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A Proposed Cost-Benefit Analysis Approach for Evaluating DOE Nuclear Facility Design Options

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Introduction

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- The National Nuclear Security Administration (NNSA) has begun an initiative to develop a methodology to perform cost-benefit analysis for some Department of Energy (DOE) nuclear facility applications as one potential input into nuclear safety decision-making processes.

- The scope, approach, precedence, and example of how it might be applied are discussed.

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Purpose

- This work is exploratory in nature and has not been endorsed by DOE or NNSA. The purpose of this presentation is to introduce the concept/methodology and seek feedback as a potential element of risk management.
  - Tie amount of safety improvement in averted accident "dollars" to actual dollars spent for a safety feature in a nuclear facility.

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Scope and Applicability

- Safety systems for accident prevention or mitigation:
  - Design options - new facilities, or
  - Upgrade/backfit - existing facilities

- Applicability criterion: Consistent with DOE Quantitative Safety Objectives and Adequate Protection.

- Can be used when:
  1. Choosing among alternatives to meet same requirement(s), or
  2. Seeking exemption from a requirement.
     - Allowed by Exemption Relief process of 10 CFR 820.62(d)(2): "Application of the requirement in the particular circumstances would not serve or is not necessary to achieve its underlying purpose, or would result in resource impacts which are not justified by the safety improvements."

Approach

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- Based on NRC's well-tested methods developed for commercial nuclear power plants.

- Relies on quantitative results of probabilistic risk analysis, but without requiring use of formal probabilistic risk assessments (PRAs)
  a) Much smaller radionuclide inventories in even largest DOE Hazard Category 2 facilities that allows conservatisms in quantification approaches (back-of-the-envelop frequency and consequence estimates would usually suffice),
  b) Approximate and conservative accident frequency and consequence information are often available from Documented Safety Analyses (DSAs) and NEPA-related documents, such as EISs, and
  c) Additional limited-scope probability and consequence assessments can always be performed as needed with modest resource requirements.

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NRC Precedent

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- NRC requires performance of Cost-Benefit Analyses for existing plants and new reactor designs along slightly different paths/regulations, but with identical methodology specified in NUREG/BR-0184.

1. Existing plants:
   a) Plant backfits under 10 CFR 50.109, and
   b) License renewals under 10 CFR 54
      - Plants must submit an environmental report under 10 CFR 51.53 that contains consideration of alternatives to mitigate severe accidents (SAMAs).
2. New Plants
   a) Design Certifications or Combined Licenses - 10 CFR 51.53 and 51.55
      - Severe Accident Mitigation Design Alternatives (SAMDAs) required in an applicant's environmental report.

NRC Precedent (Cont.)

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- NRC approach uses 4 high-level categories of "averted" accident costs:
  1. Offsite exposure
     - Public radiological exposure converted by $2,000/person-rem TEDE.
  2. Offsite economic impact
     - Calculated with codes which use a large number of inputs
  3. Onsite exposure
     - Expressed in terms of immediate and long-term doses and same $2000/person-rem.
  4. Onsite economic impact
     - Includes cleanup, repair, refurbishment, replacement power, etc.

- All of the above are adjusted to present values.

