



**UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001**

September 24, 2007

MEMORANDUM TO: George Apostolakis, Chairman
Reliability and Probabilistic Risk Assessment Subcommittee

FROM: Hossein Nourbakhsh, Senior Staff Engineer **/RA/**

SUBJECT: STATUS REPORT FOR THE MEETING OF THE
SUBCOMMITTEE ON RELIABILITY AND RISK ASSESSMENT,
OCTOBER 2, 2007, IN ROCKVILLE, MARYLAND

The purpose of this memorandum is to forward written materials for your use in preparing for the meeting of the ACRS Subcommittee on Reliability and Probabilistic Risk Assessment on October 2, 2007. The Subcommittee will discuss the next generation PSA software and model representation standards. The Subcommittee will hear presentations by representatives of ABS Consulting, Electric Power Research Institute (EPRI) and ARBoost Technologies regarding this matter. The purpose of the meeting is to gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee. Attached please find the agenda, status report, and background materials.

Attendance by the following members is anticipated and reservations have been made at the following hotels for October 1-6, 2007, unless otherwise indicated.

| | | | |
|--------------|----------------------------|---------|-------------------|
| Apostolakis | RESIDENCE INN | Kress | Hilton (Oct. 1-3) |
| Abdel-Khalik | RESIDENCE INN (Oct. 1-3) | Maynard | RESIDENCE INN |
| Bonaca | BETH.N.MARRIOTT (Oct. 2-6) | Shack | RESIDENCE INN |
| Bley | | Stetkar | Hilton (Oct. 1-6) |
| Corradini | BETH.N.MARRIOTT | Powers | RESIDENCE INN |
| Guarro | | | |

Please notify Ms. Barbara Jo White at 301-415-7130 if you need to change or cancel the above reservations.

Attachments¹:

1. Agenda
2. Status report
3. "Standard Model Representation Format for Probabilistic Safety Assessment," The Open-PSA Initiative, Draft n^o1.0c- July 17, 2007, <http://open-psa.org/>

cc: ACRS Members
cc w/o attach: F. Gillespie
C. Santos

¹Electronic copies of the attachment 3 was previously distributed (via Mail) to Members.

**Advisory Committee on Reactor Safeguards
Subcommittee on Reliability and Probabilistic Risk Assessment
Rockville, MD
October 2, 2007**

- Proposed Agenda -

Cognizant Staff Engineer: Hossein Nourbakhsh (301-415-5622, hpn@nrc.gov)

| | Topic | Presenter(s) | Time |
|-----|--|-------------------------------------|--------------------|
| | Opening Remarks and Objectives | George Apostolakis, ACRS | 8:30-8:40 am |
| I | Next Generation PSA Software, Words from History, Bits from the Future | Steve Epstein, ABS Consulting | 8:40 am -9:45 am |
| II | EPRI's Work on Next Generation PRA Software | Ken Canavan, EPRI | 9:45 -10:30 am |
| | Break | | 10:30- 10:45 am |
| III | Model Representation Standard, Version 1 | Antoine Rauzy, ARBoost Technologies | 10:45- 11:30 am |
| IV | Discussion | ALL | 11:30am-12:00 noon |
| V | Adjourn | | 12:00 noon |

Notes:

- 1 Presentation time should not exceed 50% of the total time allocated for a specific item.
- 2 Number of copies of presentation materials to be provided to the ACRS – 25

**Advisory Committee on Reactor Safeguards
Subcommittee on Reliability and Probabilistic Risk Assessment
Rockville, MD
October 2, 2007**

- Status Report -

PURPOSE

The Subcommittee will discuss the next generation PSA software and model representation standards. The Subcommittee will hear presentations by representatives of ABS Consulting, Electric Power Research Institute (EPRI) and ARBoost Technologies regarding this matter. The purpose of the meeting is to gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee.

