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to: R. Prato, U.S. Nuclear Regulatory Commission

from: S. Burns, MS 0748, Org. 6761

subject: MACCS2 external review panel report

Attached is the final version of the MACCS2 external review committee report from the public meeting conducted in Albuquerque, New Mexico on August 23-24, 2006. The contents of this report have been reviewed by the individual panelists as well as Nuclear Regulatory Commission and Sandia National Laboratories staff. The recommendations and observations contained in this report, as well as a technical evaluation, will be included in a formal Sandia National Laboratories technical report to be published in the early in calendar year 2006. An electronic archive of this report as well as the complete proceedings of the August meeting will be distributed on compact disk to meeting participants and stake holders by the end of December, 2006.

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State-of-the-Art Reactor Consequence Analysis (SOARCA) Project
MACCS2 Modeling Practices Review
August 23-24, 2006

Review Committee Report

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Acronyms

CCDF	Complimentary Cumulative Distribution Function
DCF	Dose Conversion Factor
ICRP	International Commission on Radiological Protection
LNTH	Linear No-Threshold Hypothesis
MOX	Mixed Oxide
NRC	Nuclear Regulatory Commission
SOARCA	State-of-the-Art Reactor Consequence Analysis

Executive Summary

This report summarizes the recommendations and observations of an external review committee impaneled to support the State-of-the-Art Reactor Consequence Analysis (SOARCA) project funded by the U.S. Nuclear Regulatory Commission (NRC) and executed jointly by NRC and Sandia National Laboratories. The external review focused primarily on best modeling practices to be used in the SOARCA project for analyzing off-site consequences of severe accidents at U.S. nuclear power plants using the MACCS2 analysis program. This report does not represent a consensus panel view but rather captures the individual observations and recommendations of the panelists. The impact of this review on the execution of the SOARCA project will be documented in a subsequent formal technical report to be published by Sandia National Laboratories.

Introduction

A review of off-site consequence modeling for the State-of-the-Art Reactor Consequence Analysis (SOARCA) project was conducted at a public meeting in Albuquerque, New Mexico on August 23-24, 2006. This review focused primarily on best modeling practices for the application of MACCS2 consequence analysis code but also included consideration of potential enhancements to the MACCS2 code as well as consideration of the SOARCA project in general. The review was conducted by five panelists with demonstrated expertise in the MACCS2 code and analysis of off-site consequences of severe accidents at commercial nuclear reactors. The panelists were drawn from private industry and the Department of Energy national laboratory complex. The review was coordinated by Sandia National Laboratories and attended by Nuclear Regulatory Commission staff.

The objective of the review was not to develop a consensus panel view but rather to capture the views of individual panelists in their areas of expertise. The following sections summarize the recommendations and observations of the individual panelists relative to a number of specific modeling issues. The panel recommendations are further subdivided into high priority and lower priority recommendations whenever a prioritization was suggested by the panel. Relevant reference material suggested by the panelists is also provided along with the recommendations and observations described in the following sections.

This report provides a summary of the review panel deliberations but does not provide an analysis of the panel recommendations. An analysis of information contained in this report, including specific technical impacts on the SOARCA project, will be documented in a subsequent technical report.

Project Methodology

High Priority Recommendations

- Early in the project perform an uncertainty/sensitivity study (full Latin Hypercube Sampling) of characteristic MELCOR and MACCS2 cases to identify important modeling parameters. Avoid deliberately conservative assumptions in uncertainty analysis to avoid skewing results (cf. Helton, et al., 1986, 1989, 1995, 2006). *(Jon Helton)*
- A focused multi parameter sensitivity study for typical sites and plants should be considered up front to identify and evaluate important MACCS2 modeling parameters. This allows coarser distributions for unimportant parameters to be used, prior to the more formal uncertainty analysis on a plant-specific basis. *(Mohsen Khatib-Rahbar)*
- Consequences measures of should be limited to early and latent cancer, dose and land contamination out to a maximum distance of ~250 miles (i.e., to avoid applying the straight line Gaussian plume model to extreme distances). Economic

consequences (which are even more uncertain,) should not be included. *(Mohsen Khatib-Rahbar)*

