4

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

State-of-the-Art Reactor Consequence Analyses (SOARCA)

ACRS Regulatory Policy and Practices
Sub-Committee Meeting
July 10, 2007

SOARCA
ACRS Subcommittee Meeting

Agenda

- Project Overview
- Accident Sequence Selection
- Containment System States
- MELCOR
- Emergency Preparedness
- MACCS2

2

T/46

SOARCA

Project Overview

Robert Prato

3

SOARCA Goal and Objectives

Goal

Develop a state-of-the-art, more realistic evaluation of severe accident progression, radiological releases and offsite consequences for dominant accident sequences and replace such as NUREG/CR-2239, "Technical Guidance for Siting Criteria Development."

Objectives:

- Determine best estimates of the radiological consequence
- Evaluate and update analytical methods and models
- Include mitigative measures and plant improvements
- Use updated emergency planning modeling assumptions.
- Incorporate effective risk communication techniques

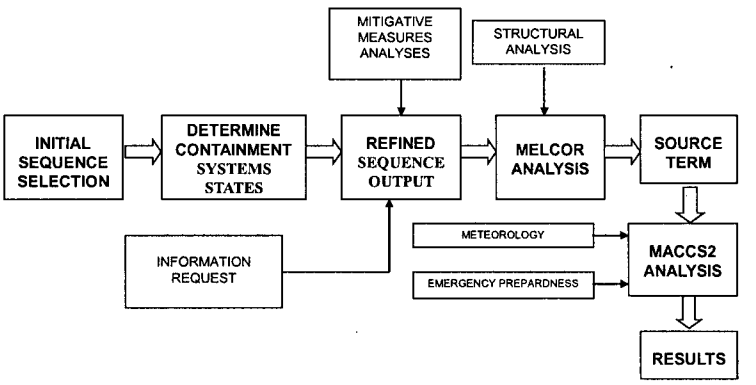
4

SOARCA Status

- Communications
  - Press Release – Issued May 7, 2007
  - OPA prepared Fact Sheet
  - Web page
  - Frequently asked questions
  - Links to related sites
- Project Plan
  - Initial scope of not more than eight plants
  - Start with a BWR (Peach Bottom) and a PWR (Surry)
  - Results will be compiled and released to the public after the project is complete

5

SOARCA PROCESS



6

Sequence Selection

Internal Events

Perform initial screening to screen out low CDF initiating and group remaining sequences based on time to core damage and equipment unavailability to identify dominant sequence groupings with a CDF $\geq$ 1.0 E-6 ($\geq$ 1.0E-7 for bypass events).

External Events

Identify the dominant externally initiated event sequence based on NUREG-1150, IPEEE submittals, external event SPAR (SPAR-EE) model, and/or generic insights to select representative sequences and to qualitatively assess related risk.

7

Containment System States

Identify the anticipated availability of containment and containment support systems that can impact post core-damage accident progression, containment failure, and radionuclide release.

8

Mitigative Measures

For each sequence groupings within the scope of the site-specific analyses, identify applicable mitigative measures that can potentially prevent or delay core damage, RCS failure, and/or containment failure and the approximate time for implementation after the initiating event for input into the MELCOR analysis.

9

Structural Analyses

Perform structural evaluation of containments to determine functional failure pressure (leakage) and structural failure pressure (rupture), and to develop leakage rate and/or area as a function of internal pressure.

10

MELCOR

- MELCOR Code Improvements model improvements are complete.
- Develop a plant-specific model for each plant being analyzed.
- Perform accident progression analyses for each plant using MELCOR computer code to determine source term, potential containment failure state and time, and time of release as input in the MACCS2 analyses.

11

Emergency Preparedness

Model the protective response afforded by current site-specific Emergency Preparedness (EP) Programs.

12

MACCS 2

- MACCS2 Code model improvements have been completed.
- Develop a site-specific model for each plant being analyzed based on meteorological data and emergency response parameters.
- Perform consequence analyses for each plant using MACCS2 computer code to determine early fatalities, and latent cancer fatalities.

