February 23, 2001

LICENSEE: Duke Energy Corporation (DEC)

FACILITY: Oconee Nuclear Station (ONS) Unit 1

SUBJECT: SUMMARY OF JANUARY 23, 2001, PUBLIC MEETING WITH DEC STAFF TO DISCUSS PRELIMINARY RESULTS OF THE NRC STAFF'S REANALYSIS OF THE RISK AT ONS DUE TO HYPOTHETICAL PRESSURIZED THERMAL SHOCK (PTS) EVENTS

Background:

The NRC Office of Nuclear Regulatory Research (NRC Research) staff is currently conducting a reanalysis of the risk due to PTS at U.S. Pressurized Water Reactors (PWRs). The results will be used as part of the bases for a subsequent re-evaluation (and possible change) of the PTS rule, 10 CFR 50.61. ONS Unit 1 is one of the four PWRs that have volunteered to be re-evaluated as part of the reanalysis.

Discussion:

On January 23, 2001, members of the NRC Research staff met in a public meeting at the DEC Corporate Headquarters in Charlotte, NC, with representatives of DEC, Idaho National Engineering and Environmental Laboratory (INEEL), and Science Applications International Corp. (SAIC) to discuss preliminary results of the NRC Research staff's reanalysis of the risk at ONS due to hypothetical PTS events. Enclosure 1 is the meeting's agenda, and Enclosure 2 is the meeting's list of attendees.

The meeting started with an NRC Research staff presentation of the overall organization of the joint NRC Research & Industry PTS risk reanalysis effort, showing how the Probabilistic Risk Analysis (PRA), Human Reliability Analysis (HRA), Thermal Hydraulic (TH), and Probabilistic Fracture Mechanics (PFM) portions of the analysis will be utilized, along with their associated uncertainty analyses, to produce the final PTS-related risk for each of the four plants included in the study (Oconee, Beaver Valley, Palisades, and Calvert Cliffs).

The NRC Research staff presentation also discussed the major objectives of the meeting, which were to present draft results of the preliminary Oconee PRA analyses, and obtain the DEC staff's comments and suggestions. The presentation indicated that the preliminary analyses were performed in a somewhat conservative way, which would nevertheless be able to identify the PTS-risk-significant areas and thus allow subsequent efforts to concentrate on making the PRA analysis of those areas more realistic. This process saves the expenditure of scarce resources in areas that do not contribute significantly to PTS risk. Enclosure 3 is the slides used during this discussion.

Next, the principal PRA contractor (from INEEL) and a subcontractor (from SAIC) representing the principal HRA contractor (Sandia National Laboratories) discussed the preliminary results, stressing areas identified by the analyses that contribute significant PTS risk, and inviting comments from the DEC staff, particularly about ways those parts of the analyses might be made more realistic. Enclosure 4 is the slides used during this discussion.

In discussions that followed, the DEC staff expressed general agreement with many of the models and techniques used by the staff and their contractors in the analyses. However, in keeping with the primary purpose of the meeting (i.e., to discuss ways the parts of the analyses that contribute significant PTS risk might be made more realistic), the remainder of the meeting was devoted primarily to comments and suggestions by the DEC staff regarding improvements they recommend. The nature of their initial feedback and comments can be logically grouped into 3 categories:

(1) The DEC staff expressed concerns about the *interface* between the HRA/PRA sequence frequencies and their corresponding mapping into the ~40 TH bins. In particular, they are concerned that the interface is not making as much use as it should of the HRA inputs.

(2) The DEC staff expressed concerns about the relevancy of some of the *timing assumptions* made in developing the human error probabilities (HEPs) used as input to the PRA portion of NRC Research's analyses.

(3) In addition to the timing issues, the DEC staff expressed other concerns about the *HEP values* themselves, *and the procedure* used to transmit results of the HEP elicitation process into the PRA, which they feel may cause unnecessary conservatism to be introduced to the PRA calculations.

Each comment category is discussed more fully below.

(1) Concern about the *Interface*. This item will be explained using an example. For many PTS events, the HRA portion of the PRA provides multiple HEPs that correspond to alternate time sequences for the event. Assume the occurrence of a PTS event (e.g., a loss-of-coolant accident (LOCA) or an overfeed) in which it's desirable to throttle the high pressure injection (HPI) system in order to limit the primary system's temperature decrease and pressure increase, and therefore minimize the probability of vessel failure. The HRA might determine quantitative values for the increasing probabilities that the operators would have throttled HPI before the end of several increasingly long time intervals. Each of the probabilities, with their associated time interval, would have a different occurrence probability (given occurrence of the event), and a different PTS-related vessel failure probability. Note that the highest vessel failure probability would occur for the sequence where the throttling occurred after the longest time interval (since the lowest temperature and highest pressure would occur for that sequence), but also note that, given occurrence of the event in this example, that sequence would also have the lowest probability of occurring.

The problem is, due to limited resources, all of the sequences that, taken together, constitute the example event might well have their consequences (i.e., vessel failure probability, given occurrence of the sequence) represented by the results of a single detailed TH calculation (such as a RELAP TH code run) which is likely to be for a conservative sequence where HPI

throttling is not assumed, or occurs very late. To “fix” this mismatch, the idea of developing “subcategories” of the thermal hydraulic runs to account for different TH profiles as a function of different HRA values was discussed.

