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Uncertainty Analysis for the U.S. NRC State-of-the-Art Reactor Consequence Analyses (SOARCA)

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Outline

- Background: SOARCA study
- Goals of the Uncertainty Analysis
- Approach
- Selected parameters
- Preliminary insights
- Status

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Background: SOARCA study

- The overall objective of the SOARCA project was to develop a body of knowledge on the realistic outcomes of severe reactor accidents
  - using self-consistent, integrated modeling of accident progression and offsite consequences drawn from current best practices, for important classes of events
- Took advantage of national and international reactor safety research and reflected updated plant design, operation, and accident management implemented over the past few decades

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Goals of the Uncertainty Analysis

- Develop insight into overall sensitivity of SOARCA results to uncertainty in inputs
- Identify most influential input parameters for releases and consequences
- Demonstrate uncertainty analysis methodology

Approach

- Focus is on epistemic (state-of-knowledge) uncertainty in parameter values
  - Aleatory (random) uncertainty due to weather is handled in the same way as the SOARCA study
- Peach Bottom, unmitigated, long-term station blackout scenario chosen
- Scenario definition not changed after Fukushima
  - A separate qualitative discussion planned for an appendix
- Looking at uncertainty in key model inputs
  - MELCOR parameters (accident progression and source term)
  - MACCS2 parameters (off-site consequences)

Approach (continued)

- Key uncertain input parameters were identified
- Uncertainty in these parameters propagated in two steps using Monte Carlo and Latin Hypercube (LHS) sampling:
  - A set of source terms generated using MELCOR model
  - A distribution of consequence results generated using MACCS2 model
- An epistemic sample set of 300 generated to complete a corresponding number of individual code runs (Monte Carlo “realizations”) to evaluate the influence of the uncertainty on the estimated outcome

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Approach (continued)

- Results reported will include:
  - Analysis of source term releases including cesium and iodine release over time
  - Distribution of latent cancer fatality risk, with three dose threshold models
  - Description of most influential uncertain parameters in study
- Tools used to analyze results include statistical regression-based methods as well as scatter plots and phenomenological investigation of individual realizations of interest
- Guidance solicited from SOARCA peer reviewers on the uncertainty analysis plan documenting the approach, chosen parameters and distributions

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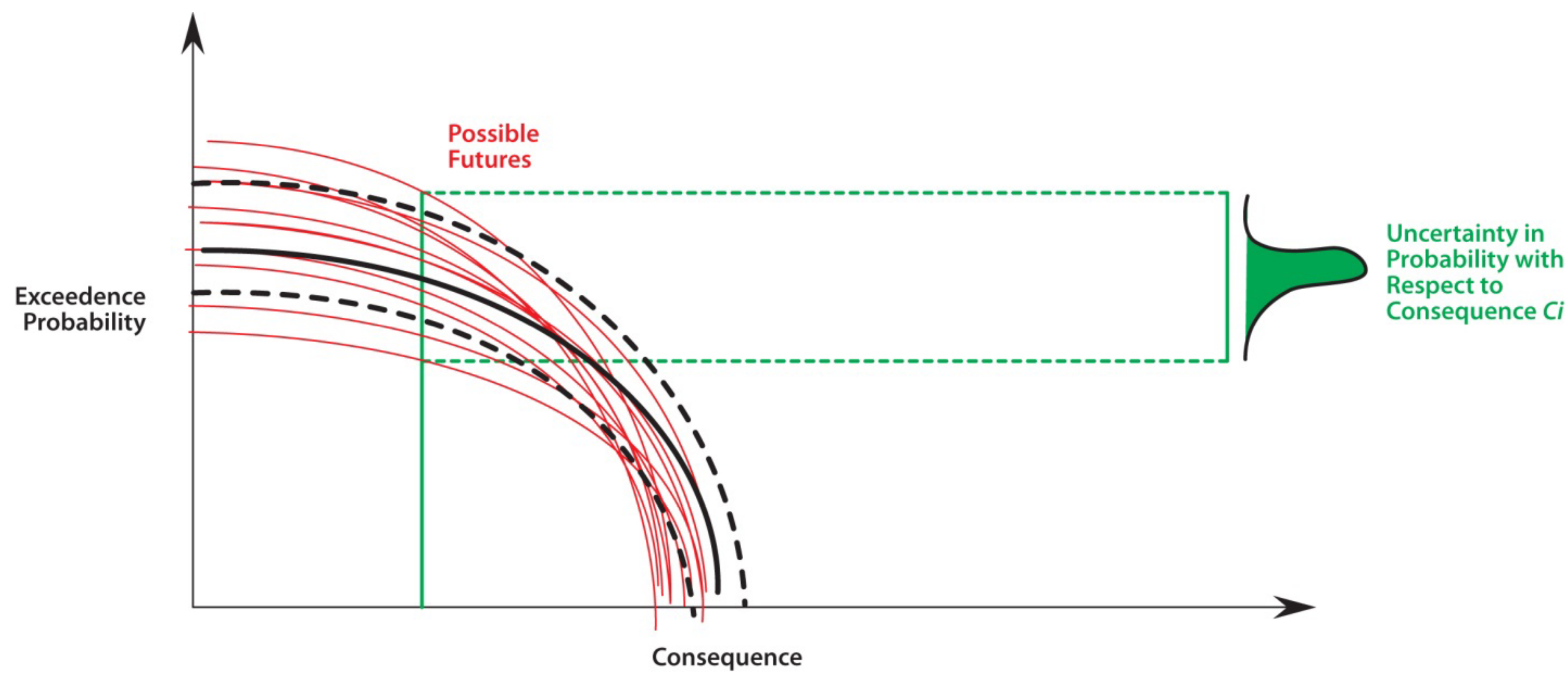
Uncertainty in exceedence probability with respect to consequence



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MELCOR Uncertain Parameters

Sequence Issues

- Battery duration
- SRV stochastic failure rate

In-Vessel Accident Progression

- SRV thermal seizure criteria, and open area fraction
- Main steam line (MSL) creep rupture open area fraction
- Zircaloy melt breakout temperature
- Molten clad drainage rate
- Fuel failure criterion
- Debris radial relocation time constants

Ex-vessel Accident Progression

- Debris lateral relocation time constants

Containment & building behavior

- Drywell liner failure flow area
- Drywell head flange leakage parameters
- Hydrogen ignition criteria (where flammable)
- Railroad doors open fraction

Fission Product release, transport, and deposition

- Cesium and iodine chemical forms
- Aerosol deposition parameters

MACCS2 Uncertain Parameters

Atmospheric Transport and Deposition

- Wet deposition model linear coefficient
- Dry deposition velocities
- Dispersion parameters

Emergency planning and response

- Shielding factors
- Hotspot and normal relocation
- Evacuation delay and speed

Health Effects

- Early health effects
- Latent health effects
  - Groundshine dose coefficients
  - Dose and dose rate effectiveness factors
  - Inhalation dose coefficients
  - Cancer mortality risk coefficients

Preliminary Insights

- There are important threshold effects in the accident progression, and it may be important to look at the influence of combinations of two or more input parameters together
- Regression analyses on the partitioned sample space can provide important insights
- Inspection of individual realizations of interest helps to both construct a phenomenological explanation of which uncertain inputs (or combinations of inputs) are most influential on the results, as well as providing insights on potential threshold effects and input space partitions of interest

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UA Status – In Progress

- Final report expected late 2012
- Separate sensitivity analyses, for example: (1) habitability criterion, (2) evaluation of the timing of two operator actions in the unmitigated LTSBO, (3) lower head penetration failure
- An appendix with discussion and qualitative comparison with Fukushima