PRA Quality
Peer Review Results of Taiwan NPPs

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Overview

- Background and Brief History
- Peer Review Results and Gap Analyses
- Comments and Regulatory Response
- PRA Applications

The Need of Robust PRA Quality

- **Maintenance Rule being implemented at the three operating NPPs in Taiwan**
  - A complementary measure to the license renewal program
- **Regulatory decisions of AEC on some incidents**
- **Urge for more “routine” on-line maintenances**
- **Efforts to achieve significant refueling outage shortening and lower collective exposure**
  - Risk-informed inservice inspection
  - Risk-informed inservice testing

A Brief History of PRA in Taiwan

Major PRA Projects (Main Sponsor)	Periods	Scope							Application	Task Force Man-year
		P	SM	TY	FR	FL	SD	L2		
Kuosheng (AEC)	1983 ~ 1985	✓	✓	✓	✓	✓		✓	Base PRA Model	37 (4.5)*
Maanshan (AEC)	1985 ~ 1987	✓	✓	✓	✓	✓		✓ (1992)	Base PRA Model	27.5 (2.0)
Chinshan (AEC)	1988 ~ 1990	✓	✓	✓	✓	✓		✓	Base PRA Model	34.5 (1.0)
1st-3 (Taipower)	1994 ~ 1997	✓	✓	✓			✓		Few cases of justification of continued operation	52
2nd-3 (Taipower)	1997 ~ 2000	DCR & experience updates (~1999)			✓	✓	✓	CSET CPET	• TIRM (risk monitor) • PRAM (PRA Maintenance) • OLM	66
3rd-3 (Taipower)	2000 ~ 2003	DCR & experience updates (~2002)						LERF	• TIRM-2 • FT Engine developed • NEI-00-02 peer review • Chinshan RIFA (Risk-informed Fire Wrapping Alternatives Analysis) • RI-ISI pilot	66
4th-3 (Taipower)	2004 ~ 2007	DCR & experience updates (~2005)							• SDP tool (PRiSE) developed • Kuosheng & Maanshan RIFA • Follow-on NEI Peer Review • Maintenance Rule	66

P: Internal at-power; SM: Seismic; TY: Typhoon; FR: Internal Fire; FL:Internal Flood; SD: Shutdown; L2: Level-2
*:from US Consultant

Scope

- **The first peer review of PRA models in Taiwan was conducted in 2002 per NEI-00-02**
- **The Follow-on peer reviews**
  - 3 reviews on Chinshan (BWR 4), Kuosheng (BWR 6), Maahshan (PWR) PRA models respectively in August, November of 2006, and January of 2007
  - Review team organized by ABS Consulting Inc. authorized via bid process
  - Team members from ABS and FP&L
- **Scope includes Level 1 $^{+}$ (ie. Level 1 and Containment system analyses), internal and external at-power and shutdown events PRA**

Review Results after F&O Addressed

- F&O levels distribution (Chinshan NPP at-power PRA)

Number of 'Fact and Observation's / Technical Element	Importance Level of F&Os									F&O SUM	
	A/B		C			D					
	2002	Follow-on (2006)	2002	Follow-on (2006)		2002	Follow-on (2006)			2002	Follow-on (2006)
Accident Sequence	8	0	10	6	7	3	2	1	0	21	16
Data Analysis	4	0	9	3	2	7	7	2	1	20	15
Dependence	1	0	8	7	0	0	0	1	1	9	9
Fire	0	0	8	6	0	2	2		0	10	8
Human Reliability Analysis	5	0	11	5	3	4	3	5	1	20	17
Initiating Event Analysis	8	0	18	10	6	3	1	5	0	29	22
L2 (Containment System)	2	0	3	2	0	4	1	1	0	9	4
Quantification	3	0	4	4	1	4	4		1	11	10
Seismic Analysis	2	0	10	6	1	1	1	0	0	13	8
Structure Analysis	2	0	2	2	2	0	0	0	0	4	4
System Analysis	4	0	16	11	2	1	1	2	2	21	18
Thermohydraulic Analysis	1	0	9	4	1	1	1	2		11	8
Typhoon Analysis	1	0	3	3	0	0	0	0	0	4	3
SUM	41	0	111	69	25	30	23	19	6	182	142

Gap Analysis after F&O Addressed

- ASME Standard Gap Analysis (Chinshan at-power PRA)

High Level Requirements	# of Supporting Requirements	# of CC I	# of CC II	# of CC III	# Not met	NA	Not reviewed
HLR-AS	21	0	3	14	3	1	0
HLR-DA	28	2	11	10	5	0	0
HLR-HR	34	3	8	18	5	0	0
HLR-IE	29	3	6	15	5	0	0
HLR-IF	28	0	2	11	6	0	9
HLR-LE	36	4	12	12	6	2	0
HLR-QU	31	3	3	13	9	1	2
HLR-SC	15	0	2	7	5	0	1
HLR-SY	41	0	7	32	2	0	0
Sum (Internal Events)	263	15	54	132	46	4	12
HLR-FR	25	0	1	1	2	1	20
HLR-HA	25	2	1	0	2	0	20
HLR-SA	24	6	4	5	9	0	0
Sum (Seismic Event)	74	8	6	6	13	1	40
Typhoon Event	14	0	3	1	5	1	4
Total*	351	23	63	139	64	6	56