(2) Concern about the *Timing assumptions*. For at least some of the PTS sequences, the DEC staff raised questions about whether HRA values were being provided for time intervals “that matter.” Continuing to use the above HPI throttling case as an example, the current approach used time intervals starting after the earliest indication at which the crew is instructed that they are allowed to throttle HPI. However, the DEC staff emphasized that the operators are not required to throttle HPI upon reaching that indication, and since risk of PTS damage becomes significant only after considerably longer time intervals following that indication, the DEC staff believe that significantly longer time intervals (and their correspondingly lower failure-to-throttle-HPI probabilities) should have been used to determine the HEPs.

(3) In addition to the timing issues, the DEC staff expressed two other concerns about the *HEP values, and the procedure* used to transmit results of the HEP elicitation process to the PRA.

Regarding the HEP values themselves, the DEC staff believe they can provide sufficient justification for their belief that NRC Research's HEP elicitation process failed to account for other factors they think are relevant to the quantification. They believe that the failure to restart reactor coolant pumps (RCPs) at Oconee is much closer to 1.0 (the current HRA uses 0.1). Additionally, the DEC staff believe there are cases where the current analysis is too biased in its treatment of complex scenarios (e.g., scenarios where more than one function has an anomaly) and scenarios involving support system faults, both being distractions/workload concerns that the NRC Research contractors said could delay the actions that are analyzed. It is the DEC staff's initial view that a) the number of staff in the control room, b) their assigned responsibilities, and c) their training's focus on attending to the highest priority items first, when taken all together, make these complex scenarios and support system failure events essentially no different than the more “common variety” sequences.

Regarding the procedure used to transmit results of the HEP elicitation process to the PRA, the DEC staff are concerned that it results in HEP values that are too conservative for the analysis. For example, for a given HEP, the HEP team's elicitation values from its four members, after the 2nd consensus attempt, were individually 0.1, 0.01, 0.01, and 0.01. In the present analysis, the more conservative value (0.1) was provided to the PRA portion of the analysis. Subsequently, an uncertainty bound was estimated; in this case, that bound is reflective of the 0.1 estimate and would be something like 0.5 as the 95% and 0.01 as the 5% bounds. If the process had instead better reflected the four elicitation values, for example, using an average of the four values = ~0.03 as the “mean,” and then assigning an uncertainty range about the 0.03 value (probably something like 0.1 as the 95% and 5E-3 as the 5% bounds), it is clear that there would be a considerable difference in the values, including uncertainties, that would be put into the PRA. As currently applied, the single most conservative elicitation value was used as “the mean”, and then an even higher uncertainty value was applied for the 95% value. This approach biases, too much in the view of the DEC staff, the higher end of the HEP range and makes the HRA inputs into the PRA generally too high.

(4) Other items discussed at the meeting.

In addition to the above three major groups of DEC staff comments, several other items were more briefly discussed, as follows:

At the DEC staff's request, the NRC Research staff agreed to provide, within the next few weeks, a detailed TH analysis report describing the sequences for which detailed TH calculations were made, and the results of those calculations, e.g. temperature, pressure, and heat transfer coefficients as functions of time. The DEC staff will review and comment on the report, for NRC Research's consideration in refining the calculations.

The DEC staff agreed to provide certain Oconee performance data that the NRC Research staff needs for use in refining the calculations, including reactor trip data.

Summary, Action Items, and Agreements

The DEC staff volunteered to submit their comments in writing to the NRC Research staff, providing further detailed bases for their comments and providing justifications for requesting the NRC Research staff to make the modifications discussed.

The NRC Research staff and its contractors will review the requested changes, and will modify their analyses to reflect the requested changes that the NRC Research staff find to be acceptable.

The NRC Research staff will provide the detailed TH report requested by the DEC staff, and will respond to DEC requests for clarification in whatever manner is mutually acceptable (e.g., by telephone, in meetings, with further written details).

This meeting was not an inspection. Instead, it was an information exchange meeting with a licensee who has volunteered to cooperate with NRC Research's PTS re-evaluation effort. As such, no “open items” were identified that require future actions or NRC approvals. During the meeting, as expected, there were NRC Research requests for further information from the DEC staff, and there were DEC requests to the NRC Research staff. Neither DEC nor NRC Research staff is required to comply with those requests (i.e., they are not enforceable in any way). However, based on verbal agreements reached during the meeting, it is anticipated that the requested information will be provided, as described above.

The NRC Research staff appreciates the extensive cooperation and suggestions that were made by the DEC staff. NRC Research understands that it is very much dependent upon such voluntary cooperation to obtain the information and feedback needed to reach our joint NRC and nuclear industry goal of achieving a PTS analysis of ONS as it is actually built and operated. We look forward to continued interactions with DEC so that we can achieve that mutually desired goal.

Hugh W. Woods, Senior Task Manager
Probabilistic Risk Analysis Branch
Division of Risk Analysis and Applications
Office of Nuclear Regulatory Research

Docket No. 50-269

Enclosures: 1. Agenda
2. List of Attendees
3. Slides used at the meeting

cc w/encls: D. LaBarge
B. Sharon
M. Reinhart
Meeting Attendees
Continued next page

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DATE	02/15/01		02/15/01		02/22/01		02/20/01		02/21/01	

