Mitigating Systems Performance Index Pilot Working Group Public Meeting March 19, 2003

High Level Overview

by

D.A. Dube
Office of Nuclear Regulatory Research

Attachment 3

Status of Independent Verification

- Completed all scheduled TI inspections
- In-depth benchmarking of NEI spreadsheets with SPAR models for all 20 units
- Undertaking effort to reconcile modeling differences between Plant PRA and SPAR models beginning with
  - Braidwood 1 & 2 (preliminary results)
  - San Onofre 2 & 3
  - Palo Verde 1, 2 & 3
  - Limerick 1 & 2
  - Salem 1 & 2
- All other Pilot Plants to follow
- Will extend completion of verification to no sooner than May 2003 from original target of March 2003

Requested Information for SPAR Model Improvement

- 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, or *.pdf), showing branch split fractions and sequence names/number if possible.
- Information received from Braidwood, San Onofre, Palo Verde, and Salem
- Awaiting information from Limerick, Millstone, Hope Creek, South Texas, Surry, and Prairie Island

Summary of Results for Braidwood

- Internal events CDF
  - Plant PRA = 3.0E-5 /yr
  - "Old" SPAR Model = 6.1E-5 /yr
  - "New" SPAR Model = 2.8E-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 2 (high or low).

Braidwood	FV/UR ratio	
Component	old SPAR/Plant PRA	new SPAR/Plant PRA
RHR Pump 1B	0.1	1.12
AFW Pump 1B	8.33	1.96
EDG 1A	0.32	0.98
SW Pump 1B	0.06	1.82
VCT Outlet Isol valve	0.14	1.24

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Top 5 Technical Issues

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Top 5 Technical Issues

- Invalid and insensitive indicators
- Treatment of Common Cause in FV determination and consequent delta CDF
- System boundaries
- Technical basis for excluding active valves with low FV/UR
- Support system initiators and impact on FV

Invalid and Insensitive Indicators

- Using the SPAR Models, about 20% of the MSPI systems have at least one component that would give an invalid indicator based on the current approach (0 to 1, or N to N+1)
- Using Plant PRA Models, 38% of systems have at least one component giving invalid indication
- About 5% of all components within scope of MSPI pose an invalid indicator problem based on the current analytical approach
  - Most often, steam-driven or diesel-driven pumps
  - Several instances of emergency diesel generators
  - Several instances of service water system pumps
  - Rarely, automatic valves

Invalid and Insensitive Indicators (cont.)

- Using most recent equipment performance data reduces the number of systems with invalid indicators in half
- Number of systems with invalid indication is sensitive to mission time. Mission time varies significantly for Emergency Diesel Generators from one Plant PRA Model to another.

Comparison of Generic Failure Rates

Component	Failure Mode	Existing Table 2 (note a)	Component Studies (1987 - 1995)(note c)	Pilot Plant Data (3Q99 - 2Q02) (note e)	EPIX (All Plants) "Year 2000" (1999 - 2001) (note f)
MOV	FTO/C	2.1E-03	~1.4E-03	7.8E-04	7.2E-04
AOV	FTO/C	2.0E-03	~1.8E-03	5.1E-04	1.4E-03
MDP (STBY)	FTS	2.1E-03	1.6E-03	1.0E-03	1.4E-03
	FTR (<1h)	Included in FTS		Included in FTS	9.3E-4/h
	FTR (>1h)	1.0E-4/h		6.7E-5/h	5.1E-5/h
MDP (Running)	FTS	3.0E-03		3.4E-04	1.2E-03
	FTR	3.0E-5/h		7.7E-6/h	4.9E-6/h
TDP (AFWS)	FTS	1.9E-02	5.8E-03	2.6E-03	5.5E-03
	FTR (<1h)	Included in FTS		Included in FTS	3.2E-3/h
	FTR (>1h)	1.6E-3/h		8.4E-4/h	<2.2E-4/h
TDP (HPCI/RCIC)	FTS	2.7E-02	~6.4E-03	<5.1E-3	1.5E-02
	FTR (<1h)	Included in FTS		Included in FTS	3.2E-3/h
	FTR (>1h)	1.6E-3/h		<1.7E-3/h	<2.2E-4/h
DDP (AFWS)	FTS	1.9E-02		2.3E-02	8.7E-03
	FTR (<1h)	Included in FTS		Included in FTS	<3.2E-3/h
	FTR (>1h)	8.0E-4/h		3.0E-2/h	No data
EDG	FTS	1.1E-02		2.6E-03	4.7E-03
	FTLR (<1h)	1.7E-03		4.1E-03	3.0E-03
	FTR (>1h)	2.3E-4/h		1.1E-3/h	7.9E-4/h
Circuit Breaker	FTO/C	3.00E-03			7.90E-04

