Attachment 5

Mitigating Systems Performance Index Pilot Working Group Public Meeting April 30, 2003

Ongoing Research Results

by

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Key Technical Issues

- Role of SPAR models in independent verification of MSPI results
- Invalid and Insensitive Indicators and solutions
- Recommended use of Year 2000 Baseline Data
- Treatment of Common Cause in FV determination and consequent delta CDF
- Resolution of system boundary issues via FAQ
- Technical basis for excluding active valves with low FV/UR or Birnbaum (CDF*FV/UR)
- Support system initiators and impact on FV

Status of Independent Verification

- In-depth benchmarking of NEI spreadsheets with SPAR models for 19 units (20th expected shortly)
- Enhanced SPAR models completed for
  - Braidwood 1 & 2
  - San Onofre 2 & 3
  - Salem 1 & 2
  - Palo Verde 1, 2 & 3 (preliminary)
- Resource *window of opportunity* closes June 30, 2003
- SPAR enhancement only for Pilot Plants that have submitted requested information by May 9, 2003
- Role of Enhanced SPAR models for full implementation of MSPI to be assessed

Requested Information for SPAR Model Enhancement

- Electronic list of all cut sets down to truncation level.
- Description and probability values for all basic events (ID strings).
- Listing of Fussell-Vesely Importance measures and Risk Achievement Worths (RAWs).
- Electronic image of event trees (*.bit, *.jpg, *.doc, or *.pdf), showing branch split fractions and sequence names/number if possible.
- Information received from Braidwood, San Onofre, Palo Verde, Prairie Island, Limerick, Hope Creek, and Salem as of late April
- Awaiting information from Millstone, South Texas, and Surry

Summary of Results for San Onofre

- Internal events CDF
  - Plant PRA = 1.9E-5 /yr
  - "Old" SPAR Model = 3.3E-5 /yr
  - "New" SPAR Model = 2.4E-5 /yr
- FV/UR was too low in the old SPAR Model by factors of 6 to 30
- With enhancements to SPAR Model, on average agreement within factor of about 2 (high or low).

(Note: need to reconcile some differences in data)

San Onofre	FV/UR or FV/UA ratio	
Component	old SPAR/Plant PRA	new SPAR/Plant PRA
containment sump suction MOV	0.01	0.56
motor-driven AFW pump 2P141	8.53	0.59
EDG Train A (T & M)	6.24	1.70
salt water cooling pump train A	0.06	0.52
CCW train B (T & M)	0.22	1.16

Summary of Results for Salem

- Internal events CDF
  - Plant PRA = 4.4E-5 /yr
  - "Old" SPAR Model = 7.4E-5 /yr
  - "New" SPAR Model = 4.0E-5 /yr
- On average, FV/UR was too low in the old SPAR Model by about a factor of 10
- With enhancements to SPAR Model, on average agreement within factor of about 3 overall, but high FV/UR components within 30% (high or low)

(Note: Need to reconcile loss of service water IE frequency)

Salem	FV/UR ratio	
Component	old SPAR/Plant PRA	new SPAR/Plant PRA
EDG "B" FTR	0.18	1.15
RHR pump suction MOV	0.05	0.68
AFW motor-driven pump FTS	0.02	1.22
SWS HX inlet AOV	0.11	0.45
HPSI RHR-to-charging MOV	0.15	1.41

Preliminary Results for Palo Verde

- Internal events CDF
  - Plant PRA = 1.4E-5 /yr
  - "Old" SPAR Model = 1.9E-5 /yr
  - "New" SPAR Model = 2.1E-5 /yr (model changes only)
  - "New" SPAR Model = 1.5E-5 /yr (model changes with selected plant data)
- Overall risk profile comparable in terms of contribution from LOSP/SBO, SGTR, Loss of ESF Bus, and other Transients
- FV/UR's on average within factor of 2 (high or low)

Palo Verde	FV/UR or FV/UA ratio	
Component	old SPAR/Plant PRA	new SPAR/Plant PRA
AFW MDP "B" FTS	0.07	0.27
AFW MDP "B" unavailability	0.27	1.27
DG "A" FTR	6.54	1.48
Essential spray PP "B" FTS	5.14	2.80
Essential cooling water "B" unavail.	0.03	1.37

MSPI Results 1st Quarter 2003

Licensees' Plant PRA Model	MSPI results 1st Quarter 2003					
	EAC	HPI	HRS	RHR	SWS	CCW
Braidwood 1						
Braidwood 2						
Hope Creek						
Limerick 1						n/a
Limerick 2						n/a
Millstone 2						
Millstone 3						
Palo Verde 1						
Palo Verde 2						
Palo Verde 3						
Prairie Island 1						
Prairie Island 2						
Salem 1						
Salem 2						
San Onofre 2						
San Onofre 3						
South Texas 1						
South Texas 2						
Surry 1						
Surry 2						

= Invalid but otherwise WHITE

Notes:

1) Braidwood Unit 1 had three failures of the diesel-driven AFW pump
2) Braidwood Unit 2 had one failure of the diesel-driven AFW pump (invalid)
3) Hope Creek had three failures of MOVs in HPI
4) Millstone 2 had one failure of a HPSI valve (invalid)
5) Palo Verde 2 had one failure of a motor-driven pump in AFW (invalid)
6) Salem 2 had one failure of an MOV in service water system (invalid)

C01

Invalid Indicators

- Using Plant PRA Models and the current approach, 38% of systems have at least one component giving invalid indication (either 0 to 1 or N to N+1 failures)
- About 5% of all components within scope of MSPI pose an invalid indicator problem based on the current analytical approach
  - Most likely, steam-driven or diesel-driven pumps
  - Several instances of emergency diesel generators
  - Several instances of motor-driven pumps
  - Some automatic valves

Solutions to Invalid Indicators

- Using the most recent equipment performance data reduces the number of systems with invalid indicators significantly
- Number of systems with invalid indication is sensitive to mission time. Using a conventional 8-hour mission time for emergency diesel generators reduces the number of invalid systems still further.
- With the above two assumptions, only 17% of systems are invalid.
- Pooling of data across similar units at a plant site further reduces the number of invalid systems to about 14%.
- If the 25th percentile of the posterior distribution is used instead of mean, only about 3% of systems invalid.