*: Fire events not included

Review Results after F&O Addressed

- F&O levels distribution (Kuosheng NPP at-power PRA)

Number of 'Fact and Observation's / Technical Element	Importance Level of F&Os									F&O SUM	
	A/B		C			D					
	2002	Follow-on (2006)	2002	Follow-on (2006)		2002	Follow-on (2006)			2002	Follow-on (2006)
Accident Sequence	7	0	10	5	3	4	4	2	1	21	15
Data Analysis	5	0	7	1	3	6	5	2	1	18	12
Dependence	1	0	7	7	0	0	0	0	1	8	8
Fire	0	0	7	6	0	1	1	0	0	8	7
Human Reliability Analysis	5	0	9	3	1	0	0	5	1	14	10
Initiating Event Analysis	6	0	13	2	6	0	0	8	0	19	16
L2 (Containment System)	3	0	2	0	0	3	2	1	0	8	3
Quantification	1	0	2	1	0	2	2	0	1	5	4
Seismic Analysis	4	0	7	5	1	1	1	1	0	12	8
Structure Analysis	2	0	2	2	2	0	0	0	0	4	4
System Analysis	7	0	14	10	5	0	0	1	2	21	18
Thermohydraulic Analysis	1	0	5	3	1	0	0	1	0	6	5
Typhoon Analysis	1	0	2	1	0	0	0	1	0	3	2
SUM	43	0	87	46	22	17	15	22	7	147	112

Gap Analysis after F&O Addressed

- ASME Standard Gap Analysis (Kuosheng at-power PRA)

High Level Requirements	# of Supporting Requirements	# of CC I	# of CC II	# of CC III	# Not met	NA	Not reviewed
HLR-AS	21	0	3	14	3	1	0
HLR-DA	28	2	11	10	5	0	0
HLR-HR	34	3	8	17	6	0	0
HLR-IE	29	4	5	15	5	0	0
HLR-IF	28	0	2	11	6	0	9
HLR-LE	36	4	12	12	6	2	0
HLR-QU	31	3	3	13	9	1	2
HLR-SC	15	0	2	7	5	0	1
HLR-SY	41	0	7	32	2	0	0
Sum (Internal Events)	263	16	53	131	47	4	12
HLR-FR	25	0	1	1	2	1	20
HLR-HA	25	2	1	0	2	0	20
HLR-SA	24	5	4	5	10	0	0
Sum (Seismic Event)	74	7	6	6	14	1	40
Typhoon Event	14	0	3	1	5	1	4
Total*	351	23	62	138	66	6	56

*: Fire events not included

Review Results after F&O Addressed

- F&O levels distribution (Maashshan NPP at-power PRA)

Number of 'Fact and Observation's / Technical Element	Importance Level of F&Os									F&O SUM	
	A/B		C			D					
	2002	Follow-on (2006)	2002	Follow-on (2006)		2002	Follow-on (2006)			2002	Follow-on (2006)
Accident Sequence	1	0	9	1	1	8	2	3	0	18	7
Data Analysis	3	0	9	2	2	9	3	6	0	21	13
Dependence	0	0	11	7	0	1	1	2	0	12	10
Fire	0	0	8	6	0	2	2	1	0	10	9
Human Reliability Analysis	1	0	8	2	0	5	4	3	1	14	10
Initiating Event Analysis	8	0	19	2	4	4	2	6	3	31	17
L2 (Containment System)	1	0	5	0	0	4	1	3	0	10	4
Quantification	2	0	2	1	1	5	5	1	1	9	9
Seismic Analysis	1	0	5	5	1	1	1	0	0	7	7
Structure Analysis	2	0	1	0	2	1	1	1	0	4	4
System Analysis	3	0	16	3	0	6	4	6	1	25	14
Thermohydraulic Analysis	1	0	8	3	1	4	3	1	0	13	8
Typhoon Analysis	0	0	3	2	0	1	1	1	0	4	4
SUM	23	0	104	34	12	51	30	34	6	178	116