Invalid Indicators by System
(work in progress)

SPAR Model	EAC		HPI		HRS		RHR		SWS		CCW	
	0 to 1	N to N+1	0 to 1	N to N+1	0 to 1	N to N+1	0 to 1	N to N+1	0 to 1	N to N+1	0 to 1	N to N+1
Braidwood 1	0	0	0	0	1	1	0	0	0	0	0	0
Braidwood 2	0	0	0	0	1	1	0	0	0	0	0	0
Hope Creek												
Limerick 1	0	0	0	0	0	0	0	0	0	0	n/a	n/a
Limerick 2	0	0	0	0	0	0	0	0	0	0	n/a	n/a
Millstone 2												
Millstone 3												
Palo Verde 1	0	1	0	0	1	1	0	0	0	1	0	0
Palo Verde 2	0	1	0	0	1	1	0	0	0	1	0	0
Palo Verde 3	0	1	0	0	1	1	0	0	0	1	0	0
Prairie Island 1	0	0	0	0	0	1	0	0	0	0	0	0
Prairie Island 2	0	0	0	0	0	1	0	0	0	0	0	0
Salem 1	0	0	0	0	1	1	0	0	0	0	0	0
Salem 2	0	0	0	0	1	1	0	0	0	0	0	0
San Onofre 2	0	0	0	0	0	1	0	0	0	0	0	0
San Onofre 3	0	0	0	0	0	1	0	0	0	0	0	0
South Texas 1	0	0	0	0	1	1	0	0	0	0	0	0
South Texas 2	0	1	0	0	1	1	0	0	0	1	0	0
Surry 1	0	0	0	0	0	0	0	0	0	0	0	0
Surry 2	0	0	0	0	0	0	0	0	0	0	0	0

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

Insensitive Indicator Study: "Composite" Steam-Driven AFW Pump from All Pilot Plant PWRs

Mean FTS Table	
# FTS	URI-no UA
0	-2.1E-06
1	-3.59E-07
2	1.38E-06
3	3.128E-06
4	4.872E-06
5	6.62E-06
6	8.36E-06
7	1.01E-05

Mean FTR Table	
# FTR	URI-no UA
0	-2.10E-06
1	3.42E-06
2	8.94E-06
3	1.45E-05
4	2.00E-05
5	2.55E-05
6	3.10E-05
7	3.65E-05
8	4.21E-05
9	4.76E-05
10	5.31E-05
11	5.86E-05
12	6.41E-05
13	6.96E-05
14	7.52E-05
15	8.07E-05
16	8.62E-05
17	9.17E-05
18	9.72E-05
19	1.03E-04