- The final consequence results should include the traditional Complimentary Cumulative Distribution Functions (CCDFs) that include the variability due to weather and the other consequence modeling parameter uncertainties. *(Mohsen Khatib-Rahbar)*
- At longer distances, e.g., beyond the low population zone, it would be useful to present average *individual* dose as a function of distance in addition to the aggregate collective dose (person-rem) that is calculated in MACCS2 and also display the average individual dose values relative to average background dose. For example, in Davis et al., (1997), the *individual* risk of permanent relocation was estimated as a function of distance based on NUREG-1150 (Nuclear Regulatory Commision, 1990) dose avoidance criteria *(Vinod Mubayi)*
- Regarding the issue to what distance the consequence estimates should be reported, it is useful to look at the regulatory framework. Part 50 establishes an ingestion pathway emergency planning zone of 50 miles. The Nuclear Regulatory Commission (NRC) safety goal policy has a 10 mile distance for estimating latent cancer risk. A 50 mile distance should be adequate for reporting consequences. *(Vinod Mubayi)*
- The indices of risk should be limited to a fifty-mile (or 80-km) basis. This is the radius used by the NRC for evaluation of the Ingestion Planning Zone around nuclear power plants (Nuclear Regulatory Commission, 1980). The 50-mile extent is also consistent with the basis for Environmental Impact Statements used by the NRC and the Department of Energy in evaluating new facilities and proposed sites. While the Gaussian model is generally viewed as accurate to approximately 10 miles (American Meteorological Society, 1978, International Atomic Energy Agency, 1987), it is generally acceptable in an approximate sense assuming relatively smooth terrain and the assumption that the weather at the point of release can govern the plume behavior at long distances. My view is that because the main value from the SOARCA Program risk indices for the various plants will be a comparative one, I am not too concerned with a Gaussian-based model such as MACCS2 in comparing 50-mile risks. However, I would be hard pressed to carry this acceptance out to risk estimates based on 200 miles and above. Early sensitivity analysis work using the boundary weather feature of MACCS2 can be used to determine if this size grid will underestimate dose and health effects. *(Kevin O'Kula)*

General Recommendations

- Consideration should be given to providing complete cumulative distribution for results and displaying as an exceedance frequency. *(Jon Helton)*
- Implementation of latent cancer fatality thresholds from exposures calculated in the MACCS2 CRONC module cannot be implemented in the current MACCS2 model. This problem is resolved by eliminating the food pathway. *(Jon Helton)*

- Computational efficiencies may be achieved by well chosen decomposition of consequence calculation based on specific scenarios. For example, emergency response can be separated from the source term and atmospheric transport calculation. Applicable to parallel calculations. *(Jun Li)*
- Restriction to 50 miles for estimating consequences will reduce the worst case numbers for the population dose and latent cancers that arise from large numbers of people accumulating small doses within the Linear No-Threshold Hypothesis (LNTH) framework. *(Vinod Mubayi)*
- It is important to specify the values and basis for temporary and permanent relocation, i.e., dose avoidance criteria (mrem/year), since this influences the calculation of population dose and latent cancers. The decisions to interdict contaminated land or relocate people depend on economic trade-offs between decontamination and relocation costs which themselves depend on the chosen dose avoidance criteria (cf. Mubayi, et al, 1995). *(Vinod Mubayi)*
- Consider limiting exposure period in CHRONC to 5-10 years. A fifty-year (50) basis is overly conservative without any technical basis. It is highly unlikely that contaminated food would be accepted into the food supply at any time post-accident, let alone between years 40 and 50. In other words, this additional population dose is meaningless and provides no commensurate insights on reactor safety. *(Kevin O'Kula)*

Observations

- In general the proposed methodology including limitations of the tools and methods are appropriate and consistent with state of the art. *(Full Panel)*
- Portrayal of results using both the LNTH and the threshold models is appropriate. Threshold results could be presented as "best estimate" while LNTH provides a "worst case". *(Mohsen Khatib-Rahbar)*

Atmospheric Transport

High Priority Recommendations

- Consider increasing number of release segments (limit release segments to less than or equal to 1hr) and increase the number of angular segments from the current 16. *(Jun Li)*
- Specification of even a coarse road network evacuation model could significantly improve consequence estimates by eliminating over conservatism due to excessive exposure to plume centerline concentrations. *(Jun Li)*
- Plume meander as currently planned is good in particular if it is tied into evacuation modeling through an uncertainty analysis. *(Mohsen Khatib-Rahbar)*
- The described mixing layer height modification to the MACCS2 model[1] is a much-needed change in that plume growth will be constrained in the vertical

[1] See the proceedings of the August 23-24, 2006 external review.

direction by the mixing layer height. My expectation is that this should lead to higher-confidence risk estimates for early health effects that depend on close-in radiation effects *(Kevin O'Kula)*

