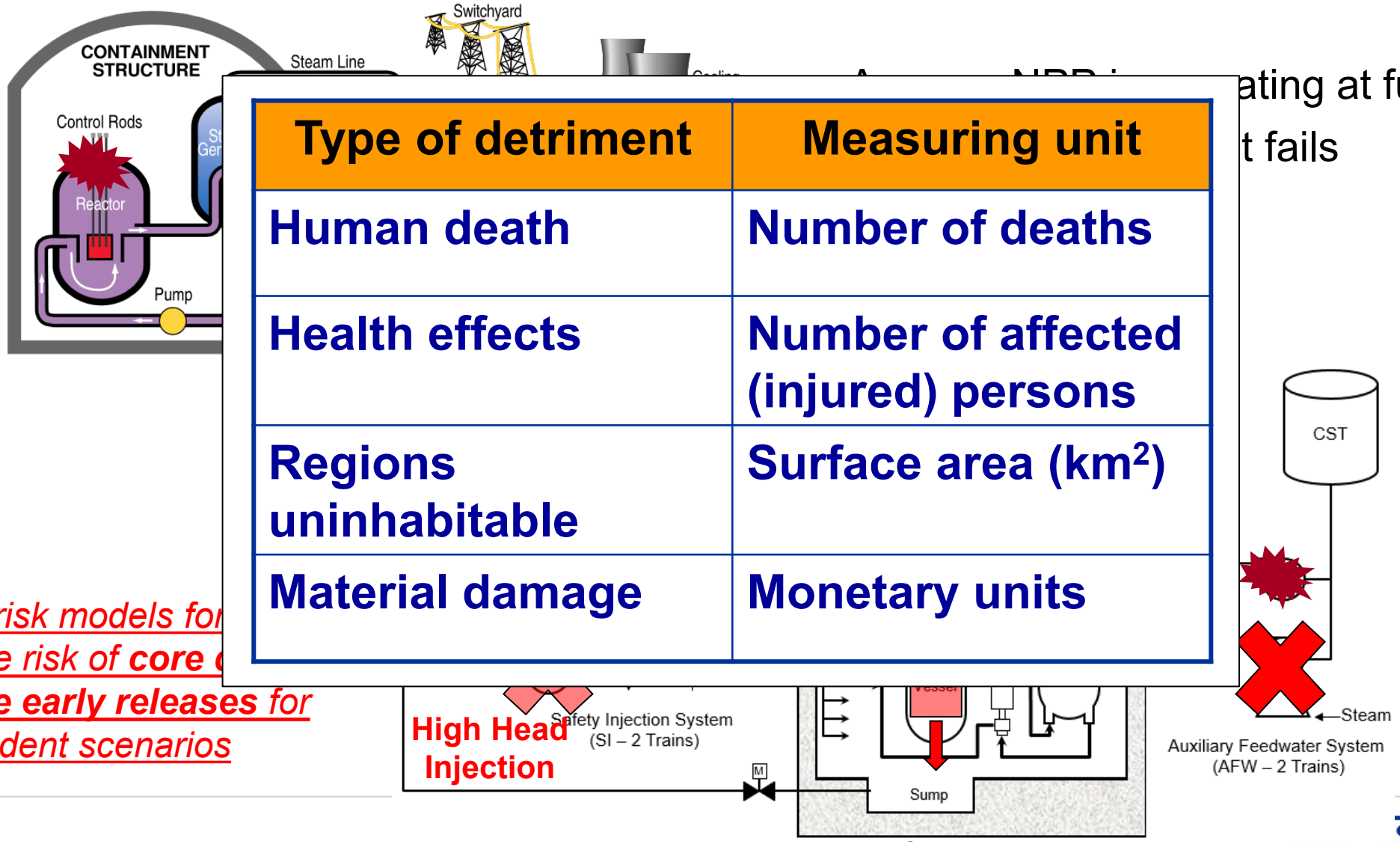


Definition of "Risk": IAEA Glossary 2022

Depending on the context, the term risk may be used to represent a quantitative measure (see (1) and (2)) or as a qualitative concept (see (3), (4) and (5)):

1) A multiattribute quantity expressing hazard, danger or chance of harmful or injurious consequences associated with exposures or potential exposures.

In mathematical terms, this can be expressed as:

$$\text{RISK}\left[\frac{\text{Detriment}}{\text{Time unit}}\right] = \text{FREQUENCY}\left[\frac{\text{Event}}{\text{Time unit}}\right] \times \text{UNDESIRED CONSEQUENCES}\left[\frac{\text{Detriment}}{\text{Event}}\right]$$

Definition of "Risk": IAEA Glossary 2022

2) **The mathematical mean (expectation value) of an appropriate measure of a specified (usually unwelcome) consequence**

3) **The probability of a specified health effect occurring in a person or group as a result of exposure to radiation.**

   - Annual Risk, Attributable Risk, Lifetime Risk, Relative Risk

4) **Radiation Risks – detrimental health effects of exposure to radiation (including the likelihood of such effects occurring), and any other safety related risks (including those to the environment) that might arise as a direct consequence of:**