BACKGROUND AND DISCUSSION

The U.S. NRC has led the development of the quantitative risk analysis for nuclear power plants. Though Probabilistic Risk Assessments (PRAs) have been used extensively in the past, they were usually limited to a variety of applications on a case by case basis as deemed necessary or useful. The NRC is now moving toward a much expanded use of PRAs in what is termed risk-informed regulatory approach. In 1995, the NRC adopted a policy that promotes increasing the use of probabilistic risk analysis in all regulatory matters to the extent supported by the state-of-the-art to complement the deterministic approach.

The NRC has applied information gained from PRAs extensively to complement other engineering analyses in improving issue specific safety regulation, and in changing the current licensing bases for individual plants. Using risk insights, the NRC has modified its oversight process and its requirements for maintenance (10CFR 50.65) and for categorization and treatment of structures, systems, and components (SSCs) (10CFR 50.69). The NRC is considering further revisions to its reactor regulations (10CFR Part 50) to focus requirements on programs and activities that are most risk significant.

ACRS has always emphasized the improvement of PRA scope and quality and the impact of such improvements on the integrated decisionmaking process that utilizes risk information. In 2003, the Committee undertook an effort to assess the agency's needs for improved PRA technology to risk inform its regulations. As part of this effort, the ACRS commissioned Karl N. Fleming of Technology Insights to prepare a report on issues whose resolution would increase the use of risk information in regulatory decisions [1]. This report was published as NUREG/CR-6813, "Issues and Recommendations for Advancement of PRA Technology in Risk-Informed Decision Making." This report identified a set of recurrent issues that arise in the use of PRAs for risk-informed decision making. Obviously such list only represented a "snapshot" at that particular time, since some of the issues has already been addressed in activities such as the standards development, the industry peer-review process, and the development of Regulatory Guide 1.200, "Guidelines for the Use of Probabilistic Risk Assessment in Regulatory Decision Making." The NUREG/CR-6813 grouped the identified

issues into a few general categories including, lack of completeness within the specified scope, lack of (or inadequate) treatment of uncertainties, and quantification issues (e.g., error due to cut-set truncation).

As stated in NUREG/6813, the existing PRA quantification software employ some form of truncation in the algorithms for quantifying the accident sequence frequencies. The CDF and LERF estimates presented in the PRA reports are based on the sequences and cut-sets left over after a truncation process in which sequence and cut-sets with frequencies below a user-defined cutoff have been deleted from the model. Those software that employ the fault tree linking technique (as opposed to event tree linking) quantify individual cut-sets prior to the completing the last steps in Boolean reduction, in which case the error introduced by truncation is not determined and the upper bounds that can be estimated are often too large to dismiss. In some cases, it may be difficult to show that the error due to truncation is small in relation to RG 1.174 risk acceptance guidelines. In addition, the PRA software tools are programmed to compute risk achievement worths (RAWs) from the truncated model in which case RAW values for some SSC may be underestimated. Calculation of RAW values for risk classification of SSC type of applications (10 CFR 50.69) can be significantly impacted by truncation, e.g., some SSC calculated as RAWs being less than 2.0 are actually greater than 2.0. Guidance could be improved for how to better manage truncation uncertainty in processing the results. There is a relatively new technique referred to as the Binary Decision Diagram (BDD) that is capable of solving fault trees without truncation or approximation which may be the longer term solution to this issue. In the mean time, it is necessary to take some extra steps to ensure that conclusions regarding risk significance of SSCs are robust in light of truncation uncertainty.

Epstein and Rauzy reported [2] the results of a comparison study of the two technologies to assess risk models: the classical approach, based on minimal cutsets and the BDD approach, improved by means of heuristics. As noted by the authors, definitive conclusions could not be drawn from a single example. However, they indicated that their test case was sufficiently large and representative to make some important observation including:

- “The Classical approach overestimates the likelihood of a core damage by almost a factor of 5”
- “Because of imprecision on the values of probabilities (when computed from the cutsets), the rankings of basic events induced by importance factors should be considered with care. This remark is especially important for the so-called RAW that can miss important basic events.”

