Nuclear Operating Company
South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

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U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

South Texas Project
Units 1 and 2
Docket Nos. STN 50-498, STN 50-499
Summary of the South Texas Project Risk-Informed
Approach to Resolve Generic Safety Issue (GSI)-191

A summary of South Texas Project's methodology towards a risk-informed resolution of GSI-191, "Assessment of Debris Accumulation on PWR Sump Performance" is provided in the Enclosure. The summary includes the initial quantification and project results to date.

There are no regulatory commitments in this letter.

Should you have any questions regarding this letter, please contact either Jamie Paul, Licensing, (361) 972-7344, or me at (361) 972-7074.

J.W. Crenshaw
VP New Plant Deployment / Special Projects

JLP

Enclosure: Summary of GSI-191 Risk-Informed Closure Pilot Project 2011: Initial Quantification

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NRR

cc:

(paper copy)

Regional Administrator, Region IV
U. S. Nuclear Regulatory Commission
612 East Lamar Blvd, Suite 400
Arlington, Texas 76011-4125

Balwant K. Singal
Senior Project Manager
U.S. Nuclear Regulatory Commission
One White Flint North (MS 8B1)
11555 Rockville Pike
Rockville, MD 20852

Senior Resident Inspector
U. S. Nuclear Regulatory Commission
P. O. Box 289, Mail Code: MN116
Wadsworth, TX 77483

C. M. Canady
City of Austin
Electric Utility Department
721 Barton Springs Road
Austin, TX 78704

Stewart Bailey
Branch Chief, Safety Issues Resolution
U. S. Nuclear Regulatory Commission
One White Flint North (MS O11F01)
11555 Rockville Pike
Rockville, MD 20852

Donnie Harrison
Branch Chief, PRA
U. S. Nuclear Regulatory Commission
One White Flint North (MS O11F01)
11555 Rockville Pike
Rockville, MD 20852

(electronic copy)

A. H. Gutterman, Esquire
Morgan, Lewis & Bockius, LLP

John Ragan
Chris O'Hara
Jim von Suskil
NRG South Texas LP

Kevin Pollo
Richard Pena
City Public Service

Peter Nemeth
Crain Caton & James, P.C.

C. Mele
City of Austin

Richard A. Ratliff
Alice Rogers
Texas Department of State Health Services

Balwant K. Singal
Stewart Bailey
Donnie Harrison
U. S. Nuclear Regulatory Commission

Summary of GSI-191 Risk-Informed Closure Pilot Project 2011: Initial Quantification

South Texas Project, Wadsworth, TX
NOC-AE-12002784

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Executive Summary

The main objective of the Risk-Informed GSI-191 Closure Project is, "Through a risk-informed approach, establish a technical basis that demonstrates that the current design is sufficient to gain NRC approval to close the safety issues related to GSI-191 by the end of 2013." The results presented in this summary are the joint work of STP Nuclear Operating Company (STPNOC) Risk Management, Los Alamos National Laboratory, The University of Texas at Austin, Texas A&M University, Alion Science and Technology, ABS Consulting, ScandPower, Mike Golay, The University of New Mexico, and KnF Consulting Services, LLC.

In the risk-informed approach, STPNOC would seek exemption from certain requirements of 10 CFR 50.46 if the risk associated with the fibrous insulation in STPNOC's containment buildings is not risk significant. If STPNOC determines this insulation to pose a significant risk, STPNOC is committed to investigating plant modifications including insulation removal and other measures to preserve sufficient margins for nuclear safety.

The 2011 preliminary results show that the change in risk for fibrous insulation in containment is less than 1.0E-06 in core damage frequency (CDF) and less than 1.0E-07 for large early release frequency (LERF), that is, very small per RG 1.174.

This result represents the uncertainties of more than 20 input parameters and the complementary execution of the physics-based (CASA Grande) model, thermal-hydraulics model, and PRA models. Although previous realistic testing has shown that chemicals are unlikely to affect the head loss in STPNOC debris beds (sump strainers and fuel assemblies), the Pilot Project has used an initial methodology that adds pessimistic head-loss estimates from chemicals. Including these estimates is believed to fully addresses NRC concerns raised in pre-licensing meetings related to sump chemistry.

This preliminary assessment of the CDF and LERF gives us confidence that the issues associated with fibrous insulation in the STPNOC reactor containment buildings will be further shown to be non-risk significant with adequate defense-in-depth and safety margins such that STPNOC will be able to provide a sufficient basis for GSI-191 closure by the end of calendar year 2013.

STPNOC will expand upon the project's technical contributions by including the uncertainties of more than 50 input parameters and the seamless integration of CASA Grande, a new jet formation model, uncertainty propagation in the thermal-hydraulics models, and PRA analysis that takes into account detailed operational conditions. The resulting framework will provide STPNOC the ability to assess future issues on risk-informed basis as they may arise.

The methodologies and results of the pilot project in 2011 are presented in the following documents: analysis of results from the physical process solver, CASA Grande and RELAP5 thermal-hydraulic analyses (Letellier, 2011); LOCA Frequency analysis (Fleming et al., 2011); Uncertainty quantification methodologies and illustrative examples (Popova and Galenko, 2011); Jet formation research (Schneider et al., 2011); and Chemical effects research and experimental design (Sande et al., 2011).

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1 Introduction

The purpose of this document is to summarize the initial quantification performed for the risk-informed closure path in STPNOC's NRC/Industry risk-informed GSI-191 pilot project (Pilot Project). In this document, significant findings from Pilot Project work in calendar year 2011 are summarized and the overall program approach is described. While the risk-informed approach is not new to investigation of GSI-191 closure, the approach in the Pilot Project is more comprehensive than previously contemplated. The closure process developed is generically applicable with site-specific information supplied. Each primary area of investigation in the Pilot Project is summarized in this document.