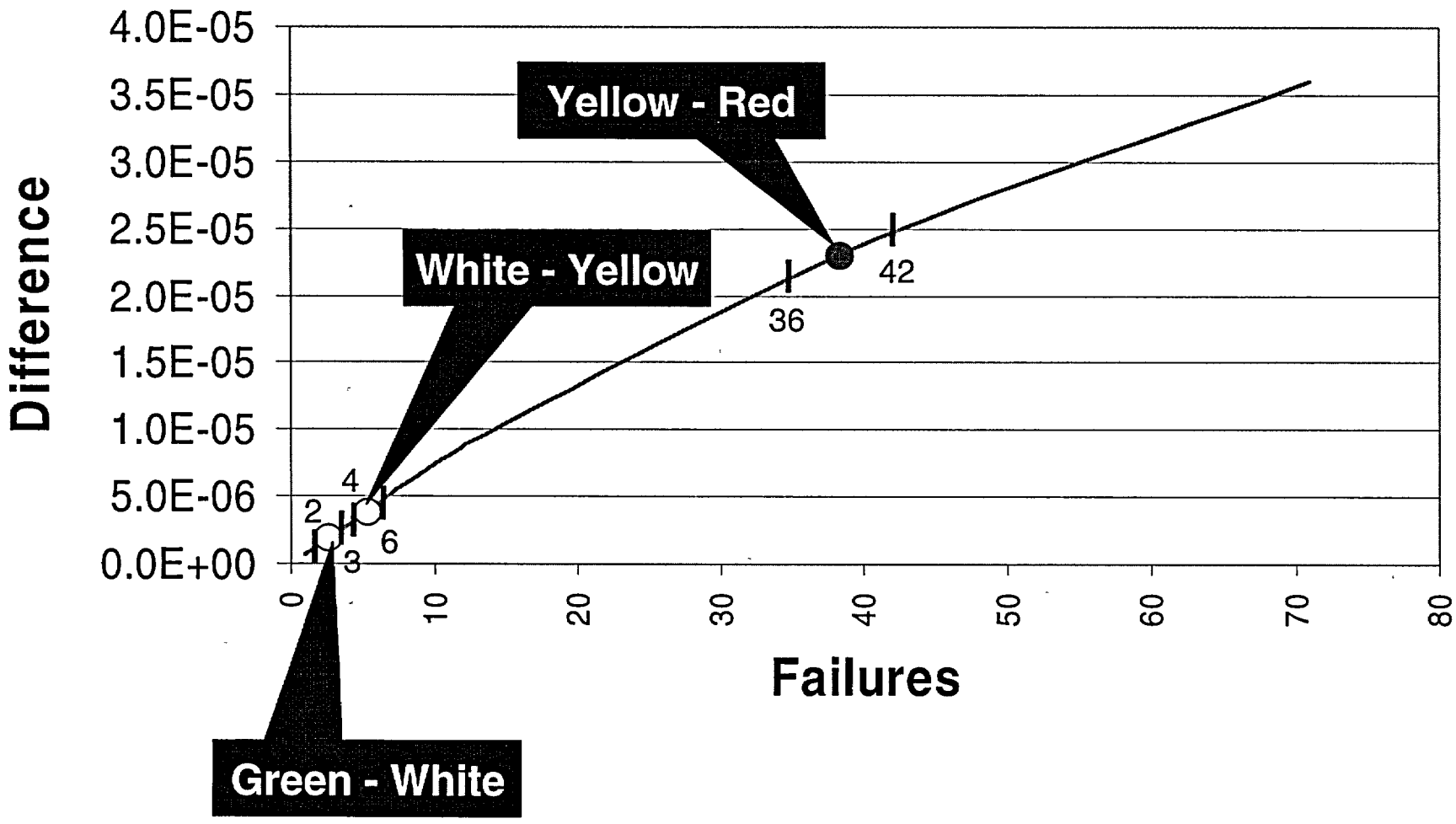
Insensitive Indicator Study: Failures to Reach G-W Threshold (San Onofre)

System	Component	Failure Mode	Unit 2 Plant PRA Model	
			# Failures to White	FV/UR
EAC	EDG	FTS	> 20	0.06
		FTLR	> 20	0.06
		FTR	> 20	0.06
HPI	MDP-SBY	FTS	7	1.93
		FTR	6	1.93
	MOV	FTO/C	1	4.46
HRS	MDP-SBY	FTS	14	1.90
		FTR	10	1.90
	TDP-AFW	FTS	7	2.45
		FTR	3	2.45
	MOV	FTO/C	11	4.32
RHR	MDP-SBY	FTS	> 20	0.02
		FTR	> 20	0.02
	MOV	FTO/C	1	7.49
SWS	MDP	FTS	5	2.61
		FTR	17	2.61
	AOV	FTO/C	5	0.51
CCW	MDP	FTS	3	4.26
		FTR	10	4.26

