CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Reactor Safeguards

Docket Number: (Not Available)

Location: Rockville, Maryland

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Rebecca Davis

Rebecca Davis
Official Reporter
Neal R. Gross & Co., Inc.

REVISED 4/10/01

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE SUBCOMMITTEE ON RELIABILITY AND PROBABILISTIC RISK ASSESSMENT
ROOM T-2B3, 11545 ROCKVILLE PIKE, ROCKVILLE, MD
April 17, 2000

ACRS Contact: Michael T. Markley (301) 415-6885
E-mail: mtm@nrc.gov

- PROPOSED SCHEDULE -

	TOPIC	PRESENTER	TIME
1)	**Introduction**		8:30-8:35 am
•	Review goals and objectives for this meeting; past ACRS deliberations on risk-based performance indicators (RBPIs)	G. Apostolakis, ACRS	
2)	**NRC Staff Presentation**		8:35-10:15 am
•	Background/Introduction - Relations of RBPIs to Revised Reactor Oversight Process (RROP) - RBPI definitions/characteristics - Potential benefits	M. Johnson, NRR P. Baranowsky, RES	
•	RBPI development process	S. Mays, RES H. Hamzehee, RES	
•	Summary of results - Initiating events: full-power/internal - Mitigating systems: full power/internal - Containment - Shutdown - Fire events - Industry-wide trending - Risk coverage - Verification and validation results	S. Mays, RES H. Hamzehee, RES	
	**** BREAK ****		10:15-10:30 am
3)	**NRC Staff Presentation - continued**		10:30-12:00 noon
•	RBPI development process	S. Mays, RES H. Hamzehee, RES	

•	Summary of results - Initiating events: full-power/internal - Mitigating systems: full power/internal - Containment - Shutdown - Fire events - Industry-wide trending - Risk coverage - Verification and validation results	S. Mays, RES H. Hamzehee, RES	
	**** LUNCH ****		12:00-1:00 pm
4)	**NRC Staff Presentation - continued**		1:00-1:45 pm
•	Discussion of implementation issues	S. Mays, RES H. Hamzehee, RES	
•	Discussion of industry comments	S. Mays, RES H. Hamzehee, RES	
5)	**Industry Comments**		1:45-2:15 pm
•	Industry perspectives on RBPIs	T. Houghton, NEI	
6)	**General Discussion and Adjournment**		2:15-2:30 pm
•	General discussion and comments by Members of the Subcommittee; items for May 10-12, 2000 ACRS meeting	G. Apostolakis, ACRS	

Note: **Presentation time should not exceed 50% of the total time allocated for a specific item. Number of copies of presentation materials to be provided to the ACRS - 35.**

INTRODUCTORY STATEMENT BY THE CHAIRMAN OF THE
MEETING OF THE ACRS SUBCOMMITTEE ON
RELIABILITY AND PROBABILISTIC RISK ASSESSMENT
11545 ROCKVILLE PIKE, ROOM T-2B3
ROCKVILLE, MARYLAND
APRIL 17, 2001

The meeting will now come to order. This is a meeting of the Advisory Committee on Reactor Safeguards (ACRS) Subcommittee on Reliability and Probabilistic Risk Assessment. I am George Apostolakis, Chairman of the Subcommittee.

Subcommittee Members in attendance are Mario Bonaca, Thomas Kress, Graham Leitch, and Robert Uhrig.

The purpose of this meeting is to discuss the results of the staff's Phase 1effort to develop risk-based performance indicators. The Subcommittees will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee. Michael T. Markley is the Cognizant ACRS Staff Engineer for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the *Federal Register* on March 26, 2001.

A transcript of the meeting is being kept and will be made available as stated in the Federal Register Notice. It is requested that speakers first identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

We have received no written comments or requests for time to make oral statements from members of the public regarding today's meeting.

(Chairman's Comments-if any)

We will now proceed with the meeting and I call upon Messrs. Mike Johnson, NRR, and Pat Baranowsky, RES, to begin.

RISK-BASED PERFORMANCE INDICATORS

RESULTS OF PHASE-1 DEVELOPMENT

PRESENTATION TO ACRS SUBCOMMITTEE ON PRA

Steven E. Mays, 415-7496
Hossein G. Hamzehee, 415-6228
Office of Nuclear Regulatory Research
Michael R. Johnson
Office of Nuclear Reactor Regulation

March 17, 2001

Phase-1 RBPI Development Results

- The purpose of this presentation is to provide an understanding of:
  - Perspective on relationship of RBPIs to ROP
  - Potential benefits of proposed RBPIs
  - RBPI development process
  - Summary of RBPI development results
  - Perspective on industry trending in ROP and other programs
- We are looking for ACRS feedback (via a letter) on:
  - Potential benefits to ROP
  - Technical adequacy of RBPIs as enhancement to ROP
  - Alternate approaches to RBPIs in response to concern over the total number of RBPIs

Phase-1 RBPI Development Results

- **Briefing includes:**
  - Relationship of RBPIs to ROP
  - Potential benefits of proposed RBPIs
  - RBPI development process
  - Summary of results
  - Key implementation issues
  - Alternate approaches for RBPI determination

<u>Presentation by NRR On Relationship of RBPIs to ROP</u>

Phase-1 RBPI Development Results

Relationship of RBPIs to ROP:

- Goals of Commission PRA Policy Statement and NRC Strategic Plan (NUREG) are to better risk-inform NRC processes.

- ROP was revised to be more risk-informed, objective, understandable, and more predictable than previous oversight process.

- Continuing advances in industry use of information technology and data

  - Gathering/analyzing more plant-specific and industry-wide data
  - Internet and micro-computers allow improved capabilities to gather/share data
  - NRC and industry continue to expand their capabilities to model/assess risk-significant attributes of plant operations

Phase-1 RBPI Development Results

Relationship of RBPIs to ROP (cont'd):

- As discussed in SECY-99-007 and 99-007A, ROP uses both inspection findings and performance indicators

- As discussed in SECY-00-049, while future success of the ROP is not predicated on the RBPI program, RBPIs would potentially support:

  - Enhancements to specific areas in current ROP where RBPIs may be applicable
  - Future development of more plant specific PIs using improved risk analysis tools

- In response to NRR User Need Letter, RES examined feasibility of selected RBPIs as part of Phase-1 report.

  - Reliability indicators
  - Unavailability indicators
  - Shutdown and fire indicators
  - Containment indicators

Phase-1 RBPI Development Results

Relationship of RBPIs to ROP (cont'd):

- Several key implementation issues are identified in Section 5 of Phase-1 report, some of which are:
  - Data quality and availability
  - SPAR model development and V &V
- Process for potential integration of RBPIs with ROP
  - Assess feedback from stakeholders on Phase-1 report to ascertain an appropriate course of action
  - Consideration of safety benefits/costs
  - Follow process for changing ROP performance indicators in IMC0608, which includes opportunity for stakeholder involvement
  - A pilot program would be conducted prior to considering any RBPIs for full implementation
  - Additional PIs may require re-assessment of ROP Action Matrix

Presentation by RES on Phase-1 RBPI Development Results

Phase-1 RBPI Development Results

Potential Benefits of Proposed RBPIs:

- **Broader sample of plant performance impacting risk than current ROP indicators. Provides more objective indication of plant performance to licensees, NRC, and the public.**

  - **Consistent with NEI 96-04**

    "..... a regulatory approach in which operating experience and engineering judgement are used in concert with the analytical insights derived from probabilistic safety assessment to focus licensee and regulatory attention on design and operational issues commensurate with their importance to public health and safety...."

    "....Performance based regulation is defined as a regulatory approach that focuses on results as the primary means of regulatory oversight, and that has the following attributes:
    - **Measurable parameters to monitor plant and licensee performance;**
    - **Objective criteria to assess performance based on risk insights, deterministic analyses and/or performance history, and**
    - **Licensee flexibility to determine how to meet established performance criteria......"**

  - **More systems/components covered by objective, risk-informed, performance-based methods.**

  - **Cross-cutting indicators across system boundaries provide objective, risk-informed, and performance-based measures of the effects of programmatic performance.**

Phase-1 RBPI Development Results

Potential Benefits of Proposed RBPIs (cont'd):

- Better understanding of plant-specific risk implications than current ROP indicators
  - Thresholds are set based on plant-specific design features and their risk contributions. These focus attention on those performance areas that are more representative of plant risk, and provide better indication of where potential problems are.
  - No averaging of diverse system trains which can mask actual risk contribution
  - Failures affecting reliability/availability are based on loss of risk-significant functions, not design-basis functions
    - Auto initiation failures do not necessarily equate to total system/function failure.
    - Credit for manual actuations are included in the models and thresholds consistent with their risk significance.
    - Fault exposure time is more consistently accounted for in RBPIs
      - Accounts for varying test interval
      - Better association with demand failure probability versus unavailability
      - More consistent with PRA treatment

Phase-1 RBPI Development Results

Potential Benefits of Proposed RBPIs (Cont'd):

- RBPI process will look similar to performance indicators in the current ROP
  - Uses same color scheme
  - Are amenable to similar presentation
  - Can be updated in a similar fashion
- RBPIs can be implemented in part rather than as an entire set.
  - RBPIs with most benefit can be implemented first, and others as needed.
  - RBPIs with readily available data can be implemented while other data being gathered/evaluated.
- RBPIs are a straightforward extension of existing models, data, and capabilities. No significant new infrastructure is needed to support them.
  - Use available off-the-shelf risk models and reliability technology
  - Required analyses are simple and routine
  - Most of data were obtained from currently available databases
  - Proposed new data are easy to get, and are simple extension of existing data

Phase-1 RBPI Development Results

RBPI Development Process:

- RBPIs were developed using four major steps:

  1. Assess potential risk impact of degraded performance
  2. Obtain performance data for risk-significant elements
  3. Identify indicators capable of detecting performance changes in a timely manner
  4. Identify performance thresholds consistent with a graded approach to performance evaluation from SECY 99-007

- Successful development of potential RBPIs requires:

  - Models that reasonably reflect risk impact
  - Baseline performance for setting thresholds
  - Ongoing performance data for assessing plant-specific performance against performance thresholds

Summary of RBPI development Results

Initiating Events - Full Power, Internal Events:

- Three data sources used in initiating event selection are:
  - NUREG/CR-5750
  - SCSS (LERs)
  - MORs

- Three RBPIs for each plant under IE cornerstone are identified
  - Table 3.1.1-1, IE RBPIs and example thresholds
  - Detailed plant-specific threshold information for 23 plants based on Rev 3i SPAR models are included in App. A

- Considered three potential choices for prior distributions
  - Non-informative (classical statistical approach)
  - Industry prior
  - Constrained non-informative prior

- Considered time frames for detecting performance in timely manner
  - Between 1 and 5 years
  - Used shortest prior that satisfied:
    - False negative rate <5%
    - False positive rate <20%

- All IE indicators used constrained non-informative prior. GT used 1 year, LOFW and LOHS used 3 years.

Table 3.1.1-1 Initiating Event RBPIs

RBPIs & Example Thresholds for BWR 3/4 Plant 18					
Initiator RBPI	Baseline Frequency (NUREG/CR-5750)	Green/White 95^{th}%ile	Green/White ΔCDF=1E-6/yr[a]	White/Yellow ΔCDF=1E-5/yr[a]	Yellow/Red ΔCDF=1E-4/yr[a]
General Transient (GT)	1.3 / year[a]	2.2 / year	2.0 / year[a]	7.9 / year[a]	67 / year[a]
Loss of Feedwater (LOFW)	6.8E-2 / year[a]	2.0E-1 / year	3.0E-1 / year[a]	2.5 / year[a]	24 / year[a]
Loss of Heat Sink (LOHS)	2.3E-1 / year[a]	3.1E-1 / year	4.1E-1 / year[a]	3.4 / year[a]	33 / year[a]
RBPIs & Example Thresholds for WE 4-Lp Plant 22					
Initiator RBPI	Baseline Frequency (NUREG/CR-5750)	Green/White 95^{th}%ile	Green/White ΔCDF=1E-6/yr[a]	White/Yellow ΔCDF=1E-5/yr[a]	Yellow/Red ΔCDF=1E-4/yr[a]
General Transient (GT)	1.0 / year[a]	1.8 / year	1.8 / year[a]	8.8 / year[a]	78 / year[a]
Loss of Feedwater (LOFW)	6.8E-2 / year[a]	2.0E-1 / year	8.0E-1 / year[a]	7.2 / year[a]	74 / year[a]
Loss of Heat Sink (LOHS)	9.6E-2 / year[a]	2.6E-1 / year	2.4E-1 / year[a]	1.5 / year[a]	15 / year[a]

- Year refers to a calendar year assumed to include 7000 critical hours.

Summary of RBPI development Results

Mitigating Systems - Full Power, Internal Events:

- Thirteen mitigating systems/component class RBPIs are identified for BWRs and eighteen for PWRs.
  - Rev 3i SPAR models (for plant-specific threshold evaluation)
  - Results are summarized in Table 3.1.2-1
  - Examples of plant-specific thresholds for two plants presented in Table 3.1.2-2 and 3.1.2.3
  - Detailed plant-specific threshold information for 23 plants are in App. A

- Primary data sources used in selection of mitigating systems RBPIs are:
  - RES System reliability studies (for baseline performance evaluation)
  - EPIX (for reliability data)
  - ROP data (for unavailability data)

- Used process similar to IE indicators for reliability indicators for selecting priors and intervals.

- Chose non-informative priors with 3 year periods.

- Several reliability indicators potentially had >20% false positive rate for crossing white threshold. Added indications of the likelihood that mean was still at or below the baseline value.

Table 3.1.2-1 Candidate Mitigating System RBPIs

BWR RBPI SYSTEMS	RBPI Parameter and Level
Emergency AC Power (EPS)	Unreliability and unavailability at the train level.
High Pressure Coolant Injection Systems • High Pressure Coolant Injection (HPCI) • High Pressure Core Spray (HPCS)	Unreliability and unavailability at the train level.
High Pressure Heat Removal Systems • Isolation Condenser (IC) • Reactor Core Isolation Cooling (RCIC)	Unreliability and unavailability at the train level.
Residual Heat Removal (SPC, RHR)	Unreliability and unavailability at the train level.
Service Water (SWS)	Unreliability and unavailability at the train level.
PWR RBPI SYSTEMS	
Auxiliary Feedwater (AFW/EFW) • Motor-driven Pump Train • Turbine-driven Pump Train	 Unreliability and unavailability at the train level. Unreliability and unavailability at the train level.
Component Cooling Water (CCW)	Unreliability and unavailability at the train level.
Emergency AC Power (EPS)	Unreliability and unavailability at the train level.
High Pressure Injection (HPI)	Unreliability and unavailability at the train level.
Power Operated Relief Valve (PORV)	Unreliability at the system level.
Residual/Decay Heat Removal (RHR)	Unreliability and unavailability at the train level.
Service Water (SWS)	Unreliability and unavailability at the train level.
COMPONENT CLASSES (all plants)	
Air-Operated Valves (AOVs)	Unreliability at the component level.
Motor-Operated Valves (MOVs)	Unreliability at the component level.
Motor-Driven Pumps (MDPs)	Unreliability at the component level.