Invalid Indicators by System
(using Year 2000 data and conventional assumptions)

Licensees' Plant PRA Model	Number of Component Types with Invalid Indicators				
	EAC	HPI	HRS	RHR	SWS / CCW
Braidwood 1			2		
Braidwood 2			2		
Hope Creek		1			
Limerick 1					
Limerick 2					
Millstone 2		2	1		5
Millstone 3			1		
Palo Verde 1			2		
Palo Verde 2			2		
Palo Verde 3			2		
Prairie Island 1					
Prairie Island 2					
Salem 1	1			1	1
Salem 2	1			1	1
San Onofre 2					
San Onofre 3		1			
South Texas 1					
South Texas 2					
Surry 1					
Surry 2					

Valid (all components within system are valid)
Invalid (one or more components are invalid)

C02

Insensitive Indicators

- Using Plant PRA Models with Year 2000 data and conventional assumptions, about 11% of systems have at least one component giving very insensitive indication (greater than 20 failures to reach White)
- Inverse relationship between FV/UR and whether a component failure mode will be insensitive
  - Low FV/UR most likely to result in insensitive indication
  - High FV/UR less likely to be insensitive
- Insensitive indicators are being assessed by evaluating
  - Varying confidence limits
  - Different prior distributions
  - A "backstop" equipment performance limit

Insensitive Indicators by System

Licensees' Plant PRA Model	Systems with Insensitive Indicators (> 20 failures to White)				
	EAC	HPI	HRS	RHR	SWS / CCW
Braidwood 1					
Braidwood 2					
Hope Creek					
Limerick 1					
Limerick 2					
Millstone 2					
Millstone 3					
Palo Verde 1					
Palo Verde 2					
Palo Verde 3					
Prairie Island 1					
Prairie Island 2					
Salem 1					
Salem 2					
San Onofre 2					
San Onofre 3					
South Texas 1					
South Texas 2					
Surry 1					
Surry 2					

Valid (all components within system are valid)
Insensitive (one or more components are insensitive)

Assessment of Different Confidence Limits

- Continued use of the *Constrained Noninformative Prior* (CNIP), with varying percentile confidence limits on the posterior
  - If > 20% probability Green at Green/White threshold, called Green (addresses *false positive*)
  - If < 80% probability White at White/Yellow threshold, called Yellow (addresses *false negative*)

Failure Outcome Using CNIP and Mean Posterior for Motor-Driven AFW Pump

		x_{FTS}						
		0	1	2	3	4	5	6
	0	1.42E-6	3.13E-6	4.84E-6	6.55E-6	8.26E-6	9.97E-6	1.17E-5
	1	2.57E-6	4.28E-6	5.99E-6	7.70E-6	9.41E-6	1.11E-5	1.28E-5
	2	3.72E-6	5.43E-6	7.13E-6	8.84E-6	1.06E-5	1.23E-5	1.40E-5
	3	4.86E-6	6.57E-6	8.28E-6	9.99E-6	1.17E-5	1.34E-5	1.51E-5
x_{FTR}	4	6.01E-6	7.72E-6	9.43E-6	1.11E-5	1.28E-5	1.46E-5	1.63E-5
	5	7.16E-6	8.87E-6	1.06E-5	1.23E-5	1.40E-5	1.57E-5	1.74E-5
	6	8.30E-6	1.00E-5	1.17E-5	1.34E-5	1.51E-5	1.68E-5	1.86E-5
	7	9.45E-6	1.12E-5	1.29E-5	1.46E-5	1.63E-5	1.80E-5	1.97E-5
	8	1.06E-5	1.23E-5	1.40E-5	1.57E-5	1.74E-5	1.91E-5	2.09E-5
	9	1.17E-5	1.35E-5	1.52E-5	1.69E-5	1.86E-5	2.03E-5	2.20E-5

Failure Outcome Using CNIP with 20% and 80% Confidence Limits for Motor-Driven AFW Pump

		x_{FTS}						
		0	1	2	3	4	5	6
	0	G	G	G	W	W	Y	Y
	1	G	G	W	W	Y	Y	Y
	2	G	W	W	Y	Y	Y	Y
	3	W	W	W	Y	Y	Y	Y
x_{FTR}	4	W	W	Y	Y	Y	Y	Y
	5	W	Y	Y	Y	Y	Y	Y
	6	W	Y	Y	Y	Y	Y	Y
	7	Y	Y	Y	Y	Y	Y	Y
	8	Y	Y	Y	Y	Y	Y	Y
	9	Y	Y	Y	Y	Y	Y	Y