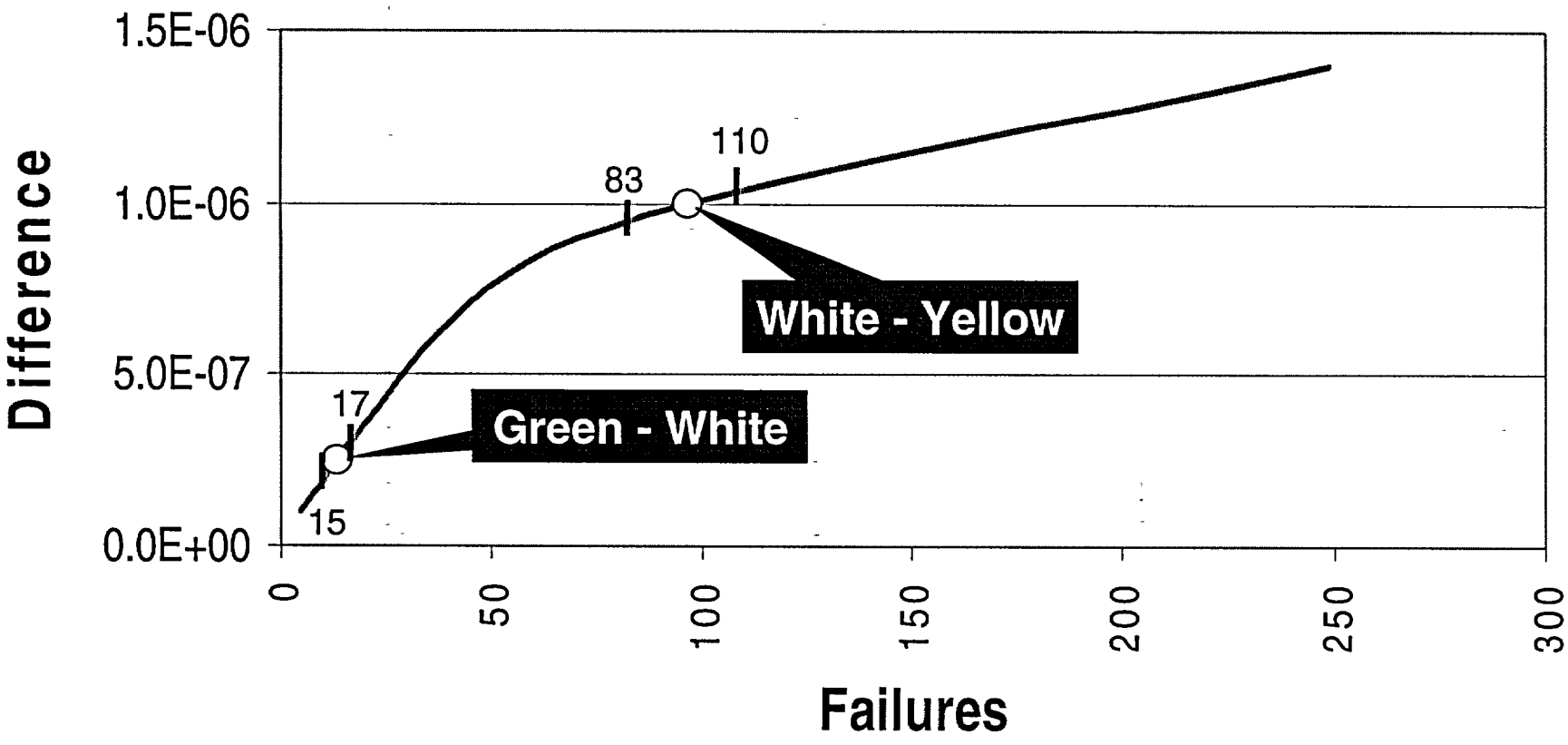
Sensitivity of Green-White Threshold to Common Cause Failure Model Contribution

Hope Creek Safety Auxiliary Cooling Pumps
Common Cause Sensitivity
Case 1

Palo Verde Spray Pond Pumps
Common Cause Sensitivity
Case 3



Palo Verde Containment Spray Pumps
Common Cause Sensitivity
Case 5



System Boundary Issues

- Refer to guidelines in NEI 99-02
- Additional generic discussion provided at January 2003 Workshop
- Plant-specific issues raised during Temporary Instruction inspections has been forwarded and must be addressed by licensees
- Final requested resolution of outstanding system boundary issues by FAQ by April 19
- Final resolution by May 18

Information Needed for FAQ for System Boundary Resolution

- Description of component in question
- Function of component
- Alternate means of providing same function, if any
- Simplified schematic of system
- FV and basic event probability
- Basis for excluding component

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

- **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.**

Technical Basis for Exclusion of Active Valves with Low FV/UR (cont.)