Table 3.1.2-2 BWR Mitigating System RBPIs

RBPIs & Example Thresholds for BWR 3/4 Plant 18					
Mitigating System	Baseline Train Unavailability or Unreliability	Green/White 95th %ile	Green/White ΔCDF =1E-6	White/Yellow ΔCDF =1E-5	Yellow/Red ΔCDF =1E-4
Emergency AC Power	(Unreliability) 4.0E-2	9.9E-2	4.2E-2	5.8E-2	1.5E-1
	(Unavailability) 9.7E-3	1.9E-2	1.4E-2	4.9E-2	3.9E-1
Reactor Core Isolation Cooling	(Unreliability) 7.9E-2	1.7E-1	9.1E-2	2.0E-1	Not Reached.
	(Unavailability) 1.3E-2	4.0E-2	2.8E-2	1.7E-1	Not Reached.
Essential Service Water	(Unreliability) 2.5E-2	8.0E-2	2.7E-2	4.2E-2	1.3E-1
	(Standby Train Unavail.) 1.9E-2	5.4E-2	2.2E-2	5.6E-2	3.9E-1
HPCI	(Unreliability) 2.4E-1	4.3E-1	2.6E-1	4.6E-1	Not Reached.
	(Unavailability) 9.7E-3	3.8E-2	8.2E-2	7.3E-1	Not Reached.
Residual Heat Removal	(Unreliability) 8.8E-3	2.3E-2	2.0E-2	6.8E-2	2.2E-1
	(Unavailability) 1.0E-2	2.5E-2	1.4E-1	Not Reached	Not Reached
AOVs	Component Class Unreliability	N/A	Increase 2.2X	Increase 13X	Increase 83X
MOVs	Component Class Unreliability	N/A	Increase 1.7X	Increase 7.0X	Increase 28X
MDPs	Component Class Unreliability	N/A	Increase 1.2X	Increase 5.1X	Increase 28X

Table 3.1.2-3 PWR Mitigating System RBPIs

RBPIs & Example Thresholds for WE 4-Lp Plant 22					
Mitigating System	Baseline Train Unavailability or Unreliability	Green/White 95th %ile	Green/White ΔCDF =1E-6	White/Yellow ΔCDF =1E-5	Yellow/Red ΔCDF =1E-4
Auxiliary Feedwater	(MDP Train Unreliability) 8.7E-3	2.1E-2	9.8E-3	1.8E-2	5.4E-2
	(TDP Train Unreliability)1.9E-1	3.4E-1	2.0E-1	2.9E-1	Not Reached
	(MDP Train Unavailability) 1.1E-3	2.5E-3	3.7E-3	2.8E-2	2.5E-1
	(TDP Train Unavailability) 4.6E-3	1.8E-2	2.1E-2	1.7E-1	Not Reached
Component Cooling Water	(Unreliability) 1.6E-2	4.7E-2	2.0E-1	6.5E-1	Not Reached
	(Standby Train Unavailability)	4.4E-2	7.8E-1	Not Reached	Not Reached
Emergency AC Power	(Unreliability) 4.2E-2	1.0E-1	4.3E-2	5.5E-2	1.3E-1
	(Unavailability) 9.7E-3	1.9E-2	1.3E-2	3.9E-2	3.0E-1
High Pressure Injection (Includes CVC trains)	(SI Unreliability) 9.7E-3	2.1E-2	8.8E-1	Not Reached	Not Reached
	(SI Unavailability) 4.2E-3	1.6E-2	Not Reached	Not Reached	Not Reached
	(CVC Unreliability) 5.9E-2	1.9E-1	4.3E-1	Not Reached	Not Reached
	(CVC Standby Train Unav) 5.4E-2	1.7E-1	Not Reached	Not Reached	Not Reached
Power Operated Relief Valves	(System Unreliability) 3.2E-2	6.8E-2	5.7E-2	2.6E-1	Not Reached
Residual/Decay Heat Removal	(Unreliability) 1.7E-2	3.8E-2	3.8E-2	1.3E-1	4.7E-1
	(Unavailability) 7.3E-3	2.4E-2	9.3E-2	8.8E-1	Not Reached[1]
Service Water	(Unreliability) 3.2E-2	9.4E-2	1.3E-1	2.1E-1	3.2E-1
	(Standby Train Unav) 2.7E-2	9.0E-2	Not Reached	Not Reached	Not Reached
AOVs	Component Class Unreliability	N/A	Increase 2.2X	Increase 13X	Increase 106X
MOVs	Component Class Unreliability	N/A	Increase 2.4X	Increase 11X	Increase 39X
MDPs	Component Class Unreliability	N/A	Increase 1.2X	Increase 3.2X	Increase 16X

Summary of RBPI development Results

Containment Performance:

- Potential containment RBPIs include:
  - Unreliability/unavailability of drywell spray (Mark I BWRs)
  - Unreliability/unavailability of large containment isolation valves (PWRs, and Mark III BWRs)
- Models and data are not currently available for these potential RBPIs to quantify baseline performance values, thresholds, or ongoing performance.

Summary of RBPI development Results

Shutdown Modes:

- No initiating event RBPIs are identified for shutdown modes due to inability to support timely detection of declining performance
- Proposed mitigating system RBPIs during shutdown reflect excess time spent in risk-significant shutdown configurations
- Four shutdown configuration categories are defined based on CCDF: Low, Medium, Early Reduced-Inventory (vented), and High
  - Table 3.2.2-1 and 3.2.2-2 provide risk category thresholds
- Risk-significant shutdown configurations are categorized by:
  - RCS conditions
  - time after shutdown
  - availability of mitigating system trains
  - Table 3.2.2-3 and 3.2.2-4 provide risk classifications
- App. B includes details of RBPI development for shutdown modes

Table 3.2.2-1 Baseline and Thresholds for Time in Risk-Significant Configurations Indicators - PWRs

Configur. Category	Baseline	G/W Threshold	W/Y Threshold	Y/R Threshold
Low	20 days	21 days	30 days	120 days
Medium	2 days	2 days + .08 day (2 hrs)	3 days	12 days
Early Reduced-Inventory (vented)[a]	1 day	1 day	1.08 days (1 day + 2 hrs)	2 days
High	0	0+	.08 day (2 hrs)	1 day

a. This configuration category assumes that measures are taken to compensate for the risk associated with early reduced-inventory operations, as explained in Appendix B. If compensatory measures are not taken, these configurations are assigned to the "High" configuration category.

Table 3.2.2-2 Baseline and Thresholds for Time in Risk-Significant Configurations Indicators - BWRs

Configuration Category	Baseline	G/W Threshold	W/Y Threshold	Y/R Threshold
Low	2 days	3 days	12 days	102 days
Medium	0.20 day (5 hrs)	0.29 day (7 hrs)	1 day	10 days
High	0	0+	.08 day (2 hrs)	1 day

Table 3.2.2-3 PWR Shutdown Configurations Risk Classification (Based on a Generic Westinghouse 4-Loop Shutdown PRA Model)

POS				No Maintenance Unavailability	Backup RHR Train Unavailable	Emergency AC Trains Unavailable			Support Cooling Trains Unavailable		Secondary Cooling Trains Unavailable			Emergency Injection Trains Unavailable			Other Trains Unavailable			
Group	Mode	RCS Boundary	Days After Shutdown		RHR	EDG	EDG(2)	One Safety-Related AC Bus	One train of ESW	One train of CCW	One train of AFW	All AFW	All SGs	RWST	SI(2)[a]	Both Sumps	PORV(2)	SG/ PORV	SG/ RWST	SG/ and Both Sumps
Low Inventory Configurations Occurring Very Early (within the first 5 days) in an Outage																				
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	Intact or isolatable	2	Low	Med	Low	Low	Low	Low	Med	High	High	High	Low	Low	High	Low	High	High	High
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	vented	< 5	ERI-V[b]	ERI-V[b]									ERI-V[b]						
Representative Configurations Occurring in a Typical Outage																				
Pressurized Cooldown	Mode 4 Hot shutdown	Intact	4			Low	Med	Low	Low					Med		Low				
Depressurized RHR Cooldown with Normal Inventory	Mode 5 Cold shutdown	Intact	8				Low	Low			Low	Low	Low	Low		Low		High	High	High
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	Intact or isolatable	12		Low		Low	Low	Low	Low	Med	Med	Med	Low		Low	Low	High	High	High
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	vented	7	Med	Med	Med	Med	High	Med	Med				High	Med	Med				
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	vented	13	Med	Med	Med	Med	High	Med	Med				High	Med	Med				
Refueling Cavity Filled	Mode 6	vented	14													Med				
Low Inventory Configurations Occurring Late in a Typical Outage																				
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	vented	24			Low	Med	Low	Low	Low				Med	Low	Low				

Notes: Shaded cells indicate combinations of POS and configuration that are not analyzed, either because the configuration violates the POS definition, or the systems involved play no role in the POS. Blank cells represent configurations whose CCDF < 1.0E-6 per day.

a. In this configuration it is assumed that a makeup pump is available.

b. This configuration category assumes that measures are taken to compensate for the risk associated with early reduced-inventory operations, as explained in Appendix B. If compensatory measures are not taken, these configurations are assigned to the "High" configuration category.

Table 3.2.2-4 BWR Shutdown Configurations Risk Classification (Based on NUREG/CR-6166 Results)

POS			No Maintenance Unavailability	Emergency AC/DC Trains Unavailable					Support Cooling Trains Unavailable		
Group	Mode	RCS Boundary		EDG I or II	4 EDG I & II	EDG I & III	One. BAT division	Two BAT divisions	SSW A	SSW C	SSW A & C
POS 4	Hot shutdown	Intact		Low	Med	Low		High		Low	Med
POS 5	Cold shutdown	Vessel head on		Low	Med	Low	Low	High	Low	Low	Med
POS 6	Refueling	Vessel head off (level raised to steam line)									
POS 7	Refueling	Upper pool filled									Low

Note: Blank cells indicate combinations of POS and configuration that are not analyzed, either because the configuration violates the POS definition, or the systems involved play no role in the POS.

POS			No Maintenance Unavailability	Emergency Cooling Trains Unavailable				Other Trains Unavailable			
Group	Mode	RCS Boundary		HPCS	LPCS & HPCS	SP empty	SRVs all	SSW A & HPCS	SSW A & CDS	RHR A and all SRVs	SDC A and SP
POS 4	Hot shutdown	Intact		Low	Low	Med	Med	Med		High	Med
POS 5	Cold shutdown	Vessel head on		Low	Low	High	High	Med	Low	High	High
POS 6	Refueling	Vessel head off (level raised to steam line)				Med					Med
POS 7	Refueling	Upper pool filled				Low		Low			Low

Note: Blank cells indicate combinations of POS and configuration that are not analyzed, either because the configuration violates the POS definition, or the systems involved play no role in the POS.

Summary of RBPI development Results

Fire Events:

- No initiating event RBPIs for fire are identified due to inability to support timely detection of declining performance.
- Potential mitigating system RBPIs are identified for reliability and availability of fire suppression system
- Data are not currently available for these RBPIs to quantify baseline performance values and thresholds

Summary of RBPI development Results

Risk Coverage by RBPIs:

- Risk coverage was assessed using two methods, one based on RAW of risk-significant elements, and the other based on coverage of dominant core damage accident sequences

- Table 4-1 shows risk coverage results for two plants using RAW importance measure

  - Approximately 40% of events in SPAR models are part of RBPIs
  - Types of elements in other 60% are operator actions, batteries, check valves, heat exchangers, tanks, strainers, etc

- Table 4.2a shows risk coverage at initiating event/system level using dominant core damage accident sequences from IPE studies for two plants

  - Almost all dominant accident sequences are covered by multiple RBPIs
  - Elements not covered are potential areas for inspection
  - Sequences with no RBPI coverage are not dominant sequences

Table 4-1 Coverage of Risk Significant Core Damage Elements from SPAR Models

Category	BWR 3/4 Plant 18	WE 4-Lp Plant 22
Total number of SPAR model elements whose failure can result in $\Delta CDF \geq 1E\text{-}6/y$	178	203
- Initiating events	14	14
- Mitigating systemelements	164	189
Elements covered by RBPIs		
- Initiating events	3/14 (21%)	3/14 (21%)
- Initiating events covered by trending	3/14 (21%)	4/14 (29%)
- Mitigating system elements	70/164 (43%)	72/189 (38%)
Types of elements not explicitly covered by RBPIs	Batteries Check valves Electrical buses Heat exchangers Post-event human errors Reactor protection system Strainers Tanks	Batteries Check valves Electrical buses Heat exchangers Post-event human errors Reactor protection system Strainers Fans

Table 4-2a RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - BWR 3/4 Plant 18 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES				
1	5.28E-07	T-LOOP	AC	EAC			
2	1.60E-07	S1	HUM				
3	2.70E-08	T-LOOP	HP1	HUM	AC		
4	2.21E-08	T-LOOP	AC	EAC			
5	2.05E-08	T-ATWS	RPS	CONDA	HUM		
6	1.80E-08	T-LOOP	HPCI(HPCS)	RCIC	AC	EAC	
7	1.34E-08	T-LOOP	HP1	HUM	AC		
8	1.16E-08	T-RX	ADS	DC			
9	1.10E-08	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
10	8.96E-09	T-LOOP	HP1	LPCI	SPC	AC	
11	8.12E-09	T-RX	DC				
12	7.76E-09	T-ATWS	RPS	LPCI	CS	CONDA	HUM
13	7.59E-09	T-LOOP	SPC	HUM	AC		
14	7.00E-09	T-LOOP	HP1	SPC	HUM	AC	
15	6.90E-09	T-LOOP	HP1	SPC	HUM	AC	
16	6.72E-09	T-LOOP	HP1	HUM	AC		
17	6.13E-09	T-ATWS	RPS	CONDA	HUM		
18	5.83E-09	T-ATWS	RPS	CONDA	HUM		
19	5.77E-09	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
20	5.66E-09	A	LPCI	CS			
21	5.53E-09	T-LOOP	HPCI(HPCS)	RCIC	HUM	AC	
22	5.43E-09	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
23	5.10E-09	T-RX	HPCI(HPCS)	RCIC	HP1	HUM	
24	5.02E-09	S2	HPCI(HPCS)	HUM			
25	4.60E-09	A	SPC	AC			
26	4.46E-09	T-LOOP	HP1	LPCI	SPC	AC	
27	4.44E-09	T-LOOP	LPCI	SPC	HUM	AC	
28	3.88E-09	T-ATWS	RPS	HP1	CONDA	HUM	
29	3.83E-09	S1	HPCI(HPCS)	HUM			
30	3.78E-09	T-LOOP	SPC	HUM	AC		
31	3.62E-09	T-ATWS	RPS	HPCI(HPCS)	CONDA	HUM	
32	3.46E-09	T-LOOP	HP1	HUM	AC		
33	3.42E-09	T-LOOP	SPC	HUM	AC		
34	3.38E-09	T-RX	HPCI(HPCS)	RCIC	MFW	HP1	HUM

Summary of RBPI development Results

Validation and Verification:

- The purpose of this effort was to show that RBPIs can be calculated using readily available data and risk models consistent with current ROP philosophy
  - Feasibility of the process was demonstrated through these calculations
  - In order for these potential RBPIs to be used in ROP, implementation issues related to model fidelity and data quality need to be resolved
- RBPIs for full power, internal events were tested by evaluating plant-specific data for 23 plants over three-year period (1997-1999)
  - Rev 3i SPAR models with industry average reflecting 1996 performance were used for baseline
  - EPIX database was used for unreliability
  - ROP data was used for unavailability
  - NUREG/CR-5750 was used for initiating event frequencies

Summary of RBPI development Results

Validation and Verification (cont'd):

- Validation and Verification effort showed that RBPIs provide:
  - More precise accounting for risk-significant design features of plants
  - More plant-specific thresholds
  - More appropriate accounting for risk impact of fault exposure time
  - "Face validity" approach used
- Results are shown in Tables 5.3-1 thru 5.3-4
- Since models/data in these tables have not been formally peer reviewed, plant-specific inferences regarding "green" or "non-green" performance from these calculations would be inappropriate.

Table 5.3-1 **Plant Performance Bands for Initiating Event RBPIs (1999)** [a, e]

	1999		
Plant	GT [b]	LOHS [c]	LOFW [c,d]
PWRs			
WE 4-Lp Plant 1	2.8E-1 (G)	5.9E-2 (G)	5.3E-2 (G)
WE 4-Lp Plant 2	2.1E+0 (W)	5.8E-2 (G)	1.6E-1 (G)
CE Plant 2	1.5E+0 (G)	2.9E-1 (W)	5.2E-2 (G)
CE Plant 3	3.2E-1 (G)	5.9E-2 (G)	5.2E-2 (G)
CE Plant 4	3.0E-1 (G)	5.9E-2 (G)	5.2E-2 (G)
CE Plant 5	1.2E+0 (G)	8.4E-2 (G)	No data (G)
B&W Plant 4	1.6E+0 (W)	6.3E-2 (G)	5.5E-2 (G)
B&W Plant 5	2.8E+0 (Y)	1.8E-1 (W)	5.3E-2 (G)
B&W Plant 6	2.8E-1 (G)	6.0E-2 (G)	5.4E-2 (G)
WE 2-Lp Plant 5	9.3E-1 (G)	1.8E-1 (W)	5.3E-2 (G)
WE 2-Lp Plant 6	2.8E-1 (G)	5.9E-2 (G)	5.4E-2 (G)
CE Plant 12	2.1E+0 (W)	5.9E-2 (G)	1.6E-1 (G)
WE 4-Lp Plant 22	2.8E-1 (G)	5.8E-2 (G)	1.6E-1 (G)
WE 4-Lp Plant 23	2.9E-1 (G)	5.7E-2 (G)	1.5E-1 (G)
BWRs			
BWR 3/4 Plant 5	3.0E-1 (G)	9.2E-2 (G)	5.3E-2 (G)
BWR 3/4 Plant 6	3.4E-1 (G)	9.1E-2 (G)	5.2E-2 (G)
BWR 3/4 Plant 8	1.6E+0 (G)	9.0E-2 (G)	5.2E-2 (G)
BWR 5/6 Plant 2	1.0E+0 (G)	2.7E-1 (G)	5.1E-2 (G)
BWR 3/4 Plant 11	3.3E-1 (G)	9.2E-2 (G)	5.2E-2 (G)
BWR 3/4 Plant 15	9.1E-1 (G)	8.6E-2 (G)	5.1E-2 (G)
BWR 3/4 Plant 16	3.2E-1 (G)	8.8E-2 (G)	5.2E-2 (G)
BWR 3/4 Plant 18	9.4E-1 (G)	9.8E-2 (G)	5.5E-2 (G)
BWR 3/4 Plant 19	3.0E-1 (G)	1.1E-1 (G)	5.8E-2 (G)

a. Plant performance bands are the following: green (G) - ΔCDF < 1.0E-6/y, white (W) - 1.0E-6/y < ΔCDF <1 .0E-5/y, yellow (Y) - 1.0E-5/y < ΔCDF <1 .0E-4/y, red (R) - ΔCDF > 1.0E-4/y.

b. A one-year data collection interval applies (1999). The 1999 data were obtained from the ROP.

c. A three-year data collection interval applies (1997 – 1999). 1997 and 1998 data were obtained from the initiating events study update (Poloski 2000), while the 1999 data were obtained from the ROP.

d. This RBPI is not covered under the ROP, so the results presented in this table include only 1997 and 1998. (1999 Licensee Event Reports will need to be reviewed to identify scrams that are LOFW, as defined in the initiating events study.)

e. Since the models and data in these tables have not completed formal peer review, plant specific inferences regarding "green" or "non-green" performance from these calculations would be inappropriate.

