State-of-the-Art Reactor Consequence Analyses (SOARCA) Surry Uncertainty Analysis (UA)

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Core Team Members and Advisors

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Outline

- Background
- Objectives
- Overview
- Parameter development process
- MELCOR analysis - example results
- MACCS consequence analysis - example results
- Overall conclusions and insights
- Status and next steps

Background on SOARCA

- SOARCA was initiated to develop a body of knowledge on the realistic outcomes of severe reactor accidents; two pilot plants

Peach Bottom

Surry

- SECY-12-0092, "State-of-the-Art Reactor Consequence Analyses – Recommendation for Limited Additional Analysis"
  - Staff recommended "UA for a severe accident scenario at Surry"

Objectives of the Surry Uncertainty Analysis

- Develop insight into overall sensitivity of results and conclusions to uncertainty in model inputs.
- Identify the most influential input parameters contributing to variations in accident progression, source term, and offsite consequence results, for the Surry pilot plant.
- “Complement and support” the NRC’s Site Level 3 PRA project and post-Fukushima activities including Tier 3 items. (Staff Requirements Memorandum SECY-12-0092)

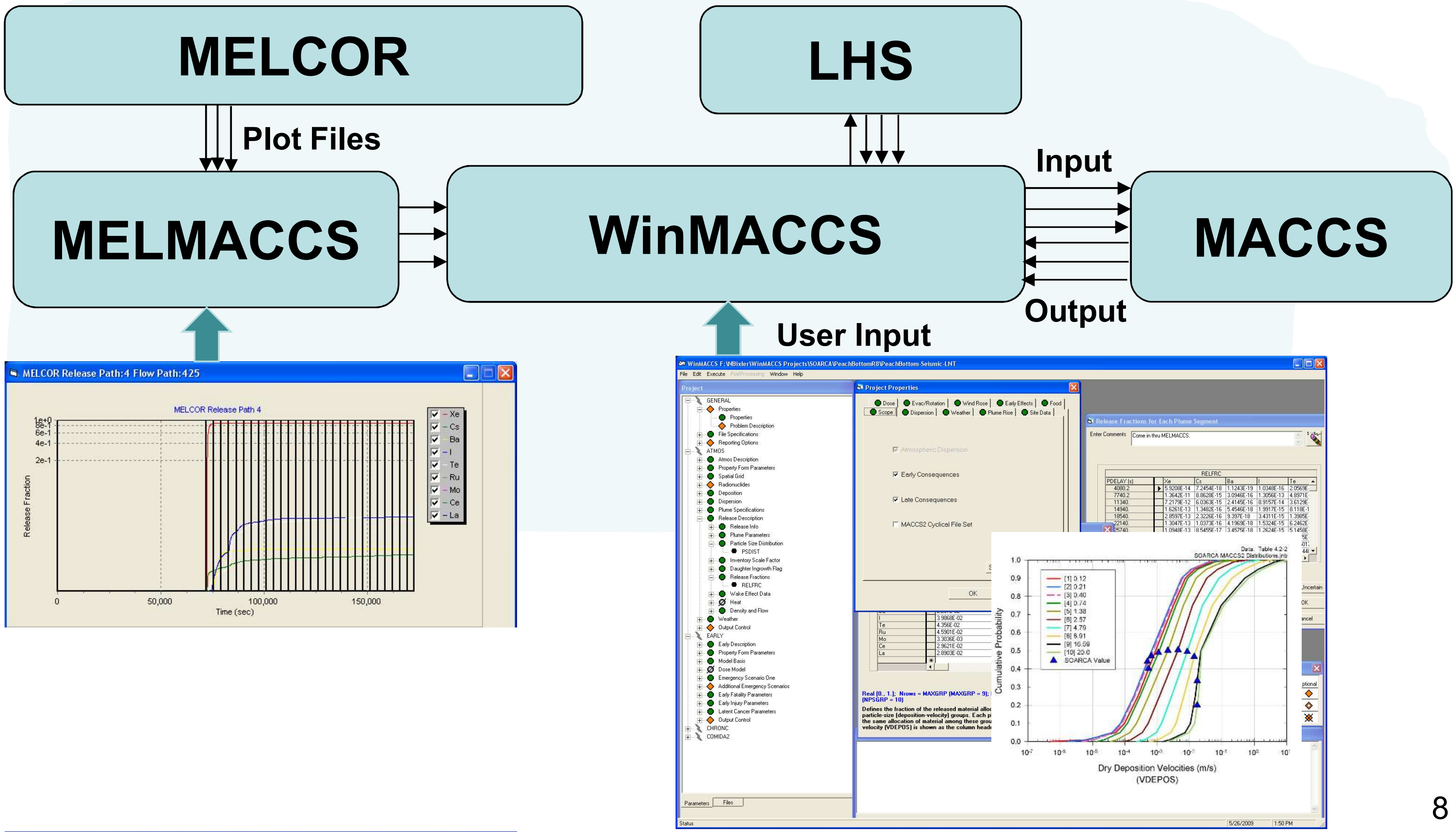
Overview

- Analysis of uncertainty in the Surry SOARCA unmitigated short term station blackout (STSBO)
- Focus on epistemic (state-of-knowledge) uncertainty in input parameter values, and limited aleatory uncertainty
  - Aleatory (random) uncertainty due to weather always handled
  - Time-at-cycle (burn-up) and stochastic nature of safety valve failure investigated (aleatory aspects of some input parameters)
- Investigated uncertainty in selected key MELCOR and MACCS inputs
- Uncertainty in these parameters was propagated in a two-step Monte Carlo simulation:
  - A set of source terms generated using MELCOR model
  - A distribution of consequence results generated using MACCS model

Overview (continued)

- 1003 successful MELCOR Monte Carlo “realizations” completed to 48 hours were each coupled with a successful MACCS realization
- Results reported with regard to figures of merit investigated:
  - MELCOR: Cesium and Iodine release to the environment by 48 hours, in-vessel hydrogen production, and timing of initial fission product release to the environment
  - 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
  - An individual realization is a single run (or “realization”) selected from the set generated in the Monte Carlo simulation

WinMACCS Calculation Framework as Used in SOARCA Uncertainty Analysis



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Parameter Development Process

Implemented a Process for Choosing Parameters and Establishing Distributions

- Involved staff from SNL and NRC with expertise in MELCOR and MACCS modeling for SOARCA
- Subject matter experts (SMEs) provided support in reviews of data and parameters
- Reviewed parameters used in Peach Bottom UA
- Performed a systematic review of phenomenological areas (sequence, in-vessel and ex-vessel accident progression, containment behavior, chemical form and aerosol deposition)
- Reviewed the phenomenological topics covered in the MELCOR Reference Manual
- Reviewed a comprehensive MACCS parameter list

Process (continued)

- An initial list of candidate parameters was then developed.
- Implemented a ‘storyboard’ process
  - Required analysts to document justification and rationale for each parameter
  - Iterative and involved joint NRC reviews
- Focused on:
  - confirming the parameter representations appropriately reflect key sources of uncertainty, and
  - ensuring model parameter representations (i.e., probability distributions) are reasonable and have a defensible technical basis.

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Process (continued)

- During the course of the project (typically storyboard reviews), some parameters were omitted from further consideration and others were added for the analysis.
- Some parameters were exploratory
  - Little basis for the uncertainty distribution, but analysts had an interest in gaining some insights
- MELCOR and MACCS parameters that were considered but not included are listed in the report.

Parameter storyboard used to capture key information for each parameter investigated

Parameter Name:	Type of Distribution:
Technical justification for the uncertainties:	
Rational for type of distribution:	
Were similar or related parameters considered and rejected.	
Graphic: (plot of the distribution)	