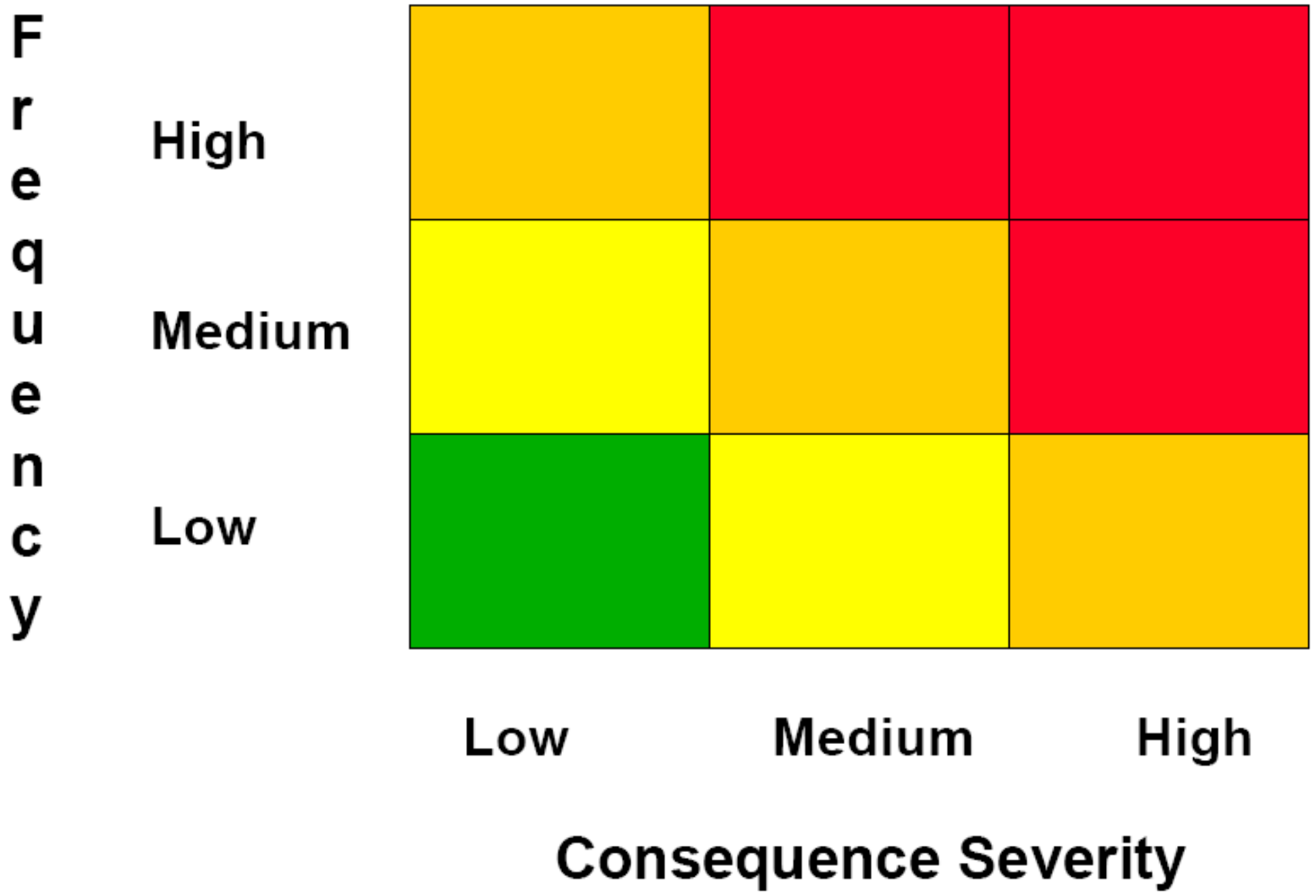
   (a) Exposure to radiation;

   (b) The presence of radioactive material (including radioactive waste) or its release to the environment;

   (c) A loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation.

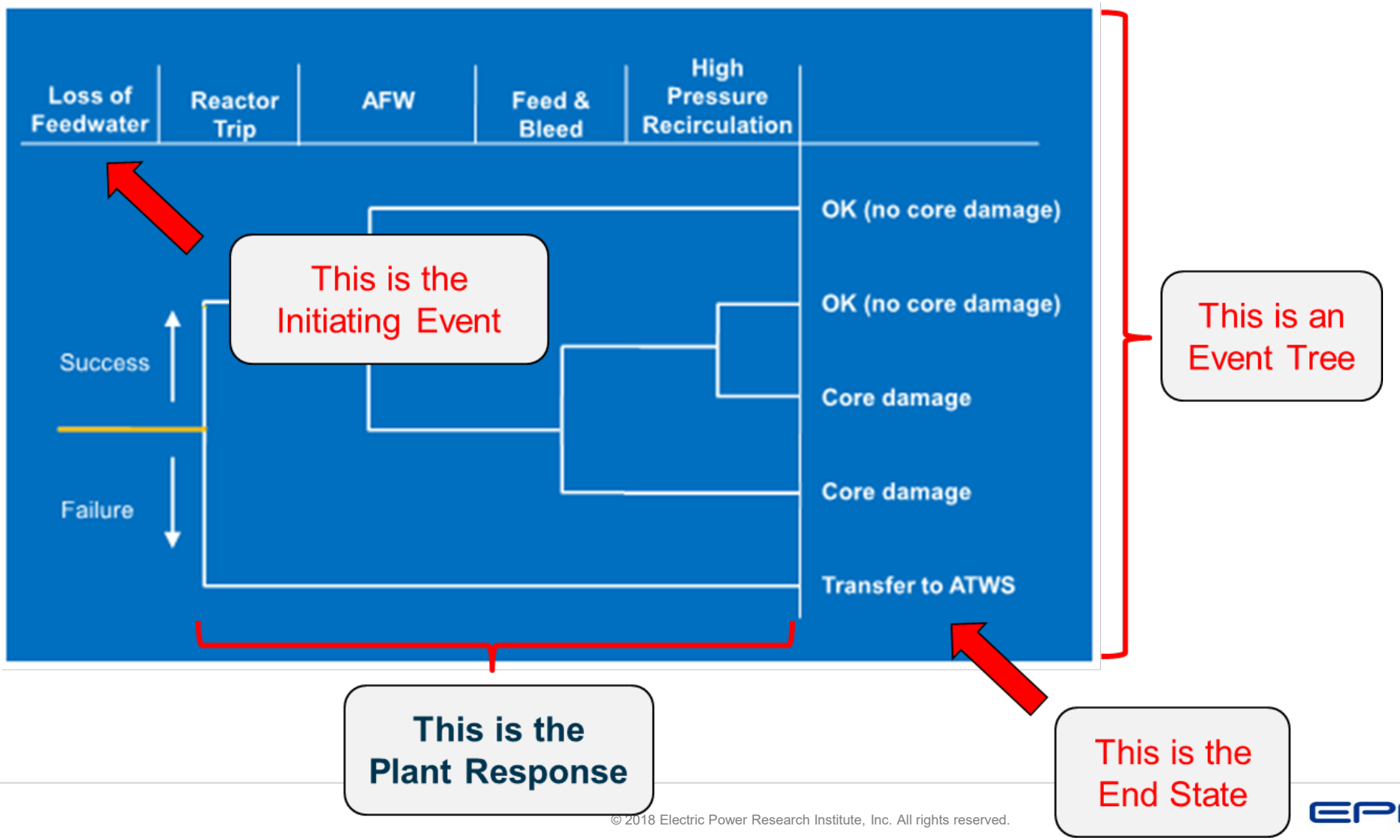
5) **The potential for an unwanted outcome resulting from a nuclear security event as determined by its likelihood and the associated consequences**

Qualitative Risk Assessment



Risk Assessment and Engineering

How are the concepts applied in practice?