1.1 Previous efforts

Since 2001 GSI-191: Assessment of Debris Accumulation on PWR Sump Performance has eluded resolution despite significant efforts by industry and the NRC. Although recent thought has been given to risk quantification (see for example Teolis et al., 2009) and early recognition of the need for risk evaluation was identified, (e.g. Darby et al., 2000), serious investigation into risk quantification has not been undertaken until now. Instead, resolution has followed a classical deterministic approach. It is STPNOC's view, following an initial 2011 PRA quantification, that a risk-informed resolution path should be pursued in preference to a deterministic approach, thereby quantifying the safety margins and identifying any scenarios that pose significant risk in GSI-191.

The primary issue here is that in a deterministic approach, examination of the uncertainty required to evaluate risk of plant operation is abandoned and an appeal to a hypothetical "worst case" scenario (assumed to encompass all uncertainty) is made. By assuming a sufficient set of nonphysical processes along with assumed equipment performance scenarios, examination of the full range of possible scenarios is avoided. Although this approach can be effective in some cases, there are shortcomings associated with it (NEI, 2009) and, relative to GSI-191 closure, have become untenable. That is, the "worst case" is so limiting that it would indicate no design would be acceptable, especially for in-vessel effects (Baier, 2011). Even the presence of tramp debris (regardless of the insulation design) may not be tolerated. Unless compromised by incorporating the time-evolution of accident phenomena and accommodation of realistic behavior, it may be difficult to provide a satisfactory closure path using a deterministic approach.

1.2 Risk-informed

In keeping with the agency's commitment to move towards increasing risk informed regulation, the NRC directed the staff (Vietti-Cook, 2010) to consider GSI-191 resolution strategies including an Option 2:

> *"The staff should take the time needed to consider all options to a risk-informed, safety conscious resolution to GSI-191. While they have not fully resolved this issue, the measures taken thus far in response to the sump-clogging issue have contributed greatly to the safety of U.S. nuclear power plants. Given the vastly enlarged advanced strainers installed, compensatory measures already taken, and the low probability of challenging pipe breaks, adequate defense-in-depth is currently being maintained.*
>
> *The operative words for Option 2 are innovation and creativity. The staff should fully explore the policy and technical implications of all available alternatives for risk informing the path forward. These alternatives include, but are not limited to, how 50.46a might impact this issue, and how the application of a no-transition-break-size approach might work."*

It is worth reemphasizing that a risk-informed analysis includes all scales of postulated accidents and the full spectrum of possible plant responses. Ideally, there should be no exclusive focus on "bounding" assumptions, no exclusive focus on "design basis" or "beyond design basis" assumptions, and no exclusive focus on "best estimate" assumptions. Every factor in the accident analysis should be described as accurately as possible by a statistical distribution that is

consistent with available data, physical models, or expert opinion, and so, factors with limited or no data necessarily have bigger uncertainties. Furthermore, the methods used to sample and propagate these uncertainties should be unbiased.

In our initial quantification numerous conservatisms are retained to maintain consistency with regulatory assumptions while developing a robust toolset and exploring parameter sensitivities.

1.3 Pilot Project

STPNOC is the plant working with the staff to develop risk-informed closure strategies while preparing a site-specific licensing submittal. Over the 2011 calendar year, several public meetings were conducted to inform the NRC staff of the modeling approach and to solicit feedback on the applicability and use of the approach for resolving GSI-191. The several meetings included supporting material so that members of the public, especially other plants could be informed as well: Rosenburg (2011), Thadani (2011), Singal (2011c,a,b,d,e,f,g).

All materials provided have been posted by the NRC on their website for public access.

In design of the Pilot Project, STPNOC has been careful to make the proposed implementation at other plants as straightforward as possible. In particular, the physical models that typically would be folded into the event trees and fault trees of the PRA have been extracted into a flexible modeling tool and held outside the PRA. In the Pilot Project this part of the toolset is called CASA Grande (Letellier, 2011). This way, the methodology is made more generic and only simple changes should be required in the site-specific PRA. The existing PRA LLOCA, MLOCA, and SLOCA branches are maintained intact and only two relatively simple changes are required in the PRA itself: the sump strainer demand failure likelihood is replaced by a value that CASA Grande produces as an output; and a top event must be added for long term cooling relative to in-vessel effects.

The rest of this report summarizes the GSI-191 risk-informed closure process and methods that have been developed over the past eight months. Several assumptions were adopted in the initial quantification in order to ensure the Pilot Project met 2011 schedule commitments. Section 2 provides a summary of the major assumptions made in the initial quantification. Section 3 summarizes some of the significant insights obtained from the Pilot Project work so far. Section 4 describes the several physical models that have been developed in 2011, others will be further refined and developed in the second project calendar year (2012). A new integration framework has been developed and is described as well in Section 4. A containment CAD model and toolset used in the project are briefly described in Section 5. Section 6 is a short description of the PRA modeling required to obtain the change in risk needed for Regulatory Guide 1.174 decision-making. In Section 7 the methodology developed in calendar year 2011 for uncertainty quantification is described. The status of the Pilot Project LOCA frequency analysis is presented Section 8. An overview of the Quality Assurance Plan is provided in Section 9. The licensing approach is designed around Regulatory Guide 1.174 (Section 10). Conclusions are in Section 11.

2 Major assumptions

Several assumptions had to be adopted in calendar year 2011 to accomplish a quantification result within the aggressive Pilot Project schedule. In some cases, the assumptions bias the resulting CDF and LERF higher, in some cases the assumptions bias the results lower. The Pilot Project has tried to adopt a policy regarding assumptions such that on balance, the CDF and LERF results would be biased higher than with all assumptions relaxed.

The following list summarizes of the major assumptions in calendar year 2011.

ZOI: The zone of influence is assumed to be 17D for all fiberglass targets regardless of configuration or the presence of piping restraints. ZOI is not truncated by the presence of compartment walls.

Chemical precipitants: All chemical precipitants (formed based on the available material in containment) are formed and introduced in bulk at 24 hours following the LOCA regardless of the

operation of containment spray. In-vessel precipitants are assumed to be of the same form and amount used by Baier (2011). The head loss due to precipitants on the strainer debris bed doubles the head loss through the bed. All chemicals are passed through the strainer if it is not entirely covered with a 1/8 inch-thick uniform debris bed.