Table 5.3-2 Plant Performance Bands for Mitigating System Unavailability RBPIs (1999)[b]

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR	SWS[a]	CCW[a]	PORV[a]
PWRs							
WE 4-Lp Plant 1	3.5E-3 (G)	3.3E-3 (G)	MDP (3.4E-3) DDP (4.3E-2) (Y)	9.1E-5 (G)	No data	No data	No data
WE 4-Lp Plant 2	3.3E-3 (G)	1.5E-2 (G)	MDP (2.4E-3) DDP (1.1E-2) (G)	8.0E-3 (G)	No data	No data	No data
CE Plant 2	6.6E-3 (G)	7.2E-3 (G)	MDP (0.0E+0) TDP (2.9E-3) (G)	1.0E-2 (G)	No data	No data	No data
CE Plant 3	7.5E-3 (G)	1.1E-2 (G)	MDP (2.4E-3) TDP (4.5E-3) (G)	1.4E-2 (G)	No data	No data	No data
CE Plant 4	9.5E-3 (G)	1.3E-3 (G)	MDP (9.8E-4) TDP (6.2E-3) (G)	2.1E-3 (G)	No data	No data	No data
CE Plant 5	1.1E-2 (G)	8.3E-3 (G)	MDP (4.9E-3) (W) TDP (6.4E-3)	4.1E-3 (G)	No data	No data	No data
B&W Plant 4	2.3E-2 (G)	5.3E-3 (G)	MDP (4.0E-3) TDP (0.0E+0) (G)	1.9E-2 (G)	No data	No data	NA
B&W Plant 5	2.4E-2 (G)	3.0E-3(G)	MDP (3.3E-3) TDP (3.1E-3) (G)	1.3E-2 (G)	No data	No data	NA
B&W Plant 6	2.2E-2 (G)	2.5E-3 (G)	MDP (6.8E-3) TDP (8.9E-4) (G)	1.1E-2 (G)	No data	No data	NA
WE 2-Lp Plant 5	1.3E-2 (G)	1.4E-3 (G)	MDP (4.4E-3) TDP (6.7E-3) (G)	1.6E-2 (G)	No data	No data	No data
WE 2-Lp Plant 6	1.0E-2 (G)	1.2E-3 (G)	MDP (4.2E-3) TDP (2.5E-3) (G)	2.6E-3 (G)	No data	No data	No data
CE Plant 12	5.1E-3 (G)	7.3E-3 (G)	MDP (5.3E-3) (W) TDP (4.6E-3)	7.1E-3 (G)	NA	No data	No data
WE 4-Lp Plant 22	9.6E-3 (G)	7.7E-3 (G)	MDP (7.6E-3) (W) TDP (4.0E-3)	4.4E-3 (G)	No data	No data	No data
WE 4-Lp Plant 23	1.2E-2 (G)	4.9E-3 (G)	MDP (1.2E-2) (W) TDP (6.3E-3)	8.2E-3 (G)	No data	No data	No data

Table 5.3-2 (Continued)

Plant BWRs	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR	SWS [a]	CCW [a]	PORV [a]
BWR 3/4 Plant 5	2.9E-3 (G)	2.4E-3 (G)	5.5E-3 (G)	0.0E+0 (G)	No data	NA	NA
BWR 3/4 Plant 6	1.3E-2 (G)	2.1E-3 (G)	1.0E-2 (G)	8.4E-3 (G)	No data	NA	NA
BWR 3/4 Plant 8	1.9E-2 (G)	2.8E-2 (G)	5.0E-2 (G)	7.8E-3 (G)	No data	NA	NA
BWR 5/6 Plant 2	3.6E-2 (W)	4.6E-3 (G)	1.5E-2 (G)	4.4E-3 (G)	No data	NA	NA
BWR 3/4 Plant 11	7.4E-3 (G)	1.8E-2 (G)	1.8E-2 (W)	1.2E-2 (G)	No data	NA	NA
BWR 3/4 Plant 15	1.5E-2 (G)	1.6E-2 (G)	8.6E-3 (G)	9.1E-3 (G)	No data	NA	NA
BWR 3/4 Plant 16	2.2E-2 (G)	2.1E-2 (G)	7.9E-3 (G)	1.3E-2 (G)	No data	NA	NA
BWR 3/4 Plant 18	2.1E-2 (W)	4.5E-1 (W)	1.7E-2 (G)	5.4E-3 (G)	No data	NA	NA
BWR 3/4 Plant 19	1.8E-2 (W)	1.7E-2 (G)	1.8E-2 (G)	7.5E-3 (G)	No data	NA	NA

a. Unavailability data are not available (not covered by the ROP) at this time. Eventually, EPIX may contain such data.

b. Since the models and data in these tables have not completed formal peer review, plant specific inferences regarding "green" or "non-green" performance from these calculations would be inappropriate.

Table 5.3-3 Plant Performance Bands for Mitigating System Unreliability RBPIs (1997 - 1999)[e]

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR[a]	SWS	CCW	PORV
PWRs							
WE 4-Lp Plant 1	< baseline (G)[b]	No data[c]	< baseline (G)	< baseline (G)	No data	No data	No data
WE 4-Lp Plant 2	< baseline (G)	No data	< baseline (G)	< baseline (G)	No data	No data	No data
CE Plant 2	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	No data	No data
CE Plant 3	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	No data	No data
CE Plant 4	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	< baseline (G)
CE Plant 5	< baseline (G)	< baseline (G)	< baseline (G)	No data	No data	< baseline (G)	No data
B&W Plant 4	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	NA
B&W Plant 5	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	NA
B&W Plant 6	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	NA
WE 2-Lp Plant 5	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	< baseline (G)	< baseline (G)
WE 2-Lp Plant 6	< baseline (G)	No data	< baseline (G)	< baseline (G)	< baseline (G)	No data	< baseline (G)
CE Plant 12	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	NA	< baseline (G)	No data
WE 4-Lp Plant 22	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)
WE 4-Lp Plant 23	< baseline (G)	< baseline (G)	1.5E-2 (MDP) (W) (0.13)[d]	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)
BWRs							
BWR 3/4 Plant 5	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 6	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 8	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 5/6 Plant 2	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	NA	NA
BWR 3/4 Plant 11	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 15	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 16	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 18	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 19	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA

a. Reflects pump data. Valve data still need to be collected and evaluated.

b. "< baseline" indicates that there were not enough failures to result in a train unreliability greater than the baseline.

c. "No data" indicates that either EPIX has no data on this system, or the RADS data load of the EPIX file did not include this system.

d. The 0.13 probability indicates that there is only a 13% chance that performance is at its baseline value.

Table 5.3-4 Plant Performance Bands for Component Class RBPIs (1997 - 1999)[e]

Plant	AOV	MOV	MDP
PWRs			
WE 4-Lp Plant 1	No data[a]	No data	< baseline (G)[b]
WE 4-Lp Plant 2	No data	No data	< baseline (G)
CE Plant 2	< baseline (G)	< baseline (G)	< baseline (G)
CE Plant 3	1.6E-3 (1.6X) (G)[c]	< baseline (G)	< baseline (G)
CE Plant 4	3.8E-3 (3.8X) (G)[c]	< baseline (G)	< baseline(G)
CE Plant 5	No data	< baseline (G)	< baseline (G)
B&W Plant 4	< baseline (G)	< baseline (G)	< baseline (G)
B&W Plant 5	< baseline (G)	< baseline (G)	< baseline (G)
B&W Plant 6	< baseline (G)	< baseline (G)	< baseline (G)
WE 2-Lp Plant 5	< baseline (G)	< baseline (G)	< baseline (G)
WE 2-Lp Plant 6	< baseline (G)	< baseline (G)	6.0E-3 (1.6X) (W)[c] (0.19)[d]
CE Plant 12	< baseline (G)	1.3E-2 (4.4X) (W)[c] (0.002)[d]	< baseline (G)
WE 4-Lp Plant 22	< baseline (G)	< baseline (G)	< baseline (G)
WE 4-Lp Plant 23	< baseline (G)	< baseline (G)	< baseline (G)
BWRs			
BWR 3/4 Plant 5	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 6	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 8	No data	< baseline (G)	< baseline (G)
BWR 5/6 Plant 2	< baseline (G)	< baseline (G)	< baseline (G)
BWR 3/4 Plant 11	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 15	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 16	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 18	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 19	No data	< baseline (G)	< baseline (G)

a. "No data" indicates that either EPIX has no data on this component class, or the RADS data load of the EPIX file did not include it.

b. "< baseline" indicates that there were not enough failures to result in a train unreliability greater than the baseline.

c. The number in parentheses "1.6X" indicates that the unreliability is 1.6 times the baseline.

d. The component class RBPIs have the potential for false-positive indications. Therefore, the probability of the underlying performance actually being at its baseline (G) value is also presented.

Industry-Wide Trending

- Industry-wide trending includes all proposed RBPIs plus risk-significant IEs and CCF events that are impractical to monitor on a plant-specific basis.
  - Table ES-2 provides a summary of proposed trends
- Industry-wide trending provides:
  - Measures of ROP effectiveness.
  - Provides feedback to ROP to adjust technical emphasis and overall inspection frequencies.
  - input to agency Strategic Plan Performance Measures

Table ES-2 Summary of Phase-1 Performance Areas Proposed for Industry-Wide Trending

Safety Cornerstone	Industry-Wide Trend
Initiating Event	**Full Power:** – All proposed IE RBPIs listed in Table ES-1 – Internal flooding – Initiators evaluated as ASPs – Loss of instrument/control air (for BWRs and PWRs) – LOOP – Loss of vital AC bus – Loss of vital DC bus – Small LOCA (including very small LOCA) – SGTR – Stuck open safety/relief valves **Shutdown:** – LOOP during shutdown modes – Loss of RHR during shutdown modes – Loss or diversion of RCS inventory during shutdown modes leading to loss of RHR – Loss of RCS level control (during transition to mid-loop) leading to loss of RHR (for PWRs only) **Fire:** – Fire events in risk-significant fire areas
Mitigating System	– All proposed mitigating system RBPIs listed in Table ES-1 – CCF events for AFW pumps – CCF events for Diesel Generators – Total CCF events
Barriers	None

Key Implementation Issues

- Are any additional performance indicators needed in ROP?
  - Stake holders expressed differing views
    - Industry questioned need for greater sample size with expectation of less inspections if more PIs are used
    - Other external stakeholders favored more PIs and more inspections
  - RBPIs support general ROP concept of increased reliance on objective indications of performance and PRA Policy Statement to increase use of PRA technology "in all matters to the extend supported by the state-of-the-art PRA methods and data..."
  - RBPIs relate to improvements under "Maintaining Safety" and "Improved Regulatory Efficiency, Effectiveness, and Realism".
  - ROP change process addresses regulatory benefits and other implementation issues.

Key Implementation Issues

- **Is the number of potential new performance indicators appropriate?**
  - **21 RBPIs for PWRs and 16 RBPIs for BWRs could replace 8 of 18 existing PIs.**
  - **Total number of indicators could potentially be about 30 compared to 18 existing indicators.**
  - **Total number of performance indicators should be commensurate with risk coverage needed.**

Key Implementation Issues

- Do data sources for RBPIs exist and have sufficient quality for use in ROP?
  - A significant portion of RBPIs requires data from EPIX
  - Data are provided by licensees on a voluntary basis
  - Validation/verification and quality of EPIX data are important to the feasibility of many RBPIs
  - Data needs to be of sufficient quality so that small errors do not result in mis-classification of risk significance
  - Needed data for containment and shutdown RBPIs are not currently being reported by licensees

Key Implementation Issues

- **Will Rev. 3i SPAR models be available for setting plant-specific thresholds for all plants?**

  - **The number of models needed depends on the level of plant-specific accuracy deemed appropriate by stakeholders**

  - **30 Rev. 3i SPAR models are currently available and remaining 40 models are scheduled to be available by the end of 2002**

  - **External stakeholders recommended peer review of Rev 3i SPAR models by licensees**

Key Implementation Issues

- Will LERF models be available for setting baseline performance and thresholds for mitigating and containment systems?

  - Limited-scope LERF models are only available for some containment types.

  - Available LERF models are not compatible with Rev. 3i SPAR models.

  - Near-term SPAR model development plans only support limited LERF model development.

  - Due to these limitations, we are currently unable to determine whether LERF or CDF are more limiting for determination of performance thresholds.

Alternative Approaches for RBPI determination

- Comments received regarding the number of PIs being "excessive".
- Reexamined bases for current selection:
  - based on devolving risk
  - thresholds set at data collection level
  - impacts based on sequence effects
- Devolved risk logic to cornerstone level (Fig. A) and functions within cornerstone (Fig. 1 & 2).
- Separated thresholds from inputs. Thresholds set on ΔCDF of all inputs to a functional group (Fig. 3).
- Devised hierarchy of groups. (Fig. 3b).

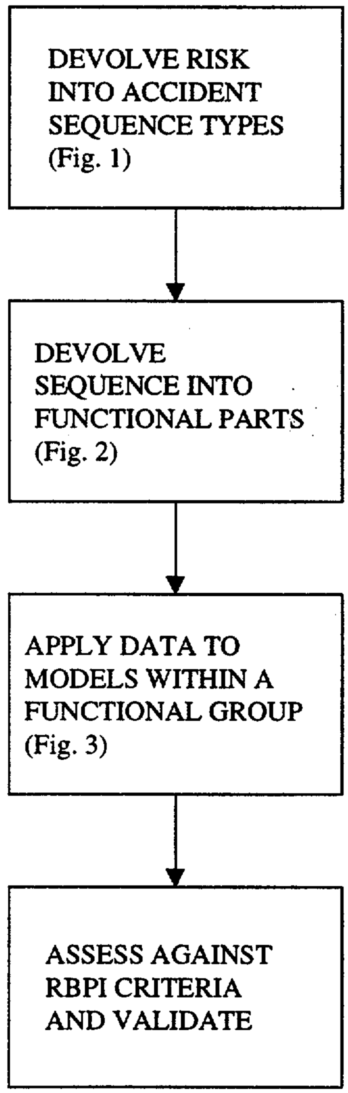

DEVOLVE RISK
INTO ACCIDENT
SEQUENCE TYPES
(Fig. 1)
DEVOLVE
SEQUENCE INTO
FUNCTIONAL PARTS
(Fig. 2)
APPLY DATA TO
MODELS WITHIN A
FUNCTIONAL GROUP
(Fig. 3)
ASSESS AGAINST
RBPI CRITERIA
AND VALIDATE