Sensitivity of Green-White Threshold to Common Cause Failure Model Contribution

Assessment of Common Cause Contribution to Delta CDF

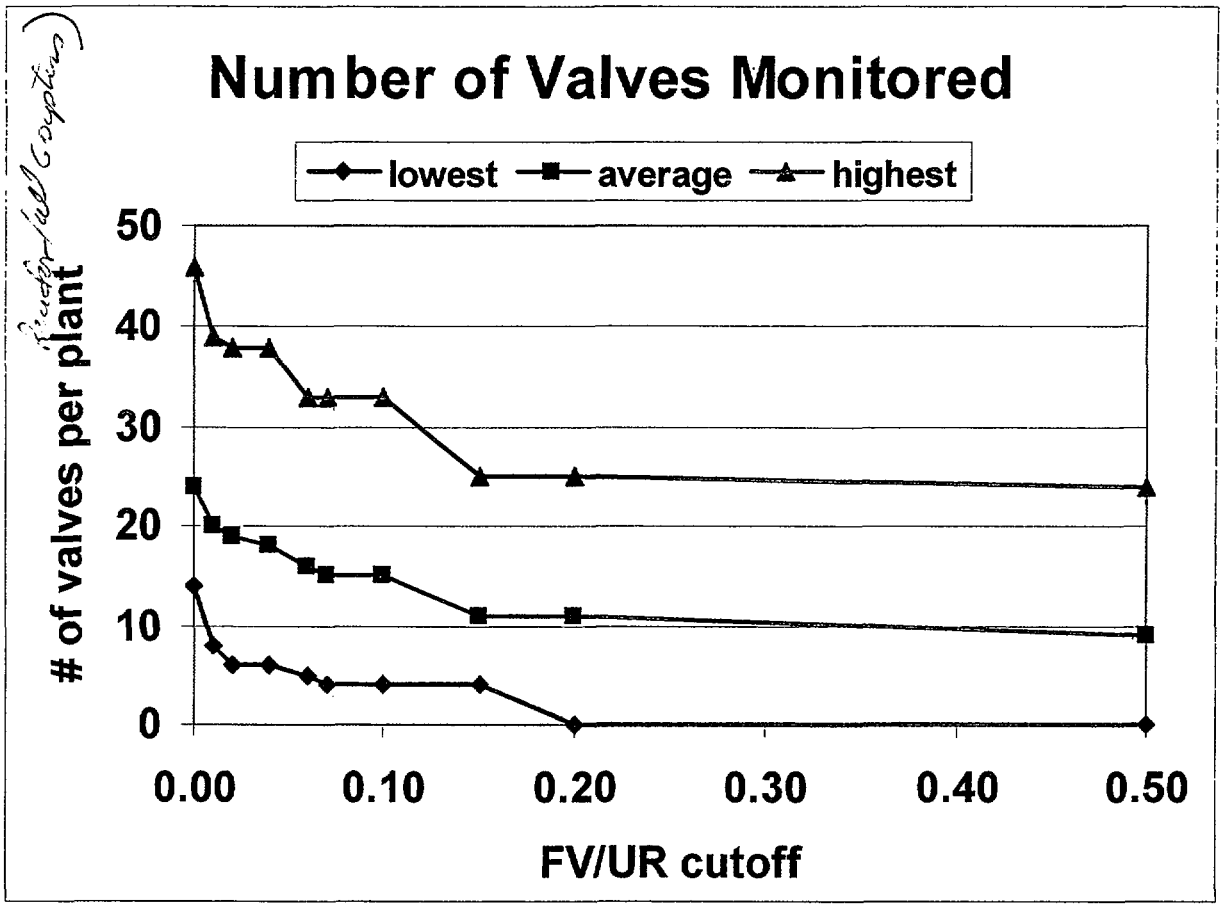
- Treatment of common cause can have low to moderate importance on MSPI results
- Currently assessing the feasibility of using a multiplier on FV depending on correlation with
  - importance of system
  - degree of redundancy
  - degree of coupling between common cause failure probability and independent failure probability
- For example, multiply FV by factors of 1.2, 1.5, and 2