Debris generation: 60% of the debris is fines, 40% is large. 1% of large debris is eroded to fines with 100% spray exposure.

Transport of fine debris: 100% go to the sump pool, 4% are retained on the strainer bed (per strainer), 13% go to dead volume (other sumps, elevator shaft, dead volumes inside the bioshield wall).

Transport of large debris: 1% is eroded to fine debris, 99% retained on gratings.

Upstream effects: Upstream effects are assumed to have insignificant contribution.

Strainer configuration: The strainer meets design at the start of the LOCA transient (open bypass paths' contribution from damage for example, is assumed negligible).

Scenario event timing: The scenario progression and associated event timing are assumed to follow nominal values in each LOCA category (small, medium, large LOCA). This also applies to Operator actions with the exception of containment spray operation. In the case of containment spray, the Operator is successful in stopping the single train (when three trains have started) as required but fails to terminate containment spray operation (the remaining two pump trains) after meeting termination criteria. Containment spray is never terminated when less than three trains have started.

LOCA frequency: The existing STPNOC PRA LOCA branch frequencies for small, medium, and large LOCA are preserved in the calculation of location-specific frequency calculations (to avoid over-estimating or under-estimating the LOCA frequency in the source term). That is, in each category of LOCA, the location-specific values for that category closely sum to its PRA initiating event frequency. For the purpose of in-vessel hydraulic effects on core flow and head loss calculations, the LOCA frequency is split evenly between hot and cold leg locations.

Qualified coatings: At time zero (at the time of the LOCA), 33 lb of Epoxy and 553 lb of IOZ coating particulate is assumed to arrive in bulk to the sump pool. This amount is present in all break scenarios (regardless of break size).

Unqualified coatings: At 24 hours, 247 lb of Alkyd, 843 lb of IOZ, 268 lb of enamel, and 294 lb of epoxy coating particulate arrives in the sump pool.

Latent debris: 170 lb of particulate and 12.5 ft^3 of fiber arrive at the sump pool at the start of the LOCA (time 0).

Strainer bypass: Strainer bypass is a function of face velocity and the number of operating trains only (Zigler, 2011). All debris bypassed is deposited in the core and evenly spread over the fuel assemblies.

Strainer head loss: Head loss follows the behavior described by Zigler et al. (1995). The strainers do not collapse from overload due to differential pressure.

3 Findings in 2011

In calendar year 2011, a primary objective was to obtain an initial PRA quantification of the risk associated with fibrous insulation in containment. The results of the initial quantification were included in the project plan as a criteria for going forward or terminating the project and taking aggressive corrective action to correct any high risk scenarios revealed in the risk assessment. A major finding of the 2011

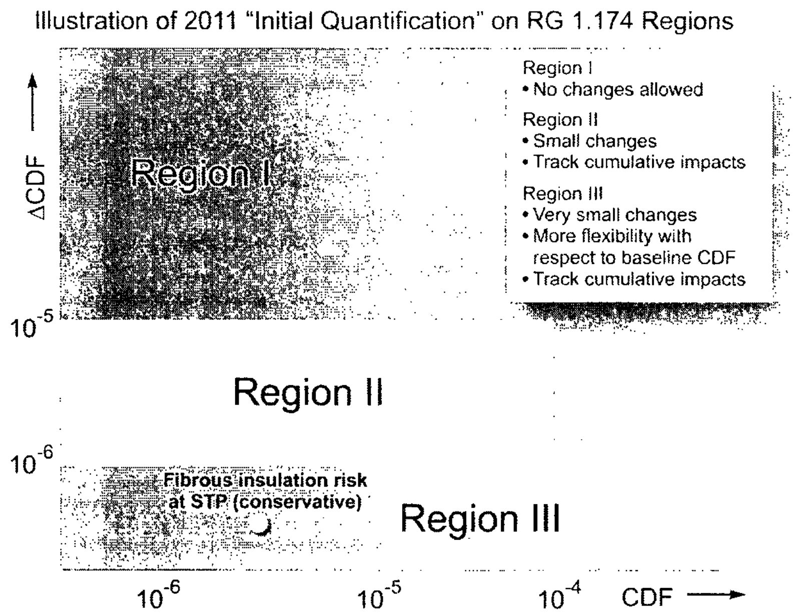

Figure 1: Illustration of the core damage (CDF, ΔCDF) risk associated with as-designed fibrous insulation in the STPNOC containment on the Regulatory Guide 1.174 decision-making Region map.

quantification is the risk is "very small" in the language of Regulatory Guide 1.174 as illustrated in Figure 1. Regulatory Guide 1.174 is concerned with the need to make changes guided by risk.

The risk of ongoing operation is maintained in the site-specific PRA average risk model for CDF and LERF. The STPNOC PRA meets the ASME/ANS PRA Standard as Capability Category II and has successfully provided the technical basis for several risk-informed applications at STPNOC, for example RMTS (Yilmaz et al., 2009; EPRI, 2008). A change to the plant may increase risk (CDF and/or LERF) and is expressed as ΔCDF and ΔLERF. Clearly, if a change results in a large change in risk, it could affect the plant average risk. But if the ΔCDF is less than 1.0×10^{-6} and the ΔLERF is less than 1.0×10^{-7}, the change in risk is considered to be very small and the cumulative risk to CDF and LERF do not need to be considered in decision-making. On the other hand, the effect on plant average risk must be considered if the changes are not very small. In this case, based on the "very small" risk evaluation, STPNOC management has authorized the project to go forward as communicated in the calendar year 2011 Pilot Project plan.

3.1 Chemical effects

Based on early prototypical experiments performed by Dallman et al. (2006) and (much later) based on studies by Sande et al. (2011), STPNOC has maintained that in the initial quantification, chemical effects could be minimized. STPNOC understood from the start of the project that any assertions about chemical effects would require experimental verification. However, based on the feedback from the NRC staff during the Pilot Project meetings, (Singal, 2011g), chemical effects were added to the initial quantification. The approach was modified to include the results found by Baier (2011) in experiments intended for deterministic evaluations.