Risk Assessment and Engineering

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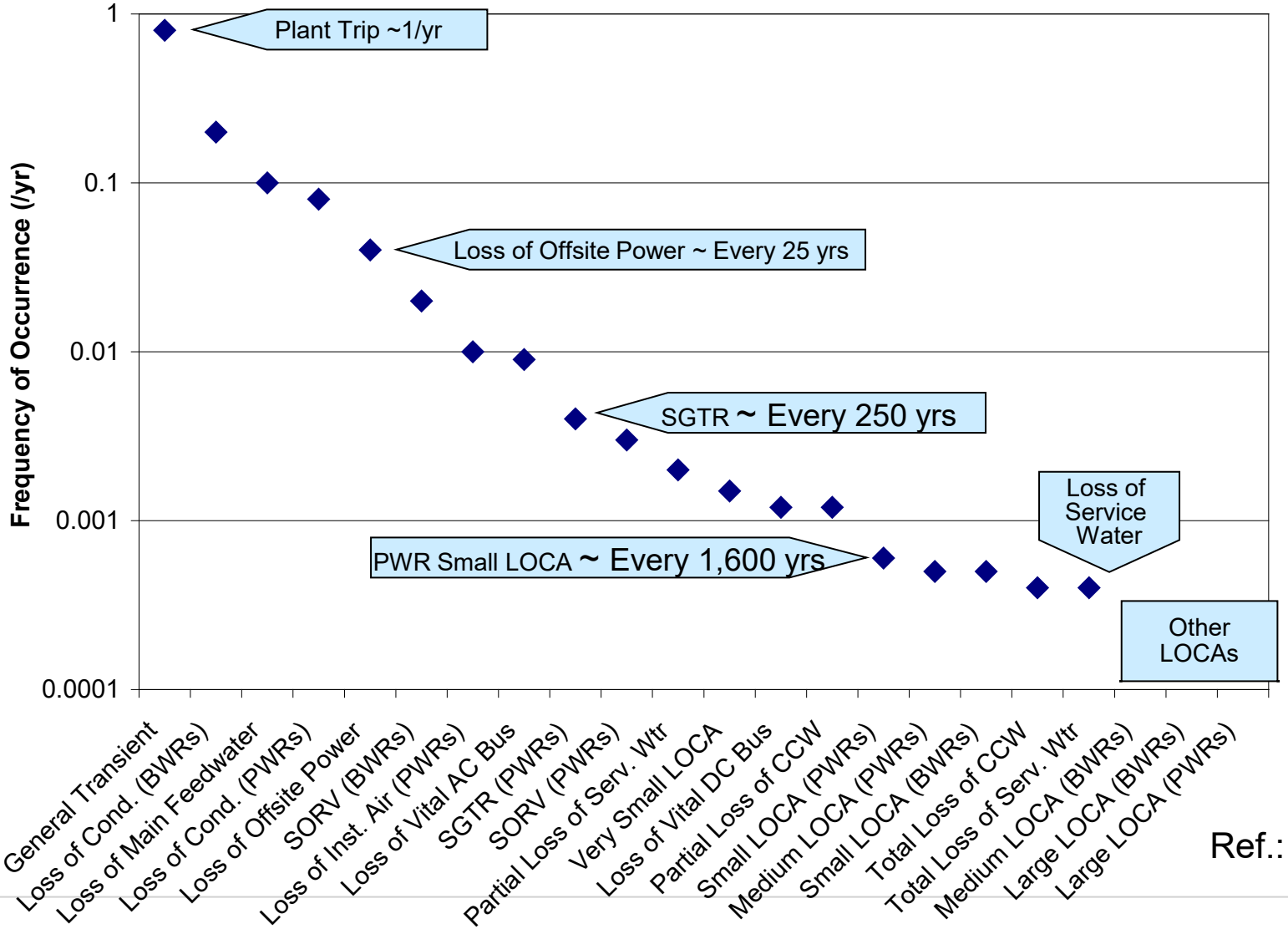