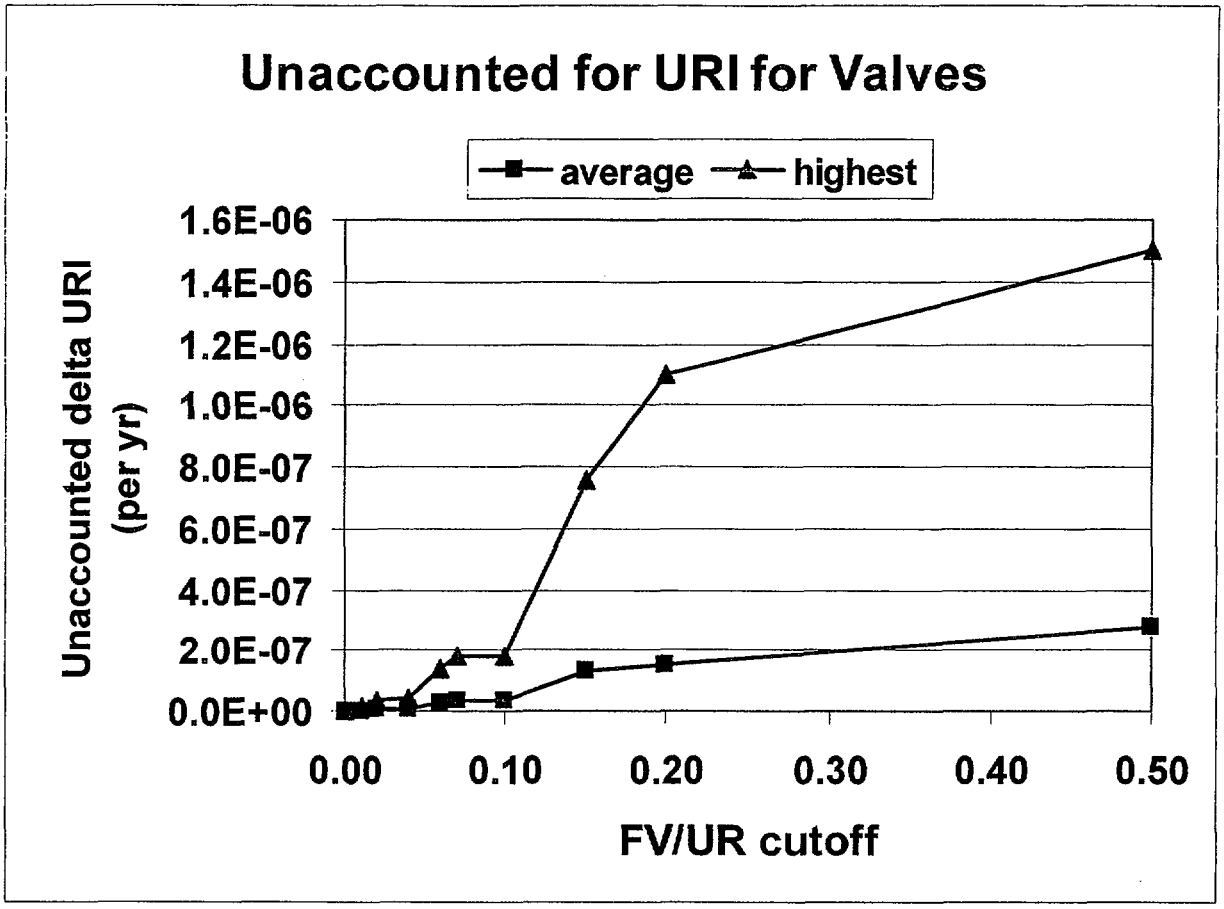
System Boundary Issues

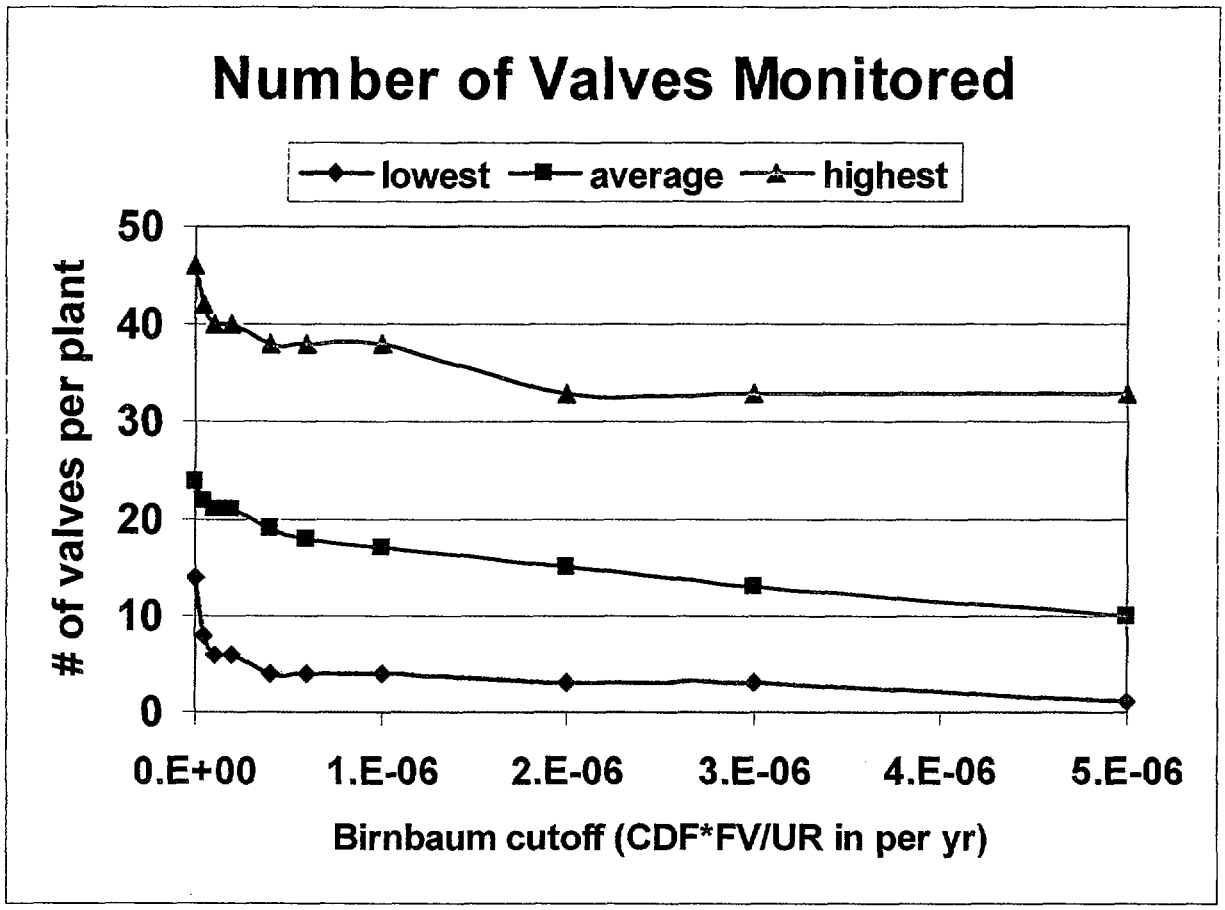
- Received ten pages of FAQs and have responded to all but one question
- Final requested resolution of outstanding system boundary issues by FAQ by April 30
- Final resolution by May 21