In its 2006 biennial report to the Commission on review and evaluation of NRC Safety Research Program (NUREG-1635, Vol. 7), the ACRS noted that considerable research was being reported in the literature regarding Binary Decision Diagrams as tools for solving large fault trees without resort to cutoff frequencies as is now done. The Committee further stated that “the staff needs to review the literature concerning Binary Decision Diagrams and evaluate the need to adopt this technology.” The Committee further stated that “the growing importance of the SAPHIRE code and the SPAR models in the regulatory process warrants such an investigation.”

Another quantification issue that was identified in NUREG/6813 was the lack of capability and effort applied to eliminate logic errors from complex logic models. The event tree/ fault tree logic for a state-of-the-art PRA is so complex that it is very difficult to review the PRA model to identify simple errors in the logic. This is a limitation that could be minimized with better tools and better

guidance on a structured process to build the logic model. In the current PRA models, there is too much reliance on the review of individual cut-sets as a means to ensure proper logic. Typically only 100 or so cut-sets for CDF and LERF are even presented in a PRA summary report and in some cases this many only represent a few percent of the total CDF and LERF estimates. Logic errors that incorrectly suppress the risk contribution of sequence cut-sets are not reliably identified using this process. The linked fault tree models are simply too large to rely on manual review of the trees as only a small portion of the logic can be seen and assimilated at one time. In the industry PRA peer reviews, there were many examples of illogical cut-sets identified in the presented results. Not enough effort is being applied to perform logic error reviews and the tools are not very good at assisting with this task.

More recently, a group of international researchers has started an initiative for the Next Generation PSA to provide an open public forum to disseminate information and independently review new ideas. This group is sponsored by ABS Consulting, ARBoost technologies, Electricité de France (EdF), and Electric Power Research Institute (EPRI). The issues, which has been identified to be addressed before new calculation engines or next generation user interfaces are put into place include:

- Quality assurance of calculations;
- Un-founded reliance on numerical approximations and truncation;
- Portability of the models between different software;
- Clarity of the models;
- Completeness of the models;
- Correct uncertainty and importance calculations;
- Modeling of human actions;
- Better visualization of PSA results;
- Difficulty of different software working with the same PSA model;
- Lack of data and software backward and forward compatibility;
- No universal format for industry data.

As a part of Open PSA initiative, working groups in the areas of data visualization, dynamic PSA, new models for human actions, integrated PSA documentation, new calculation techniques, and standard representation formats for PSA models and data are formed. The first working group meeting in standard representation formats for PSA models and data was held at EdF, on July 19, 2007, and a first draft of the Standard Model Representation Format for Probabilistic Safety Assessment [3] has been developed. The Subcommittee will be briefed by representatives of ABS Consulting, Electric Power Research Institute (EPRI) and ARBoost Technologies regarding this matter.

Among the questions that should be answered is whether adopting the BDD approach would affect the NRC's decisionmaking processes significantly to justify the resources required to adopt this technology?

REFERENCES

1. Letter, Dated April 29, 2003, from Mario V. Bonaca, Chairman, ACRS, to William D. Travers, EDO, Subject: NUREG-CR-6813, "ISSUES AND RECOMMENDATIONS FOR ADVANCEMENT OF PRA TECHNOLOGY IN RISK-INFORMED DECISION MAKING" (<http://www.nrc.gov/reading-rm/doc-collections/acrs/letters/2003/r2034.pdf>)

2. Epstein, S., and A. Rauzy, "Can We Trust PRA?" *Reliability Engineering and System Safety*, Volume 88, Issue 3, pp 195-205, June 2005.
(http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V4T-4DGW607-1&_user=5250395&_coverDate=06%2F01%2F2005&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000066197&_version=1&_urlVersion=0&_userid=5250395&md5=1c40fad0730af022e7d4b1915657808f)
3. "Standard Model Representation Format for Probabilistic Safety Assessment," The Open-PSA Initiative, Draft n^o1.0c- July 17, 2007, <http://open-psa.org/>

SUBCOMMITTEE ACTION

The Subcommittee should be prepared to provide its views and recommendations to the Full Committee, at the October meeting. The Committee is not expected to write a letter on this matter. However, the Committee will consider this information, as appropriate, in its 2008 biennial report to the Commission on its review and evaluation of the NRC Safety Research Program.