Once per reactor year

Once in 10 reactor years

Once in 100 reactor years

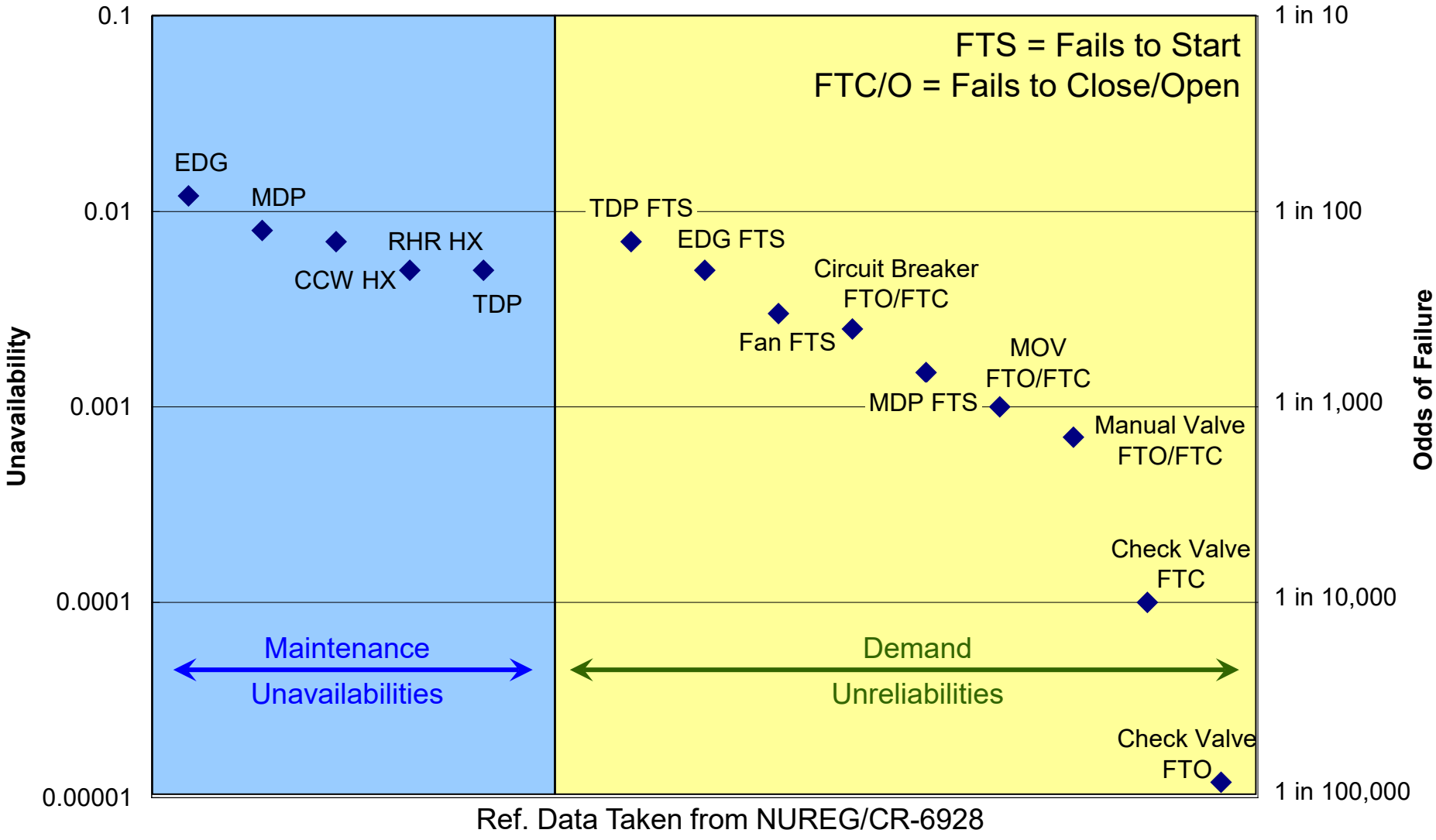
Once in 1,000 reactor years

Once in 10,000 reactor years

Ref.: NUREG/CR-6928

WHAT ARE THE OUTPUTS OF PRA?

Outputs depend on component probabilities modeled



Ref. Data Taken from NUREG/CR-6928

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WHAT ARE THE OUTPUTS OF RISK ASSESSMENTS?

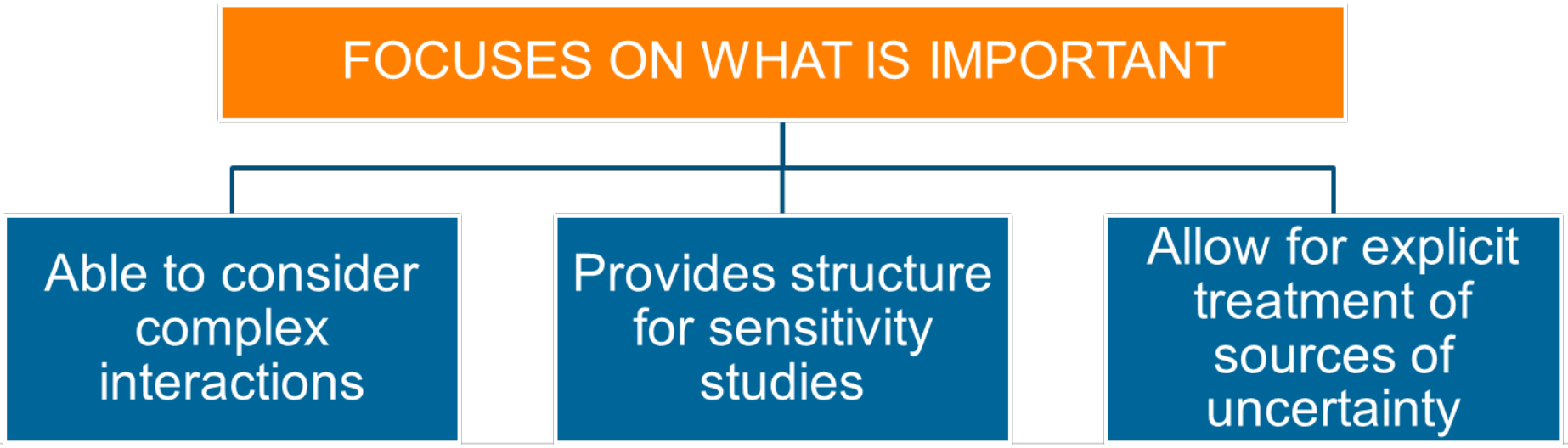
While overall quantification results receive a lot of attention, real benefits are derived from the risk insights, e.g.,

- Understanding the most risk significant systems and components in your plant
- Recognizing specific human actions that may need more training than others
- Finding combinations of failures not previously known (e.g., shared dependency)
- Recognizing specific evolutions during an outage that may increase/decrease risk
- Identifying systems or components that have very little risk contribution (e.g., reduce cost)
- Anticipate specific actions that may help reduce risk during events (e.g., weather)

BENEFITS AND CHALLENGES

Strengths of Risk Assessment and RIDM

- Rigorous, systematic analysis tool to capture complex interactions
- Integrates multidisciplinary information concerning plant design and operating practices, through a common language
- Allows for more rational safety and regulatory decisions
- Allows allocation of resources commensurate with the real safety significance, resulting in more safety at a lower cost