FIGURE A

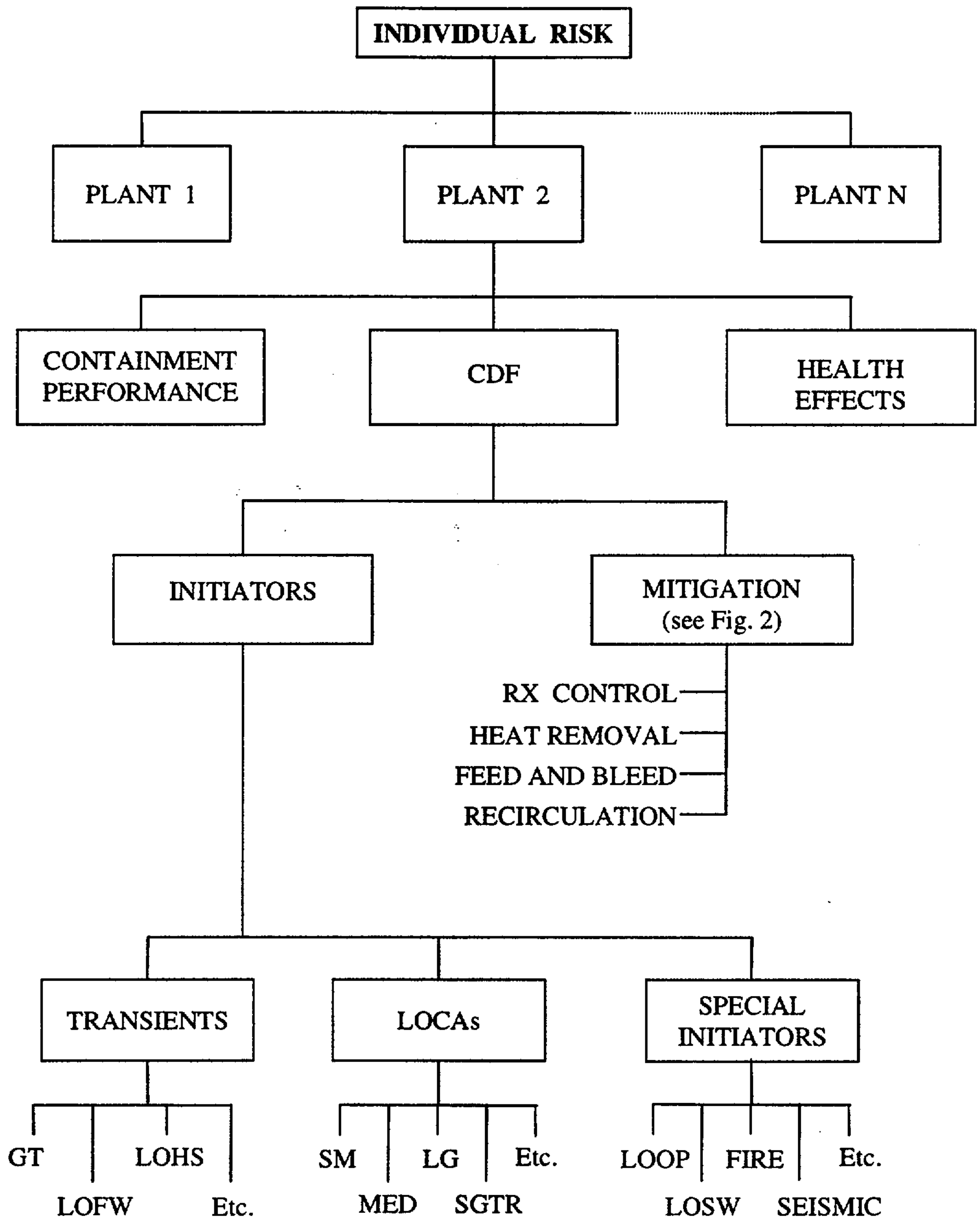
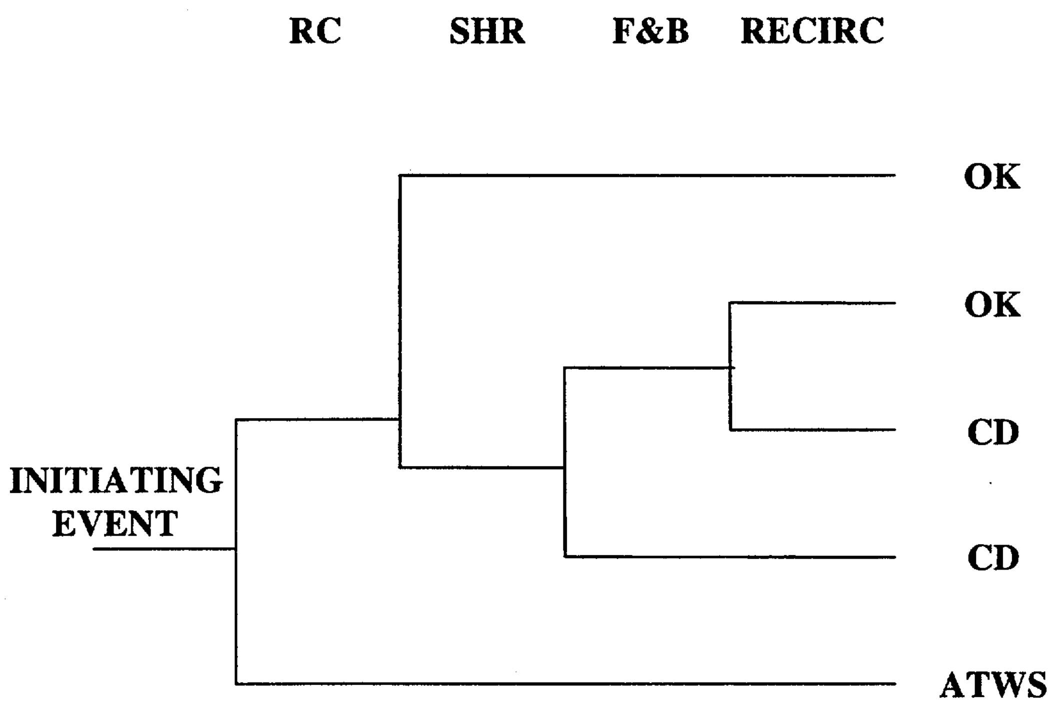

INDIVIDUAL RISK
PLANT 1
PLANT 2
PLANT N
CONTAINMENT PERFORMANCE
CDF
HEALTH EFFECTS
INITIATORS
MITIGATION (see Fig. 2)
RX CONTROL
HEAT REMOVAL
FEED AND BLEED
RECIRCULATION
TRANSIENTS
LOCAs
SPECIAL INITIATORS
GT
LOFW
LOHS
Etc.
SM
MED
LG
SGTR
Etc.
LOOP
LOSW
FIRE
SEISMIC
Etc.

FIGURE 1



RC: REACTIVITY CONTROL
SHR: SECONDARY HEAT REMOVAL
F&B: FEED AND BLEED
RECIRC: RECIRCULATION

FIGURE 2

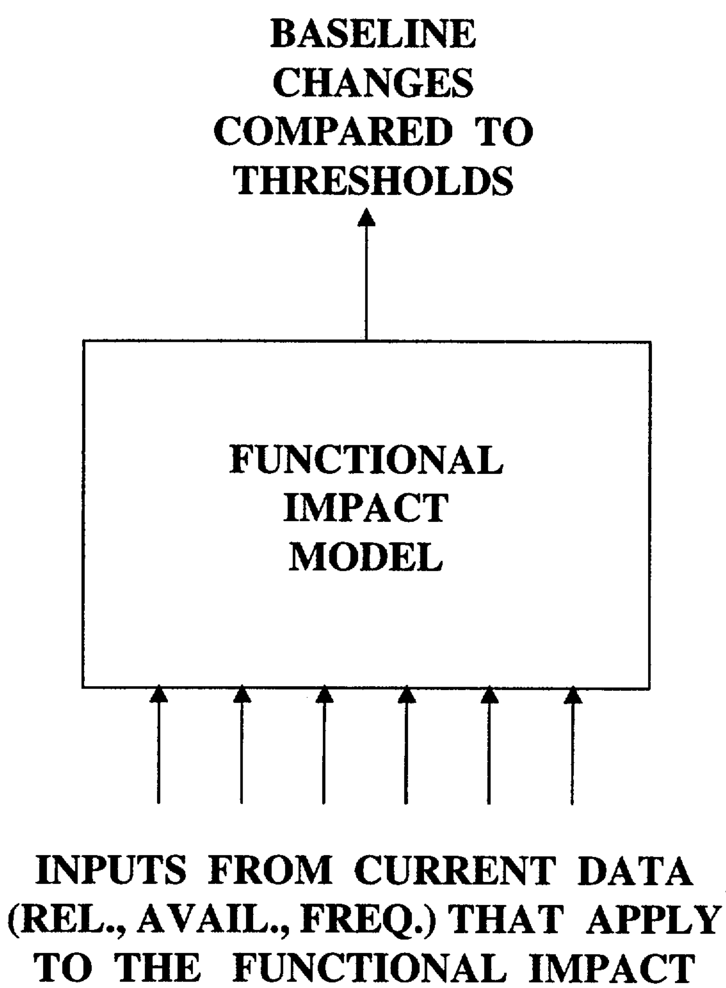

BASELINE
CHANGES
COMPARED TO
THRESHOLDS
FUNCTIONAL
IMPACT
MODEL
INPUTS FROM CURRENT DATA
(REL., AVAIL., FREQ.) THAT APPLY
TO THE FUNCTIONAL IMPACT

FIGURE 3

Potential Indicator Hierarchy

- **CORNERSTONE LEVEL - One indicator for IE and mitigating systems for at power operation.**
- **FUNCTIONAL LEVEL - 3-5 indicators for each cornerstone.**
  - **Grouped by initator**
  - **Grouped by mitigating system/function**
- **COMPONENT/TRAIN LEVEL**
  - **RBPIs in Phase 1 report**
  - **System/function indicators grouped by initiating events**

POTENTIAL LEVELS OF RBPIs

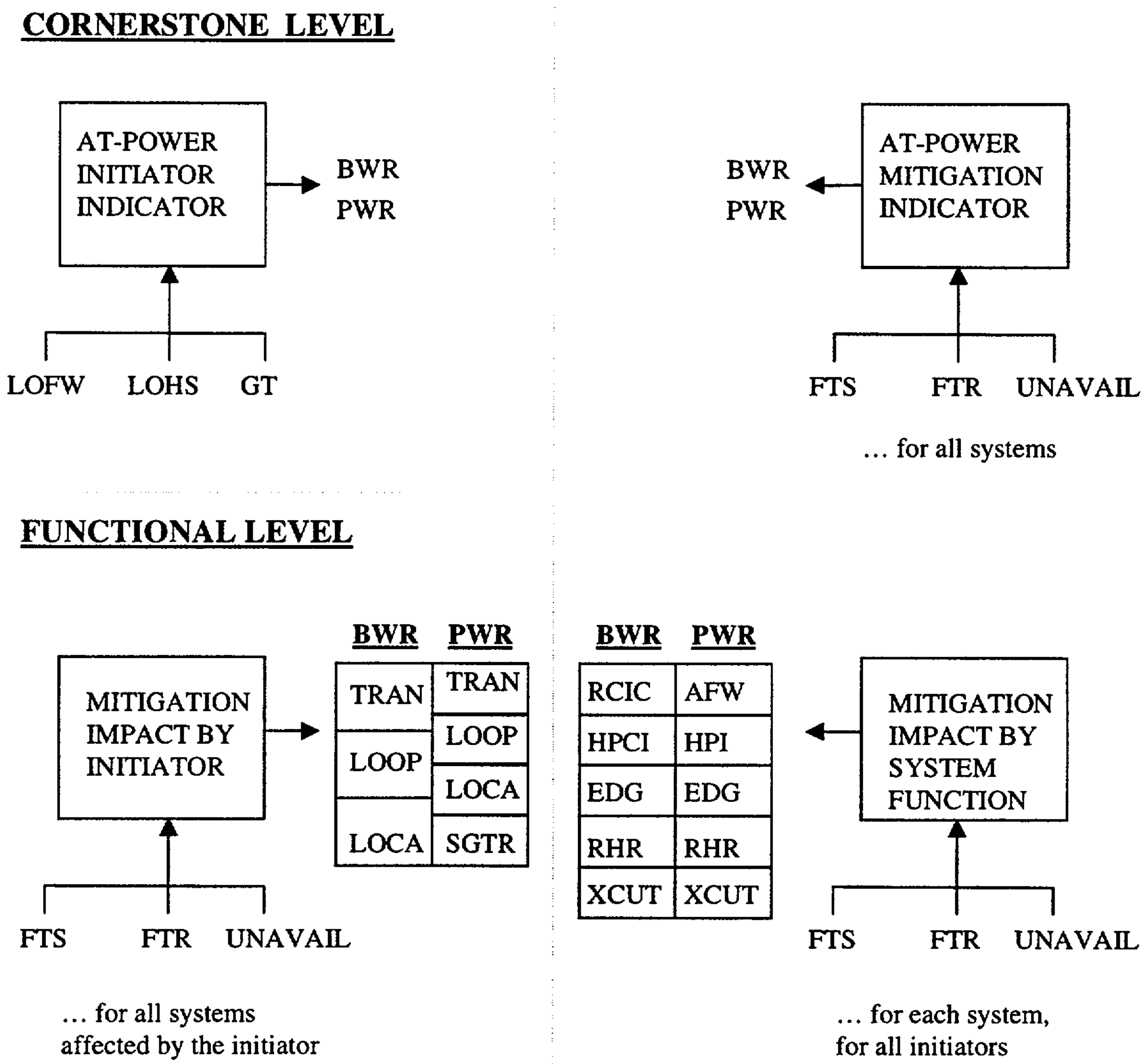


FIGURE 3b

Table 1 Cornerstone Level RBPIs

	Baseline CDF	**Green**	**White**	**Yellow**	**Red**
BWR Plant 18	2.0E-05	< 2.1E-05	<3.0E-05	< 1.2E-04	> 1.2E-04
All Systems (EPS, HPCI, RCIC, RHR)			2.5E-5 (W)		
All Initiators Combined		2.0E-5 (G)			
	Baseline CDF	**Green**	**White**	**Yellow**	**Red**
PWR Plant 23	3.4E-05	< 3.5E-05	< 4.4E-05	< 1.3E-04	> 1.3E-04
All Systems (AFW, EPS, HPI/PORV, RHR)			3.7E-5 (W)		
All Initiators Combined		3.4E-5 (G)			

NOTES:

1. (G) - Calculated CDF falls within the 'GREEN' performance band.
2. (W) - Calculated CDF falls within the 'WHITE' performance band.
3. Calculated CDF generated by quantifying model with all of the applicable failure values (e.g., FTS, FTR, UA) currently used for individual RBPIs.

Table 2 Functional Level Mitigation RBPI by Initiator

BWR Plant 18					
Baseline Plant CDF (2.0E-05)	**Baseline CDF**	**Green**	**White**	**Yellow**	**Red**
Baseline LOCA Group (SLOCA, MLOCA, LLOCA) CDF	1.6E-08	< 1.0E-06	< 1.0E-05	< 1.0E-04	> 1.0E-04
- Front Line Systems (RCIC, HPCI, RHR) & Components		3.7E-08 (G)			
Baseline LOOP/SBO Group CDF	1.8E-05	< 1.9E-05	< 2.8E-05	< 1.2E-04	> 1.2E-04
- Front Line Systems (RCIC, HPCI, EPS, RHR) & Components			2.2E-05 (W)		
Baseline TRANSIENT Group (TRAN, LDCB, LOSWS) CDF	2.2E-06	< 3.2E-06	< 1.2E-05	< 1.0E-04	> 1.0E-04
- Front Line Systems (RCIC, HPCI, RHR) & Components		2.4E-06 (G)			
PWR Plant 23					
Baseline Plant CDF (3.4E-05)	**Baseline CDF**	**Green**	**White**	**Yellow**	**Red**
Baseline LOCA Group (SLOCA, MLOCA, LLOCA) CDF	2.5E-07	< 1.2E-06	< 1.0E-05	< 1.0E-04	> 1.0E-04
- Front Line Systems (AFW, HPI/PORV, RHR) & Components		2.0E-07 (G)			
Baseline LOOP/SBO Group CDF	1.6E-05	< 1.7E-05	< 2.6E-05	< 1.2E-04	> 1.2E-04
- Front Line Systems (AFW, HPI/PORV, EPS, RHR) & Components		1.0E-05 (G)			
Baseline TRANSIENT Group (TRAN, LDCA, LOCCW, LOSWS) CDF	1.2E-05	< 1.3E-05	< 2.3E-05	< 1.1E-04	> 1.1E-04
- Front Line Systems (AFW, HPI/PORV, RHR) & Components			1.9E-05 (W)		
Baseline SGTR Group CDF	4.2E-06	< 5.2E-06	< 1.4E-05	< 1.0E-04	> 1.0E-04
- Front Line Systems(AFW, HPI/PORV, RHR) & Components		4.0E-06 (G)			

NOTES:
1. (G) - Calculated CDF falls within the 'GREEN' performance band.
2. (W) - Calculated CDF falls within the 'WHITE' performance band.

Table 3 Functional Level Mitigation RBPI by System

	Baseline CDF	Green	White	Yellow	Red
BWR Plant 18	2.0E-05	< 2.1E-05	< 3.0E-05	< 1.2E-04	> 1.2E-04
EPS		2.0E-5 (G)			
HPCI			2.6E-5 (W)		
RCIC		2.0E-5 (G)			
RHR		2.0E-5 (G)			
Component Groups (AOVs, MOVs, MDPs)		2.0E-5 (G)			
	Baseline CDF	**Green**	**White**	**Yellow**	**Red**
PWR Plant 23	3.4E-05	< 3.5E-05	< 4.4E-05	< 1.3E-04	> 1.3E-04
AFW			4.3E-5 (W)		
EPS		2.9E-5 (G)			
HPI & PORVs		3.4E-5 (G)			
RHR		3.4E-5 (G)			
Component Groups (AOVs, MOVs, MDPs)		3.4E-5 (G)			

NOTES:
1. (G) - Calculated CDF falls within the 'GREEN' performance band.
2. (W) - Calculated CDF falls within the 'WHITE' performance band.
3. Calculated CDF generated by quantifying model with all of the applicable failure values (e.g., FTS, FTR, UA) currently used for individual RBPIs.

