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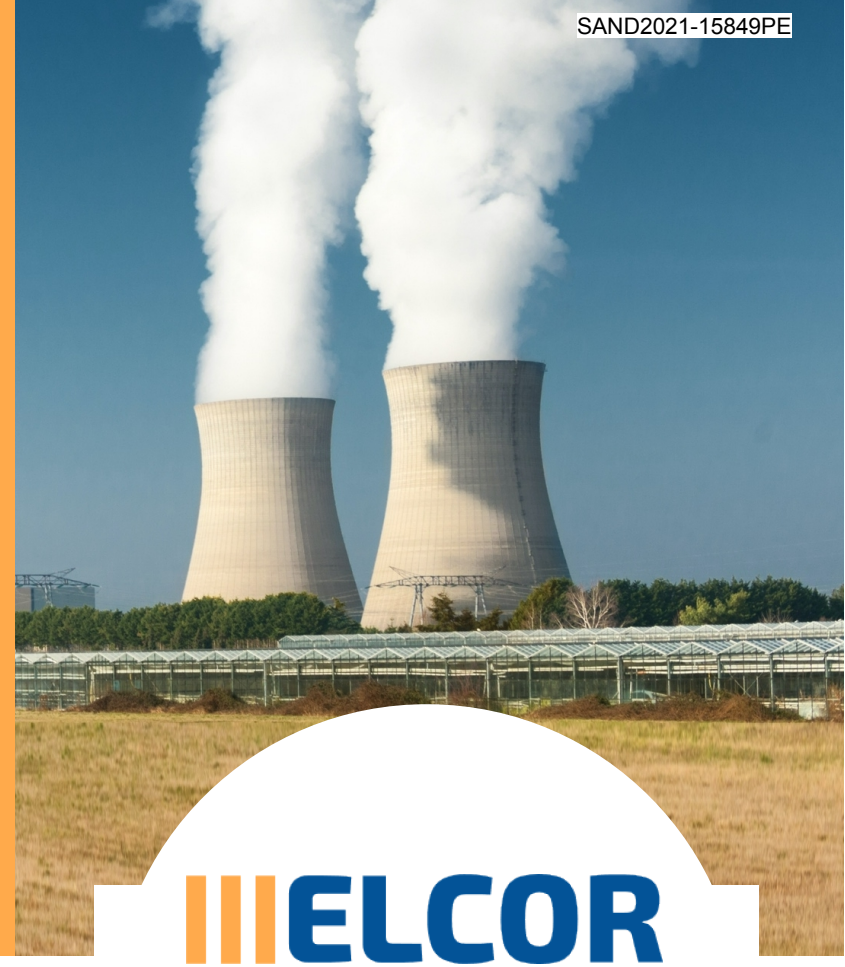
Securing the future of Nuclear Energy



ELCOR

Regulatory Perspective

David L. Luxat, Nuclear Energy Safety Modeling and Analysis (8852)

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Historically Significant Studies

- TID-14844: “Calculation of Distance Factors for Power and Test Reactors,” –USAEC 1962
  - Specification of radioactive fission product (FP) release from reactor core to containment, the “source term,” during a postulated accident
  - Used to determine compliance with 10 CFR Part 100 (reactor site criteria)
- NUREG-1465 – “Accident Source Terms for Light-Water Nuclear Power Plants,” – USNRC 1995
  - Evaluation of revised, “Alternative Source Terms” for regulatory application that addresses relevant insights to provide a more realistic containment source term
  - The source term is expressed as times and rates of appearance of radioactive FP species to containment
- NUREG-1560 – “Individual Plant Examination Program”
  - Determined the relative contribution of various postulated accidents to the total core damage frequency of PWRs and BWRs
- SAND2011-0128 – “Accident Source Terms for Light- Water Nuclear Power Plants Using High-Burnup or MOX Fuel”
  - Defined alternative accident source terms for LWR regulatory applications pertaining to reactor cores utilizing fuels in excess of 40 GWd/MTU or MOX fuel

Regulatory Guide 1.183

Alternative radiological source terms for evaluating design basis accidents at nuclear power reactors

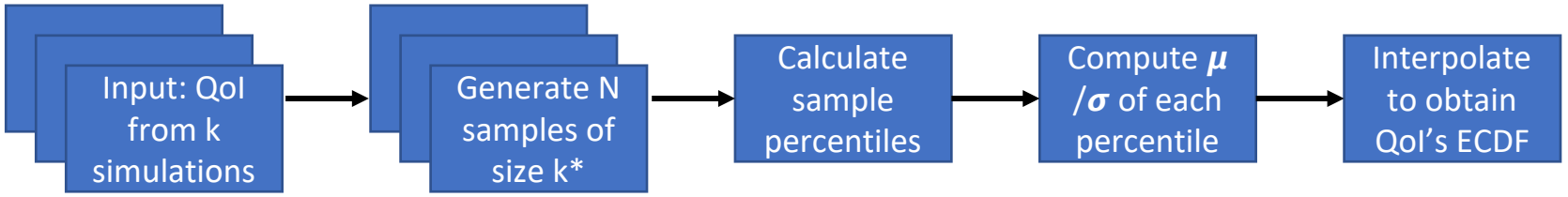
- Provides guidance to licensees of operating power reactors on acceptable applications of alternative source terms
- Lists the attributes of an acceptable AST (summarized below)
    1. Must be based on major accidents (substantial meltdown and release of appreciable quantities of fission products)
    2. Must be expressed in times and rates of appearance of radioactive fission products released *into containment.*
    3. Must represent a spectrum of credible severe accident events.
    4. Must have a defensible technical basis.
    5. Must be peer-reviewed by appropriately qualified subject matter experts.
- "This regulatory guide endorses a source term derived from NUREG-1465 and provides guidance on the acceptable attributes of other alternative source terms."

Severe Accident Knowledge Evolution Since NUREG-1465

- **Evolution of severe accident progression and phenomena state-of-knowledge**
  - Phébus FP Program
    - Efficient transport of Te group materials to containment
    - Identified reaction between Cs and Mo leading to Cs_2MoO_4 formation
    - Suggested negligible Cs vapor release (CsOH)
    - Confirmed CsI formation and transport
    - Cs compounds (CsI and Cs_2MoO_4) release to containment as vapors/aerosols at high core temperatures
- **Evolution of MELCOR modeling best practices**
  - Refined modeling of core damage progression relative to NUREG-1465 (e.g., Source Term Code Package) tends to lead to progressive and extended core degradation
    - Longer times to lower head failure typically observed in current MELCOR simulations relative to NUREG-1465 study
  - Induced failure of reactor system into containment following core damage
    - Key insight established under SOARCA
  - Low pressure scenarios dominate current study unlike NUREG-1465
    - BWR simulations consistently predict thermal SRV seizure
    - PWR simulations consistently predict hot leg creep rupture

Non-Parametric Bootstrap Analysis

- Non-parametric methodologies have been used in past source term studies including NUREG-1465 and SAND2011-0128
- These methods can be applied to data that follow any distribution, standard or otherwise.
  - Repeated re-sampling (bootstrapping) of data
  - Evaluation of empirical cumulative distribution function (ECDF) of a given QoI



D. Brooks, "Non-Parametric Source Term Uncertainty Estimation," SAND2020-6636R, Sandia National Laboratories, 2020.