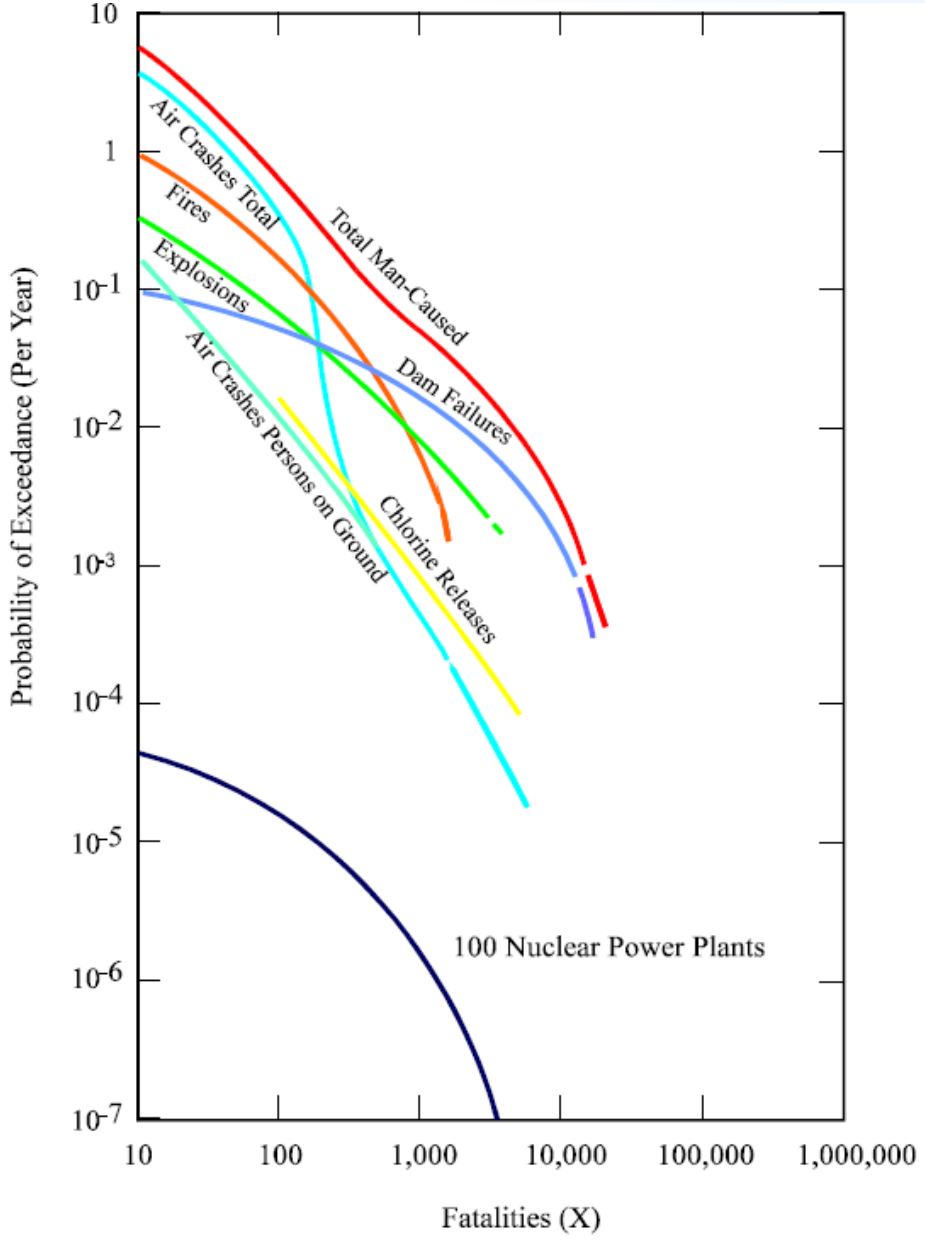
BENEFITS AND CHALLENGES

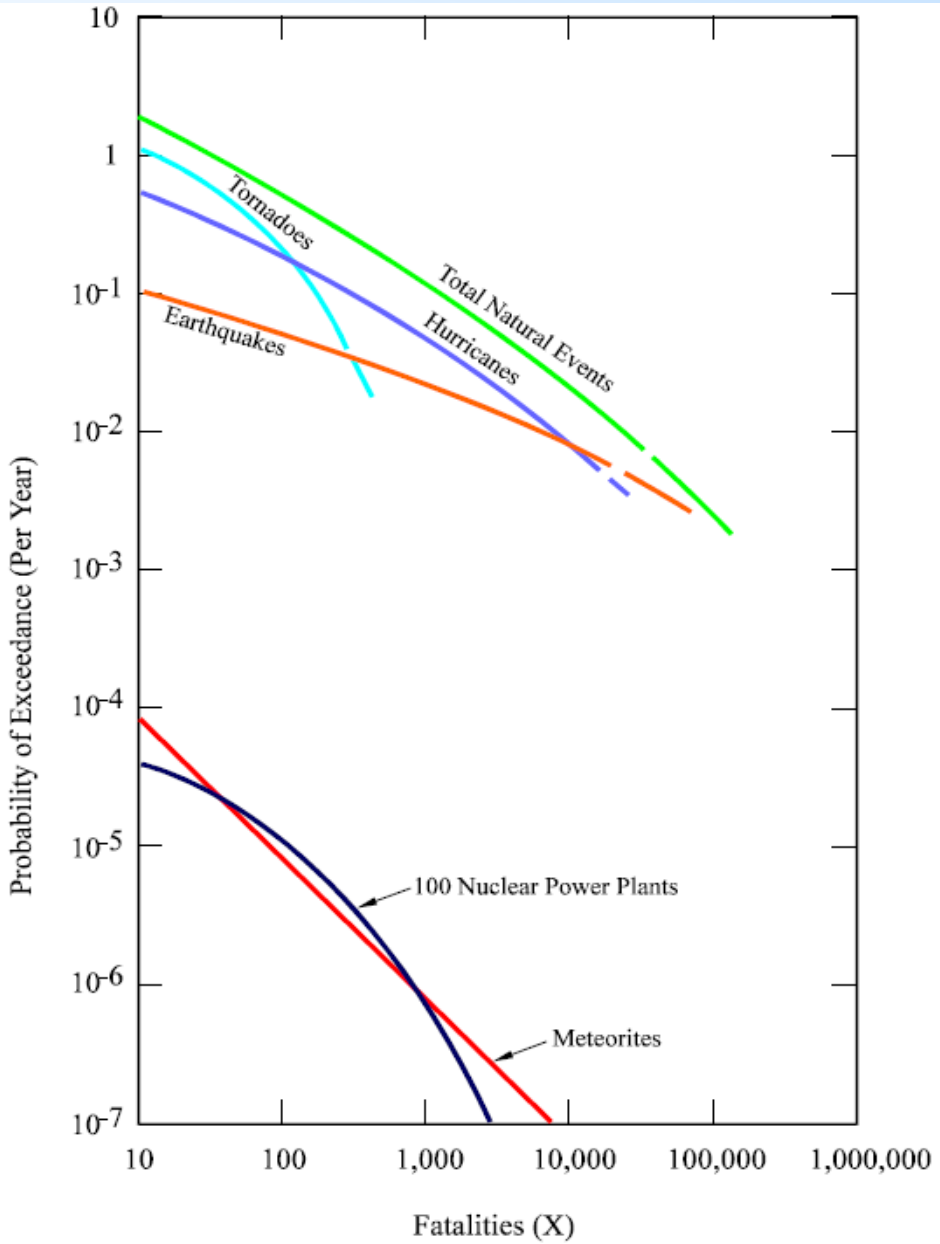
Risk complements and enhances traditional approaches

CONSIDERATION	TRADITIONAL APPROACH (DESIGN BASIS)	RISK ASSESSMENT
Scope of Events Analyzed	• Pre-defined set of events • Assumes design basis events are bounding	• Not constrained by pre-defined rules
Failure Scenarios Included	• Worst single active failure assumed to occur	• Unlimited number of failures considered probabilistically
Common Cause Failures	• Assumed to be precluded through design, testing, inspections, etc.	• Probabilistically considered for common components based on experience
Human Actions	• Assumed effective when proceduralized	• All human actions probabilistically considered
Approach to Uncertainties	• Dependent upon bounding assumptions	• Focus on mean (realistic) estimate • Assess uncertainties quantitatively