Benefits/Limitations of Potential Alternate RBPIs

Cornerstone Level

- **Benefits:**
  - Single indicator for each cornerstone indicates overall performance at highest level
  - Takes into account intra- and inter- system impacts of performance in different areas (reliability vs availability, train vs system, and system vs. system)
- **Limitations:**
  - Causes of >green performance not directly known without further breakdown of indicator model, but it can be done practically

Benefits/Limitations of Potential Alternate RBPIs

Functional Level

- Benefits:

  - Fewer number of indicators (<6) for each cornerstone
  - Accounts for intra- and inter-system impacts
  - Can be grouped by either initiators (LOOP, TRANS, LOCA, etc) or by system functions (heat removal, emergency power, etc.)

- Limitations:

  - Doesn't directly provide cornerstone-level performance (still need to use Action Matrix)
  - Causes of >green performance not directly known, but can be derived by devolving indicators into parts.

Benefits/Limitations of Potential Alternate RBPIs

Component/Train Level

- **Benefits:**
  - Broadest evaluation of individual performance attributes
  - Causes of >green performance readily identified
  - Greater similarity to current indicators
- **Limitations:**
  - Intra- and Inter-system impacts not accounted for (synergies of impacts can be conservative or non-conservative depending on accident sequence logic)
  - Nearly doubles current number of PIs
  - Requires thresholds set for each data input

Summary of RBPI development Results

- We are looking for ACRS feedback (via a letter)on:
  - Potential benefits to ROP
  - Technical adequacy of RBPIs as enhancement to ROP
  - Alternate approaches to RBPIs in response to concern over the total number of RBPIs

RISK-BASED PERFORMANCE INDICATORS

RESULTS OF PHASE-1 DEVELOPMENT

PRESENTATION TO ACRS SUBCOMMITTEE ON PRA

Steven E. Mays, 415-7496
Hossein G. Hamzehee, 415-6228
Office of Nuclear Regulatory Research
Michael R. Johnson
Office of Nuclear Reactor Regulation

March 17, 2001

<u>Phase-1 RBPI Development Results</u>

- The purpose of this presentation is to provide an understanding of:
  - Perspective on relationship of RBPIs to ROP
  - Potential benefits of proposed RBPIs
  - RBPI development process
  - Summary of RBPI development results
  - Perspective on industry trending in ROP and other programs
- We are looking for ACRS feedback (via a letter) on:
  - Potential benefits to ROP
  - Technical adequacy of RBPIs as enhancement to ROP
  - Alternate approaches to RBPIs in response to concern over the total number of RBPIs

Phase-1 RBPI Development Results

- Briefing includes:
  - Relationship of RBPIs to ROP
  - Potential benefits of proposed RBPIs
  - RBPI development process
  - Summary of results
  - Key implementation issues
  - Alternate approaches for RBPI determination

<u>Presentation by NRR On Relationship of RBPIs to ROP</u>

Phase-1 RBPI Development Results

Relationship of RBPIs to ROP:

- Goals of Commission PRA Policy Statement and NRC Strategic Plan (NUREG) are to better risk-inform NRC processes.
- ROP was revised to be more risk-informed, objective, understandable, and more predictable than previous oversight process.
- Continuing advances in industry use of information technology and data
  - Gathering/analyzing more plant-specific and industry-wide data
  - Internet and micro-computers allow improved capabilities to gather/share data
  - NRC and industry continue to expand their capabilities to model/assess risk-significant attributes of plant operations

Phase-1 RBPI Development Results

Relationship of RBPIs to ROP (cont'd):

- As discussed in SECY-99-007 and 99-007A, ROP uses both inspection findings and performance indicators

- As discussed in SECY-00-049, while future success of the ROP is not predicated on the RBPI program, RBPIs would potentially support:

  - Enhancements to specific areas in current ROP where RBPIs may be applicable
  - Future development of more plant specific PIs using improved risk analysis tools

- In response to NRR User Need Letter, RES examined feasibility of selected RBPIs as part of Phase-1 report.

  - Reliability indicators
  - Unavailability indicators
  - Shutdown and fire indicators
  - Containment indicators

Phase-1 RBPI Development Results

Relationship of RBPIs to ROP (cont'd):

- Several key implementation issues are identified in Section 5 of Phase-1 report, some of which are:
  - Data quality and availability
  - SPAR model development and V &V
- Process for potential integration of RBPIs with ROP
  - Assess feedback from stakeholders on Phase-1 report to ascertain an appropriate course of action
  - Consideration of safety benefits/costs
  - Follow process for changing ROP performance indicators in IMC0608, which includes opportunity for stakeholder involvement
  - A pilot program would be conducted prior to considering any RBPIs for full implementation
  - Additional PIs may require re-assessment of ROP Action Matrix

Presentation by RES on Phase-1 RBPI Development Results

Phase-1 RBPI Development Results

Potential Benefits of Proposed RBPIs:

- **Broader sample of plant performance impacting risk than current ROP indicators. Provides more objective indication of plant performance to licensees, NRC, and the public.**

  - **Consistent with NEI 96-04**

    "..... a regulatory approach in which operating experience and engineering judgement are used in concert with the analytical insights derived from probabilistic safety assessment to focus licensee and regulatory attention on design and operational issues commensurate with their importance to public health and safety...."

    "....Performance based regulation is defined as a regulatory approach that focuses on results as the primary means of regulatory oversight, and that has the following attributes:
    - **Measurable parameters to monitor plant and licensee performance;**
    - **Objective criteria to assess performance based on risk insights, deterministic analyses and/or performance history, and**
    - **Licensee flexibility to determine how to meet established performance criteria......"**

  - **More systems/components covered by objective, risk-informed, performance-based methods.**

  - **Cross-cutting indicators across system boundaries provide objective, risk-informed, and performance-based measures of the effects of programmatic performance.**

Phase-1 RBPI Development Results

Potential Benefits of Proposed RBPIs (cont'd):

- Better understanding of plant-specific risk implications than current ROP indicators
  - Thresholds are set based on plant-specific design features and their risk contributions. These focus attention on those performance areas that are more representative of plant risk, and provide better indication of where potential problems are.
  - No averaging of diverse system trains which can mask actual risk contribution
  - Failures affecting reliability/availability are based on loss of risk-significant functions, not design-basis functions
    - Auto initiation failures do not necessarily equate to total system/function failure.
    - Credit for manual actuations are included in the models and thresholds consistent with their risk significance.
    - Fault exposure time is more consistently accounted for in RBPIs
      - Accounts for varying test interval
      - Better association with demand failure probability versus unavailability
      - More consistent with PRA treatment

Phase-1 RBPI Development Results

Potential Benefits of Proposed RBPIs (Cont'd):

- RBPI process will look similar to performance indicators in the current ROP
  - Uses same color scheme
  - Are amenable to similar presentation
  - Can be updated in a similar fashion
- RBPIs can be implemented in part rather than as an entire set.
  - RBPIs with most benefit can be implemented first, and others as needed.
  - RBPIs with readily available data can be implemented while other data being gathered/evaluated.
- RBPIs are a straightforward extension of existing models, data, and capabilities. No significant new infrastructure is needed to support them.
  - Use available off-the-shelf risk models and reliability technology
  - Required analyses are simple and routine
  - Most of data were obtained from currently available databases
  - Proposed new data are easy to get, and are simple extension of existing data

Phase-1 RBPI Development Results

RBPI Development Process:

- RBPIs were developed using four major steps:

  1. Assess potential risk impact of degraded performance
  2. Obtain performance data for risk-significant elements
  3. Identify indicators capable of detecting performance changes in a timely manner
  4. Identify performance thresholds consistent with a graded approach to performance evaluation from SECY 99-007

- Successful development of potential RBPIs requires:

  - Models that reasonably reflect risk impact
  - Baseline performance for setting thresholds
  - Ongoing performance data for assessing plant-specific performance against performance thresholds

Summary of RBPI development Results

Initiating Events - Full Power, Internal Events:

- Three data sources used in initiating event selection are:
  - NUREG/CR-5750
  - SCSS (LERs)
  - MORs

- Three RBPIs for each plant under IE cornerstone are identified
  - Table 3.1.1-1, IE RBPIs and example thresholds
  - Detailed plant-specific threshold information for 23 plants based on Rev 3i SPAR models are included in App. A

- Considered three potential choices for prior distributions
  - Non-informative (classical statistical approach)
  - Industry prior
  - Constrained non-informative prior

- Considered time frames for detecting performance in timely manner
  - Between 1 and 5 years
  - Used shortest prior that satisfied:
    - False negative rate <5%
    - False positive rate <20%

- All IE indicators used constrained non-informative prior. GT used 1 year, LOFW and LOHS used 3 years.

Table 3.1.1-1 Initiating Event RBPIs

RBPIs & Example Thresholds for BWR 3/4 Plant 18					
Initiator RBPI	Baseline Frequency (NUREG/CR-5750)	Green/White 95th%ile	Green/White ΔCDF=1E-6/yr[a]	White/Yellow ΔCDF=1E-5/yr[a]	Yellow/Red ΔCDF=1E-4/yr[a]
General Transient (GT)	1.3 / year[a]	2.2 / year	2.0 / year[a]	7.9 / year[a]	67 / year[a]
Loss of Feedwater (LOFW)	6.8E-2 / year[a]	2.0E-1 / year	3.0E-1 / year[a]	2.5 / year[a]	24 / year[a]
Loss of Heat Sink (LOHS)	2.3E-1 / year[a]	3.1E-1 / year	4.1E-1 / year[a]	3.4 / year[a]	33 / year[a]
RBPIs & Example Thresholds for WE 4-Lp Plant 22					
Initiator RBPI	Baseline Frequency (NUREG/CR-5750)	Green/White 95th%ile	Green/White ΔCDF=1E-6/yr[a]	White/Yellow ΔCDF=1E-5/yr[a]	Yellow/Red ΔCDF=1E-4/yr[a]
General Transient (GT)	1.0 / year[a]	1.8 / year	1.8 / year[a]	8.8 / year[a]	78 / year[a]
Loss of Feedwater (LOFW)	6.8E-2 / year[a]	2.0E-1 / year	8.0E-1 / year[a]	7.2 / year[a]	74 / year[a]
Loss of Heat Sink (LOHS)	9.6E-2 / year[a]	2.6E-1 / year	2.4E-1 / year[a]	1.5 / year[a]	15 / year[a]

- Year refers to a calendar year assumed to include 7000 critical hours.

Summary of RBPI development Results

Mitigating Systems - Full Power, Internal Events:

- Thirteen mitigating systems/component class RBPIs are identified for BWRs and eighteen for PWRs.
  - Rev 3i SPAR models (for plant-specific threshold evaluation)
  - Results are summarized in Table 3.1.2-1
  - Examples of plant-specific thresholds for two plants presented in Table 3.1.2-2 and 3.1.2.3
  - Detailed plant-specific threshold information for 23 plants are in App. A

- Primary data sources used in selection of mitigating systems RBPIs are:
  - RES System reliability studies (for baseline performance evaluation)
  - EPIX (for reliability data)
  - ROP data (for unavailability data)

- Used process similar to IE indicators for reliability indicators for selecting priors and intervals.

- Chose non-informative priors with 3 year periods.

- Several reliability indicators potentially had >20% false positive rate for crossing white threshold. Added indications of the likelihood that mean was still at or below the baseline value.

Table 3.1.2-1 Candidate Mitigating System RBPIs

BWR RBPI SYSTEMS	**RBPI Parameter and Level**
Emergency AC Power (EPS)	Unreliability and unavailability at the train level.
High Pressure Coolant Injection Systems • High Pressure Coolant Injection (HPCI) • High Pressure Core Spray (HPCS)	Unreliability and unavailability at the train level.
High Pressure Heat Removal Systems • Isolation Condenser (IC) • Reactor Core Isolation Cooling (RCIC)	Unreliability and unavailability at the train level.
Residual Heat Removal (SPC, RHR)	Unreliability and unavailability at the train level.
Service Water (SWS)	Unreliability and unavailability at the train level.
PWR RBPI SYSTEMS	
Auxiliary Feedwater (AFW/EFW) • Motor-driven Pump Train • Turbine-driven Pump Train	 Unreliability and unavailability at the train level. Unreliability and unavailability at the train level.
Component Cooling Water (CCW)	Unreliability and unavailability at the train level.
Emergency AC Power (EPS)	Unreliability and unavailability at the train level.
High Pressure Injection (HPI)	Unreliability and unavailability at the train level.
Power Operated Relief Valve (PORV)	Unreliability at the system level.
Residual/Decay Heat Removal (RHR)	Unreliability and unavailability at the train level.
Service Water (SWS)	Unreliability and unavailability at the train level.
COMPONENT CLASSES (all plants)	
Air-Operated Valves (AOVs)	Unreliability at the component level.
Motor-Operated Valves (MOVs)	Unreliability at the component level.
Motor-Driven Pumps (MDPs)	Unreliability at the component level.

Table 3.1.2-2 BWR Mitigating System RBPIs

RBPIs & Example Thresholds for BWR 3/4 Plant 18					
Mitigating System	Baseline Train Unavailability or Unreliability	Green/White 95th %ile	Green/White ΔCDF =1E-6	White/Yellow ΔCDF =1E-5	Yellow/Red ΔCDF =1E-4
Emergency AC Power	(Unreliability) 4.0E-2	9.9E-2	4.2E-2	5.8E-2	1.5E-1
	(Unavailability) 9.7E-3	1.9E-2	1.4E-2	4.9E-2	3.9E-1
Reactor Core Isolation Cooling	(Unreliability) 7.9E-2	1.7E-1	9.1E-2	2.0E-1	Not Reached.
	(Unavailability) 1.3E-2	4.0E-2	2.8E-2	1.7E-1	Not Reached.
Essential Service Water	(Unreliability) 2.5E-2	8.0E-2	2.7E-2	4.2E-2	1.3E-1
	(Standby Train Unavail.) 1.9E-2	5.4E-2	2.2E-2	5.6E-2	3.9E-1
HPCI	(Unreliability) 2.4E-1	4.3E-1	2.6E-1	4.6E-1	Not Reached.
	(Unavailability) 9.7E-3	3.8E-2	8.2E-2	7.3E-1	Not Reached.
Residual Heat Removal	(Unreliability) 8.8E-3	2.3E-2	2.0E-2	6.8E-2	2.2E-1
	(Unavailability) 1.0E-2	2.5E-2	1.4E-1	Not Reached	Not Reached
AOVs	Component Class Unreliability	N/A	Increase 2.2X	Increase 13X	Increase 83X
MOVs	Component Class Unreliability	N/A	Increase 1.7X	Increase 7.0X	Increase 28X
MDPs	Component Class Unreliability	N/A	Increase 1.2X	Increase 5.1X	Increase 28X

Table 3.1.2-3 PWR Mitigating System RBPIs

RBPIs & Example Thresholds for WE 4-Lp Plant 22					
Mitigating System	Baseline Train Unavailability or Unreliability	Green/White 95th %ile	Green/White ΔCDF =1E-6	White/Yellow ΔCDF =1E-5	Yellow/Red ΔCDF =1E-4
Auxiliary Feedwater	(MDP Train Unreliability) 8.7E-3	2.1E-2	9.8E-3	1.8E-2	5.4E-2
	(TDP Train Unreliability)1.9E-1	3.4E-1	2.0E-1	2.9E-1	Not Reached
	(MDP Train Unavailability) 1.1E-3	2.5E-3	3.7E-3	2.8E-2	2.5E-1
	(TDP Train Unavailability) 4.6E-3	1.8E-2	2.1E-2	1.7E-1	Not Reached
Component Cooling Water	(Unreliability) 1.6E-2	4.7E-2	2.0E-1	6.5E-1	Not Reached
	(Standby Train Unavailability)	4.4E-2	7.8E-1	Not Reached	Not Reached
Emergency AC Power	(Unreliability) 4.2E-2	1.0E-1	4.3E-2	5.5E-2	1.3E-1
	(Unavailability) 9.7E-3	1.9E-2	1.3E-2	3.9E-2	3.0E-1
High Pressure Injection (Includes CVC trains)	(SI Unreliability) 9.7E-3	2.1E-2	8.8E-1	Not Reached	Not Reached
	(SI Unavailability) 4.2E-3	1.6E-2	Not Reached	Not Reached	Not Reached
	(CVC Unreliability) 5.9E-2	1.9E-1	4.3E-1	Not Reached	Not Reached
	(CVC Standby Train Unav) 5.4E-2	1.7E-1	Not Reached	Not Reached	Not Reached
Power Operated Relief Valves	(System Unreliability) 3.2E-2	6.8E-2	5.7E-2	2.6E-1	Not Reached
Residual/Decay Heat Removal	(Unreliability) 1.7E-2	3.8E-2	3.8E-2	1.3E-1	4.7E-1
	(Unavailability) 7.3E-3	2.4E-2	9.3E-2	8.8E-1	Not Reached[1]
Service Water	(Unreliability) 3.2E-2	9.4E-2	1.3E-1	2.1E-1	3.2E-1
	(Standby Train Unav) 2.7E-2	9.0E-2	Not Reached	Not Reached	Not Reached
AOVs	Component Class Unreliability	N/A	Increase 2.2X	Increase 13X	Increase 106X
MOVs	Component Class Unreliability	N/A	Increase 2.4X	Increase 11X	Increase 39X
MDPs	Component Class Unreliability	N/A	Increase 1.2X	Increase 3.2X	Increase 16X

Summary of RBPI development Results

Containment Performance:

- Potential containment RBPIs include:
  - Unreliability/unavailability of drywell spray (Mark I BWRs)
  - Unreliability/unavailability of large containment isolation valves (PWRs, and Mark III BWRs)
- Models and data are not currently available for these potential RBPIs to quantify baseline performance values, thresholds, or ongoing performance.