With the inclusion of Baier's chemical effects using mass of fiber as the success criteria, the ΔCDF increases from extremely low to roughly 5×10^{-7}. The ΔLERF remains unchanged. Based on this result and based on earlier NRC staff Pilot Project feedback, an important finding is that chemical effects on debris bed head loss needs to be better understood. STPNOC has accelerated and expanded the risk-informed chemical effects experimental program in order to better understand chemical effects on head losses in ECCS strainer and fuel assembly debris beds. The chemical effects experiments will also be designed to produce results that can be used to develop correlations for realistic physical models of chemical performance for use in CASA Grande.

3.2 Strainer and downstream performance

As mentioned earlier, the deterministic approach uses a hypothetical "worst case" scenario assumed to encompass all uncertainty assuming nonphysical models and scenarios. Although it does create a bounding case in some sense, the deterministic approach has assumed chemicals as precipitants are produced effectively at the start of the LOCA and during a hypothetical equipment alignment that produces maximum ECCS flow rate through the strainer. None of these conditions would ever exist simultaneously in the unlikely event of a LOCA requiring recirculation switchover with fibrous debris present.

Debris beds in the core and on the strainers increase resistance to flow as the bed builds up thickness, but more importantly (based on experiment results for deterministic evaluations), the resistance increases more when chemical precipitants collect on them also. Generally, head loss is higher order (normally second order) with flow in a closed channel system.

Zigler et al. (1995) utilized porous media correlations where head loss, H, equals to $H = aQ + bQ^2$, where Q is the flow, and the coefficients a and b are determined by the fluid and debris bed conditions.

Referring to Figure 2, one can imagine how dramatically the head loss would increase at constant flow rate as the coefficients a and b increase (causing the system characteristic to steepen) due to fiber loading and chemical precipitant addition. In fact, NRC staff has stated in Pilot Project review meetings (Singal, 2011e,f) this behavior has been observed during experiments as chemical precipitants were added at constant flow and the head loss increased significantly (Baier, 2011). However, and again as illustrated in the figure, this behavior might not be realized in an actual scenario because in the unlikely event of a LOCA that produces an in-vessel debris bed, the required flow decreases dramatically (linearly with decay heat which is effectively an exponential function). Additionally, chemical precipitants simply can't be created while the required flows are high (say within the first day to one week).

A significant result of the risk-informed analysis that takes into account the evolution of the physical processes is that: there are no ECCS failures due to strainer blockage (this needs to be examined for some infrequent potential sequences that, for example may cause mechanical collapse of the strainer); all hypothesized small LOCA events succeed; almost all medium LOCA events succeed; and most large LOCA events succeed. All scenarios resulting in core damage were associated with in-vessel effects, not strainer blockage. That is, in a realistic setting that retains significant conservative assumptions, chemical effects turn out to be less important than previously thought. For example, a 15 gm/FA acceptance criteria would cause failure for essentially all cases based on the latent debris alone. But in a realistic setting, it was demonstrated (again with conservatisms) that most hypothesized LOCA events would not cause core blockage.

3.3 Destruction zone

A somewhat surprising result from the initial quantification is the insensitivity to the "zone of influence" or ZOI for use in for example, ANSI (1988). A great deal of effort in experimentation and study by the industry has been devoted to understanding if the ZOI could be reduced to much lower volumes of damage than the widely accepted deterministic value defined by a sphere of 17D, where D is the break diameter. In fact Schneider et al. (2011) have been studying jet

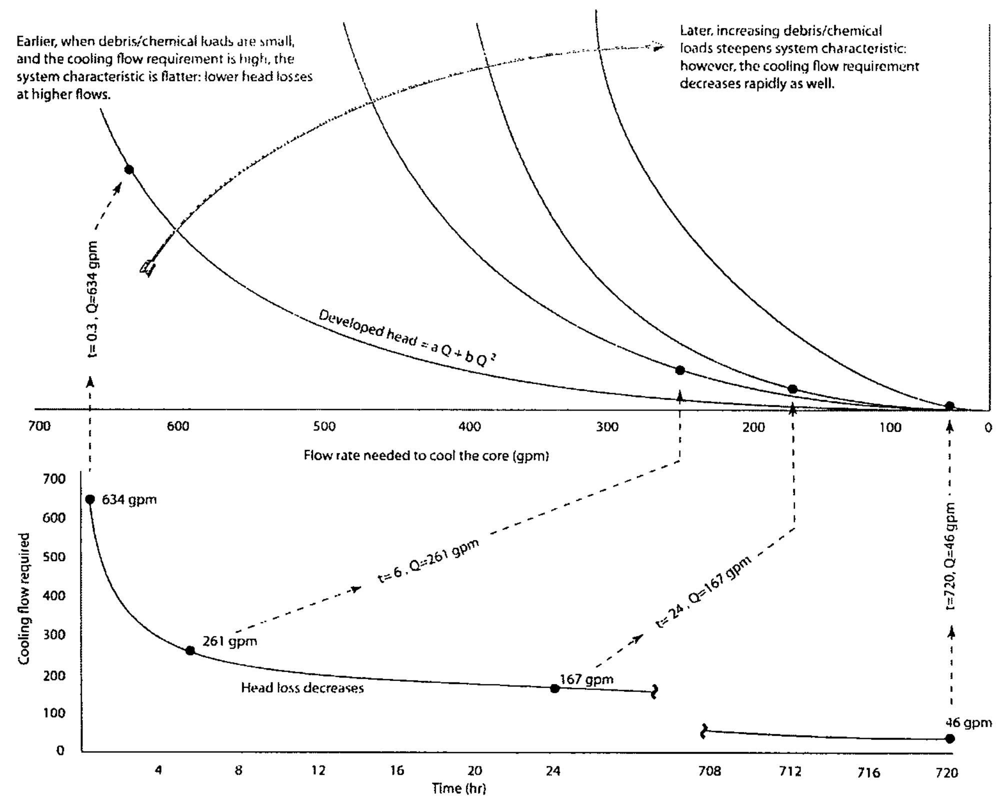

Figure 2: Illustration showing how decreasing decay heat removal flow requirement over time reduces cooling flow requirements that would result in significant reductions in head loss across debris beds. Experiments of in-core performance with chemical effects show significantly greater tolerance (higher mass loadings) for fully loaded debris beds at lower flow rates.

formation for use in the risk-informed methodology. The sense is that these destruction volumes are much too large. For example, a 31 inch pipe break would create a sphere of destruction about 44 feet in diameter. A commonly accepted practice is to limit the ZOI such that it can't extend beyond the concrete walls of containment compartments.