- Exclude valves whose contribution to URI under conservative assumptions amount to less than 1% of the 1E-6/yr Green-White threshold
- Re-arrange and simplify URI = CDF Σ $[FV/UR]_{max}$ $(UR - UR_{BL})$ to get

$$FV/UR < 1E\text{-}8 / [\ CDF * (\ UR_B - UR_{BL}\ )\ ]$$

- Maximize the above using

  CDF = 1E-4

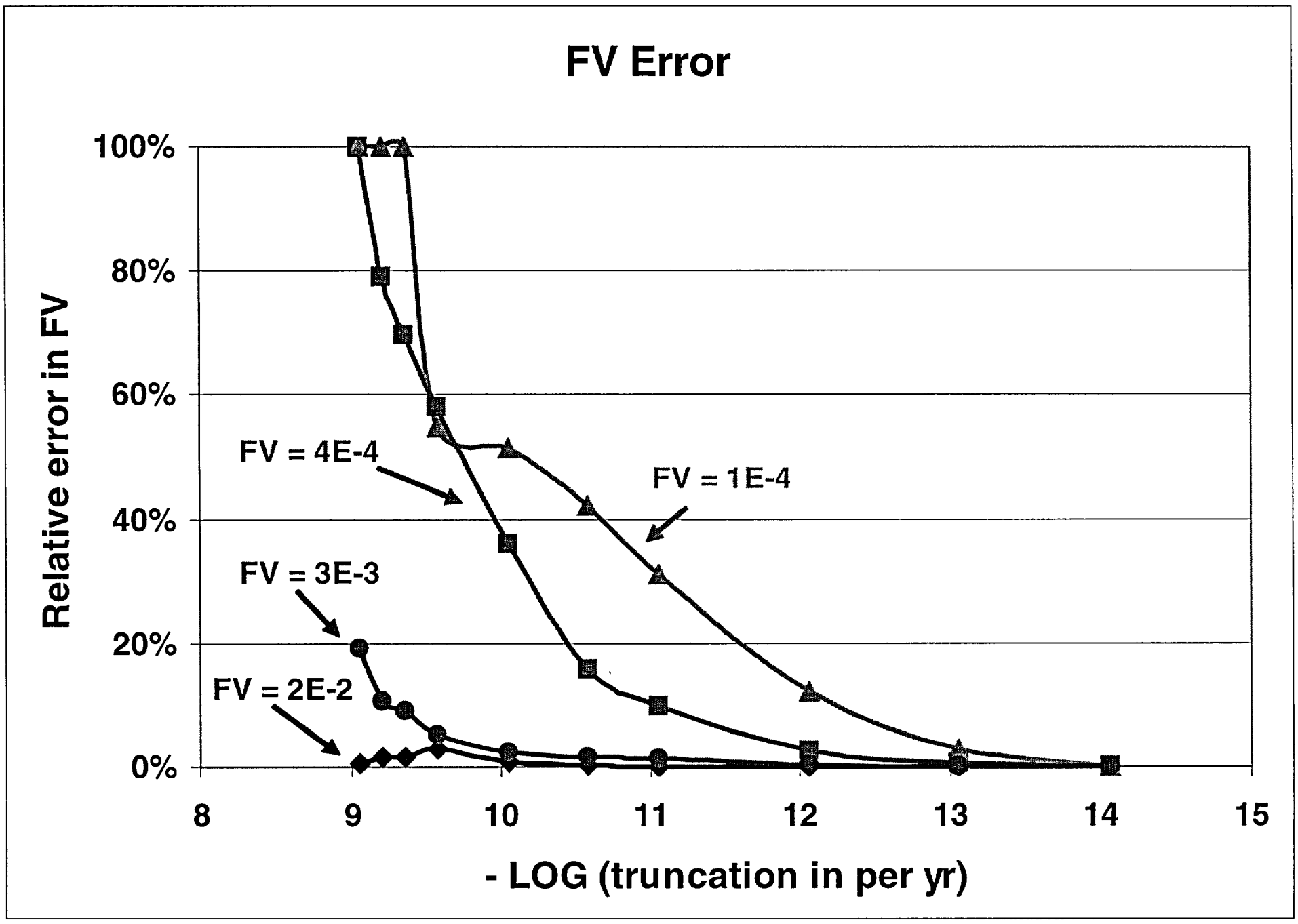
  $UR_B - UR_{BL}$ = 1E-2

FV/UR < 0.01 as a criterion to exclude active valves

Validation of FV/UR Criterion

Table 1. Effect on URI of removing components with low FV/UR values

Plant	System	Component	Type	Plant PRA FV/UR	Component 2nd QTR URI	Component URI with 3 failures
Limerick-2	HPI	2F041	MOV	5.19E-03	-2.27E-11	1.35E-10
SONGS-3	HPI	3HV9434	MOV	7.63E-03	-5.40E-11	1.48E-09
SONGS-3	AFW	3HV4713	MOV	4.88E-03	-9.46E-11	5.24E-10
SONGS-3	RHR	3HV9368	MOV	1.11E-02	-1.07E-10	1.95E-09
Surry-1	AFW	1-FW-MOV-160A	MOV	8.32E-03	-6.24E-11	2.69E-09
Surry-1	RHR	1-SI-MOV-1864A	MOV	7.29E-04	-1.43E-11	1.74E-10
Braidwood-1	RHR	1RH8716A	MOV	1.14E-02	-3.32E-10	2.00E-09
Prairie Island-2	HPI	MV-32198	MOV	6.37E-03	-8.29E-11	1.19E-09
Salem-1	AFW	11AF52	AOV	6.60E-03	-2.33E-10	1.84E-09
Hope Creek	SW	2371A	AOV	4.00E-03	-4.30E-11	1.15E-10


FV Error
Relative error in FV
100%
80%
60%
40%
20%
0%
FV = 4E-4
FV = 1E-4
FV = 3E-3
FV = 2E-2
8
9
10
11
12
13
14
15
- LOG (truncation in per yr)

Conclusion on FV/UR Criterion

- Exclusion of active valves with FV/UR less than 0.01 would not impact overall system URI from a "false negative" perspective
- However, fewer valves reduces population pool, and could result in more "false positives."
- Exclusion of valves should be reserved for situation with burdensome number of active valves that otherwise would be monitored.
- Truncation limit must be adequately low to ensure that FV has converged.

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
- Probably accounts for FV/UR varying by three orders of magnitude for service water pump from one plant PRA to the next in the Pilot Program

Support System FV for Initiators (cont.)

- For Plant PRA models that include support system initiator fault trees, issue is resolved assuming that the same basic event names are used in the system and initiator fault trees.
