State-of-the-Art Reactor Consequence Analyses (SOARCA) Project: Summary of Uncertainty Analyses (UAs) for Station Blackout Scenarios

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Outline

• Background on SOARCA and UAs
• Objectives of the project
• Overview of approach
• Sample results
• Overall conclusions and summary
• Status
Background on SOARCA

• SOARCA was initiated to develop a body of knowledge on the realistic outcomes of severe reactor accidents; three pilot plant analyses complete

Peach Bottom
• Boiling water reactor with Mark I containment
• Located in Pennsylvania
• UA on LTSBO

Surry
• 3-loop Westinghouse pressurized reactor with large, dry containment
• Located in Virginia
• UA on STSBO/induced SGTR

Sequoyah
• 4-loop Westinghouse pressurized reactor with ice condenser containment
• Located in Tennessee
• UA on STSBO (no SGTR)
Objectives of the SOARCA Uncertainty Analyses & Summary

- Develop insight into overall sensitivity of results and conclusions from original SOARCA study to uncertainty in model inputs.
- Identify the most influential input parameters contributing to variations in accident progression, source term, and offsite consequence results.
- “Complement and support” the NRC’s Site Level 3 PRA project and post-Fukushima accident regulatory activities.
- Purpose of summary report is to provide a useful reference for future regulatory applications that require the evaluation of offsite consequence risk from severe accidents.
Overview

• Analysis of uncertainty in each of the three SOARCA plant analyses, one unmitigated station blackout (SBO) scenario
• Focus on epistemic (state-of-knowledge) uncertainty in input parameter values, and limited aleatory uncertainty
• Investigate uncertainty in key MELCOR and MACCS inputs
• Propagate uncertainty in these parameters in a two-step Monte Carlo (MC) simulation
  - Generate a set of source terms using MELCOR model
  - Generate distribution of consequence results using MACCS model
Overview (continued)

• >500-1,000 successful MC realizations analyzed
• Results reported with regard to figures of merit:
  – MELCOR: Cesium and Iodine release to the environment by 72 hours, in-vessel hydrogen production, timing of initial fission product release to the environment, and others
  – MACCS: Individual early and latent cancer fatality (LCF) risk
• Results analyzed with statistical regression based methods, scatter plots, and phenomenological investigation of selected individual realizations

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*Highlighted if main contribution larger than 0.02 or joint contribution larger than 0.1
Sequoyah STSBO UA Containment Failure Outcomes

Long-term containment over-pressurization failure due to prolonged steam production and non-condensable gas generation.

Early containment overpressure failures due to sufficiently large burns in containment.

No BOC cases exhibit long-term overpressure failure before 72 hours.
Scatterplot of iodine environmental release fraction versus primary safety valve (SV) cycles in Sequoyah STSBO UA
Cesium release for SOARCA Peach Bottom unmitigated LTSBO scenario
Overall Conclusions and Summary

• SOARCA UAs corroborate conclusions from the original SOARCA project:
  – Public health consequences from severe nuclear accident scenarios modeled are smaller than those projected in NUREG/CR-2239.
  – Calculated delay in releases provides more time for emergency response actions (such as evacuating or sheltering).
  – “Essentially zero” absolute early fatality risk is projected.
Overall Conclusions and Summary (Continued)

- The three UAs revealed interesting insights with respect to accident progression, radionuclide release, offsite consequences, and which uncertain parameters are most influential on outcomes of interest for the modeled scenarios at the three plants.

- Regarding UA methodologies, the more advanced regression techniques were essential to explain the variations in possible source terms and consequences and use of select single-realization analyses proved useful in validating the results of the statistical regression analyses and providing phenomenological explanations.

- The SOARCA analyses of the three plants have been useful in many ways beyond their original objectives.
Status

• Revised SOARCA Surry Uncertainty Analysis with updates following Advisory Committee Reactor Safeguards (ACRS) review on the SOARCA Sequoyah Analysis; updated report expected in late 2019.

• Peach Bottom SOARCA UA models (originally completed almost 10 years ago now) are being updated and implemented in the current version of the MELCOR code (version 2.2 versus 1.86) and taken out to a 72-hour simulation time.

• Developing summary NUREG report on insights from the SOARCA Peach Bottom, Surry, and Sequoyah Uncertainty Analyses, which should be more user-friendly.
Core Team Members

• MELCOR and severe accident progression: Kyle Ross, Casey Wagner, Troy Haskin, Chris Faucett, Larry Humphries, Randy Gauntt (SNL); Mark Leonard (formerly dycoda); Hossein Esmaili, Salman Haq, Trey Hathaway (NRC)

• MELMACCS: Nathan Bixler, Doug Osborn, Fotini Walton (SNL); Trey Hathaway (NRC)

• MACCS, consequence analysis and emergency response: Nathan Bixler, Matt Dennis, Doug Osborn, Fotini Walton (SNL); Joe Jones (formerly SNL); Jonathan Barr, Keith Compton, Trey Hathaway (NRC)

• UA methodology: Dusty Brooks, Matthew Denman, Aubrey Eckert-Gallup, Patrick Mattie (SNL); Cedric Sallaberry (formerly SNL); Tina Ghosh, Trey Hathaway (NRC)

• NRC management: Patricia Santiago
References

• NUREG/BR-0359, Modeling Potential Reactor Accident Consequences, Rev. 1 (December 2012)
• NUREG/CR-7110, Vol. 1, SOARCA Project Peach Bottom Integrated Analysis, Rev. 1, (May 2013)
• NUREG/CR-7008, MELCOR Best Practices as Applied in the SOARCA Project (August 2014)
• NUREG/CR-7009, MACCS Best Practices as Applied in the SOARCA Project (August 2014)
• NUREG/CR-7155, SOARCA Project Uncertainty Analysis of the Unmitigated Long-Term Station Blackout of the Peach Bottom Atomic Power Station (May 2016)
• NUREG/CR-7245, SOARCA Project Sequoyah Integrated Deterministic and Uncertainty Analyses (forthcoming in 2018)