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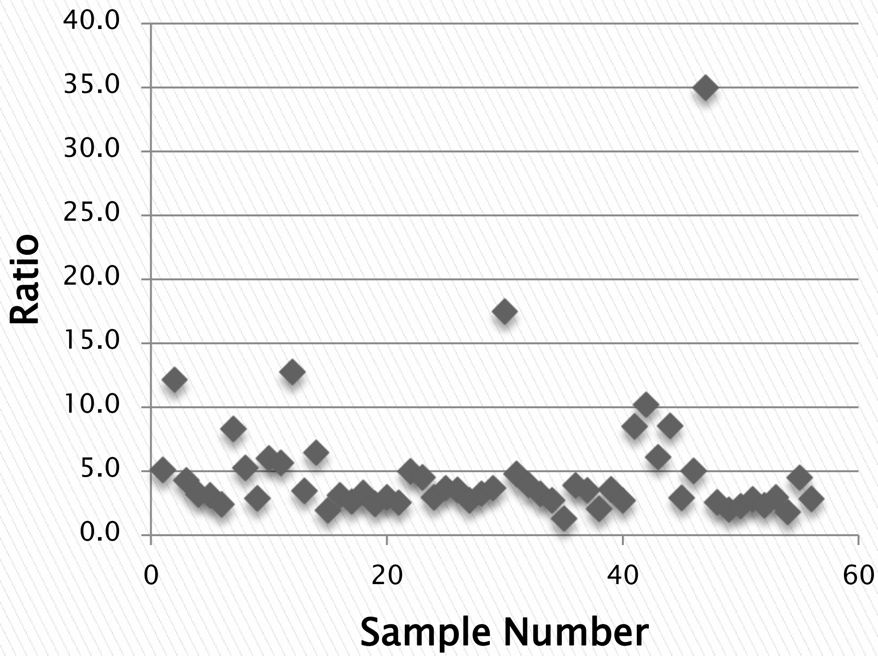
Commercial nuclear plant submittals – maximum SAMA and SAMDA benefits

Ratios of Averted Costs
Total/Public Exposure for All Nuclear Power Plants in the Sample



	w/ outliers	w/o outliers
Mean	5.0	3.5
Median	3.4	3.2

Generic Plant Maximum SAMA and SAMDA benefits

NEI (generic plant)	Rounded $
public exposure	200,000
public property damage	200,000
onsite exposure	500
onsite property damage	10,000
Total	400,000

Hitachi (ESBWR)	Rounded $
public exposure	200,000
public property damage	50,000
onsite exposure	500
onsite property damage	5,000
Total	250,000

Areva (EPR)	Rounded $
public exposure	5,000
public property damage	3,000
onsite exposure	500
onsite property damage	10,000
Total	20,000

Mitsubishi (APWR)	Rounded $
public exposure	30,000
public property damage	500
onsite exposure	2000
onsite property damage	70,000
Total	100,000

DOE Adaptation of NRC Precedents

- DOE can select a scaled value of $10,000 per person-rem of averted public accident dose to account for ALL cost categories.

- Population dose is an integrated sum of individual doses out to a radius of 50 miles. This quantity is generally available from NEPA-related documents for many types of accidents.

Example

- Total accident risk is dominated by 2 accident scenarios:

- Accident 1:
  - Source term frequency = 3E-4 /yr
  - 50-mile population dose 20,000 rem TEDE
- Accident 2:
  - Source term frequency = 1E-4 /yr
  - 50-mile population dose 100,000 rem TEDE

Example (Continued)

- **Maximum benefit** – Averted accident benefit obtained by eliminating facility (or both scenarios).
  - 3E-4 * 20,000 + 1E-4 * 100,000 = 6 + 10 = 16 person-rem/yr
  - Remaining facility life is 50 years – approximate discounted facility life-time is 15 years.
  - Total facility life-time dose = 16 * 15 = 240 person-rem TEDE
  - Maximum benefit: 240 (person-rem) * 10,000 ($/person-rem) = $2,400,000

- **Control-specific safety benefit.** An additional safety system is proposed to reduce consequence of Accident 2 by a factor of 1000.
  - 1E-4 * (100,000 – 100) = 10 person-rem/yr
  - Change in averted facility life-time dose = 10 * 15 = 150 person-rem TEDE
  - Benefit of specific safety upgrade:
    - 150 (person-rem) * 10,000 ($/person-rem) = $1,500,000

Example (Continued)

- If there are safety upgrades that cost more to implement than the "maximum benefit," considerations other than the improvement in safety would be warranted to fully justify the upgrade.
    - Especially useful when maximum benefit amounts are low. If not, then must perform control-specific safety benefit analysis.

- If there are safety upgrades that cost less than their "control-specific" safety benefit, they should be implemented from a cost-benefit consideration alone.

Summary

- A DOE-approved cost-benefit analysis methodology may pay dividends in safety decision-making processes for significant expenditures.

- An approach, based on current NRC methods that have been tested and matured through numerous stakeholder challenges including court-tested cases for over 50 years, is being evaluated.