(RES File Code) RES __-2C-1A____

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PROPOSED AGENDA

MEETING WITH DUKE ENERGY CORPORATION TO DISCUSS
PRESSURIZED THERMAL SHOCK REANALYSIS RESULTS

January 23, 2001, 9:30 AM - 4:30 PM

Duke Energy Corporation
526 S. Church St.
Room ECII 12115
Charlotte, NC

9:30-10:00	Introduction/Overview Introduction of Attendees Purpose/Goals of meeting Status/Schedule of PTS Program	Nathan Siu (NRC) (NRC and Duke)
10:00-11:00	Presentation of PRA Approach and Preliminary Results	Bill Galyean (INEEL) Alan Kolaczkowski (SAIC)
11:00-12:00	Discussion	All (NRC and Duke)
12:00-1:00	Lunch	
1:00-4:00	Continuation of Discussion	All (NRC and Duke)
4:00-4:30	Summary	All (NRC and Duke)

Enclosure 1

LIST OF ATTENDEES

MEETING WITH DEC STAFF TO DISCUSS PRELIMINARY RESULTS OF THE NRC STAFF'S REANALYSIS OF THE RISK AT ONS DUE TO HYPOTHETICAL PRESSURIZED THERMAL SHOCK (PTS) EVENTS

JANUARY 23, 2001

NAME	ORGANIZATION
Eric Thornsbury	NRC/RESEARCH
Nathan Siu	NRC/RESEARCH
David Bessette	NRC/RESEARCH
Roy Woods	NRC/RESEARCH
Alan Kolaczkowski	Science Applications International Corp. (SAIC)
William Galyean	Idaho National Engineering & Environmental Lab. (INEEL)
Steve Nader	Duke Energy Corp.
Cam Eflin	Duke Energy Corp.
Bob McAuley	Duke Energy Corp.
Mike Barrett	Duke Energy Corp.
Duncan Brewer	Duke Energy Corp.
Dennis Henneke	

Enclosure 2

PRA for PTS Rule Revision

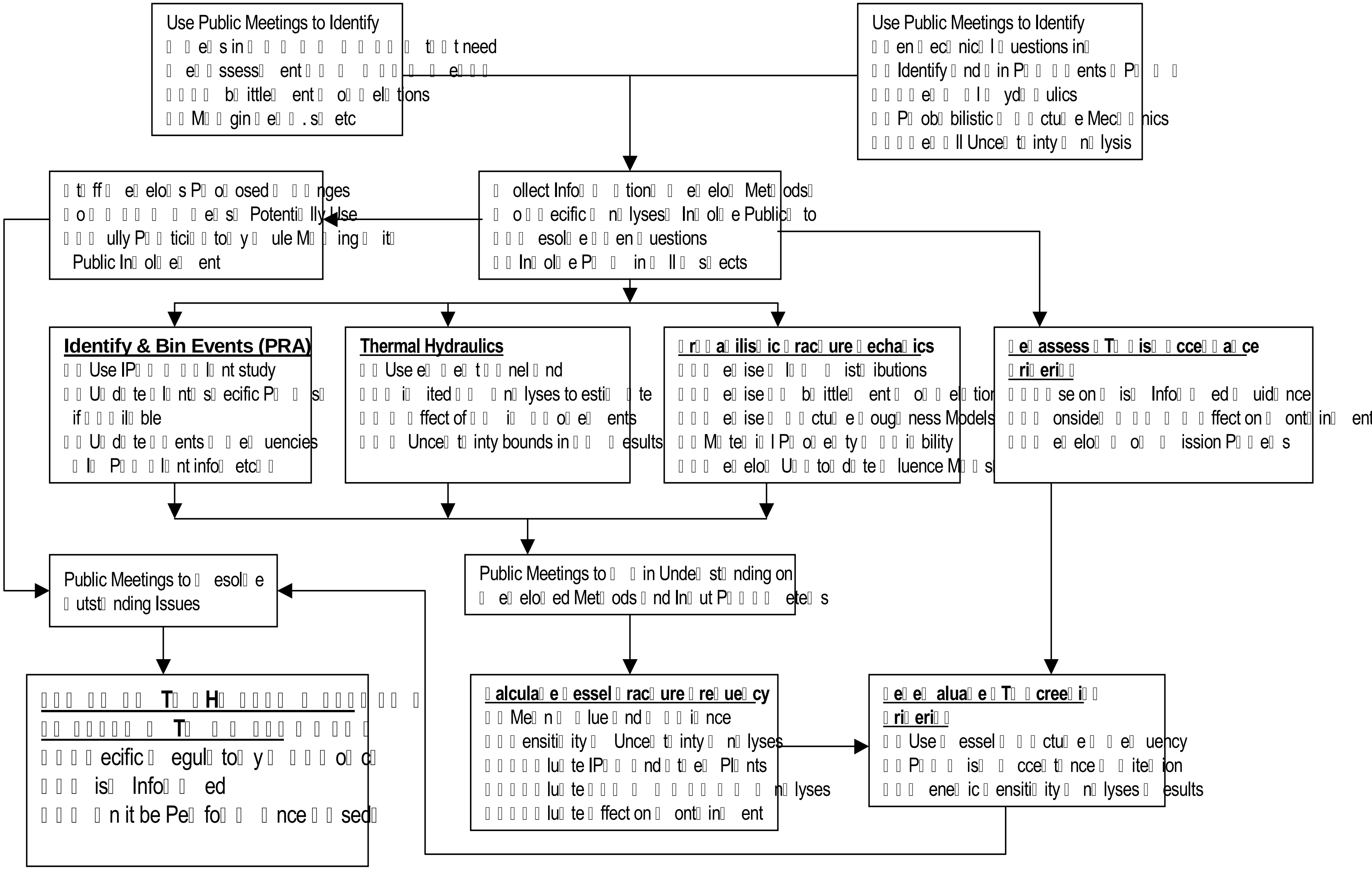
N. Siu, H. Woods, E. Thornsbury

Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Presented at Duke Energy Corporation
Charlotte, NC
January 23, 2001