Summary of RBPI development Results

Shutdown Modes:

- No initiating event RBPIs are identified for shutdown modes due to inability to support timely detection of declining performance
- Proposed mitigating system RBPIs during shutdown reflect excess time spent in risk-significant shutdown configurations
- Four shutdown configuration categories are defined based on CCDF: Low, Medium, Early Reduced-Inventory (vented), and High
  - Table 3.2.2-1 and 3.2.2-2 provide risk category thresholds
- Risk-significant shutdown configurations are categorized by:
  - RCS conditions
  - time after shutdown
  - availability of mitigating system trains
  - Table 3.2.2-3 and 3.2.2-4 provide risk classifications
- App. B includes details of RBPI development for shutdown modes

Table 3.2.2-1 Baseline and Thresholds for Time in Risk-Significant Configurations Indicators - PWRs

Configur. Category	Baseline	G/W Threshold	W/Y Threshold	Y/R Threshold
Low	20 days	21 days	30 days	120 days
Medium	2 days	2 days + .08 day (2 hrs)	3 days	12 days
Early Reduced-Inventory (vented)[a]	1 day	1 day	1.08 days (1 day + 2 hrs)	2 days
High	0	0+	.08 day (2 hrs)	1 day

a. This configuration category assumes that measures are taken to compensate for the risk associated with early reduced-inventory operations, as explained in Appendix B. If compensatory measures are not taken, these configurations are assigned to the "High" configuration category.

Table 3.2.2-2 Baseline and Thresholds for Time in Risk-Significant Configurations Indicators - BWRs

Configuration Category	Baseline	G/W Threshold	W/Y Threshold	Y/R Threshold
Low	2 days	3 days	12 days	102 days
Medium	0.20 day (5 hrs)	0.29 day (7 hrs)	1 day	10 days
High	0	0+	.08 day (2 hrs)	1 day

Table 3.2.2-3 PWR Shutdown Configurations Risk Classification (Based on a Generic Westinghouse 4-Loop Shutdown PRA Model)

POS				No Maintenance Unavailability	Backup RHR Train Unavailable	Emergency AC Trains Unavailable			Support Cooling Trains Unavailable		Secondary Cooling Trains Unavailable			Emergency Injection Trains Unavailable			Other Trains Unavailable			
Group	Mode	RCS Boundary	Days After Shutdown		RHR	EDG	EDG(2)	One Safety-Related AC Bus	One train of ESW	One train of CCW	One train of AFW	All AFW	All SGs	RWST	SI(2)[a]	Both Sumps	PORV(2)	SG/ PORV	SG/ RWST	SG/ and Both Sumps
Low Inventory Configurations Occurring Very Early (within the first 5 days) in an Outage																				
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	Intact or isolatable	2	Low	Med	Low	Low	Low	Low	Med	High	High	High	Low	Low	High	Low	High	High	High
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	vented	< 5	ERI-V[b]	ERI-V[b]									ERI-V[b]						
Representative Configurations Occurring in a Typical Outage																				
Pressurized Cooldown	Mode 4 Hot shutdown	Intact	4			Low	Med	Low	Low					Med		Low				
Depressurized RHR Cooldown with Normal Inventory	Mode 5 Cold shutdown	Intact	8				Low	Low			Low	Low	Low	Low		Low		High	High	High
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	Intact or isolatable	12		Low		Low	Low	Low	Low	Med	Med	Med	Low		Low	Low	High	High	High
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	vented	7	Med	Med	Med	Med	High	Med	Med				High	Med	Med				
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	vented	13	Med	Med	Med	Med	High	Med	Med				High	Med	Med				
Refueling Cavity Filled	Mode 6	vented	14													Med				
Low Inventory Configurations Occurring Late in a Typical Outage																				
Depressurized RHR Cooling with Reduced Inventory	Mode 5 Cold shutdown	vented	24			Low	Med	Low	Low	Low				Med	Low	Low				

Notes: Shaded cells indicate combinations of POS and configuration that are not analyzed, either because the configuration violates the POS definition, or the systems involved play no role in the POS. Blank cells represent configurations whose CCDF < 1.0E-6 per day.

a. In this configuration it is assumed that a makeup pump is available.

b. This configuration category assumes that measures are taken to compensate for the risk associated with early reduced-inventory operations, as explained in Appendix B. If compensatory measures are not taken, these configurations are assigned to the “High” configuration category.

Table 3.2.2-4 BWR Shutdown Configurations Risk Classification (Based on NUREG/CR-6166 Results)

POS			No Maintenance Unavailability	Emergency AC/DC Trains Unavailable					Support Cooling Trains Unavailable		
Group	Mode	RCS Boundary		EDG I or II	4 EDG I & II	EDG I & III	One. BAT division	Two BAT divisions	SSW A	SSW C	SSW A & C
POS 4	Hot shutdown	Intact		Low	Med	Low		High		Low	Med
POS 5	Cold shutdown	Vessel head on		Low	Med	Low	Low	High	Low	Low	Med
POS 6	Refueling	Vessel head off (level raised to steam line)									
POS 7	Refueling	Upper pool filled									Low

Note: Blank cells indicate combinations of POS and configuration that are not analyzed, either because the configuration violates the POS definition, or the systems involved play no role in the POS.

POS			No Maintenance Unavailability	Emergency Cooling Trains Unavailable				Other Trains Unavailable			
Group	Mode	RCS Boundary		HPCS	LPCS & HPCS	SP empty	SRVs all	SSW A & HPCS	SSW A & CDS	RHR A and all SRVs	SDC A and SP
POS 4	Hot shutdown	Intact		Low	Low	Med	Med	Med		High	Med
POS 5	Cold shutdown	Vessel head on		Low	Low	High	High	Med	Low	High	High
POS 6	Refueling	Vessel head off (level raised to steam line)				Med					Med
POS 7	Refueling	Upper pool filled				Low		Low			Low

Note: Blank cells indicate combinations of POS and configuration that are not analyzed, either because the configuration violates the POS definition, or the systems involved play no role in the POS.

Summary of RBPI development Results

Fire Events:

- No initiating event RBPIs for fire are identified due to inability to support timely detection of declining performance.
- Potential mitigating system RBPIs are identified for reliability and availability of fire suppression system
- Data are not currently available for these RBPIs to quantify baseline performance values and thresholds

Summary of RBPI development Results

Risk Coverage by RBPIs:

- Risk coverage was assessed using two methods, one based on RAW of risk-significant elements, and the other based on coverage of dominant core damage accident sequences

- Table 4-1 shows risk coverage results for two plants using RAW importance measure

  - Approximately 40% of events in SPAR models are part of RBPIs
  - Types of elements in other 60% are operator actions, batteries, check valves, heat exchangers, tanks, strainers, etc

- Table 4.2a shows risk coverage at initiating event/system level using dominant core damage accident sequences from IPE studies for two plants

  - Almost all dominant accident sequences are covered by multiple RBPIs
  - Elements not covered are potential areas for inspection
  - Sequences with no RBPI coverage are not dominant sequences

Table 4-1 Coverage of Risk Significant Core Damage Elements from SPAR Models

Category	BWR 3/4 Plant 18	WE 4-Lp Plant 22
Total number of SPAR model elements whose failure can result in $\Delta CDF \geq 1E\text{-}6/y$	178	203
- Initiating events	14	14
- Mitigating systemelements	164	189
Elements covered by RBPIs		
- Initiating events	3/14 (21%)	3/14 (21%)
- Initiating events covered by trending	3/14 (21%)	4/14 (29%)
- Mitigating system elements	70/164 (43%)	72/189 (38%)
Types of elements not explicitly covered by RBPIs	Batteries Check valves Electrical buses Heat exchangers Post-event human errors Reactor protection system Strainers Tanks	Batteries Check valves Electrical buses Heat exchangers Post-event human errors Reactor protection system Strainers Fans

Table 4-2a RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - BWR 3/4 Plant 18 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES				
1	5.28E-07	T-LOOP	AC	EAC			
2	1.60E-07	S1	HUM				
3	2.70E-08	T-LOOP	HP1	HUM	AC		
4	2.21E-08	T-LOOP	AC	EAC			
5	2.05E-08	T-ATWS	RPS	CONDA	HUM		
6	1.80E-08	T-LOOP	HPCI(HPCS)	RCIC	AC	EAC	
7	1.34E-08	T-LOOP	HP1	HUM	AC		
8	1.16E-08	T-RX	ADS	DC			
9	1.10E-08	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
10	8.96E-09	T-LOOP	HP1	LPCI	SPC	AC	
11	8.12E-09	T-RX	DC				
12	7.76E-09	T-ATWS	RPS	LPCI	CS	CONDA	HUM
13	7.59E-09	T-LOOP	SPC	HUM	AC		
14	7.00E-09	T-LOOP	HP1	SPC	HUM	AC	
15	6.90E-09	T-LOOP	HP1	SPC	HUM	AC	
16	6.72E-09	T-LOOP	HP1	HUM	AC		
17	6.13E-09	T-ATWS	RPS	CONDA	HUM		
18	5.83E-09	T-ATWS	RPS	CONDA	HUM		
19	5.77E-09	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
20	5.66E-09	A	LPCI	CS			
21	5.53E-09	T-LOOP	HPCI(HPCS)	RCIC	HUM	AC	
22	5.43E-09	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
23	5.10E-09	T-RX	HPCI(HPCS)	RCIC	HP1	HUM	
24	5.02E-09	S2	HPCI(HPCS)	HUM			
25	4.60E-09	A	SPC	AC			
26	4.46E-09	T-LOOP	HP1	LPCI	SPC	AC	
27	4.44E-09	T-LOOP	LPCI	SPC	HUM	AC	
28	3.88E-09	T-ATWS	RPS	HP1	CONDA	HUM	
29	3.83E-09	S1	HPCI(HPCS)	HUM			
30	3.78E-09	T-LOOP	SPC	HUM	AC		
31	3.62E-09	T-ATWS	RPS	HPCI(HPCS)	CONDA	HUM	
32	3.46E-09	T-LOOP	HP1	HUM	AC		
33	3.42E-09	T-LOOP	SPC	HUM	AC		
34	3.38E-09	T-RX	HPCI(HPCS)	RCIC	MFW	HP1	HUM

Summary of RBPI development Results

Validation and Verification:

- The purpose of this effort was to show that RBPIs can be calculated using readily available data and risk models consistent with current ROP philosophy
  - Feasibility of the process was demonstrated through these calculations
  - In order for these potential RBPIs to be used in ROP, implementation issues related to model fidelity and data quality need to be resolved
- RBPIs for full power, internal events were tested by evaluating plant-specific data for 23 plants over three-year period (1997-1999)
  - Rev 3i SPAR models with industry average reflecting 1996 performance were used for baseline
  - EPIX database was used for unreliability
  - ROP data was used for unavailability
  - NUREG/CR-5750 was used for initiating event frequencies

Summary of RBPI development Results

Validation and Verification (cont'd):

- Validation and Verification effort showed that RBPIs provide:
  - More precise accounting for risk-significant design features of plants
  - More plant-specific thresholds
  - More appropriate accounting for risk impact of fault exposure time
  - "Face validity" approach used
- Results are shown in Tables 5.3-1 thru 5.3-4
- Since models/data in these tables have not been formally peer reviewed, plant-specific inferences regarding "green" or "non-green" performance from these calculations would be inappropriate.

Table 5.3-1 Plant Performance Bands for Initiating Event RBPIs (1999) [a, e]

	1999		
Plant	GT [b]	LOHS [c]	LOFW [c,d]
PWRs			
WE 4-Lp Plant 1	2.8E-1 (G)	5.9E-2 (G)	5.3E-2 (G)
WE 4-Lp Plant 2	2.1E+0 (W)	5.8E-2 (G)	1.6E-1 (G)
CE Plant 2	1.5E+0 (G)	2.9E-1 (W)	5.2E-2 (G)
CE Plant 3	3.2E-1 (G)	5.9E-2 (G)	5.2E-2 (G)
CE Plant 4	3.0E-1 (G)	5.9E-2 (G)	5.2E-2 (G)
CE Plant 5	1.2E+0 (G)	8.4E-2 (G)	No data (G)
B&W Plant 4	1.6E+0 (W)	6.3E-2 (G)	5.5E-2 (G)
B&W Plant 5	2.8E+0 (Y)	1.8E-1 (W)	5.3E-2 (G)
B&W Plant 6	2.8E-1 (G)	6.0E-2 (G)	5.4E-2 (G)
WE 2-Lp Plant 5	9.3E-1 (G)	1.8E-1 (W)	5.3E-2 (G)
WE 2-Lp Plant 6	2.8E-1 (G)	5.9E-2 (G)	5.4E-2 (G)
CE Plant 12	2.1E+0 (W)	5.9E-2 (G)	1.6E-1 (G)
WE 4-Lp Plant 22	2.8E-1 (G)	5.8E-2 (G)	1.6E-1 (G)
WE 4-Lp Plant 23	2.9E-1 (G)	5.7E-2 (G)	1.5E-1 (G)
BWRs			
BWR 3/4 Plant 5	3.0E-1 (G)	9.2E-2 (G)	5.3E-2 (G)
BWR 3/4 Plant 6	3.4E-1 (G)	9.1E-2 (G)	5.2E-2 (G)
BWR 3/4 Plant 8	1.6E+0 (G)	9.0E-2 (G)	5.2E-2 (G)
BWR 5/6 Plant 2	1.0E+0 (G)	2.7E-1 (G)	5.1E-2 (G)
BWR 3/4 Plant 11	3.3E-1 (G)	9.2E-2 (G)	5.2E-2 (G)
BWR 3/4 Plant 15	9.1E-1 (G)	8.6E-2 (G)	5.1E-2 (G)
BWR 3/4 Plant 16	3.2E-1 (G)	8.8E-2 (G)	5.2E-2 (G)
BWR 3/4 Plant 18	9.4E-1 (G)	9.8E-2 (G)	5.5E-2 (G)
BWR 3/4 Plant 19	3.0E-1 (G)	1.1E-1 (G)	5.8E-2 (G)

a. Plant performance bands are the following: green (G) - ΔCDF < 1.0E-6/y, white (W) - 1.0E-6/y < ΔCDF <1 .0E-5/y, yellow (Y) - 1.0E-5/y < ΔCDF <1 .0E-4/y, red (R) - ΔCDF > 1.0E-4/y.

b. A one-year data collection interval applies (1999). The 1999 data were obtained from the ROP.

c. A three-year data collection interval applies (1997 – 1999). 1997 and 1998 data were obtained from the initiating events study update (Poloski 2000), while the 1999 data were obtained from the ROP.

d. This RBPI is not covered under the ROP, so the results presented in this table include only 1997 and 1998. (1999 Licensee Event Reports will need to be reviewed to identify scrams that are LOFW, as defined in the initiating events study.)

e. Since the models and data in these tables have not completed formal peer review, plant specific inferences regarding "green" or "non-green" performance from these calculations would be inappropriate.

