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State-of-the-Art Reactor Consequence Analyses (SOARCA) Project: Results of Sequoyah Analyses

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Outline

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- Short-Term Station Blackout (STSBO) Analyses
  - Severe Accident Progression
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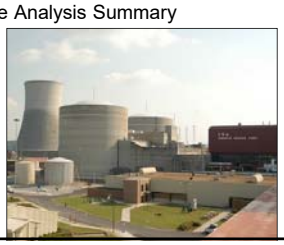
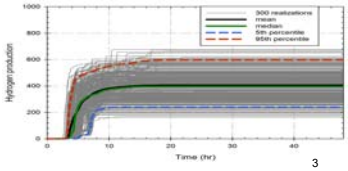
- Lessons Learned
- Summary



Overview and Objectives

- SOARCA goals and objectives
  - Develop body of knowledge on the realistic outcomes of severe reactor accidents
  - Incorporate state of the art modeling (MELCOR/MACCS)
- SRM SECY-2012-0092
  - Limited to station blackouts (SBOs)
  - Focused on issues unique to ice condenser containment and hydrogen challenges

SOARCA Sequoyah NUREG/CR report is in the NRC publication process



Severe Accident Progression
STSBO High Level General Observations

- Consequences strongly (and intuitively) affected by *early vs. late* containment failure.
  - Early containment failure dominated by hydrogen combustion
  - Late containment failure results mainly from ex-vessel phenomena (e.g., core-concrete interaction)
- Early containment failures occur *only on the first hydrogen burn* (subsequent burns do not challenge containment integrity)

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Severe Accident Progression
STSBO High Level General Observations (cont.)

- Protracted safety valve (SV) cycling produces *lower in-vessel hydrogen* by the time of first burn
- Pressurizer SV failure to close (with large open area) results in greater hydrogen production and transport to the containment prior to the first burn
  - Which increases the potential for early containment failure
- Late containment failures generally have reduced source term release benefiting from gravitational settling

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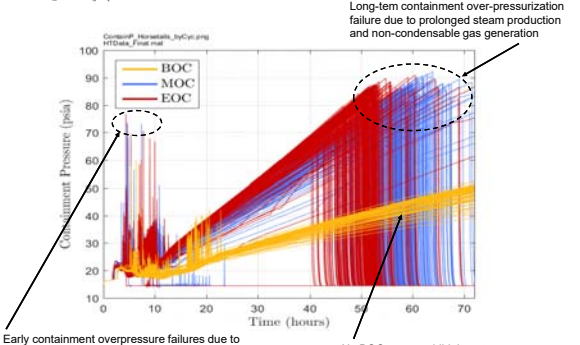
Containment Failure Outcomes



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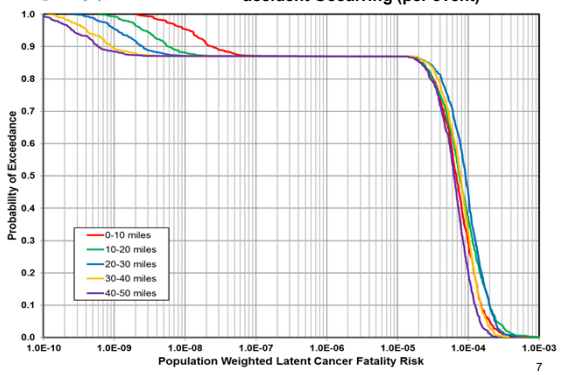
Latent Cancer Fatality Risk (mean over weather trials), Conditional on the STSBO accident Occurring (per event)



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Offsite Consequence Analysis Summary

- Essentially zero individual early fatality risk was calculated for Sequoyah STSBO
- Individual, conditional LCF risks:
  - Small, even for cases resulting in early release to environment
  - Generally dominated by intermediate and long-term phase exposures compared to emergency phase exposures
- Parameters most important to uncertainty in LCF risk:
  - Time during fuel cycle when accident occurs
  - Cancer fatality risk factors for “residual” organ, lungs, and colon
  - Containment rupture pressure
  - Number of safety valve cycles prior to failing open (more important at shorter distances)
  - Normal relocation time (important beyond 10-mile EPZ)

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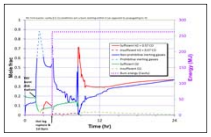
Lessons Learned