In this initial risk-informed quantification, the 17D destruction volume was assumed in all break locations without restriction for compartment walls. A sensitivity study was conducted to see the effect of reducing the ZOI to about 1/2 17D. While some reduction was observed, this change did not significantly affect the risk. This surprising result can be explained by understanding the scenarios leading to core damage. Because the STPNOC strainer design was modified to install very large strainers compared to the original strainer design, risk for loss of ECCS NPSH is effectively eliminated. However, the sump performance gain comes at a price for core damage risk, especially when deterministic-based chemical effects are used for success criteria.

The amount of fiber arriving on the fuel is almost entirely governed by the strainer face velocity at the time of recirculation switchover and for a few minutes following recirculation switchover. Except for the smallest breaks, the fiber load is governed by the number of ECCS trains running and the train configuration. That is, the core fiber load (which as mentioned above is limiting) is (almost) independent of break size and ZOI.

4 CASA Grande

The risk analysis examines the full spectrum of LOCA accident conditions ranging from predominant, but small accidents that are easily managed up to and including extreme, but unlikely accidents that challenge the design basis. The analysis framework, CASA Grande, ultimately develops cumulative distribution functions (cdf) for exceedance of a particular value used in success criteria (for example, fiber loading per fuel assembly) for each of the standard PRA initiating event LOCA categories, LLOCA, MLOCA, and SLOCA, and for each of the possible equipment configurations as analyzed in the PRA. Once developed, the failure likelihood for each scenario can be determined knowing the associated value as illustrated in Figure 3. Note that if a value coming from a bounding deterministic experiment is available, then below that amount, success is assured.

For example, if the amount of fiber is the criteria value, and say 75 gm/FA is the amount of fiber from an LLOCA, two available ECCS trains, and that value falls below the intersection of the distribution on the abscissa, conceptually one would draw a vertical line from that value to the distribution curve and look up the split fraction value (the failure probability) on the ordinate. It is important to understand that thousands of samples for different scenarios produce the complementary distribution and it is possible that the same likelihood would come from different scenarios. For example, a small break with a lot of fiber nearby may result in the same value (say fiber loading) as a larger break having less damage opportunity. From CASA Grande, each scenario can be traced from where the break occurs to, for example, the strainer loading and the downstream (core FA) loading.

The inputs to CASA Grande are a combination of conservative, yet realistic, treatments of accident phenomenology and decision criteria based on precursors to possible system damage. This methodology enables risk-informed insights without compromising the traditional safety basis. In the initial risk quantification for calendar year 2011, the plant performance metrics of head loss across the recirculation strainers and fiber deposition per fuel assembly were used to assess the risk of flow blockage leading to core damage during recirculation scenarios. Detailed description of the models and methods that constitute CASA Grande can be found in Letellier (2011).

5 Plant configuration

The basis for the insulation source term and locations for all welds and plant components in containment is the current STPNOC plant design drawings and design configuration database. Although other formats may be equally useful, the Pilot Project chose to exploit the availability of computer aided design tools (CAD) as the method to capture and integrate the spatial information required to accurately calculate the weld LOCA locations, debris quantity (heterogeneously distributed insulation) and type of debris. Additionally, specialized CAD interface tools were developed that efficiently and reliably interrogate the CAD model. The output of the tool set reduces the spatial information contained in the CAD to a database accessible by CASA Grande such that the debris source term can be calculated accurately for all locations, break orientations, and break sizes.

Although not credited in the initial quantification, compartment wall information is included in the database so that when wall truncation is implemented in 2012, the ZOI will be properly shaped and limited by their presence. A configuration database is required because CASA Grande samples all welds at every location in each replication of the total calculation. For each LOCA category and at each location, 10 to 15 samples, random in size and direction, are taken for the source term calculation. Each sample

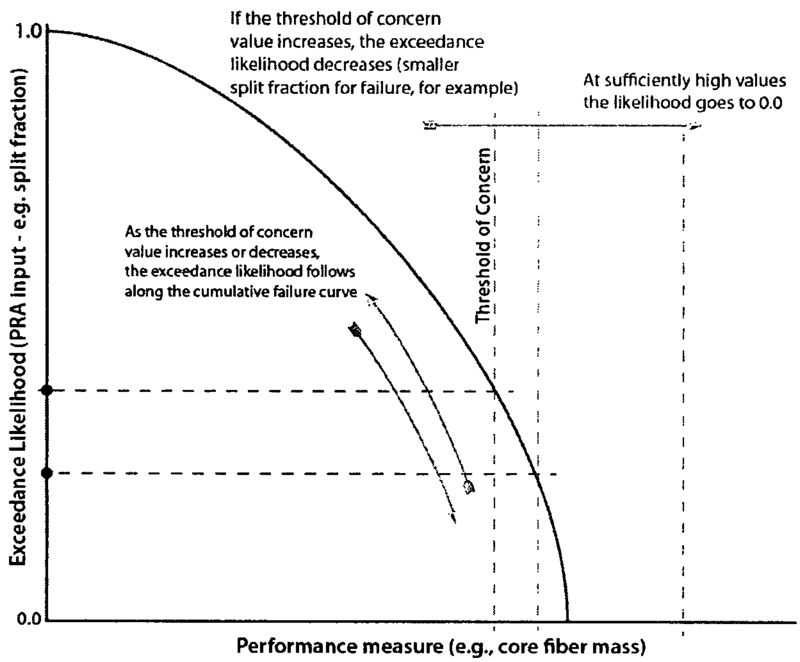

Figure 3: Illustration of a CASA Grande (complementary) cumulative distribution and the method used to develop input for the PRA from it.

always includes the largest possible break (double-ended guillotine, DEGB) at each location. A full spherical ZOI shape is used for the DEGB sample. Otherwise, a full hemispherical ZOI shape is used. The configuration database is designed to support automatic calculation of the debris source terms (thousands of calculations in each CASA Grande repetition).