Table 5.3-2 Plant Performance Bands for Mitigating System Unavailability RBPIs (1999)[b]

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR	SWS[a]	CCW[a]	PORV[a]
PWRs							
WE 4-Lp Plant 1	3.5E-3 (G)	3.3E-3 (G)	MDP (3.4E-3) DDP (4.3E-2) (Y)	9.1E-5 (G)	No data	No data	No data
WE 4-Lp Plant 2	3.3E-3 (G)	1.5E-2 (G)	MDP (2.4E-3) DDP (1.1E-2) (G)	8.0E-3 (G)	No data	No data	No data
CE Plant 2	6.6E-3 (G)	7.2E-3 (G)	MDP (0.0E+0) TDP (2.9E-3) (G)	1.0E-2 (G)	No data	No data	No data
CE Plant 3	7.5E-3 (G)	1.1E-2 (G)	MDP (2.4E-3) TDP (4.5E-3) (G)	1.4E-2 (G)	No data	No data	No data
CE Plant 4	9.5E-3 (G)	1.3E-3 (G)	MDP (9.8E-4) TDP (6.2E-3) (G)	2.1E-3 (G)	No data	No data	No data
CE Plant 5	1.1E-2 (G)	8.3E-3 (G)	MDP (4.9E-3) (W) TDP (6.4E-3)	4.1E-3 (G)	No data	No data	No data
B&W Plant 4	2.3E-2 (G)	5.3E-3 (G)	MDP (4.0E-3) TDP (0.0E+0) (G)	1.9E-2 (G)	No data	No data	NA
B&W Plant 5	2.4E-2 (G)	3.0E-3(G)	MDP (3.3E-3) TDP (3.1E-3) (G)	1.3E-2 (G)	No data	No data	NA
B&W Plant 6	2.2E-2 (G)	2.5E-3 (G)	MDP (6.8E-3) TDP (8.9E-4) (G)	1.1E-2 (G)	No data	No data	NA
WE 2-Lp Plant 5	1.3E-2 (G)	1.4E-3 (G)	MDP (4.4E-3) TDP (6.7E-3) (G)	1.6E-2 (G)	No data	No data	No data
WE 2-Lp Plant 6	1.0E-2 (G)	1.2E-3 (G)	MDP (4.2E-3) TDP (2.5E-3) (G)	2.6E-3 (G)	No data	No data	No data
CE Plant 12	5.1E-3 (G)	7.3E-3 (G)	MDP (5.3E-3) (W) TDP (4.6E-3)	7.1E-3 (G)	NA	No data	No data
WE 4-Lp Plant 22	9.6E-3 (G)	7.7E-3 (G)	MDP (7.6E-3) (W) TDP (4.0E-3)	4.4E-3 (G)	No data	No data	No data
WE 4-Lp Plant 23	1.2E-2 (G)	4.9E-3 (G)	MDP (1.2E-2) (W) TDP (6.3E-3)	8.2E-3 (G)	No data	No data	No data

Table 5.3-2 (Continued)

Plant BWRs	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR	SWS [a]	CCW [a]	PORV [a]
BWR 3/4 Plant 5	2.9E-3 (G)	2.4E-3 (G)	5.5E-3 (G)	0.0E+0 (G)	No data	NA	NA
BWR 3/4 Plant 6	1.3E-2 (G)	2.1E-3 (G)	1.0E-2 (G)	8.4E-3 (G)	No data	NA	NA
BWR 3/4 Plant 8	1.9E-2 (G)	2.8E-2 (G)	5.0E-2 (G)	7.8E-3 (G)	No data	NA	NA
BWR 5/6 Plant 2	3.6E-2 (W)	4.6E-3 (G)	1.5E-2 (G)	4.4E-3 (G)	No data	NA	NA
BWR 3/4 Plant 11	7.4E-3 (G)	1.8E-2 (G)	1.8E-2 (W)	1.2E-2 (G)	No data	NA	NA
BWR 3/4 Plant 15	1.5E-2 (G)	1.6E-2 (G)	8.6E-3 (G)	9.1E-3 (G)	No data	NA	NA
BWR 3/4 Plant 16	2.2E-2 (G)	2.1E-2 (G)	7.9E-3 (G)	1.3E-2 (G)	No data	NA	NA
BWR 3/4 Plant 18	2.1E-2 (W)	4.5E-1 (W)	1.7E-2 (G)	5.4E-3 (G)	No data	NA	NA
BWR 3/4 Plant 19	1.8E-2 (W)	1.7E-2 (G)	1.8E-2 (G)	7.5E-3 (G)	No data	NA	NA

a. Unavailability data are not available (not covered by the ROP) at this time. Eventually, EPIX may contain such data.

b. Since the models and data in these tables have not completed formal peer review, plant specific inferences regarding "green" or "non-green" performance from these calculations would be inappropriate.

Table 5.3-3 Plant Performance Bands for Mitigating System Unreliability RBPIs (1997 - 1999)[e]

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR[a]	SWS	CCW	PORV
PWRs							
WE 4-Lp Plant 1	< baseline (G)[b]	No data[c]	< baseline (G)	< baseline (G)	No data	No data	No data
WE 4-Lp Plant 2	< baseline (G)	No data	< baseline (G)	< baseline (G)	No data	No data	No data
CE Plant 2	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	No data	No data
CE Plant 3	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	No data	No data
CE Plant 4	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	< baseline (G)
CE Plant 5	< baseline (G)	< baseline (G)	< baseline (G)	No data	No data	< baseline (G)	No data
B&W Plant 4	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	NA
B&W Plant 5	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	NA
B&W Plant 6	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	NA
WE 2-Lp Plant 5	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	< baseline (G)	< baseline (G)
WE 2-Lp Plant 6	< baseline (G)	No data	< baseline (G)	< baseline (G)	< baseline (G)	No data	< baseline (G)
CE Plant 12	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	NA	< baseline (G)	No data
WE 4-Lp Plant 22	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)
WE 4-Lp Plant 23	< baseline (G)	< baseline (G)	1.5E-2 (MDP) (W) (0.13)[d]	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)
BWRs							
BWR 3/4 Plant 5	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 6	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 8	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 5/6 Plant 2	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	NA	NA
BWR 3/4 Plant 11	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 15	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 16	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 18	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA
BWR 3/4 Plant 19	< baseline (G)	< baseline (G)	< baseline (G)	< baseline (G)	No data	NA	NA

a. Reflects pump data. Valve data still need to be collected and evaluated.

b. "< baseline" indicates that there were not enough failures to result in a train unreliability greater than the baseline.

c. "No data" indicates that either EPIX has no data on this system, or the RADS data load of the EPIX file did not include this system.

d. The 0.13 probability indicates that there is only a 13% chance that performance is at its baseline value.

Table 5.3-4 Plant Performance Bands for Component Class RBPIs (1997 - 1999)[e]

Plant	AOV	MOV	MDP
PWRs			
WE 4-Lp Plant 1	No data[a]	No data	< baseline (G)[b]
WE 4-Lp Plant 2	No data	No data	< baseline (G)
CE Plant 2	< baseline (G)	< baseline (G)	< baseline (G)
CE Plant 3	1.6E-3 (1.6X) (G)[c]	< baseline (G)	< baseline (G)
CE Plant 4	3.8E-3 (3.8X) (G)[c]	< baseline (G)	< baseline(G)
CE Plant 5	No data	< baseline (G)	< baseline (G)
B&W Plant 4	< baseline (G)	< baseline (G)	< baseline (G)
B&W Plant 5	< baseline (G)	< baseline (G)	< baseline (G)
B&W Plant 6	< baseline (G)	< baseline (G)	< baseline (G)
WE 2-Lp Plant 5	< baseline (G)	< baseline (G)	< baseline (G)
WE 2-Lp Plant 6	< baseline (G)	< baseline (G)	6.0E-3 (1.6X) (W)[c] (0.19)[d]
CE Plant 12	< baseline (G)	1.3E-2 (4.4X) (W)[c] (0.002)[d]	< baseline (G)
WE 4-Lp Plant 22	< baseline (G)	< baseline (G)	< baseline (G)
WE 4-Lp Plant 23	< baseline (G)	< baseline (G)	< baseline (G)
BWRs			
BWR 3/4 Plant 5	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 6	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 8	No data	< baseline (G)	< baseline (G)
BWR 5/6 Plant 2	< baseline (G)	< baseline (G)	< baseline (G)
BWR 3/4 Plant 11	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 15	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 16	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 18	No data	< baseline (G)	< baseline (G)
BWR 3/4 Plant 19	No data	< baseline (G)	< baseline (G)

a. "No data" indicates that either EPIX has no data on this component class, or the RADS data load of the EPIX file did not include it.

b. "< baseline" indicates that there were not enough failures to result in a train unreliability greater than the baseline.

c. The number in parentheses "1.6X" indicates that the unreliability is 1.6 times the baseline.

d. The component class RBPIs have the potential for false-positive indications. Therefore, the probability of the underlying performance actually being at its baseline (G) value is also presented.

Industry-Wide Trending

- Industry-wide trending includes all proposed RBPIs plus risk-significant IEs and CCF events that are impractical to monitor on a plant-specific basis.
  - Table ES-2 provides a summary of proposed trends
- Industry-wide trending provides:
  - Measures of ROP effectiveness.
  - Provides feedback to ROP to adjust technical emphasis and overall inspection frequencies.
  - input to agency Strategic Plan Performance Measures

Table ES-2 Summary of Phase-1 Performance Areas Proposed for Industry-Wide Trending

Safety Cornerstone	Industry-Wide Trend
Initiating Event	**<u>Full Power:</u>** – All proposed IE RBPIs listed in Table ES-1 – Internal flooding – Initiators evaluated as ASPs – Loss of instrument/control air (for BWRs and PWRs) – LOOP – Loss of vital AC bus – Loss of vital DC bus – Small LOCA (including very small LOCA) – SGTR – Stuck open safety/relief valves **<u>Shutdown:</u>** – LOOP during shutdown modes – Loss of RHR during shutdown modes – Loss or diversion of RCS inventory during shutdown modes leading to loss of RHR – Loss of RCS level control (during transition to mid-loop) leading to loss of RHR (for PWRs only) **<u>Fire:</u>** – Fire events in risk-significant fire areas
Mitigating System	– All proposed mitigating system RBPIs listed in Table ES-1 – CCF events for AFW pumps – CCF events for Diesel Generators – Total CCF events
Barriers	None

Key Implementation Issues

- Are any additional performance indicators needed in ROP?
  - Stake holders expressed differing views
    - Industry questioned need for greater sample size with expectation of less inspections if more PIs are used
    - Other external stakeholders favored more PIs and more inspections
  - RBPIs support general ROP concept of increased reliance on objective indications of performance and PRA Policy Statement to increase use of PRA technology "in all matters to the extend supported by the state-of-the-art PRA methods and data..."
  - RBPIs relate to improvements under "Maintaining Safety" and "Improved Regulatory Efficiency, Effectiveness, and Realism".
  - ROP change process addresses regulatory benefits and other implementation issues.

Key Implementation Issues

- **Is the number of potential new performance indicators appropriate?**
  - **21 RBPIs for PWRs and 16 RBPIs for BWRs could replace 8 of 18 existing PIs.**
  - **Total number of indicators could potentially be about 30 compared to 18 existing indicators.**
  - **Total number of performance indicators should be commensurate with risk coverage needed.**

Key Implementation Issues

- Do data sources for RBPIs exist and have sufficient quality for use in ROP?
  - A significant portion of RBPIs requires data from EPIX
  - Data are provided by licensees on a voluntary basis
  - Validation/verification and quality of EPIX data are important to the feasibility of many RBPIs
  - Data needs to be of sufficient quality so that small errors do not result in mis-classification of risk significance
  - Needed data for containment and shutdown RBPIs are not currently being reported by licensees

Key Implementation Issues

- Will Rev. 3i SPAR models be available for setting plant-specific thresholds for all plants?

  - The number of models needed depends on the level of plant-specific accuracy deemed appropriate by stakeholders
  - 30 Rev. 3i SPAR models are currently available and remaining 40 models are scheduled to be available by the end of 2002
  - External stakeholders recommended peer review of Rev. 3i SPAR models by licensees

Key Implementation Issues

- Will LERF models be available for setting baseline performance and thresholds for mitigating and containment systems?
  - Limited-scope LERF models are only available for some containment types.
  - Available LERF models are not compatible with Rev. 3i SPAR models.
  - Near-term SPAR model development plans only support limited LERF model development.
  - Due to these limitations, we are currently unable to determine whether LERF or CDF are more limiting for determination of performance thresholds.

Alternative Approaches for RBPI determination

- Comments received regarding the number of PIs being "excessive".
- Reexamined bases for current selection:
  - based on devolving risk
  - thresholds set at data collection level
  - impacts based on sequence effects
- Devolved risk logic to cornerstone level (Fig. A) and functions within cornerstone (Fig. 1 & 2).
- Separated thresholds from inputs. Thresholds set on ΔCDF of all inputs to a functional group (Fig. 3).
- Devised hierarchy of groups. (Fig. 3b).

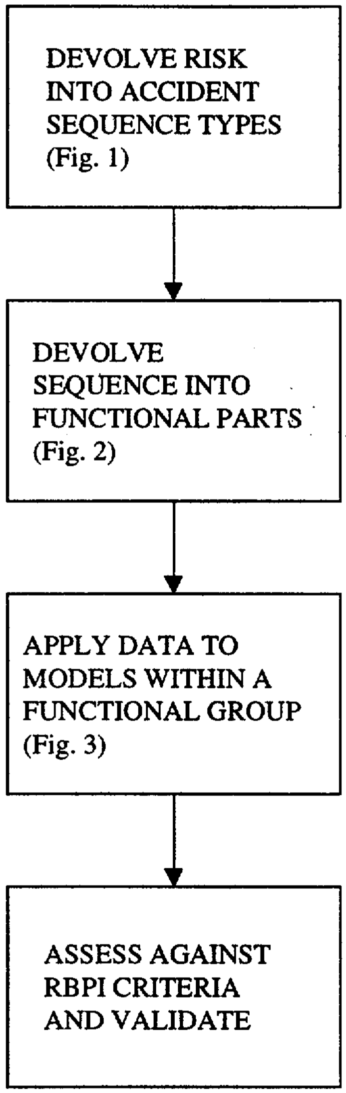

DEVOLVE RISK INTO ACCIDENT SEQUENCE TYPES (Fig. 1)
DEVOLVE SEQUENCE INTO FUNCTIONAL PARTS (Fig. 2)
APPLY DATA TO MODELS WITHIN A FUNCTIONAL GROUP (Fig. 3)
ASSESS AGAINST RBPI CRITERIA AND VALIDATE

FIGURE A

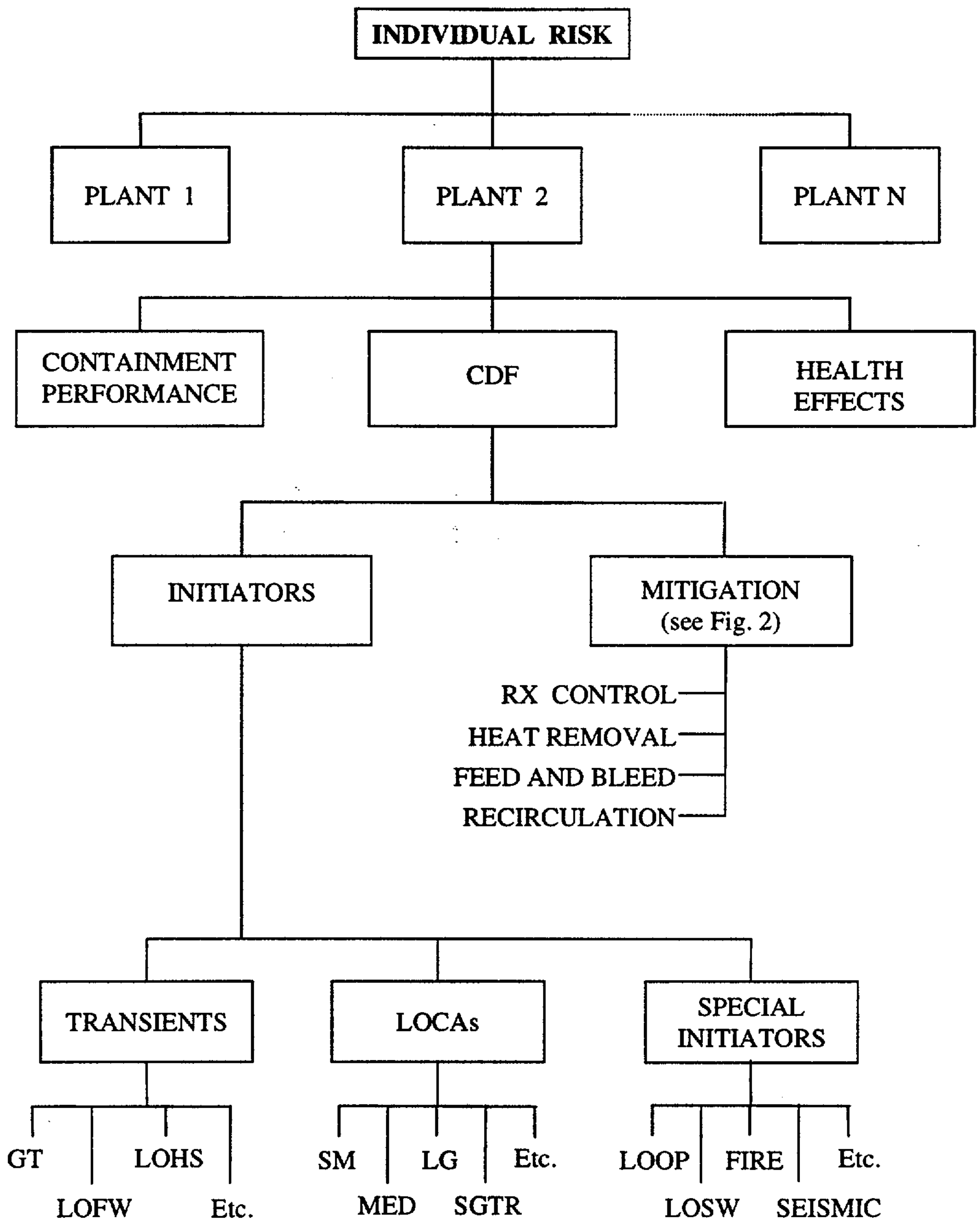
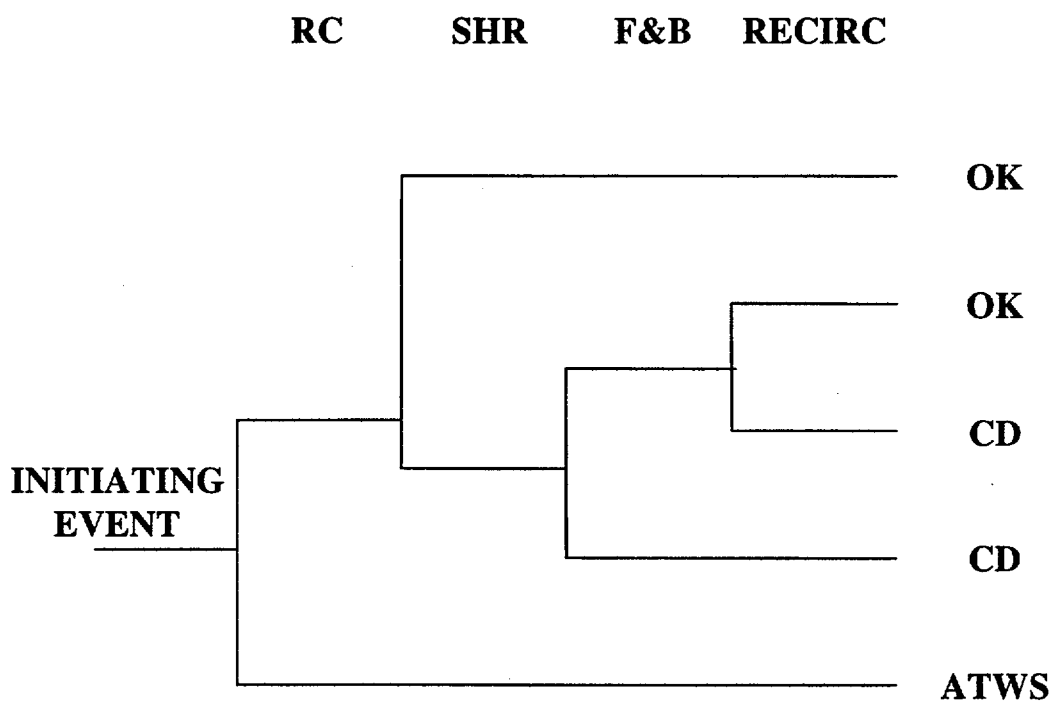