Enclosure 3

Development of Technical Basis to Revise PTS Rule 10 CFR 50.61



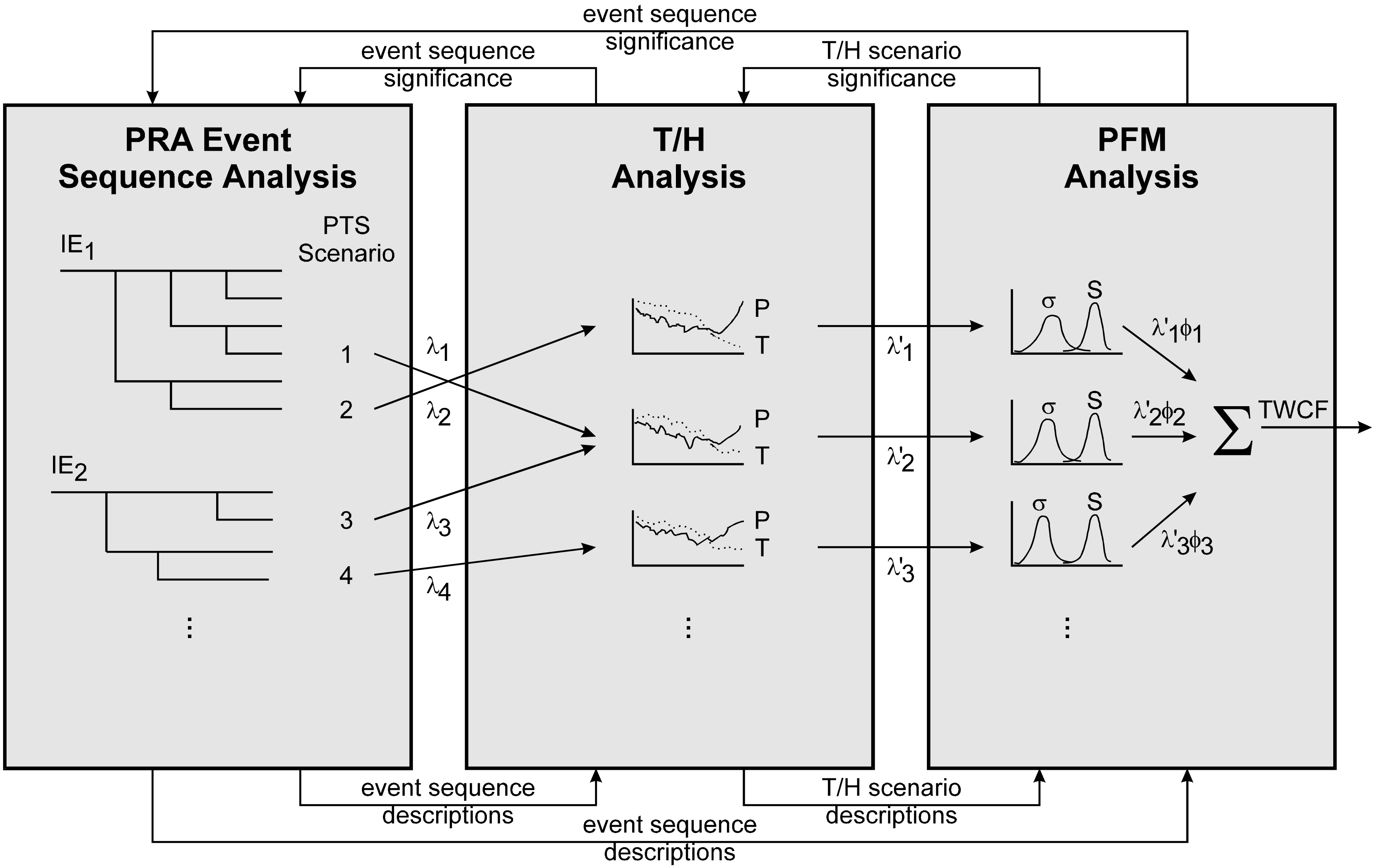
PRA Objective

Support development of technical basis for revised rule

- **Ensure overall process is coherent, risk-informed**
  - **Appropriate integration of T/H, PFM, and PRA**
  - **Consistent treatment of uncertainties**
  -
- **Support development of screening criteria**
  - **Derivation of embrittlement criteria from risk figures of merit**
  - **Criteria for risk figures of merit**
  -
- **Update old PTS/PRA studies**
  - **Reflect changes to study plants**
  - **Reflect changes to PRA state of the art, knowledge base**
  - **Update HRA**
  - **Address other plants**