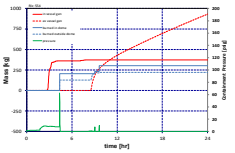
- A single “best-estimate” severe accident simulation is elusive due to many and varied uncertainties
- UA is an iterative process requiring complementary statistical and phenomenological expertise and analyses

Cesium Regression Table

	Rank Regression		Quadratic		Recursive Partitioning		MARS		Main Contribution	Interaction Contribution
Final R^2	0.40		0.77		0.51		0.77			
Input	R^2 contrib	SRRC	S_i	T_i	S_i	T_i	S_i	T_i		
prSVcyc	0.26	-0.53	0.32	0.08	0.50	0.06	0.41	0.79	0.280	0.294
Cycle	0.01	0.15	0.04	0.10	0.01	0.02	0.21	0.21	0.051	0.059
Rupture	0.05	-0.22	0.01	0.14	---	---	0.01	0.09	0.016	0.051
Ex_Mod_T	0.02	-0.15	0.02	0.27	0.02	0.49	0.01	0.30	0.013	0.205
Shape_Fact	0.04	0.21	---	---	0.00	0.00	0.00	0.00	0.010	0.009
Cv_Model	0.01	0.09	0.01	0.16	---	---	0.00	0.00	0.004	0.039
Final_Pressure	---	---	0.00	0.02	---	---	0.01	0.01	0.002	0.005
Seal_Open_A	0.01	-0.07	0.00	0.01	---	---	0.00	0.00	0.002	0.004
Burn_Dir	0.00	0.07	0.00	0.02	---	---	0.00	0.01	0.001	0.008

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

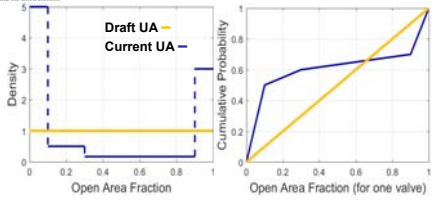


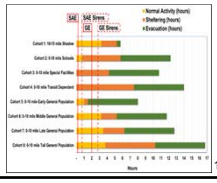


The case with earliest containment rupture – RLZ 554

Lessons Learned (cont.)

- Important to consider uncertainty within the overall analysis
  - SV Open Area Fraction distribution updated
- Integrated modeling important
  - Impact of assumed seismic initiator on evacuation





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Summary

- Objectives met for SOARCA pilot analyses
- Major step forward in realistic, integrated approach
- SOARCA important reference domestically and internationally
- Improved accident codes and models
- Key knowledge development and experience for staff

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Core Team Members

- MELCOR and severe accident progression: Kyle Ross, Jeff Cardoni, Chris Faucett, Troy Haskin, Randy Gauntt (SNL); Casey Wagner (dycoda); Hossein Esmaili, Trey Hathaway, Allen Notafrancesco, Salman Haq, Ed Fuller (NRC)
- MELMACCS: Nathan Bixler, Doug Osborn** (SNL); Trey Hathaway (NRC)
- MACCS, consequence analysis and emergency response: Nathan Bixler, Matthew Dennis, Joe Jones, Doug Osborn**, Fotini Walton (SNL); Trey Hathaway, Jonathan Barr, Keith Compton, Todd Smith, Edward Roach (NRC);
- UA methodology: Dusty Brooks, Matthew Denman (SNL); Tina Ghosh**, Trey Hathaway (NRC)
- Accident scenario development: Selim Sancaktar, Jose Pires (NRC)

***Co-leads*

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Acronyms

BOC	Beginning of cycle (burnup cycle between refueling outages)
EOC	End of cycle
EPZ	Emergency planning zone
LCF	Latent cancer fatality
MACCS	MELCOR Accident Consequence Code System
MELCOR	Not an acronym
MOC	Middle of cycle
NRC	U.S. Nuclear Regulatory Commission
PWR	Pressurized water reactor
RLZ	Realization (of Monte Carlo Simulation)
SNL	Sandia National Laboratories
SOARCA	State-of-the-Art Reactor Consequence Analyses
SRM	Staff Requirements Memorandum
STSBO	Short term station blackout
SV	Safety valve
UA	Uncertainty Analysis

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