General Recommendations

- Care should be taken in decreasing release segments to very short durations, as the present MACCS atmospheric dispersion formulation does not support a continuous release representation. *(Mohsen Khatib-Rahbar)*
- The uncertainties in the various parameters of the dispersion model should be included as probability distributions, and propagated through the model in order to better portray the expected range of severe accident consequences. *(Mohsen Khatib-Rahbar)*
- The significance of the mixing height parameter has not been established but could be considered as an uncertainty parameter. *(Mohsen Khatib-Rahbar)*
- The new Briggs plume model and dispersion parameter distributions described are appropriate; however, some analysis would be useful in evaluating the impact and determining the importance of the changes made to these models on the results. *(Vinod Mubayi)*
- Future changes in land use may be an important consideration at specific sites in assessing the reasonableness of the proposed surface roughness parameter estimate approach. *(Vinod Mubayi)*
- Mixing height may only be an important issue at particular sites. Site specific data on mixing height should be used as much as possible. *(Vinod Mubayi)*
- Use of improved Briggs plume model is a good idea. Care should be taken in area fire scenarios. Data handoff from MELCOR should be examined to ensure energy from fire is represented. *(Kevin O'Kula)*
- The basis for the initial seed of the random number generator (IRSEED) selection should be described. In the past, it has been our experience that for a given meteorological data file, this input parameter selection can change the high-consequence, low probability portion of the CCDF. *(Kevin O'Kula)*

Observations

- It is unclear that increasing the angular resolution will be consistent with the overall resolution of the analysis. *(Jon Helton)*
- Plume rise modeling approach is appropriate but not very important. *(Mohsen Khatib-Rahbar)*
- Roughness approach described is useful. *(Mohsen Khatib-Rahbar)*
- The proposed plume meander approach is a good idea. *(Vinod Mubayi)*
- The feasibility of increasing the angular resolution will depend on availability of site specific data. *(Vinod Mubayi)*

Deposition Modeling

General Recommendations

- In MACCS2 calculation the skin dose is inconsistent in terms of deposition velocity. The deposition velocity used for the skin dose is hard wired. This may be an opportunity to make the velocities more consistent. *(Jun Li)*
- Since deposition is size dependent, inhalation dose should also include size dependence. *(Jun Li)*
- Wet deposition modeling is not as important as dry deposition but it should still be considered.For example, size dependence of wet deposition model could be neglected if project is time constrained. *(Kevin O'Kula)*

Observations

- Wet deposition might be important in determining early health effects. *(Jon Helton)*
- The improvements to dry deposition models described are generally useful and appropriate but they may have an impact on the relative importance of different exposure pathways, e.g., inhalation vs. cloudshine or groundshine. Wet deposition usually has a significant influence on early health effects. *(Vinod Mubayi)*
- Only some of the sites will have sufficient rainfall for refinements to wet deposition to be an issue. *(Kevin O'Kula)*

Consequence Modeling

High Priority Recommendations

- Take a close look at conversion from dose to health effects and associated uncertainties. LNTH is only one aspect of this issue. *(Jon Helton)*
- Look at high burnup and Mixed Oxide (MOX) cases for unique radioisotopes to determine if the current isotopic library in MACCS needs to be expanded. *(Mohsen Khatib-Rahbar)*
- Determine if radionuclide set is complete and covers current high burnup and MOX scenarios which may involve low volatility species. *(Kevin O'Kula)*
- Apply the International Commission on Radiological Protection's (ICRP's) newer dose conversion factors. The ICRP has updated its recommendations for dose conversion factors (DCFs) for workers and the general public. We have seen factors of two to three reduction in doses for non-reactor source terms. These DCF changes affect both inhalation and ingestion pathways. I strongly recommend the SOARCA Program implement these DCFs (International Commission on Radiological Protection, 2001). The current MACCS2 groundshine and cloudshine DCFs can be maintained in the SOARCA Program. *(Kevin O'Kula)*

General Recommendations

- If an uncertainty issue to be studied includes the parameters impacting early health effects then a source term that can drive early health effects must be considered in early uncertainty evaluation (e.g., risk factors). *(Jon Helton)*
- This study should use the updated ICRP 68 and 72 dose conversion factors. Thyroid dose should be added to consequence analysis. *(Kevin O'Kula)*

Emergency Planning

High Priority Recommendations

- Evacuation delay is a very important parameter in determining consequences. Care should be taken to ensure that evacuation delay is realistic. *(Jun Li)*

General Recommendations

- A criteria needs to be developed to evaluate the amount of detail that should be incorporated into EP modeling. This is a policy issue. *(Vinod Mubayi)*
- If there are some plants where the efficacy of different plans is of interest, off-line sensitivity studies using constant weather could be considered. *(Kevin O'Kula)*

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