6 PRA

The typical PRA will have initiating events for LLOCA, MLOCA, and SLOCA. It is interesting to understand that before GSI-191 became an issue, each of the LOCA initiating event branches already contemplated a sump screen plugging event (most likely as in the STPNOC PRA) represented as a demand failure of the containment sump screens at the time of recirculation. Additionally, in each of these branches, there are the preexisting scenarios for the different combinations of ECCS equipment depending on support system and component successes or failures. The Pilot Project exploits this existing structure by replacing failure likelihoods based on the results of CASA Grande as described in Section 4 instead of the simplistic demand failure likelihood.

As described in Section 1.3, the physical models have been extracted out of the PRA to enhance portability, simplify incorporation of different plant information and characteristics, and facilitate adoption of the methodology. Another inherent complexity fundamental to typical PRA design is overcome by performing the uncertainty quantification in CASA Grande. In the Pilot Project, time-dependent and multivariate uncertainty distributions (described in Section 7) have been identified in the physical models

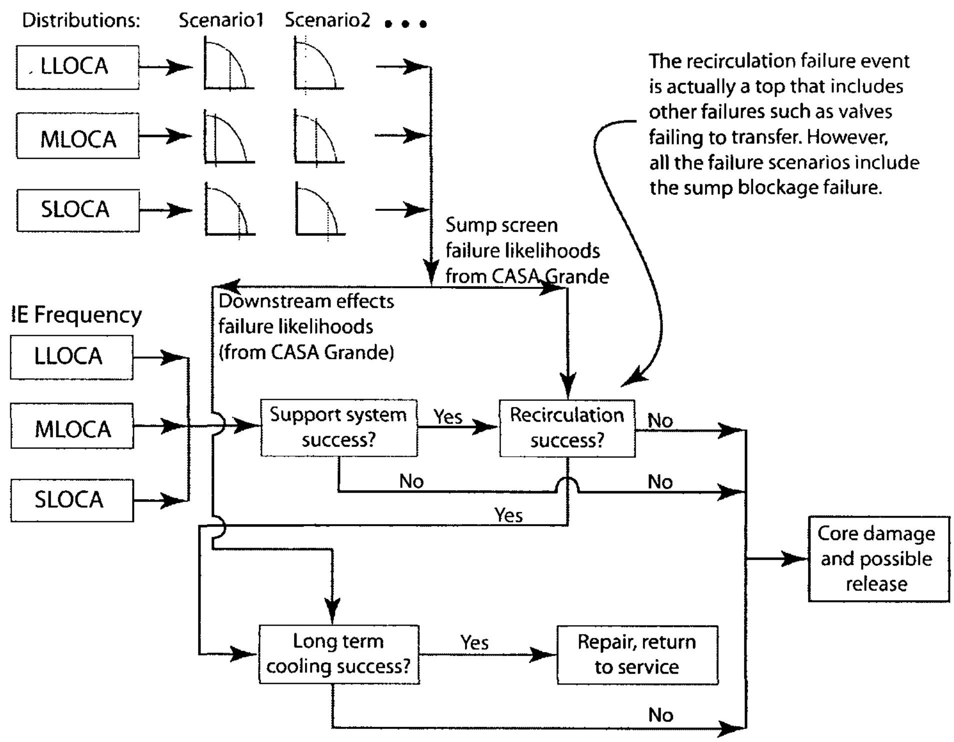

Figure 4: High level illustration of the inputs and outputs overlaid on a schematic diagram of the PRA event tree structure. The event tree structure, with the exception of the long term cooling top event, already exists in the typical nuclear power plant PRA.

required to understand GSI-191. CASA Grande also provides the platform to propagate the time-dependent and multivariate uncertainties outside the PRA. In fact, this is a basic requirement of a risk-informed analysis because current commercial PRA methodology is not fully capable of propagating the required uncertainties.

Referring to Figure 4, the preexisting event tree structure and LOCA initiating event frequencies are not changed by the Pilot Project methodology. The distributions from CASA Grande described in Section 4 are used in the recirculation switchover event to substitute specific scenario likelihoods for the (invariant) simplified demand recirculation likelihood (a single basic event in the preexisting model). A new top event was required in the STPNOC PRA to address the possibility of core flow blockage (long term cooling). This is the only structural change required in the PRA and is considered to be a relatively minor change.

A calculation can be performed (at any particular plant) by summing the current frequencies associated with each LOCA initiating event that go through recirculation to success. With each of these initiating event frequencies in hand, one can multiply each by its associated failure likelihood from CASA Grande. The resulting frequency sum is the new success frequency and the difference between the original frequency (the unchanged frequencies) sum from the new frequency (multiplied by the CASA Grande