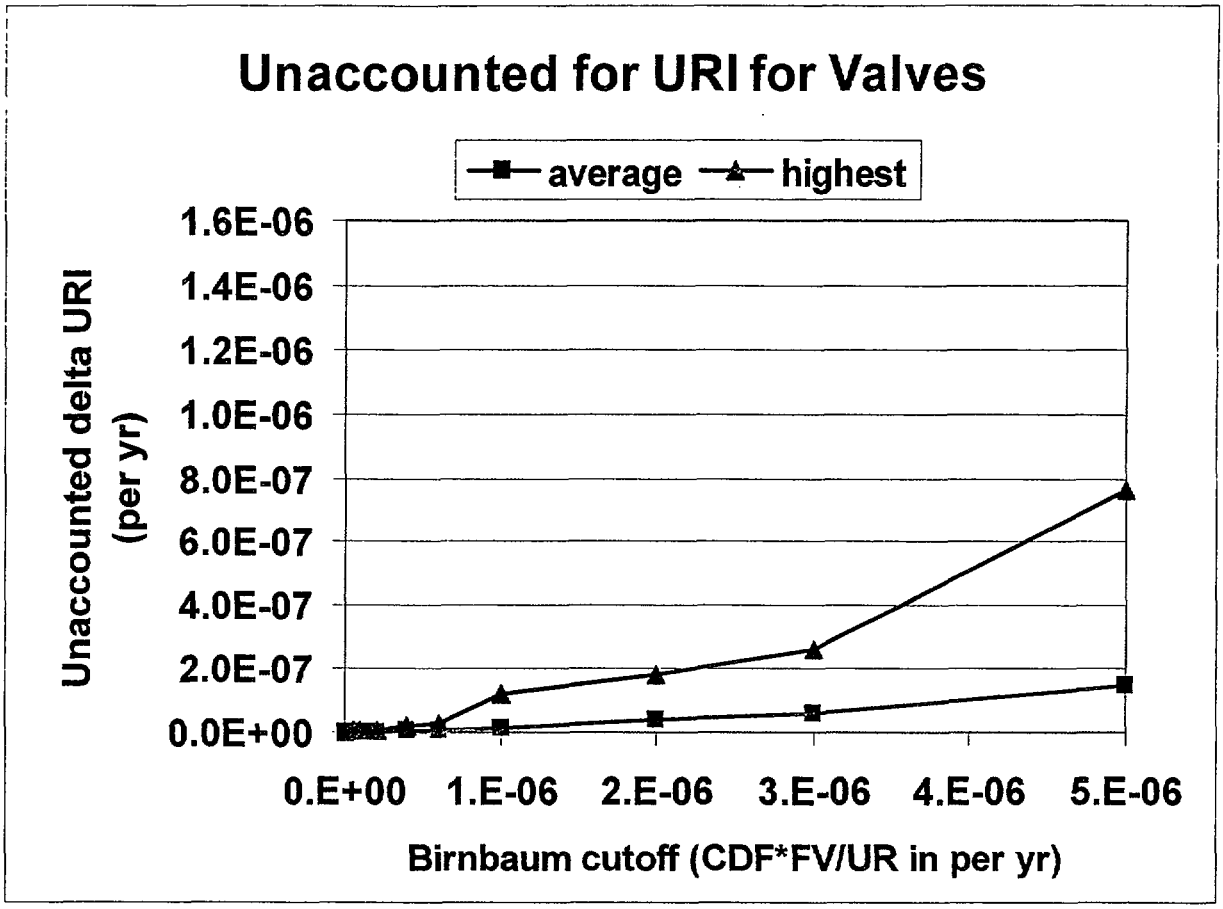
Technical Basis for Exclusion of Active Valves with Low FV/UR and/or Birnbaum

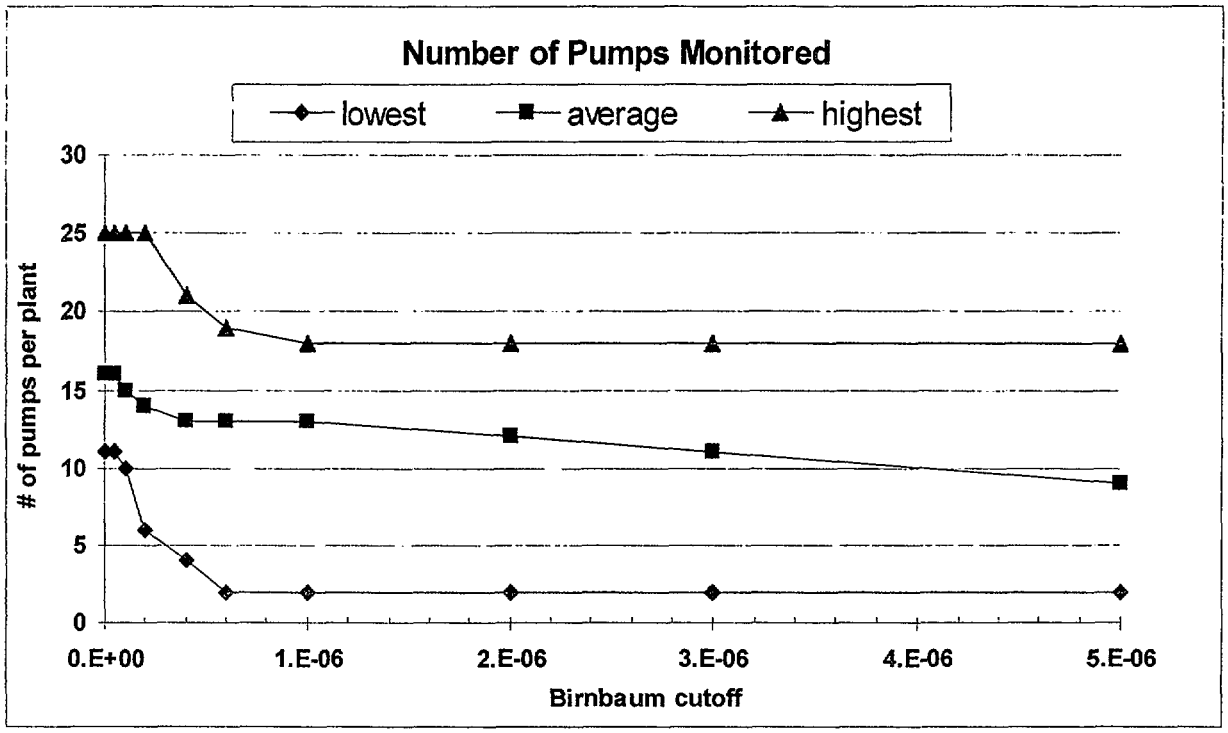
- NEI 99-02 Guidelines:
  - Redundant valves within a train not included...
  - Redundant valves within a multi-train system, whether in series or parallel, where the failure of both valves would prevent all trains in the system from performing a risk-significant function are included.
- Some ambiguity arise when multiple pumps feed common header, with multiple series/parallel valves supplying multiple lines.
- Also, valves on infrequently used test lines, or alternate tank make-up flow paths.
- In some cases, as many as 50 automatic valves may need to be monitored, though some have no contribution to URI.