Expectation: PFM provides most of the margin

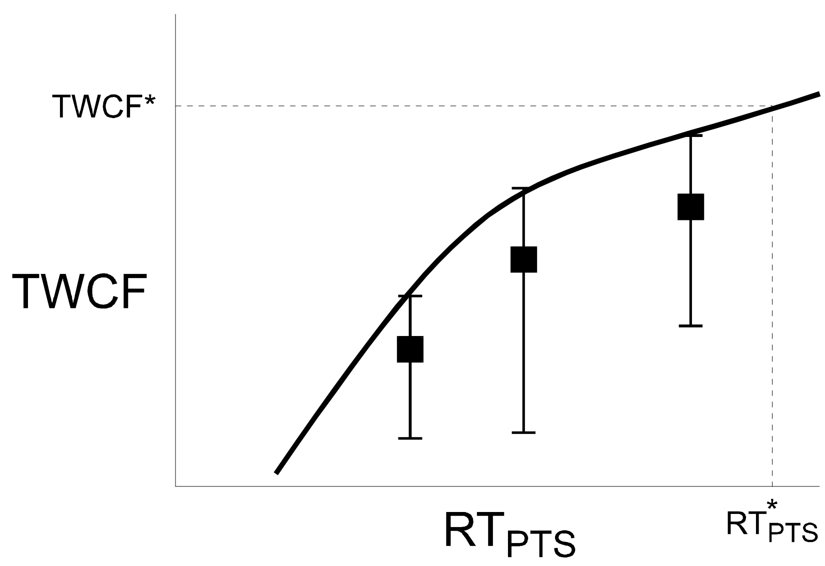
Overall Analysis Framework



Overall PTS/PRA Analysis Approach

- **Estimate PTS-induced through-wall crack frequencies (TWCFs) for 4 plants, including uncertainties**
  - **Develop PTS/PRA models for Oconee and Beaver Valley**
  - **Review PTS/PRAs for Calvert Cliffs and Palisades**
  - **Resolve inconsistencies, generalize results to population**

- **Develop TWCF vs. RT_{PTS} relationship, e.g.,**



PTS/PRA Analysis Status

- Oconee
-
  - Kickoff meeting at Oconee: March, 2000
  - Initial results: December, 2000
  - Review meeting at Duke Energy: January, 2001
  - Model revised and requantified: March, 2001

- Beaver Valley
-
  - Kickoff meeting at Beaver Valley: July, 2000
  - Initial results: January, 2001
  - Review meeting: TBD
  - Model revised and requantified: May, 2001

Meeting Objectives

- Present draft results of PTS PRA analysis for Oconee

- Obtain feedback on analysis results

1. PTS PRA Analysis

W. J. Galyean
A. M. Kolaczkowski (SAIC)
Charlotte, NC - January 23, 2001

2. Overall Approach

Use original Oconee PTS analysis as starting point
Update:
- ***New event frequencies and probabilities***
  - ***Updated HRA***
- ***Reflect current plant designs***
- ***Incorporate current understanding of phenomena***

3. PTS Sequence Event Trees

Structure follows "original" Oconee ETs
- ***Primary Integrity***
  - ***LOCA, stuck open PORV/SRV, etc.***
- ***Secondary Integrity***
  - ***steam line break, stuck open SRV/TBV, etc.***
- ***Secondary Feed***
  - ***MFW, EFW, CBP, etc.***
- ***Primary Flow***
  - ***HPI, RCPs, etc.***

4. Event Trees Used to Generate PTS Sequence of Events

System and operator responses listed as event tree top events
Individual branch points dependent on preceding path through the event tree
- ***Specifics of event can vary***
- ***Probability can vary***

Each event tree end state represents a single unique path through the event tree (unique sequence of events)
- ***Approximately 14,500 unique sequences generated***

5. Individual Input Parameters Quantified Using a Variety of Sources

Oconee experience data used to update a Bayesian (non-informative) prior distribution
Industry-wide experience data used to update a Bayesian prior distribution
Oconee-PRA data
Engineering judgement
ATHEANA approach for Human Failure Events (HFEs)

6. Human Failure Events (HFEs) Considered in the Oconee PTS Analysis

	PRIMARY INTEGRITY CONTROL	SECONDARY PRESSURE CONTROL	SECONDARY FEED AND TEMPERATURE CONTROL	PRIMARY FLOW & PRESSURE CONTROL
FAILURES (i.e., HFEs)	-Operator fails to isolate an isolable LOCA in a timely manner (e.g., close block valve to a stuck-open PORV) -Operator induces a LOCA (e.g., opens PORV or letdown path) that induces or adds to cooldown	-Operator fails to isolate in a timely manner -Operator isolates when not needed (may create a new de-pressurization challenge, lose heat sink...) -Operator isolates wrong path/SG (de-pressurization continues) -Operator creates an excess steam demand such as opening steam dumps, etc. prior to or in response to Rx trip	-Operator fails to stop/throttle or properly align feed in a timely manner (over-cooling continues) -Operator feeds wrong (affected) SG (over-cooling continues) -Operatory stops or throttles feed when inappropriate (causes under-feed, may have to go to feed & bleed & possible overcooling that way)	-Operator does not properly throttle injection to control RCS pressure -Operator trips RCPs when not supposed to and/or fails to restore them when desirable -Operator fails to trip RCPs appropriately -Operator does not inject enough when required (heading for core damage rather than a PTS concern)

7. Bases for HFE Estimates

Review of "old" Oconee PTS Study and other PTS Studies
Review of EOPs/AOPs
Input from Oconee staff:
- ***Discussions regarding potential scenarios, operator training/biases, procedures…***
- ***Several rounds of questions/answers***
- ***Observations of PTS-related simulator events***

Review of relevant Oconee plant features (equipment/control features, MCR layout - controls, alarms, indications...)
HFEs estimated using following scale (tended toward conservative):
- ***Likely (0.5)***
- ***Infrequently (0.1)***
- ***Unlikely (0.01)***
- ***Extremely unlikely (not expected) (0.001)***
- ***Estimates considered scenario (complexity/workload), time available…and is reason for ranges shown in following slides***