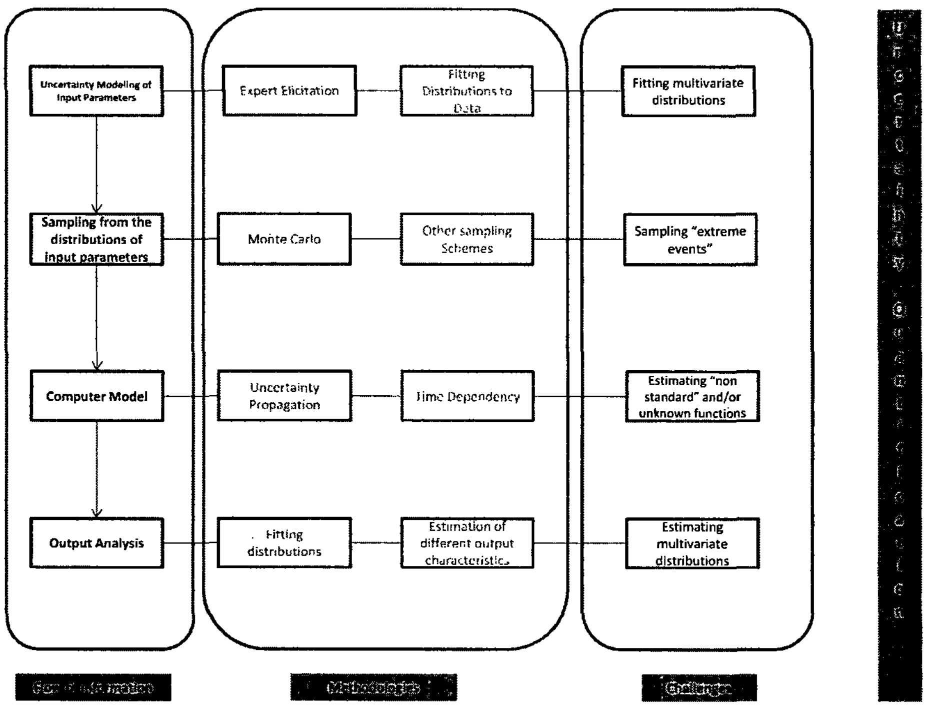

Figure 5: Uncertainty quantification for complex computer models

likelihoods) sum is a close approximation to the new ΔCDF due to having fibrous insulation in containment.

7 Uncertainty Quantification (UQ)

The modeling and propagation of uncertainties for the GSI-191 project involves several steps. Figure 5 shows the collection of information flow, methodologies and challenges for UQ of computer models that approximate a complex real system like the one being considered in this pilot project. The main challenges faced by the Pilot Project during the 2011 were the choice of probability distributions for the input parameters of CASA Grande and how to sample from them.

One of the inputs to CASA Grande is the LOCA frequency table, Fleming et al. (2011). The probabilities associated with LLOCA are extremely small and simple Monte Carlo sampling approach will almost never produce that observation. In order to have the LLOCA in all of the scenarios, nonuniform Latin Hypercube Sampling was applied, Helton and Davis (2003). This methodology generates observations from the whole space (i.e. the LLOCA is always included) and weights them by the correspond-

ing probabilities. The Pilot Project will expand upon this approach in 2012 to be able to generate correlated samples and estimate quantiles using the data generated by CASA Grande.

Another major task during the 2012 will be the verification and validation of the methodology applied to solve the GSI-191. The verification part will make sure that all the code written is "bug-free" and represents correctly the theory and methods implemented. The validation part is challenging since it will have to be shown that the approximation produced is very close to the real system. Popova and Galenko (2011) provide a detailed description and illustrative examples of the UQ methodology applied to the initial quantification.

8 LOCA frequency

In order to explore all possible scenarios, the risk-informed analysis requires knowledge of the likelihood of a pressure boundary failure for all possible locations and possible sizes of failure. Per design, significant rupture failures of Class 1 piping in domestic light water reactors have not been observed. Obtaining the appropriate likelihoods where there is no evidence presents a challenging problem for the GSI-191 risk-informed closure investigator.

In the initial quantification, Fleming et al. (2011) performed a substantial study designed to build upon the established EPRI risk-informed In-Service Inspection program (EPRI, 1999). EPRI (1999) methodology was used as primary basis to develop the size and location-specific rupture frequencies for the quantification. In the Pilot Project study, Fleming et al. (2011) showed the total frequency in the standard PRA methodology (SLOCA, MLOCA, and LLOCA) were preserved. Although the overall methodology is considered to be sound based on peer review (Mosleh, 2011), and reasonableness of the values obtained, NRC review feedback in the Pilot Project has resulted in further review of the approach. In 2012 an alternative to the LOCA frequency methodology will be performed on a new basis to fully address NRC concerns.

9 Quality Assurance

A quality assurance plan has been developed in calendar year 2011. The plan includes regularly scheduled (nominally weekly) technical review teleconferences supplemented at critical product development steps with on-site review. The STPNOC PRA analyst (Technical Team Lead) is responsible for review and verification of the PRA inputs developed. However, the STPNOC PRA analyst review is supplemented by independent critical peer review intended to help disclose any overlooked technical gaps that would compromise results and also help ensure that the overall product is academically defensible even though it is developed for the industrial setting. Independent technical oversight was a part of the STPNOC 2011 efforts and was used to further focus analysis efforts.

The overall quality assurance plan is illustrated in Figure 6 as a flow chart. Due to the diverse technology required to be implemented in the GSI-191 scope, the PRA inputs originate with products developed by experts in their respective field. The CASA Grande integrating framework uses the inputs to generate the two main inputs to the PRA, the sump demand failure likelihood and the in-vessel cooling failure likelihood (for each category of LOCA and all possible equipment configurations). These elements are documented by the vendor and the normal vendor document review process is followed to assure they are suitable for use as input to the PRA. The overall Pilot Project quality assurance methodology is expected to be similar to most utilities' processes for PRA activities although the details are most likely different.