Cesium Release Fraction to Environment

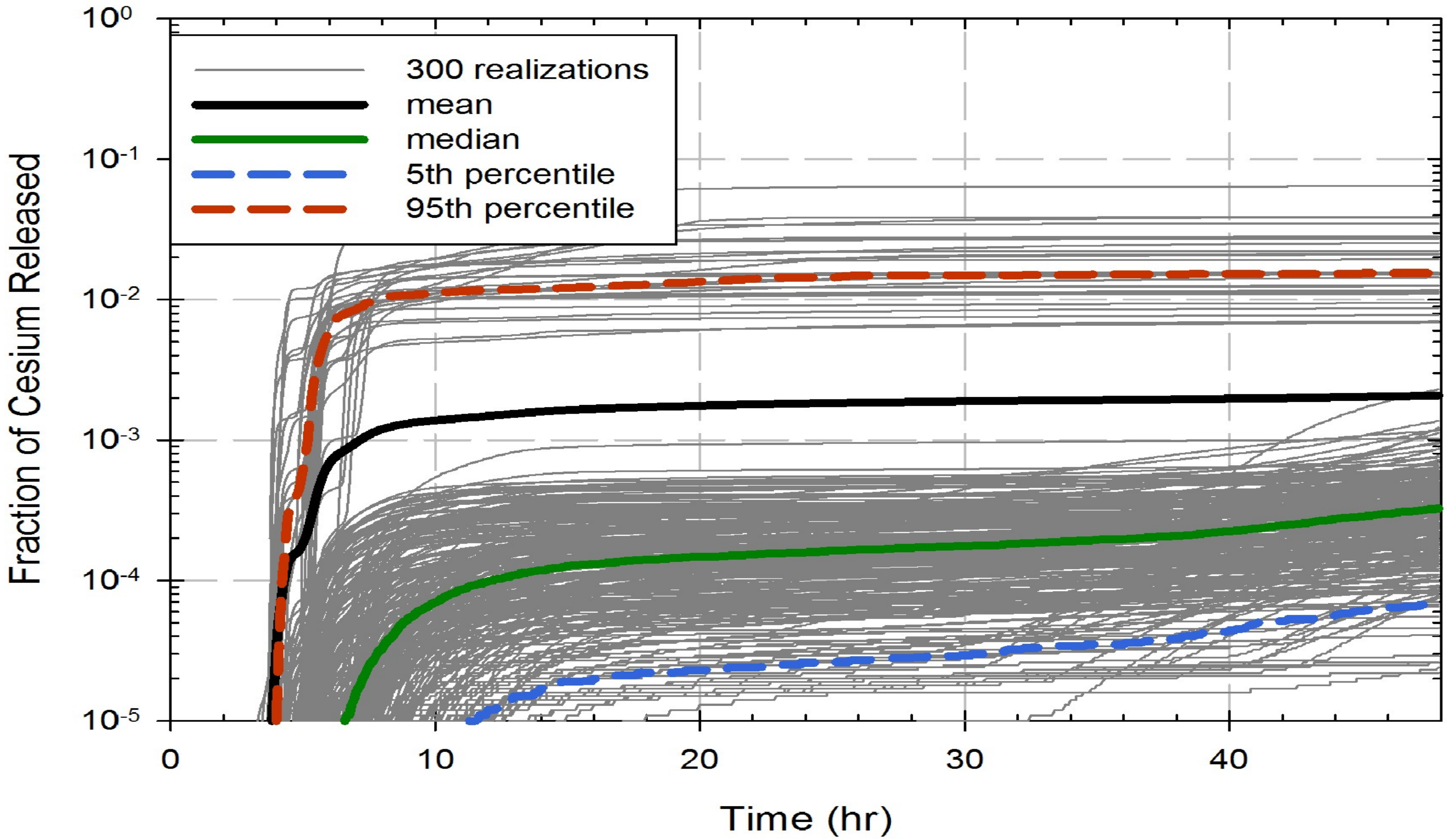