INDIVIDUAL RISK
PLANT 1
PLANT 2
PLANT N
CONTAINMENT PERFORMANCE
CDF
HEALTH EFFECTS
INITIATORS
MITIGATION (see Fig. 2)
RX CONTROL
HEAT REMOVAL
FEED AND BLEED
RECIRCULATION
TRANSIENTS
LOCAs
SPECIAL INITIATORS
GT
LOFW
LOHS
Etc.
SM
MED
LG
SGTR
Etc.
LOOP
LOSW
FIRE
SEISMIC
Etc.

FIGURE 1



RC: REACTIVITY CONTROL
SHR: SECONDARY HEAT REMOVAL
F&B: FEED AND BLEED
RECIRC: RECIRCULATION

FIGURE 2

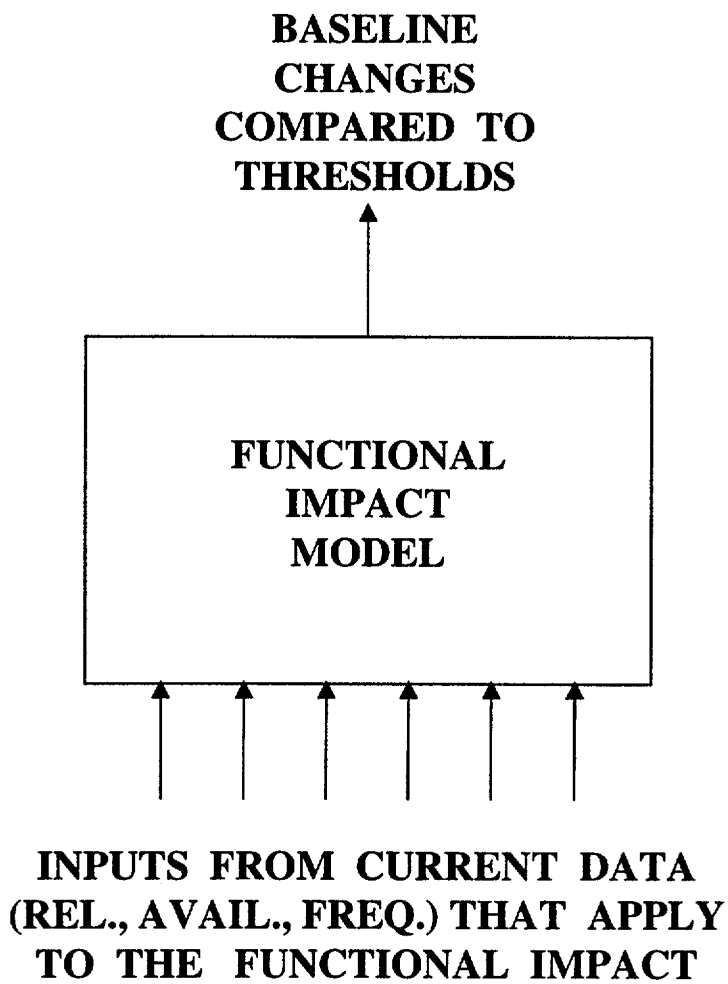

BASELINE CHANGES COMPARED TO THRESHOLDS
FUNCTIONAL IMPACT MODEL
INPUTS FROM CURRENT DATA (REL., AVAIL., FREQ.) THAT APPLY TO THE FUNCTIONAL IMPACT

FIGURE 3

Potential Indicator Hierarchy

- **CORNERSTONE LEVEL - One indicator for IE and mitigating systems for at power operation.**

- **FUNCTIONAL LEVEL - 3-5 indicators for each cornerstone.**

  - **Grouped by initator**
  - **Grouped by mitigating system/function**

- **COMPONENT/TRAIN LEVEL**

  - **RBPIs in Phase 1 report**
  - **System/function indicators grouped by initiating events**

POTENTIAL LEVELS OF RBPIs

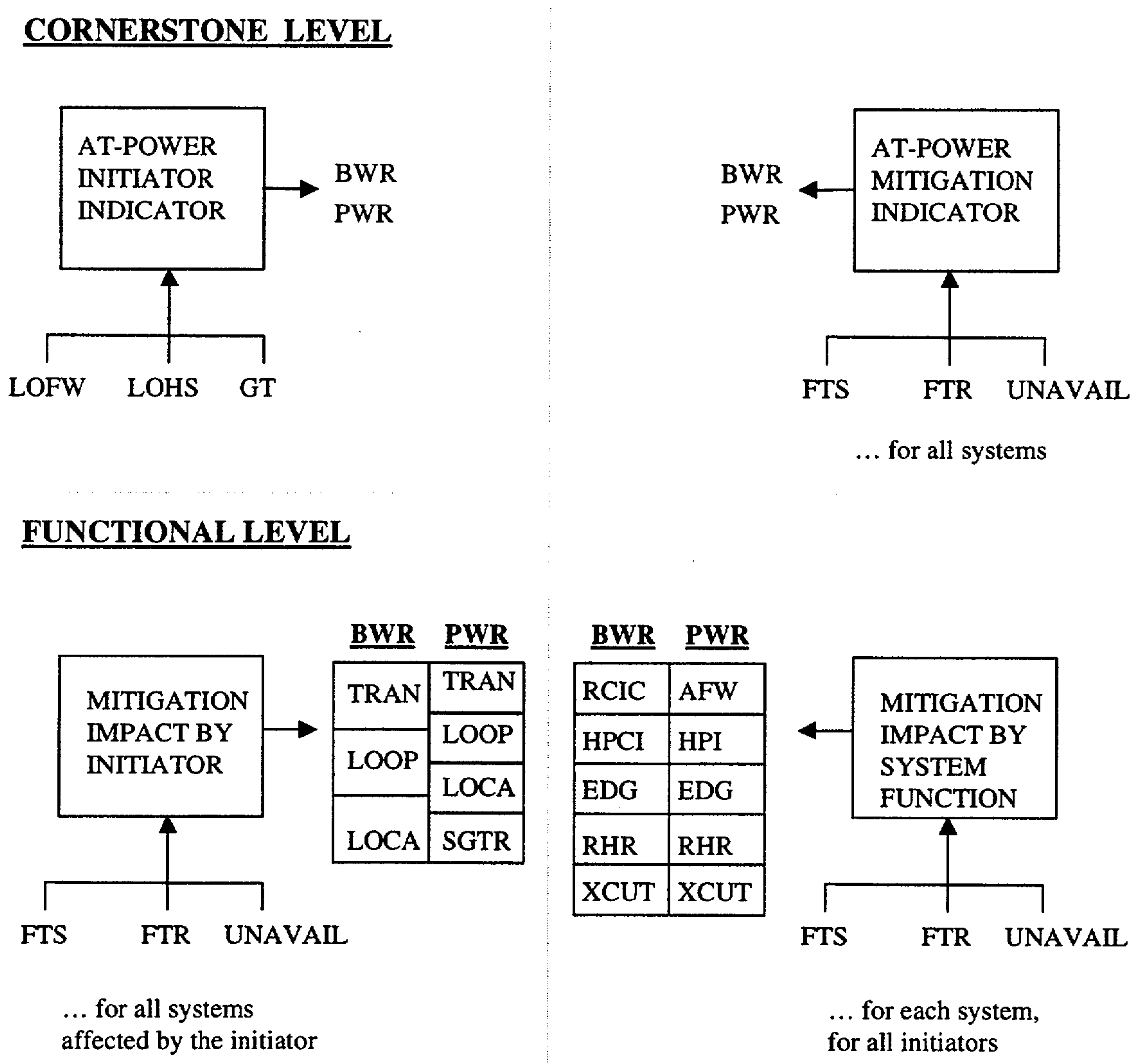


FIGURE 3b

Table 1 Cornerstone Level RBPIs

	Baseline CDF	Green	White	Yellow	Red
BWR Plant 18	2.0E-05	< 2.1E-05	<3.0E-05	< 1.2E-04	> 1.2E-04
All Systems (EPS, HPCI, RCIC, RHR)			2.5E-5 (W)		
All Initiators Combined		2.0E-5 (G)			
	Baseline CDF	**Green**	**White**	**Yellow**	**Red**
PWR Plant 23	3.4E-05	< 3.5E-05	< 4.4E-05	< 1.3E-04	> 1.3E-04
All Systems (AFW, EPS, HPI/PORV, RHR)			3.7E-5 (W)		
All Initiators Combined		3.4E-5 (G)			

NOTES:
1. (G) - Calculated CDF falls within the 'GREEN' performance band.
2. (W) - Calculated CDF falls within the 'WHITE' performance band.
3. Calculated CDF generated by quantifying model with all of the applicable failure values (e.g., FTS, FTR, UA) currently used for individual RBPIs.

Table 2 Functional Level Mitigation RBPI by Initiator

BWR Plant 18					
Baseline Plant CDF (2.0E-05)	**Baseline CDF**	**Green**	**White**	**Yellow**	**Red**
Baseline LOCA Group (SLOCA, MLOCA, LLOCA) CDF	1.6E-08	< 1.0E-06	< 1.0E-05	< 1.0E-04	> 1.0E-04
- Front Line Systems (RCIC, HPCI, RHR) & Components		3.7E-08 (G)			
Baseline LOOP/SBO Group CDF	1.8E-05	< 1.9E-05	< 2.8E-05	< 1.2E-04	> 1.2E-04
- Front Line Systems (RCIC, HPCI, EPS, RHR) & Components			2.2E-05 (W)		
Baseline TRANSIENT Group (TRAN, LDCB, LOSWS) CDF	2.2E-06	< 3.2E-06	< 1.2E-05	< 1.0E-04	> 1.0E-04
- Front Line Systems (RCIC, HPCI, RHR) & Components		2.4E-06 (G)			
PWR Plant 23					
Baseline Plant CDF (3.4E-05)	**Baseline CDF**	**Green**	**White**	**Yellow**	**Red**
Baseline LOCA Group (SLOCA, MLOCA, LLOCA) CDF	2.5E-07	< 1.2E-06	< 1.0E-05	< 1.0E-04	> 1.0E-04
- Front Line Systems (AFW, HPI/PORV, RHR) & Components		2.0E-07 (G)			
Baseline LOOP/SBO Group CDF	1.6E-05	< 1.7E-05	< 2.6E-05	< 1.2E-04	> 1.2E-04
- Front Line Systems (AFW, HPI/PORV, EPS, RHR) & Components		1.0E-05 (G)			
Baseline TRANSIENT Group (TRAN, LDCA, LOCCW, LOSWS) CDF	1.2E-05	< 1.3E-05	< 2.3E-05	< 1.1E-04	> 1.1E-04
- Front Line Systems (AFW, HPI/PORV, RHR) & Components			1.9E-05 (W)		
Baseline SGTR Group CDF	4.2E-06	< 5.2E-06	< 1.4E-05	< 1.0E-04	> 1.0E-04
- Front Line Systems(AFW, HPI/PORV, RHR) & Components		4.0E-06 (G)			

NOTES:
1. (G) - Calculated CDF falls within the 'GREEN' performance band.
2. (W) - Calculated CDF falls within the 'WHITE' performance band.

Table 3 Functional Level Mitigation RBPI by System

	Baseline CDF	Green	White	Yellow	Red
BWR Plant 18	2.0E-05	< 2.1E-05	< 3.0E-05	< 1.2E-04	> 1.2E-04
EPS		2.0E-5 (G)			
HPCI			2.6E-5 (W)		
RCIC		2.0E-5 (G)			
RHR		2.0E-5 (G)			
Component Groups (AOVs, MOVs, MDPs)		2.0E-5 (G)			
	Baseline CDF	**Green**	**White**	**Yellow**	**Red**
PWR Plant 23	3.4E-05	< 3.5E-05	< 4.4E-05	< 1.3E-04	> 1.3E-04
AFW			4.3E-5 (W)		
EPS		2.9E-5 (G)			
HPI & PORVs		3.4E-5 (G)			
RHR		3.4E-5 (G)			
Component Groups (AOVs, MOVs, MDPs)		3.4E-5 (G)			

NOTES:
1. (G) - Calculated CDF falls within the 'GREEN' performance band.
2. (W) - Calculated CDF falls within the 'WHITE' performance band.
3. Calculated CDF generated by quantifying model with all of the applicable failure values (e.g., FTS, FTR, UA) currently used for individual RBPIs.

Benefits/Limitations of Potential Alternate RBPIs

Cornerstone Level

- **Benefits:**
  - Single indicator for each cornerstone indicates overall performance at highest level
  - Takes into account intra- and inter- system impacts of performance in different areas (reliability vs availability, train vs system, and system vs. system)
- **Limitations:**
  - Causes of >green performance not directly known without further breakdown of indicator model, but it can be done practically

Benefits/Limitations of Potential Alternate RBPIs

Functional Level

- Benefits:
  - Fewer number of indicators (<6) for each cornerstone
  - Accounts for intra- and inter-system impacts
  - Can be grouped by either initiators (LOOP, TRANS, LOCA, etc) or by system functions (heat removal, emergency power, etc.)

- Limitations:
  - Doesn't directly provide cornerstone-level performance (still need to use Action Matrix)
  - Causes of >green performance not directly known, but can be derived by devolving indicators into parts.

Benefits/Limitations of Potential Alternate RBPIs

Component/Train Level

- Benefits:
  - Broadest evaluation of individual performance attributes
  - Causes of >green performance readily identified
  - Greater similarity to current indicators
- Limitations:
  - Intra- and Inter-system impacts not accounted for (synergies of impacts can be conservative or non-conservative depending on accident sequence logic)
  - Nearly doubles current number of PIs
  - Requires thresholds set for each data input

Summary of RBPI development Results

- We are looking for ACRS feedback (via a letter)on:
  - Potential benefits to ROP
  - Technical adequacy of RBPIs as enhancement to ROP
  - Alternate approaches to RBPIs in response to concern over the total number of RBPIs