13

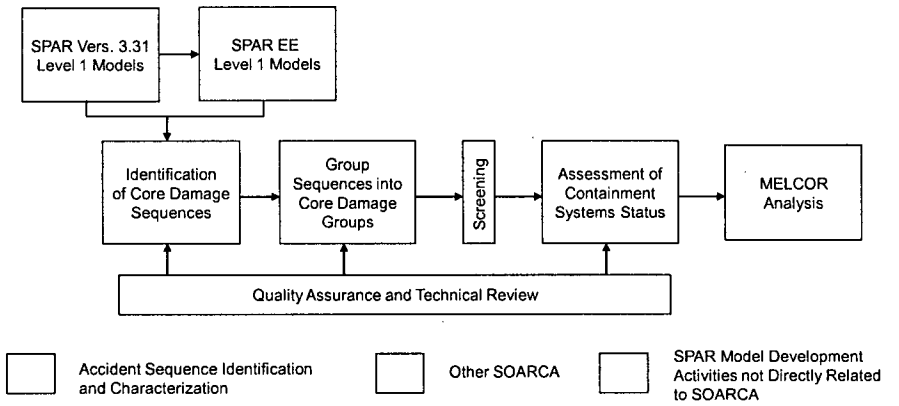
SOARCA

Accident Sequence Selection
and
Containment System States

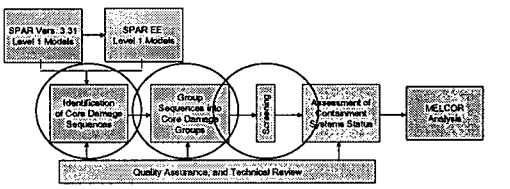
Richard Sherry

14

SOARCA Accident Sequence Identification and Characterization



15



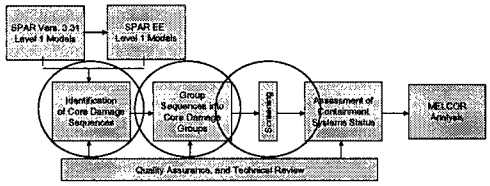
Internal Events

- CD sequences determined using plant specific "Level 1" SPAR models and licensee PRA results
- Selection process considers groups of sequences
- Identify sequence groups with freq. $>10^{-6}$ per RY for most sequence groups and $>10^{-7}$ per RY for sequence groups that are known to have the potential for higher consequences

Outputs

- Internal event (IE) CD sequence groups, the individual sequences included in the group and the group frequency
- Description of the dominant IE sequences included in each sequence group
- Dominant IE sequence cutsets and their descriptions

16



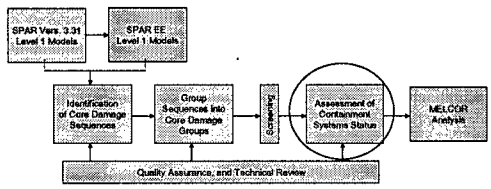
External Events

- Determined using available plant/design-specific assessments (e.g. NUREG-1150, IPEEE, etc.)
- SPAR-EE information used when available
- Generic insights also used to define and select representative sequences

Outputs

- Representative sequences for EE initiators with estimated frequency ranges
- Sequence descriptions, containment systems status, and a sequence frequency estimates are provided
- Report documenting sequences and basis for selection

17



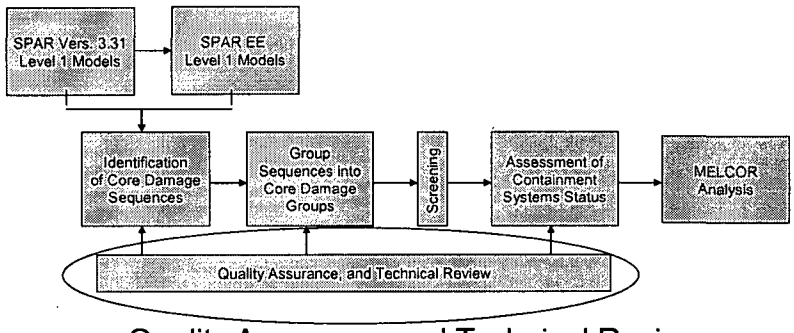
Containment Systems Status

- Availability of systems that impact post-core damage
  - containment accident progression
  - containment failure
  - radionuclide release
- Use system dependency tables and existing SPAR system models (which do not fully assess containment systems)

Outputs

- Availability of containment systems for identified sequence groups.
- Availability of "Level 1" systems that impact containment accident progression
- Identification of important plant physical states (e.g. RPV pressure at core damage) and sequence timing

18



Quality Assurance and Technical Review

- Cutset level reviews from Level 1 SPAR core damage models with licensee PRA results.
- Peer review by an internal review panel

19

SOARCA

MELCOR

Jason Schaperow

20

MELCOR Improvements

- Fission product release and deposition
  - CORSOR-Booth release model benchmarked to PHEBUS and VERCORS tests (cesium volatility based on vapor pressure of cesium molybdate)
  - Aerosol release from Ag-In-Cd control rods and from zircaloy (Sn)
- Explicit accounting of mechanisms for relief valve seizure (fail open) and resulting depressurization
- In-vessel debris behavior
  - Modeling of molten pool formation with possible crust formation
    - Modeling guided by ongoing TMI assessment
  - Modeling of the core shroud failure and the bypass region between shroud and core barrel
  - More detailed representation of material relocated to lower plenum and of the bottom head