8. Specific HFE Results (examples)

Fail to trip RCPs "quickly" after 0°F subcooling	***0.01***
Trip RCPs when not required	***event data***
Fail to restart RCPs "soon" after subcooling restored (50F)	***0.1***
Fail to trip turbine manually in 15-30 sec. if auto trip fails	***0.001***
Fail to throttle HPI after 5°F subcooling restored	
Within 1 minute	***0.5-0.1***
Within 5 minutes	***0.1(conservative?)***
Fail to throttle EFW (from t=0) given it is overfeeding SG(s)	
Within 10 minutes	***0.1-0.01***
Within 30 minutes	***0.01-0.001***
Fail to isolate secondary depressurization (from t=0)	
Within 5 minutes	***0.5-0.1***
Within 10 minutes	***0.1-0.01***
Isolate wrong SG	***0.001***

9. Specific HFE Results (continued)

Fail to close PORV/block valve (from t=0)	
Within 5 minutes	***0.5-0.1***
Within 10 minutes	***0.1-0.01***
Fail to control cooldown in SGTR & lose subcooling	***0.1***

Other noteworthy actions
- ***Assumed (~1.0) crew would induce depressurization/cooldown in loss of heat sink event in an attempt to use condensate feed (for sequences where condensate available)***
- ***Assumed (~1.0) crew would use feed and bleed primary cooling if conditions warrant (apparent loss of secondary cooling and >2300psig in primary)***
- ***Assumed (~1.0) crew would induce depressurization/cooldown in scenario involving insufficient HPI (but it is needed) in an attempt to use core flood tanks/LPI***

10. PTS LER Search

SCSS used to search LERs

- ***effectively 25,000 LERs 1985-1999***
- ***Key word searches***
  - ***Overcooling***
  - ***Excessive cooling***
  - ***Thermal shock***
- ***Functional search***
  - ***High S/G level***

11. PTS LERs Identified and Reviewed

265 LERs identified

- ***Overcooling - 144***
- ***Excessive cooling - 13***
- ***Thermal Shock - 49***
- ***High S/G level - 72***

Only two LERs indicated post-trip RCS temp < 440°F

- ***Oconee switchgear fire (26989002)***
- ***Davis Besse MSSV stuck open (34698011)***
- ***Recently, IP2 SGTR (February 15, 2000)***

12. PTS Event Trees Generate Sequence of Events (PTS Transients)

System and operator responses listed as event tree top events

Individual branch points dependent on preceding path through the event tree

- ***Specifics of event can vary***
- ***Probability can vary***

Each event tree end state represents a single unique path through the event tree (unique sequence of events)

- ***Approximately 14,500 unique sequences generated***

13. Each Event Tree Endstate Sequence Mapped into SID

Sequence Identifier (SID) mapping used to group similar sequences

Eight character vector used to capture most relevant information (with respect to T/H response)

Approximately 2500 unique PTS-SIDs

- ***Each SID maintains link to member sequences***

14. Eight Character SID *(see first backup slide following slide #25 for further details of SIDs)*

1 - Initial Power
2 - Primary System Integrity Status
3 - Secondary System Integrity Status
4 - Main Feedwater Status
5 - Emergency Feedwater Status
6 - Condensate Booster Pump Cooling of S/Gs
7 - High Pressure Injection Status
8 - Reactor Coolant Pumps Status

15. Each PTS-SID Mapped into TH Bin

Second stage processing maps each PTS-SID into one of the available Thermal-Hydraulic cases

45 Available TH bins

- ***40 TH case***
- ***4 “other” bins (CD but not PTS, or OK’s)***
- ***1 residual bin***

31 TH bins actually used

16. SID of TH Runs

The 8 columns below define the "SID" - see BU#1 slide after #25

Min. Temp (deg. F)	Description	T/H #	PWR 1	PRI 2	SEC 3	MFW 4	EFW 5	CBP 6	HPI 7	RCP 8	Comment
	CD/LOCA not PTS	99	x	L	x	x	x	x	F	x	Core Damage (LOCA w/ failed SI), but not PTS
	CD/F&B not PTS	98	x	x	x	T	F	F	F	x	Core Damage (all FW lost, Feed and Bleed fails)
	OK/LOCA	89	x	L	x	C	C	C	C	x	ok, LOCA w/ successful SI and controlled FW
	OK/F&B	88	x	x	x	T	F	F	C	x	all FW lost, but Feed and Bleed successful
527	1" LOCA	1	P	Z	0	T	C	N	I	R	do not lose subcooling
438	1.414" LOCA	2	P	Z	0	T	C	N	I	R	EFW not demanded, do not lose subcooling, min. SCM=5F
121	2" LOCA	3	P	L	0	T	C	N	I	T	appears to be worst-case PTS
89	2.828" LOCA	4	P	L	0	T	C	N	I	T	> 2.8", RCS at low pressure
73	4" LOCA	5	P	Y	0	T	C	N	I	T	RCS at low pressure
436	1.4" LOCA	6	P	Z	0	T	C	N	I	R	TH#2 but cold leg rupture - less severe than TH#2
243	2' LOCA	7	P	L	0	T	C	N	I	T	TH#3 but cold leg rupture - less severe than TH#3
336	1" + 1 MS-SRV SO	8	P	Z	1	T	C	N	I	R	do not lose subcooling
305	1" + 2 MS-SRV SO	9	P	Z	2	T	C	N	I	R	do not lose subcooling
288	1.4"+2 MS-SRV SO	10	P	Z	2	T	C	N	I	R	do not lose subcooling
408	TH#8 w/HPI trip	11	P	Z	1	T	C	N	X	R	TH#8 w/ HPI tripped at 100F subcooling - Not in PRA
370	TH#8 w/HPI throttled	12	P	Z	1	T	C	N	C	R	TH#8 w/ HPI throttled to control subcooling - RCS 25F hotter than TH#8
278	TH#9 w/HPI trip	13	P	Z	2	T	C	N	X	R	TH#9 w/HPI tripped at 100F subcooling - Not in PRA
262	1" LOCA +RCP trip	14	P	Z	0	T	C	N	I	T	TH#1 + RCPs tripped at 5F subcooling
162	1" LOCA	15	P	Z	0	T	C	N	F	T	TH#1 + HPI fails -> depressurize to CFT actuation
426	HZP - 1" LOCA	16	Z	Z	0	T	C	N	I	R	RCS does not lose subcooling
291	HZP 1" LOCA plus 1 MS-SRV SO	17	Z	Z	1	T	C	N	I	R	
511	EFW trips @ 96%	18	P	N	0	T	C	N	N	R	not PTS - Tmin=515F
508	EFW floods S/G	19	P	N	0	T	C	N	N	R	EFW throttled after SG flooded, not PTS - Tmin=505F
390	TBV SO	20	P	N	1	T	1	N	C	R	EFW-2 (EFW feeds faulted S/G), HPI actuates, Tmin=395F @ 1000 sec.