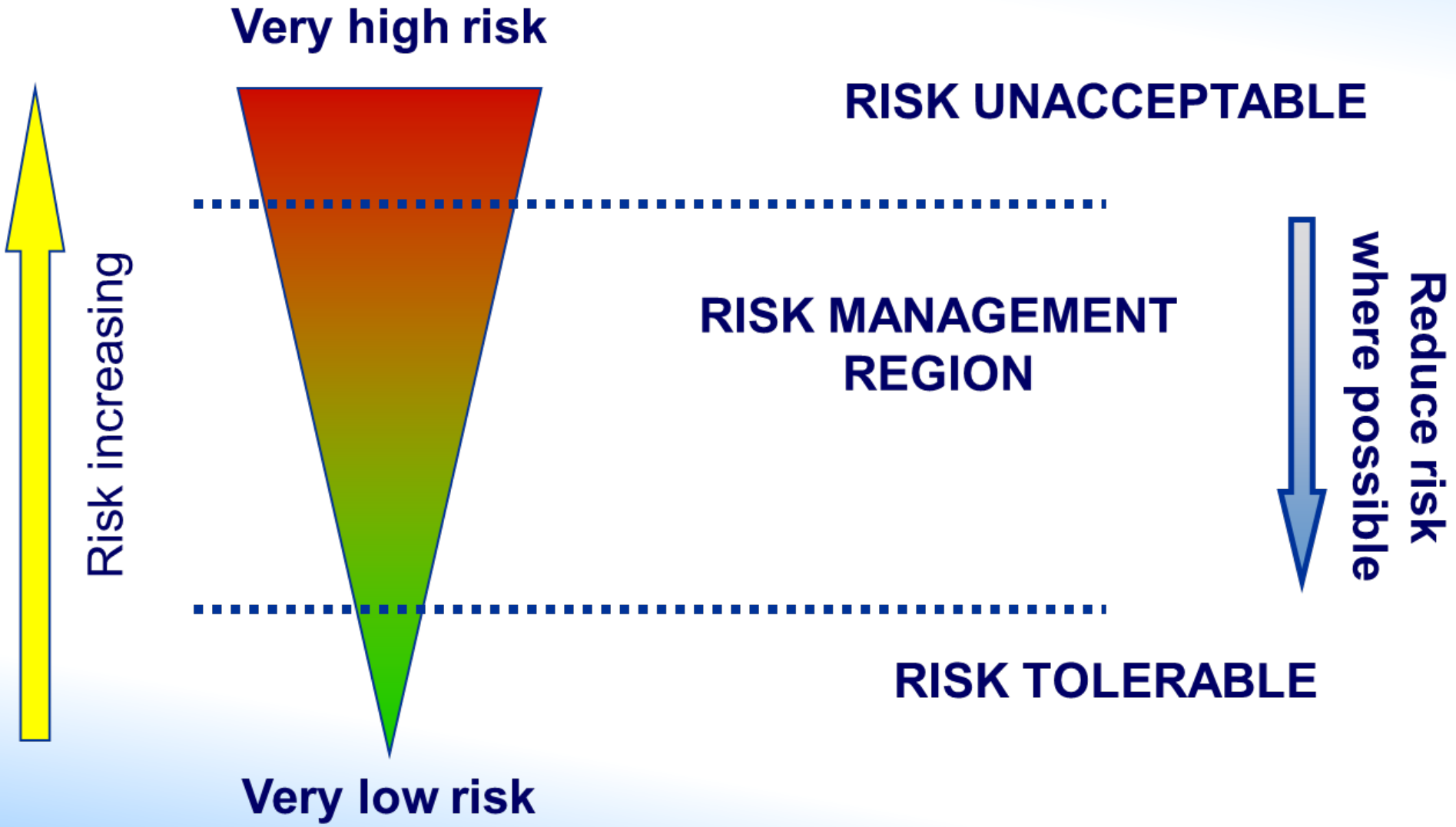
“Triplet” Definition of “Risk”

NUREG/CR-6042, Rev. 2 [1:4] Cover - Appendix 2.4, SAND 93-0971, Perspectives on Reactor Safety