21

MELCOR Improvements
(BWR)

- Updated fuel assembly and core data
  - Geometry and material composition for current 10x10 fuel design
  - New estimates of decay power and fission product inventory for mid-cycle and end-of-cycle
  - Spatial distribution based on axial and radial power data for several recent cycles
- Refined description of reactor upper internals
  - Radionuclide deposition surfaces
  - Heat sinks influence advection to steam line nozzles and potential for steam line creep rupture

22

MELCOR Improvements
(PWR)

- RCS at high pressure with core uncovered – improvements from ongoing effort with SCDAP/RELAP5 and CFD on thermally induced tube rupture
- Natural circulation modeling
  - Steam-to-wall radiation
  - Heat loss from RCS to containment provides 2 MW heat removal (at 10 hrs., decay power is 20 MW)
  - Hot leg natural circulation rate matched to observations from recent CFD calcs
  - Hot-leg-to-tube recirculation ratio (2.0) and inlet plenum mixing fraction (85%)
  - Individual pressurizer relief valves to better reflect natural circ. flow disruption
- Pump seal leakage modeling
  - Seal leakage location updated
  - Simplified leakage model flowrate (vs. pressure) compares well with detailed models
- Creep rupture modeling
  - Both carbon steel hot leg nozzle and stainless steel hot leg piping included
  - More accurate stress formulation (previously used a thin wall formulation)

23

SOARCA

Emergency Preparedness

Joseph Jones

24

EP Modeling

- Modeling the emergency response afforded by NPP Emergency Preparedness programs substantially improves realism
- All NPPs have regularly inspected and exercised EP programs
- Modeling realistically represents NRC Defense-in-Depth Policy

25

EP Modeling Assumptions

- Officials will implement emergency plans
- The public is expected to obey direction from officials
- Emergency workers will implement the plans
- Basis from NUREG/CR-6864, "Identification and Analysis of Factors Affecting Emergency Evacuations" and PAR Study Focus Groups

26

WinMACCS Revisions For EP Modeling

- Allows up to 20 cohorts
- Each cohort may change speed 3 times
- Allows road network to be modeled
- Allows evacuation speed to be changed in any grid element to model freeways and bottlenecks

27

SOARCA

MACCS2

Jocelyn Mitchell

28

MACCS2 Improvements

- User-friendly interface, called WinMACCS
- Memory management
- More cohorts for evacuation
- Enable network evacuation
- Evacuation speed change by grid element and for precipitation
- Alternative models for latent cancer dose-response

29

MACCS2 Improvements (cont.)

- Plume rise model (older Briggs model)
- Plume meander Reg Guide 1.145
- Potassium Iodine (KI) ingestion
- Long range lateral plume spread
- More compass directions
- More plume segments to model release
- Shorter than 1-hour time intervals in meteorological file

30

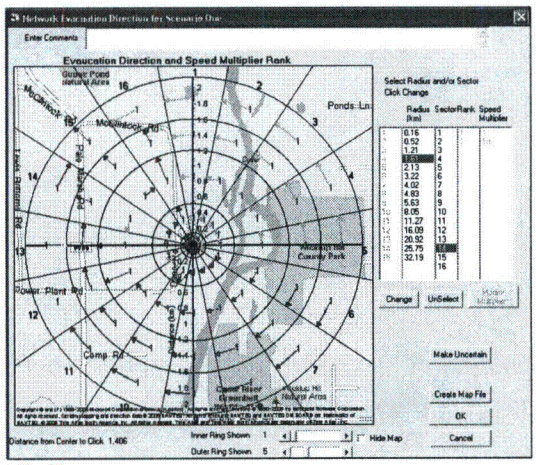
MACCS2 Improvements (cont.)

- Parameter uncertainty can be assessed
  - Meteorological as usual (sample from weather bins)
  - Source term - repeat use of equally-likely samples from MELCOR
  - Ranges of values, degrees of belief for floating point variables
  - Latin Hypercube sampling

31

Enable Network Evacuation Model

Network Evacuation Model – Evacuation Direction and Speed Interface



32

Dose Conversion Factor File

- Based on Federal Guidance Report 13
  - Equivalent to ICRP Publications 68 and 72
- MACCS2 data file set consists of 51 files
  - 50 DCF files for one year's worth of dose commitment – years 1 through 50
  - 51st file DCF for a fifty-year dose commitment
- Cloudshine, groundshine based on FGR 12

33

Input Values Other Than Site-Specific

- US/CEC study "Probabilistic Accident Consequence Uncertainty Analysis"
  - Elicitation of "experts in the different scientific disciplines featured within an accident consequence code"
    - Atmospheric science, radioecology, metabolism, dosimetry, radiobiology, economics
  - Use 50th percentile of distribution

34