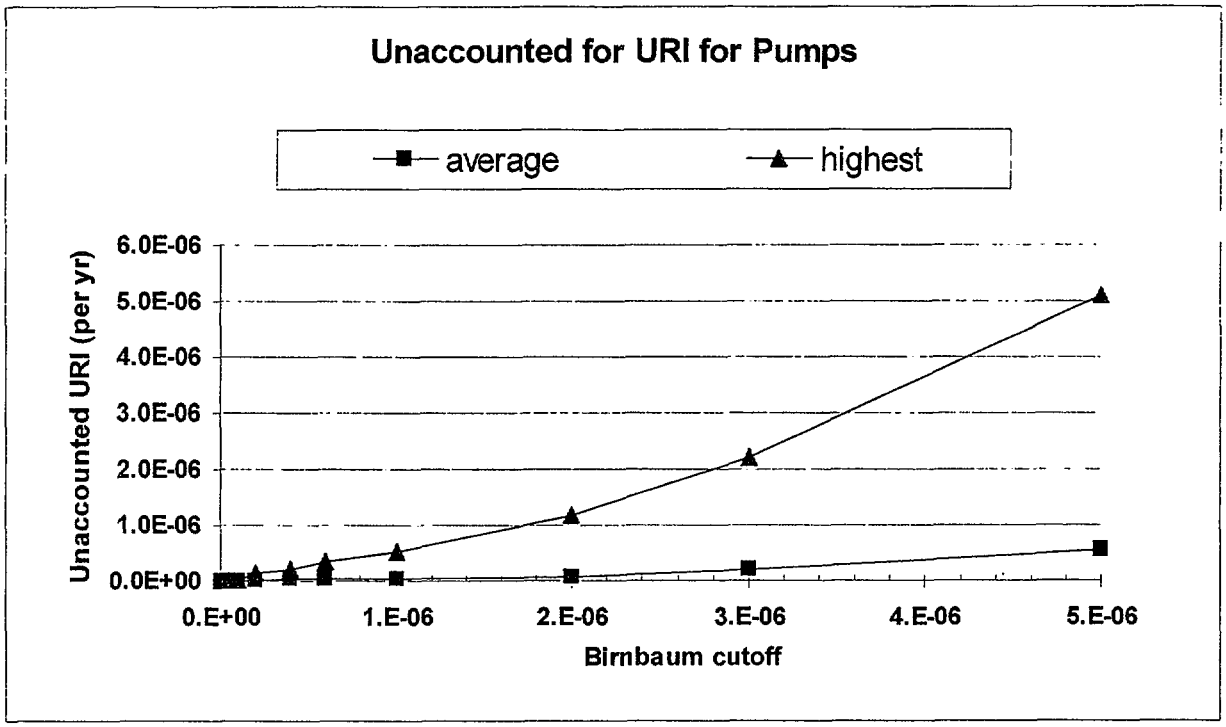

Number of Valves Monitored
lowest
average
highest
# of valves per plant
50
40
30
20
10
0
0.00
0.10
0.20
0.30
0.40
0.50
FV/UR cutoff


Unaccounted for URI for Valves
average
highest
1.6E-06
1.4E-06
1.2E-06
1.0E-06
8.0E-07
6.0E-07
4.0E-07
2.0E-07
0.0E+00
Unaccounted delta URI (per yr)
0.00
0.10
0.20
0.30
0.40
0.50
FV/UR cutoff


Number of Valves Monitored
lowest
average
highest
# of valves per plant
50
40
30
20
10
0
0.E+00
1.E-06
2.E-06
3.E-06
4.E-06
5.E-06
Birnbaum cutoff (CDF*FV/UR in per yr)


Unaccounted for URI for Valves
average
highest
1.6E-06
1.4E-06
1.2E-06
1.0E-06
8.0E-07
6.0E-07
4.0E-07
2.0E-07
0.0E+00
Unaccounted delta URI (per yr)
0.E+00
1.E-06
2.E-06
3.E-06
4.E-06
5.E-06
Birnbaum cutoff (CDF*FV/UR in per yr)


Number of Pumps Monitored
lowest
average
highest
30
25
20
15
10
5
0
# of pumps per plant
0.E+00
1.E-06
2.E-06
3.E-06
4.E-06
5.E-06
Birnbaum cutoff


Unaccounted for URI for Pumps
average
highest
Unaccounted URI (per yr)
6.0E-06
5.0E-06
4.0E-06
3.0E-06
2.0E-06
1.0E-06
0.0E+00
0.E+00
1.E-06
2.E-06
3.E-06
4.E-06
5.E-06
Birnbaum cutoff

Conclusion on Cut-off Criterion

- Exclusion of active valves with FV/UR less than 0.1 or Birnbaum less than about 1E-6/yr would not impact overall system URI from a "false negative" perspective
- However, fewer valves reduces population pool, and could result in more "false positives." The minimum number of valves to be monitored needs to be further explored, but 10 is a reasonable lower limit.
- For pumps, because the average number per plant is low, and the unaccounted for URI can be high, there should be no cut-off.