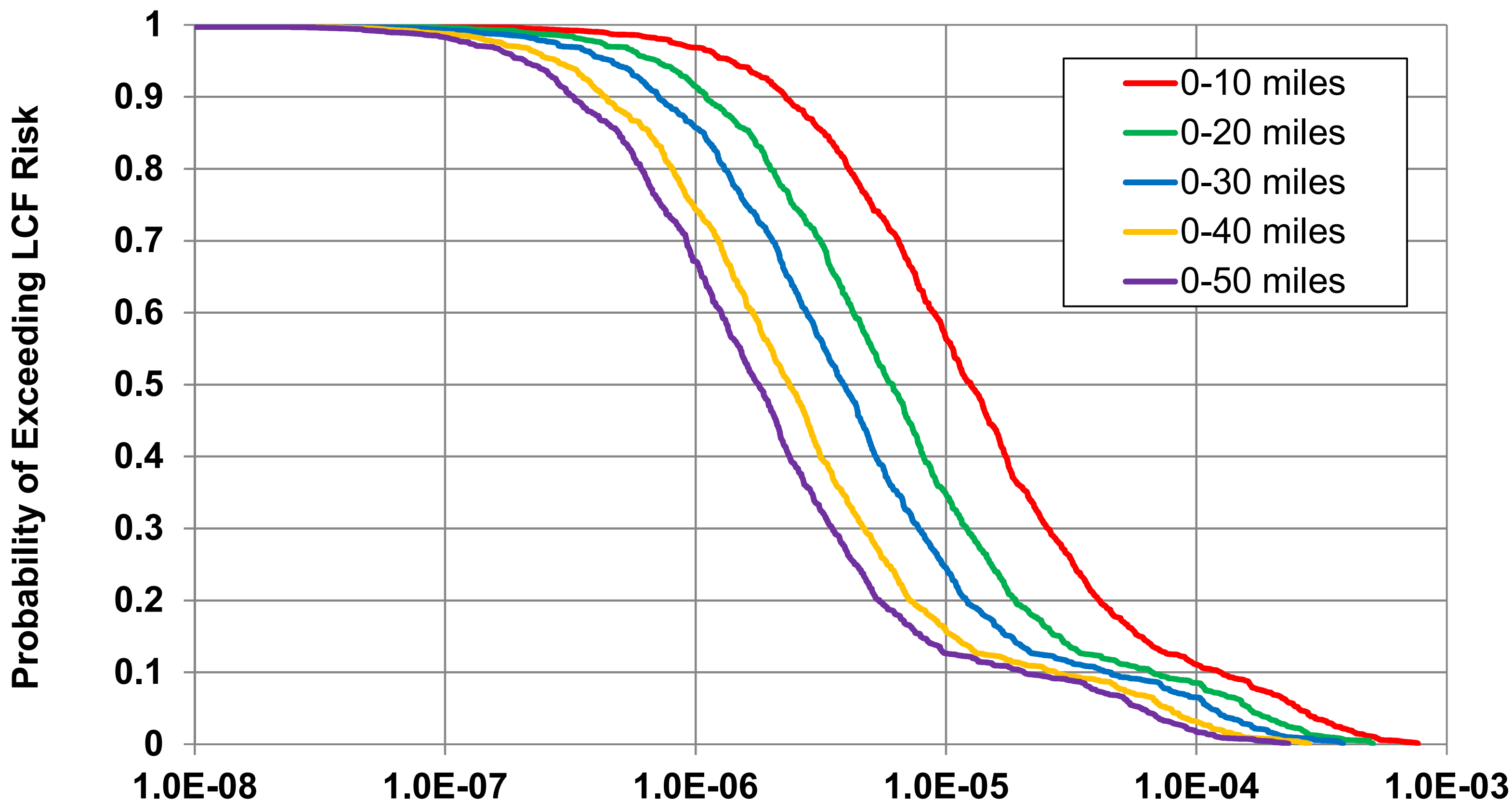