Framework for Defining Risk Acceptance Criteria

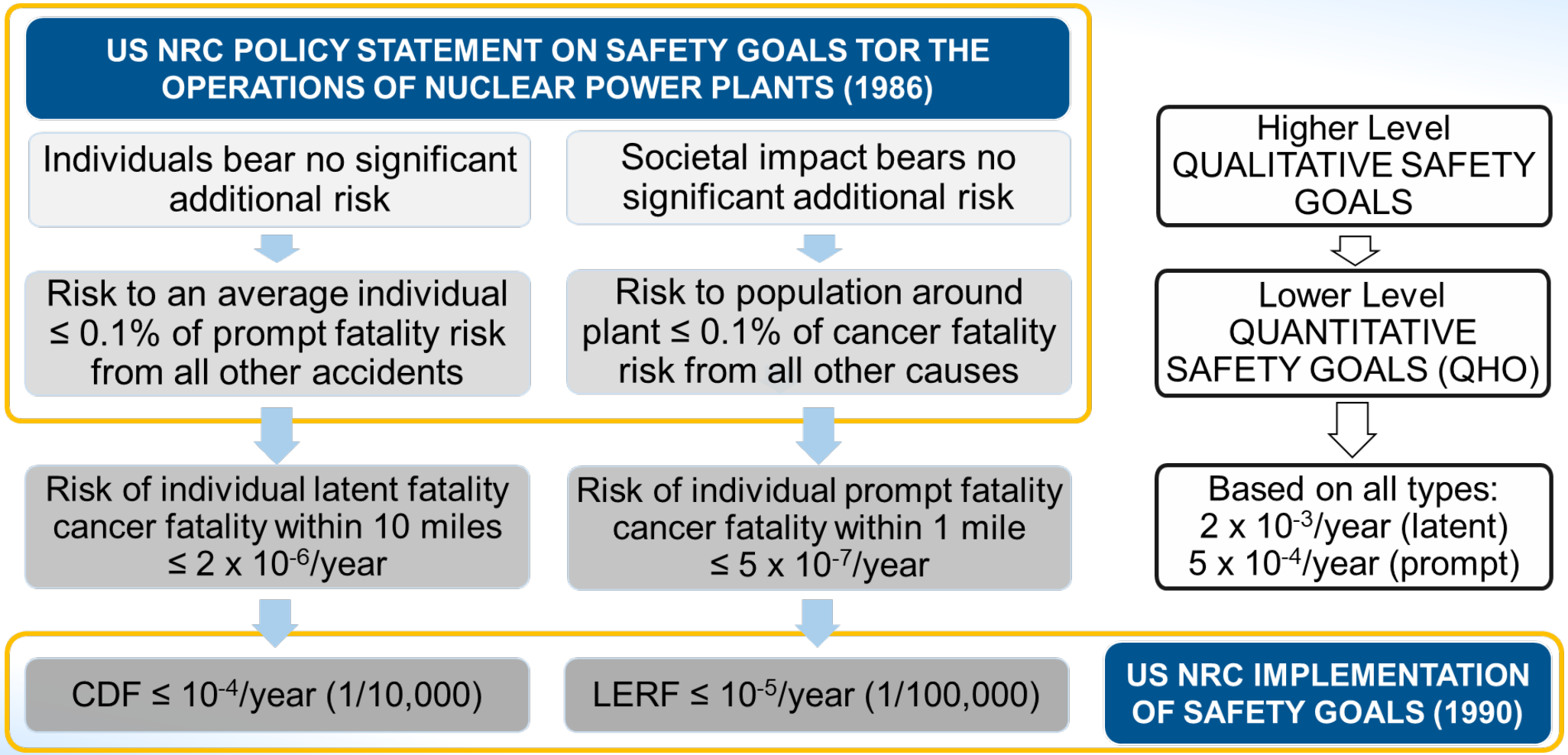


How Safe is Safe Enough?

- **This is a very important question that safety organizations around the world must assess**
  - **It requires a robust public policy discussion**
  - **"How safe" depends on comparison, context**
    - ✓**Given that risks exist in all human activities**
    - ✓**The risk tolerance may vary depending on context**
  - **"Safe enough" is ultimately a societal decision**
    - ✓**Must be enforced by the responsible authorities**
  - **As new information arises, may require some revisiting**
    - ✓**But must also be transparent, stable, enforceable**

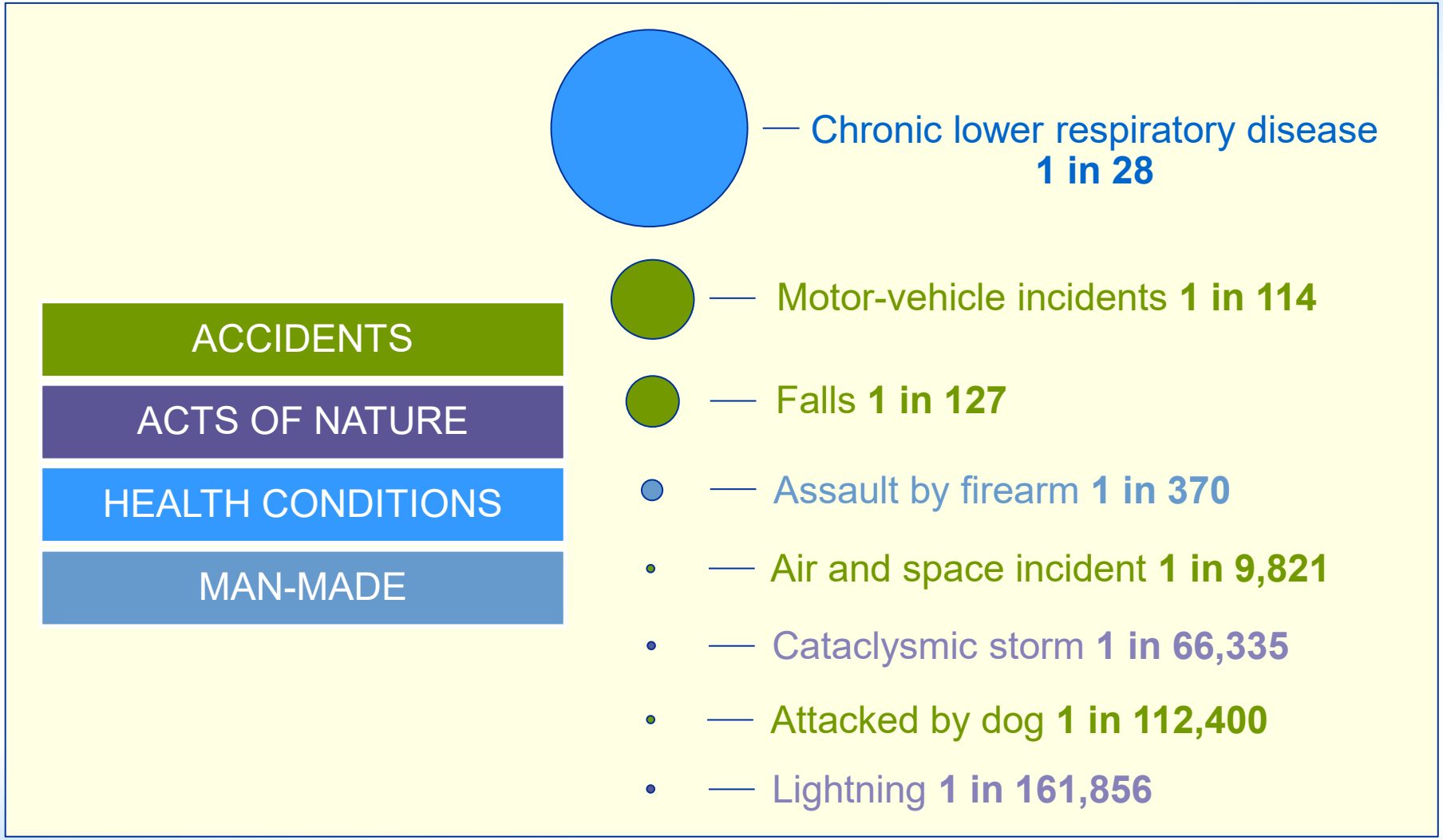
How Safe is Safe Enough?

- **Example from the United States**



Why are these numbers used?!?