- For Plants with Emergency Service Water and/or Safety Auxiliary Cooling systems that are standby only, issue is moot. No further work necessary.
- For Plants where a point-estimate initiator is used for loss of service water and/or loss of component cooling water, an alternate approach may be possible.

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

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

Alternate Approach to Calculate FV for Support System Initiators - Example

- Assume that the FV for service water pump "A" fail-to-start is determined to be 0.01 (i.e. $FV_c = 0.01$).
- Assume that the Loss of Service Water initiator contributes 5% to CDF (i.e. $FV_{ie} = 0.05$).
- Assume that the service water system failure probability is 1E-4 as calculated by the fault tree. Service water pump "A" FTS appears in cut sets in the fault tree summing to 2E-5 failure probability. Thus, $FV_{sc} = 2E\text{-}5/1E\text{-}4 = 0.2$
- The adjusted FV for service water pump "A" FTS is

  $0.01 + 0.05 * 0.2 = 0.02$

- If the service water pump FTS were 4E-3, then

  FV/UR (adjusted) = 0.02 / 4E-3 = 5

Alternate Approach to Calculate FV for Support System Initiators - Caveat

This approach assumes that the support system initiator fault tree is the same as the system fault tree. That is, the success criteria and basic event probabilities as an initiator and as a support system are identical.

Summary

- Progress is being made on reconciliation of large differences in FV between Plant PRA and SPAR models. Request licensees provide PRA model details.
- Invalid indicators falling into a pattern. Insensitive indicators just now being fully understood. Several possible solutions being evaluated.
- Including CCF model contribution to FV will lower the Green-White threshold and make it less insensitive. This needs serious consideration.
- FV/UR < 0.01 is a good criterion to exclude active valves without impacting results when burdensome.
- Alternate approach possible to include contribution of support system initiators to FV where appropriate. We will need industry participation to investigate feasibility.