17. SID of TH Runs (Cont'd)

Min. Temp (deg. F)	Description	T/H #	PWR 1	PRI 2	SEC 3	MFW 4	EFW 5	CBP 6	HPI 7	RCP 8	Comment
549	routine Rx-trip	21	P	N	0	T	C	N	N	R	No operator actions
469	w/PORV SO	22	P	P	0	T	C	N	I	R	EFW not demanded
458	EFW overfeeds S/Gs	23	P	N	0	T	2	N	N	R	S/G flooding continues, Tmin=460F, Pmin=1700 psig (No HPI actuation)
538	MFW overfeeds	24	P	N	0	2	N	N	I	R	Full HPI flow, RCS pressurized to PORV setpoint
221	MSLB-Large	25	P	N	L	T	1	N	I	R	Both motor-driven and turbine driven EFW pumps feed faulted S/G
221	MSLB-Large	26	P	N	L	T	1	N	I	R	TH#25 but TD-EFW pump tripped by MSLB isolation logic
223	MSLB-Large	27	P	N	L	T	1	N	C	R	TH#25 but HPI throttled to maintain 50F subcooling
359	1 MS-SRV SO	28	P	N	1	T	C	N	I	R	TH#8 but w/o 1”-LOCA
315	2 MS-SRV SO	29	P	N	2	T	C	N	I	R	TH#9 but w/o 1”-LOCA
323	HZP 1 MS-SRV SO	30	Z	N	1	T	C	N	I	R	TH#17 but w/o 1”-LOCA
283	HZP 2 MS-SRV SO	31	Z	N	2	T	C	N	I	R	TH#17 but w/o 1”-LOCA and w/ 2 MS-SRV SO
538	MFW overfeeds	32	P	N	0	2	N	N	C	R	TH#24 but HPI flow throttled
493	TBV SO/ isolated	33	P	N	I	T	1	N	C	R	TH#20 but TBV isolated after 10-min.
115	SRV SO	34	P	S	0	T	C	N	I	R	TH#22 but with SRV SO instead of PORV
394	1MS-SRV SO	35	P	N	I	T	C	N	C	R	TH#8 but w/o 1”-LOCA, and w/ HPI throttled
339	2MS-SRV SO	36	P	N	2	T	C	N	C	R	TH#9 but w/o 1”-LOCA, and w/ HPI throttled
365	HZP 1 MS-SRV SO	37	Z	N	1	T	C	N	C	R	TH#17 but w/o 1”-LOCA, and w/ HPI throttled
312	HZP 2 MS-SRV SO	38	Z	N	2	T	C	N	C	R	TH#17 but w/o 1”-LOCA, w/ 2 MS-SRV SO, & w/ HPI throttled
?	SGTR 1 MS-SRV SO	39	P	G	1	T	C	N	C	R	Nominal SGTR response except for stuck open MS-SRV
?	SGTR Loss of SCM	40	P	G	0	T	C	N	C	T	Operators depress RCS w/ PZR sprays, lose SCM, open PORV (SO)

18. Example Rule for Binning (TH24)

```
If both primary and secondary systems are intact,
overfeeding S/Gs, HPI full (not throttled) then map into TH24
if
"PTS-PN01??I?" + "PTS-PN0?1?I?" + "PTS-PN0??1I?" +
"PTS-PN02??I?" + "PTS-PN0?2?I?" + "PTS-PN0??2I?" +
"PTS-PI01??I?" + "PTS-PI0?1?I?" + "PTS-PI0??1I?" +
"PTS-PI02??I?" + "PTS-PI0?2?I?" + "PTS-PI0??2I?" +
"PTS-PNI1??I?" + "PTS-PNI?1?I?" + "PTS-PNI??1I?" +
"PTS-PNI2??I?" + "PTS-PNI?2?I?" + "PTS-PNI??2I?" +
"PTS-PII1??I?" + "PTS-PII?1?I?" + "PTS-PII??1I?" +
"PTS-PII2??I?" + "PTS-PII?2?I?" + "PTS-PII??2I?"
 then
 GlobalPartition = "TH24-PN02NNIR";
```