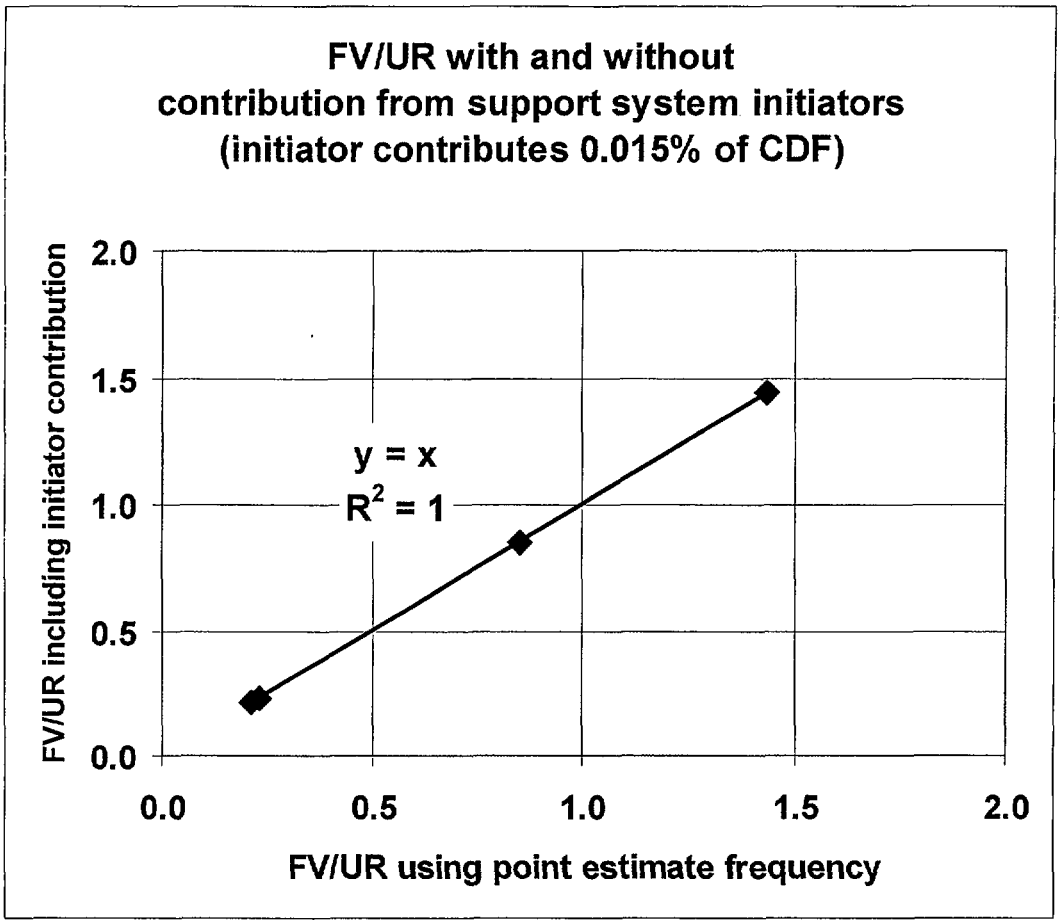
Support System FV for Initiators

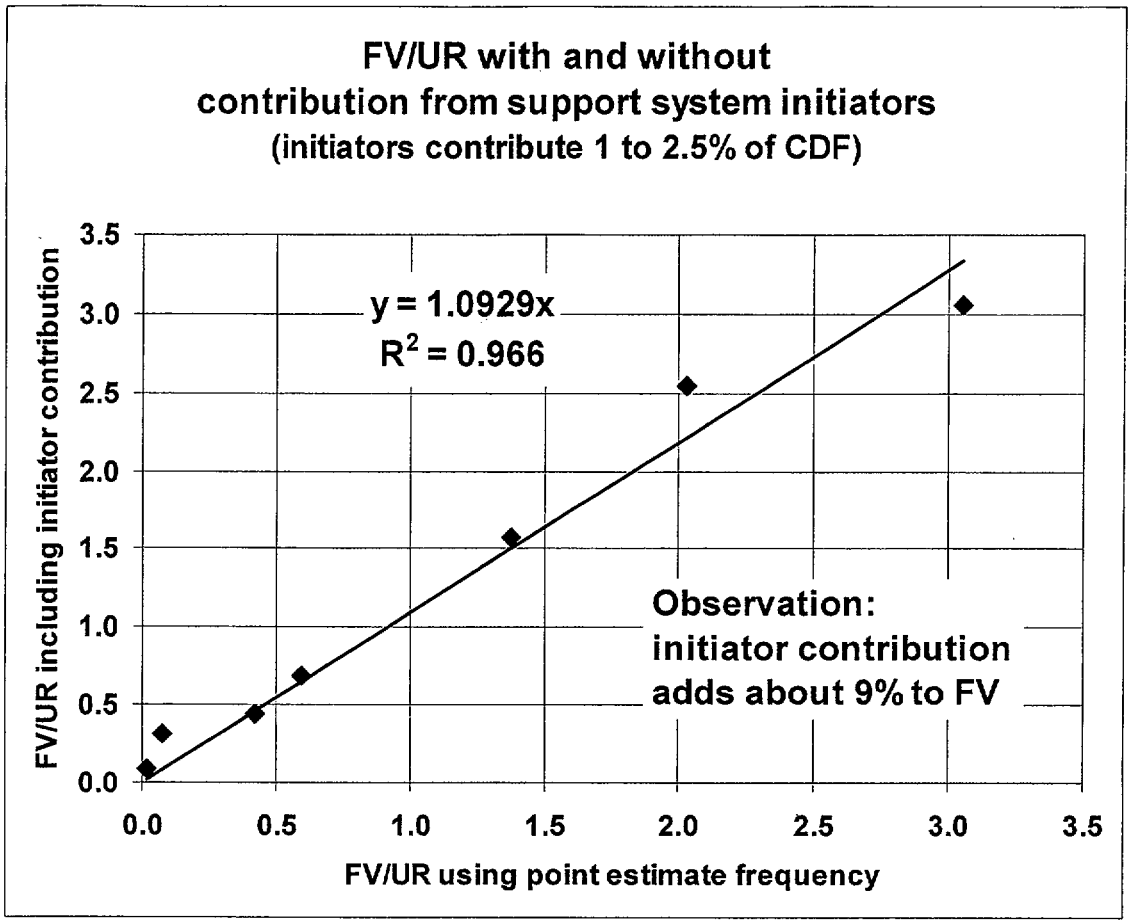
- Failures of components leading to a support system initiator (e.g. loss of service water) contribute to CDF
- About two-thirds of plant PRAs use fault trees to quantify initiating event frequency; the remainder use a point-estimate frequency, based on plant and/or industry experience
- Calculated FV for support system components can differ dramatically from one approach to another, significantly affecting FV/UR