EXAMPLE: General Context of Risk Numbers (Lifetime Odds)



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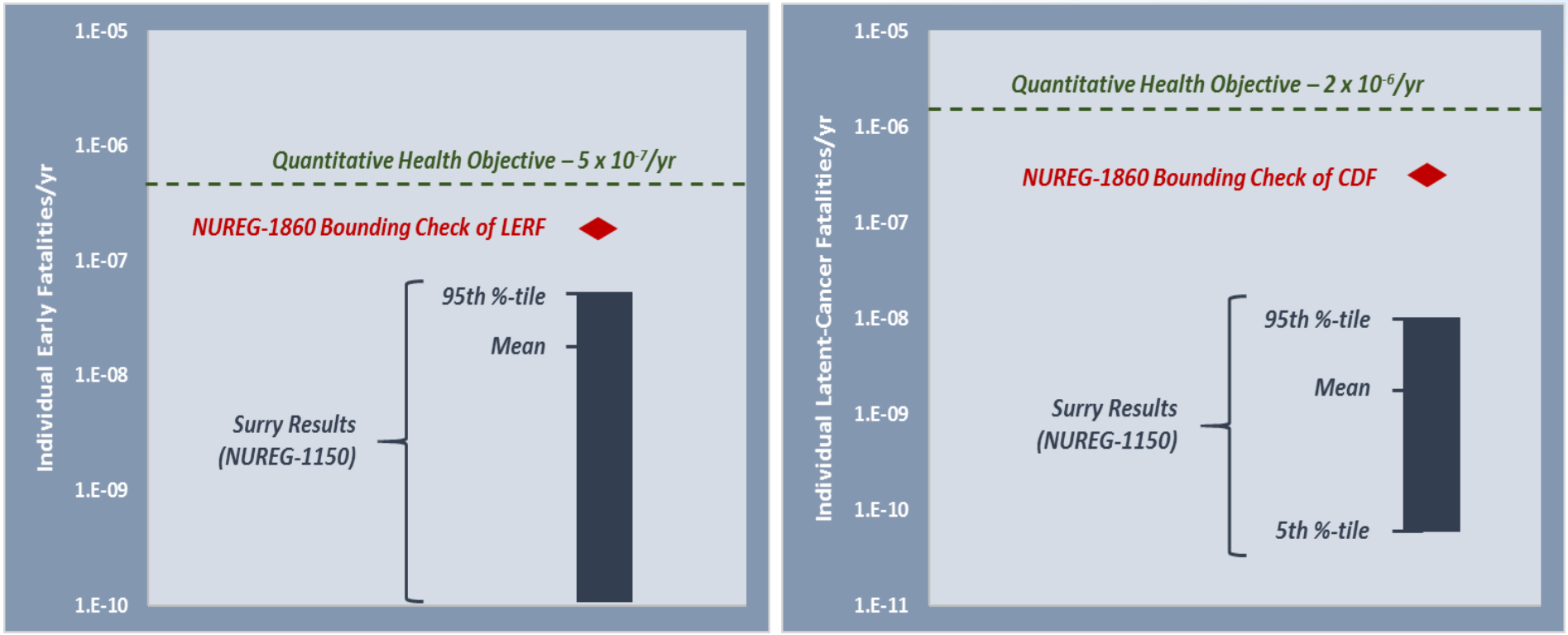

- Detailed risk assessment studies performed in the 1980s investigated the resulting estimates for fatalities and their relationship to specific events
- This supported establishing “surrogate” goals to core damage and early release
- More recent research confirms the margin exists and meets the policy goals

*From the EPRI report on risk margins at nuclear power plants: EPRI 3002012967

SUMMARY

- The notion of risk is widely used in everyday life
- It can provide a useful framework to assess the risk of specific activities (e.g., electricity generation from nuclear power plants)
- Risk assessments can include quantitative and qualitative aspects that aggregate different scenarios and multiple disciplines
- “How safe is safe enough?” critical topic assessed via policy
- This framework has provided a stable approach to assess the safety of nuclear power plants around the world for decades (and will continue to be used)

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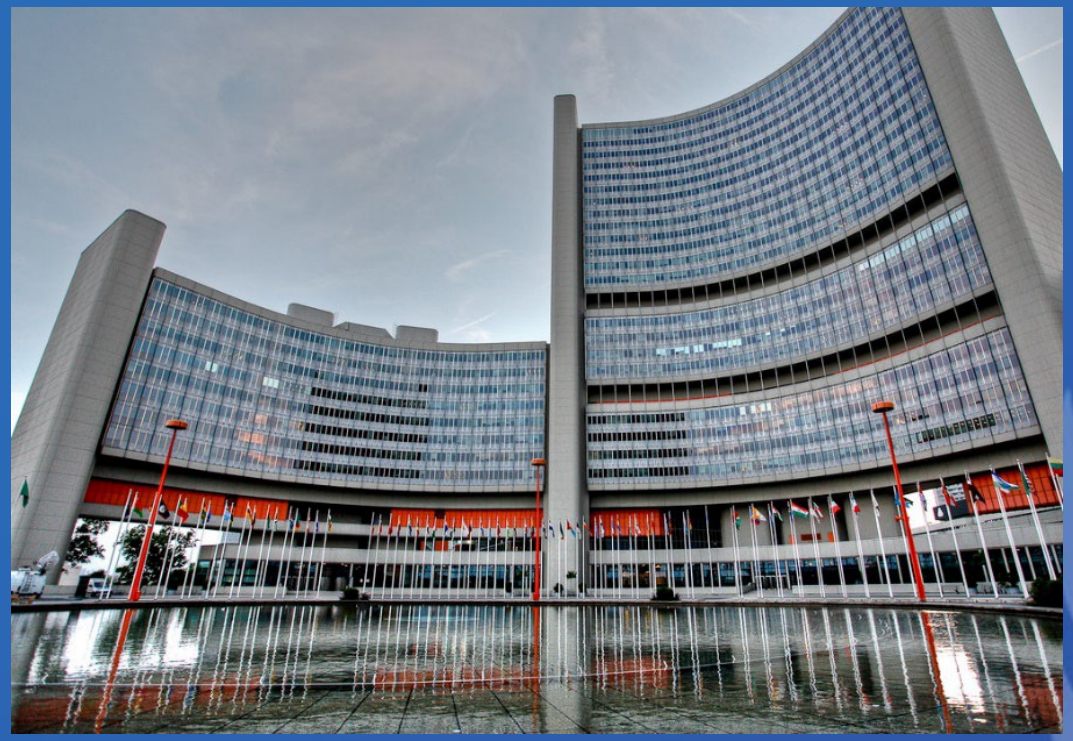

Thank you!