19. PTS-SIDs Contributing to TH24*

TH24-PN02NNIR

Total Frequency = 5.4E-5

*PTS-SID**	*Frequency*	*Contribution*
PTS-PN02NNIR	*2.7E-5*	*51%*
PTS-PN0T2FIT	*1.7E-5*	*32%*
PTS-PN0T1FIT	*6.2E-6*	*12%*
PTS-PN0T2NIR	*1.0E-6*	*2%*
PTS-PN01NNIR	*9.3E-7*	*2%*

**see backup slide #1 (after slide #25) for “key” to reading the Sequence Identifiers (SIDs)*

20. Final Binning Process Relies on Engineering Judgement

Binning of event tree sequences into PTS-SIDs, relatively straight-forward

If EFW successful, then “C” in 5th position

Binning of PTS-SIDs into THxx-SIDs somewhat subjective

E.g., is PTS-ZS0T2NIR closer to

TH17-ZZ1TCNIR or

TH34-PS0TCNIR

Final review of Binning process will be done once conditional (on THxx) PFM results are available

21. Conventional Treatment of PRA Uncertainties

Failure rates

- ***Assumed to be time independent***
- ***Determined by specific boundary conditions on operation of component***
- ***Uncertainties typically treated as epistemic***

Failure probabilities and Sequence Frequencies

- ***Occurrence modeled as random process***
  - ***Binomial or Poisson***
- ***Uncertainties typically treated as aleatory***

22. Uncertainty Propagated Step-wise

Event Tree top events quantified (with uncertainty)
PTS-SIDs then quantified (with uncertainty)
TH bins than quantified (with uncertainty) using the results of the PTS-SID uncertainty analysis
Can use either Monte Carlo or Latin Hypercube sampling
Entire process takes about 4 - 5 hours on PC (Pentium II running at 366 MHz)
Output is probability density represented by a histogram (19 bins)

23. Original Oconee Results

	Transient Freq.	***P(TWC/T)***	***F(TWC)***
Residual Group (LSLB both S/G blowdown)	***4.9E-4***	***5.4E-3***	***2.6E-6***
Large SLB (one S/G blowdown)	***1.6E-3***	***6.2E-4***	***9.8E-7***
Stuck Open TBV (one S/G blowdown)	***2.3E-4***	***2.0E-3***	***4.5E-7***
All TSVs fail to close (both S/G blowdown)	***1.0E-3***	***6.2E-4***	***3.1E-7***

24. Original Oconee TWC Frequency Estimate

Maximum conditional TWC probability from Oconee

5E-3 (Residual sequence group)

Estimated conditional TWC probability for 400^{o}F min RCS temperature

1E-7

Range of TWC frequency (per Rx-year)

Max:8E-6

Min:1.5E-10

25. Current Analysis More Focused Compared to Original IPTS Study

Many details of original IPTS unavailable
Original work was a series of separate almost independent analyses
Original IPTS analysis for Oconee resulted in residual (un-binned) group as dominant risk contributor
Better understanding of most key issues
Fully integrated analysis

Backup Slides

BU #1 - Explanation of 8 character Sequence Identifier (SID):

"PTS-" before the 8 character SID indicates a PTS sequence, followed by 8 characters (the SID) signifying the folowing:

1st Character - Initial Power:
Z - Hot Zero Power
P - Operating Power

2nd Character - Primary Integrity:
N - No Leak (RCS intact)
Z - Small LOCA (<1.4 inches equivalent diameter)
L - LOCA (1.4" < L < 2.8")
P - PORV stuck open (not isolated)
S - SRV stuck open
I - PORV initially open, subsequently isolated
G - SGTR
Y - Large LOCA (> 2.8")

3rd Character - Secondary Integrity:
Number of TBV and/or SSRV stuck open:
0 - zero secondary valves stuck open
1 - one secondary valve stuck open
2 - two secondary valves stuck open
A - one on each of two S/Gs (2 total)
S - small steam line break (SSLB)

L - large steam line break (LSLB)
I - TBV or SLB initially open, subsequently isolated

4th Character - MFW Status:
C - Controlling at appropriate level
T - Tripped
1 - 1 S/G being overfed
2 - 2 S/Gs being overfed
? Overfeed - exceed high level in S/G, or fail to isolate a faulted steam generator (i.e., any feed to a faulted S/G is overfeed)

5th Character - EFW Status:
C - Controlling at appropriate level
F - Failed
N - Not demanded
1 - 1 S/G being overfed
2 - 2 S/Gs being overfed

6th Character - Condensate Booster Pump Status:
C - Controlling at appropriate level
F - Failed
N - Not demanded
1 - 1 S/G being overfed
2 - 2 S/Gs being overfed

7th Character - High Pressure Injection Status:
N - Not demanded
C - Controlled injection (Operators throttle flow)
I - Full injection (not throttled)
F - Failed
X - Modeled situation not included in the PRA (e.g., HPI tripped at 100^{o}F subcooling)

8th Character - RCP Status:
R - Running
T - Tripped
U - Tripped and subsequently restarted

Note: “x” in any of the 8 positions means the characteristic described by that position is not specified.

BU#2 - Probability Density Functions Reflect Confidence in Parameter Estimate
- Estimate in "true" value of failure rate characterized using lognormal or gamma distribution
- **Generated Using**
  - **Engineering judgement**
  - **Bayesian methods**
- **Typically Interpreted as Representing Degree-of-Belief**