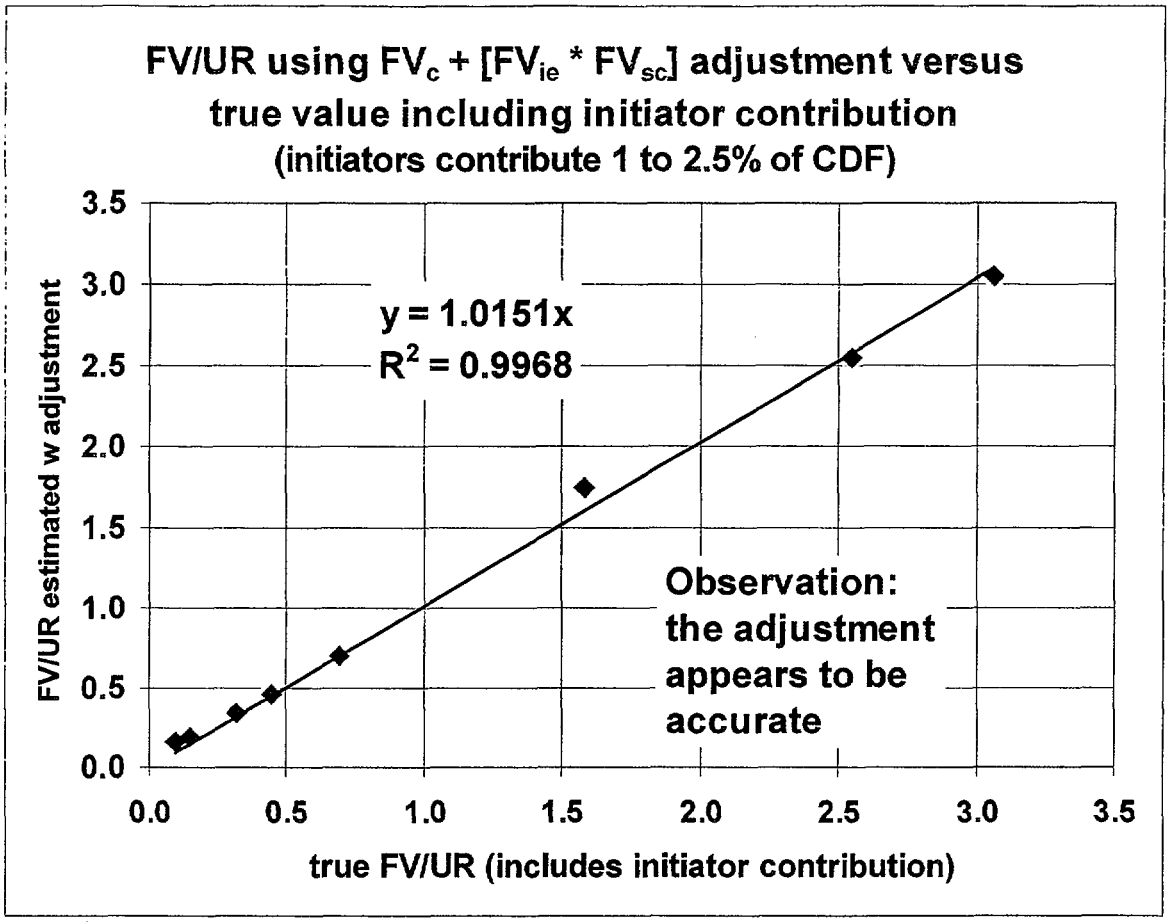
Possible Alternate Approach to Calculate FV for Support System Initiators

- Let FV_c be the Fussell-Vesely for CDF for component c as calculated from the PRA Model. This does not include any contribution from initiating events.
- Let FV_{ie} be the Fussell-Vesely contribution for the initiating event in question (e.g. loss of service water).
- Let FV_{sc} be the Fussell-Vesely *within the system fault tree only* for component c (i.e. the ratio of the sum of the cut sets contribution in which that component appears to the overall system failure probability).
- The adjusted FV is then

$$FV_c + \left[FV_{ie} * FV_{sc} \right]$$


FV/UR with and without
contribution from support system initiators
(initiator contributes 0.015% of CDF)
FV/UR including initiator contribution
2.0
1.5
1.0
0.5
0.0
y = x
R2 = 1
0.0
0.5
1.0
1.5
2.0
FV/UR using point estimate frequency


FV/UR with and without
contribution from support system initiators
(initiators contribute 1 to 2.5% of CDF)
y = 1.0929x
R² = 0.966
Observation:
initiator contribution
adds about 9% to FV
FV/UR including initiator contribution
FV/UR using point estimate frequency
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5


FV/UR using $FV_c + [FV_{ie} * FV_{sc}]$ adjustment versus
true value including initiator contribution
(initiators contribute 1 to 2.5% of CDF)
y = 1.0151x
R^2 = 0.9968
Observation:
the adjustment
appears to be
accurate
FV/UR estimated w adjustment
true FV/UR (includes initiator contribution)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Summary

- Enhanced SPAR models are necessary for Independent Verification of MSPI results.
- Several possible solutions being evaluated to address both Invalid and Insensitive Indicators.
- Including CCF model contribution to FV will lower the Green-White threshold and make it less insensitive. Adjustment factors may be necessary.
- FV/UR < 0.1 or B < 1E-6/yr are good criteria to exclude active valves without impacting results. No cut-off for pumps should be used.
- Industry comparisons for support system initiators show small effect on FV so long as CDF contribution is only a few percent. The Alternate Approximation seems to be accurate if not slightly conservative.
- Resolutions to all technical issues are feasible, but require commitment to implement some alternate solutions.