Figure 6-13 Cesium release fractions over 48 hours with mean, median, 5th and 95th percentiles (which are calculated at each point in time)

Individual LCF Risk Consequence Results

Mean (over weather), individual, latent cancer fatality (LCF) risk (based on LNT) per event



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Consequence Regression Analyses, LNT (10 mile, All Rlzs)

- The most important parameter is tube thickness.
- Second most important is the SV open area fraction.
- The third most important input parameter is the time at cycle.
- Fourth is groundshine shielding factor for normal activity during the emergency phase, GSHFAC.2, which is fully correlated with the groundshine shielding factor for the long-term phase.

	Rank Regression		Quadratic		Recursive Partitioning		MARS		Main Contr.*	Conjoint Contr. *
Final R^2	0.54		0.60		0.86		0.74			
Input	R^2 contr.	SRRC	S_i	T_i	S_i	T_i	S_i	T_i		
TUBTHICK	0.04	-0.20	0.33	0.53	0.30	0.86	0.35	0.80	0.189	0.309
SVOAFRAC	0.03	-0.18	0.23	0.40	0.09	0.55	0.11	0.45	0.082	0.250
CYCLE	0.18	0.44	0.01	0.02	0.01	0.01	0.02	0.02	0.050	0.005
GSHFAC.2	0.13	0.35	0.02	0.05	0.00	0.00	0.01	0.03	0.038	0.011
DLEAK	0.08	0.26	0.01	0.04	0.01	0.01	0.00	0.01	0.022	0.010
CFRISK.8	0.02	0.15	0.02	0.05	0.00	0.06	0.02	0.08	0.011	0.037
SV_STATUS	---	---	0.04	0.04	---	---	---	---	0.006	0.000
DDREFA.8	0.01	-0.12	0.00	0.02	0.00	0.05	0.00	0.03	0.004	0.025
CYSIGA.1	0.02	-0.13	---	---	---	---	---	---	0.004	0.000
TUBETEMP	---	---	0.02	0.02	0.00	0.00	0.01	0.03	0.004	0.006
DEV_DEC_HEAT	0.01	-0.09	0.00	0.03	0.00	0.03	0.01	0.02	0.004	0.015
VDEPOS.1	0.01	0.09	0.01	0.01	0.00	0.04	---	---	0.003	0.011
CFRISK.7	0.01	0.09	---	---	---	---	---	---	0.002	0.000
CFC	0.01	-0.09	---	---	---	---	0.00	0.01	0.002	0.001
CFRISK.6	0.01	0.07	---	---	---	---	0.00	0.02	0.002	0.003
PROTIN.2	---	---	---	---	0.01	0.09	---	---	0.001	0.023
CHEMFORMCS	0.01	-0.06	---	---	---	---	---	---	0.001	0.000
SGTRLOC	0.00	0.06	0.00	0.01	---	---	---	---	0.001	0.002
CFRISK.2	---	---	0.00	0.03	---	---	---	---	0.001	0.005
LA.140_ICH.9	---	---	0.00	0.04	0.00	0.03	0.00	0.01	0.000	0.018
PARTSHAPE	---	---	0.00	0.01	0.00	0.01	---	---	0.000	0.004
CHEMFORMI2	---	---	---	---	0.00	0.02	0.00	0.01	0.000	0.009

** highlighted if main contribution larger than 0.02 or conjoint contribution larger than 0.1*

Table 6-24 Mean, individual, LCF risk (based on LNT) regression results within a 10-mile circular area for all realizations.

- The top two parameters largely control whether an SGTR occurs, which has a dominant effect on consequences. Both parameters have large conjoint contributions which imply that there is some synergistic influence on LCF risk from TUBTHICK and SVOAFRAC in conjunction with each other or other parameters.

Overall Conclusions and Insights

- Surry UA corroborates SOARCA study conclusions
  - Public health consequences from severe nuclear accident scenarios that were modeled are smaller than previously calculated, and very small in absolute terms
  - Delayed releases calculated provide time for emergency response actions such as evacuating or sheltering
  - Long-term phase dominates health effect risks because emergency response is faster than progression to release
  - “Essentially zero” early fatality risk projected

Overall Conclusions and Insights from Draft Surry UA

- SGTRs occurred in about 10% of the realizations and produce source terms that are one to two orders of magnitude greater
- Due to updated containment model, source terms are smaller than in the original SOARCA study
- Lower source terms lead to lower LCF risks
- Source term uncertainty contributes more than consequence parameter uncertainty when dose response is not varied
- Uncertainties in dose response may be much more significant than any other uncertainty
- The most significant parameters are those that influence the likelihood of SGTR (SV open fraction and SG hottest tube thickness)
- The other most significant parameters are
  - Time at cycle, which affects decay heat levels and isotopic inventory
  - Parameters that affect groundshine doses, especially in the long term

Status and Next Steps

- Currently revising SOARCA Surry Uncertainty Analysis with updates following the Advisory Committee Reactor Safeguards subcommittee review meetings on the SOARCA Surry Uncertainty Analysis and SOARCA Sequoyah Analysis in February 2016 and May 2016 respectively.
  - Expect updated Surry UA report in 2018

- Next steps include developing summary NUREG report on insights from the SOARCA Peach Bottom, Surry, and Sequoyah Uncertainty Analyses.