10 Licensing

STPNOC will rigorously quantify the risk contribution to core damage and large early release of recirculation scenarios that are encompassed by GSI-191. The licensing strategy is based on looking at the difference in risk between a hypothetical containment design that has no fibrous insulation and the existing STPNOC design. The expectation is that the hypothetical containment design would have lower risk

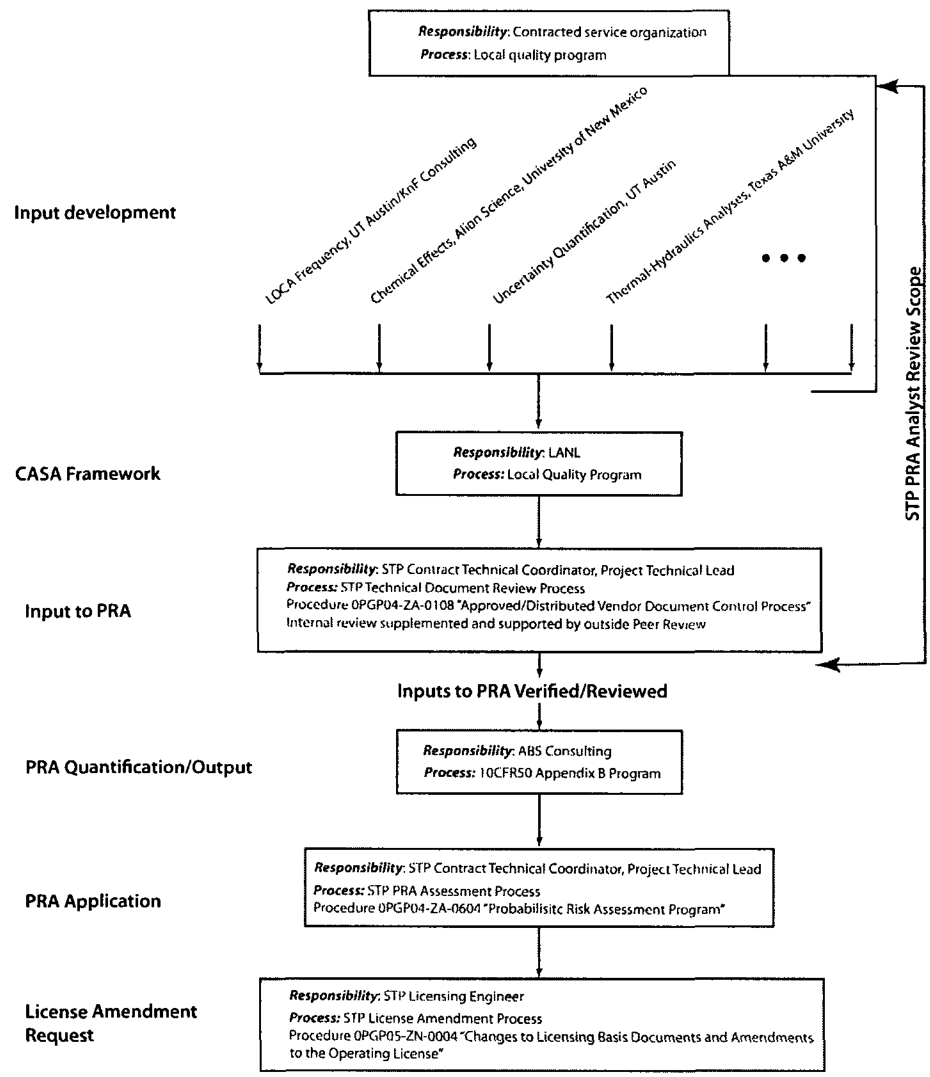

Figure 6: Illustration of the major elements of the STPNOC quality assurance plan for risk-informed closure of GSI-191.

than the existing design. Clearly an ideal outcome would be the difference in risk between the two designs to be roughly zero.

The difference between a comparison of the risk analysis to the Regulatory Guide 1.174, Region III limit of ΔCDF$< 10^{-6}$ yr^{-1} and ΔLERF$< 10^{-7}$ yr^{-1} will provide a basis for GSI-191 closure via exemption to certain requirements in 10 CFR 50.46. The

terms ΔCDF and ΔLERF in the context of this work mean the difference in CDF and LERF between a hypothetically perfect containment building having no fibrous insulation and the existing plant design. The purpose of the initial quantification in calendar year 2011 was to understand if the risk associated with fiber insulation in containment would exceed the Region III limits.

If the final analysis (calendar year 2013) continues to support recirculation failure as a Risk Region-III event, preventative measures (safety margin, defense in depth) will be identified to address contributing factors that carry the largest potential impacts in the analysis. Regardless of the quantitative findings, STPNOC will use the risk analysis to prioritize specific actions and determine the degree of remediation that may be required. Thus, it is essential that all parties fully understand the theory, implementation methods and interpretation of a risk-informed decision process. STPNOC intends to continue to communicate regularly and openly with the NRC staff and industry in calendar years 2012 and 2013, and continually refine and enhance communication and communication tools as the Pilot Project evolves.

11 Conclusions

The calendar year 2011 initial quantification in the Pilot Project has demonstrated the viability of a risk-informed closure path to GSI-191. Even at the early stage, the usefulness of the risk-informed approach has been demonstrated in initial findings related to ZOI, chemical effects, time-dependency, and LOCA frequency. In a short amount of time, a comprehensive understanding of the GSI-191 important physical phenomena has been accomplished and has been used by the Pilot Project to develop a new, robust, risk-informed framework for study and closure of GSI-191.

The Pilot Project has worked closely and effectively with the NRC to incorporate feedback and inform the NRC staff of progress and the technology developed. In some cases, NRC feedback has redirected the efforts of the Pilot Project and accelerated the schedule (for example, chemical effects and LOCA frequency). The interaction and feedback is appreciated by the Pilot Project due to the aggressive schedule and complexity of the issues.

The Pilot Project is designed generically so that other plants can easily take advantage of it. The design provides for simple integration of site-specific models in a method that extracts complexities out of the PRA and integrates them in a flexible modeling tool, CASA Grande. A straightforward licensing approach is proposed and generally accepted quality assurance methods can be applied.

Even with conservative margins retained, the Pilot Project in the initial quantification has shown that the risk from fibrous insulation in containment at STPNOC is very small (in Region III) based on the decision-making criteria of Regulatory Guide 1.174. This helps assure both the NRC and STPNOC that defense against ECCS failures can be easily identified and reasonable measures can be undertaken to avoid excessive risk in a risk-informed closure path.

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