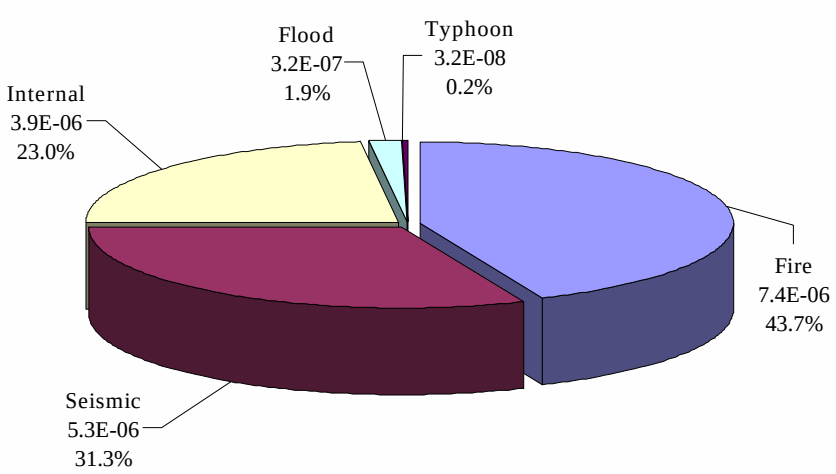
Gap Analysis after F&O Addressed

- **ASME Standard Gap Analysis (Maanshan at-power PRA)**

High Level Requirements	# of Supporting Requirements	# of CC I	# of CC II	# of CC III	# Not met	NA	Not reviewed
HLR-AS	21	0	3	17	0	1	0
HLR-DA	28	2	11	9	6	0	0
HLR-HR	34	3	8	18	5	0	0
HLR-IE	29	4	5	14	6	0	0
HLR-IF	28	0	2	11	6	0	9
HLR-LE	36	4	14	12	6	0	0
HLR-QU	31	3	3	13	10	1	1
HLR-SC	15	0	2	7	5	0	1
HLR-SY	41	0	7	32	2	0	0
Sum (Internal Events)	263	16	55	133	46	2	11
HLR-FR	25	0	1	1	2	1	20
HLR-HA	25	2	1	0	2	0	20
HLR-SA	24	6	4	5	9	0	0
Sum (Seismic Event)	74	8	6	6	13	1	40
Typhoon Event	14	0	3	1	5	1	4
Total*	351	24	64	140	64	4	55

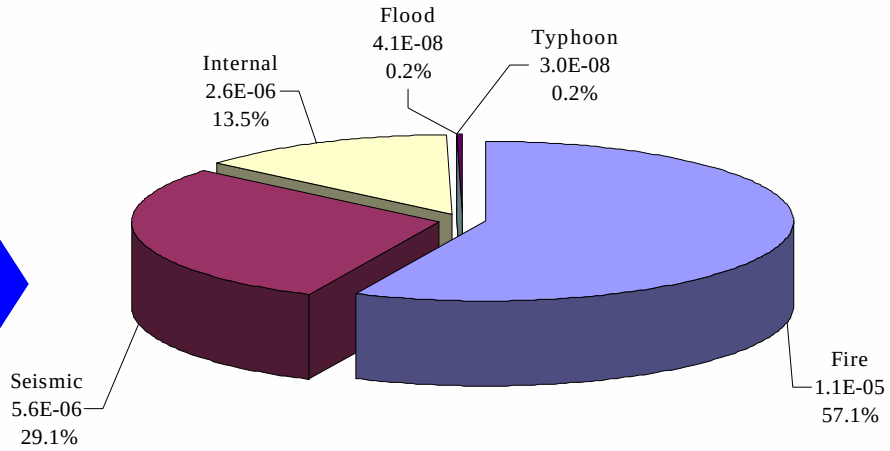
*: Fire events not included

CDF Results (Chinshan)



Total CDF = 1.7E-5

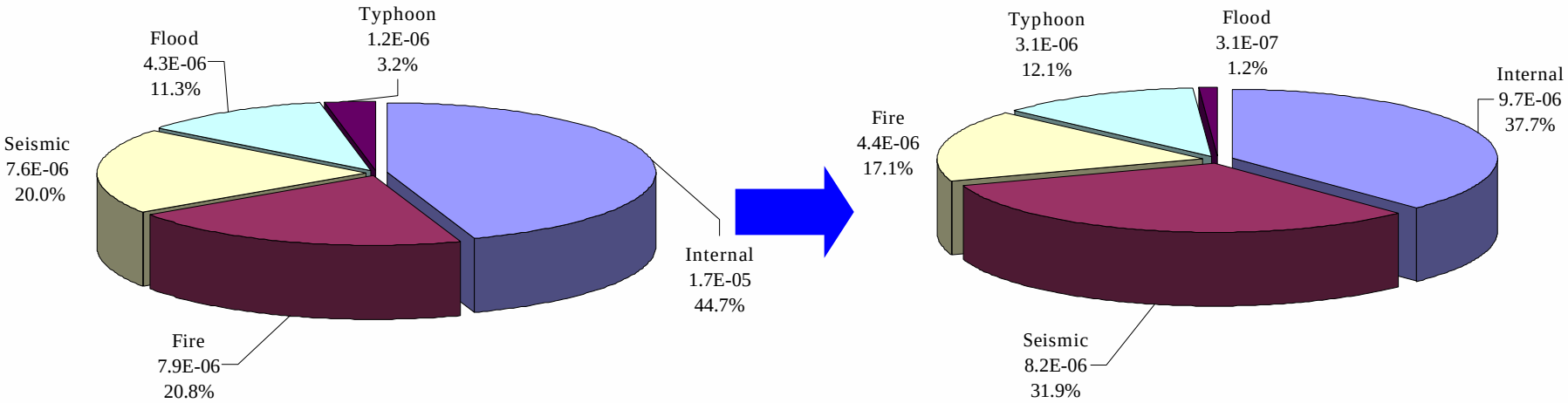
Before follow-on review



Total CDF = 1.9E-5

After follow-on review

CDF Results (Kuosheng)



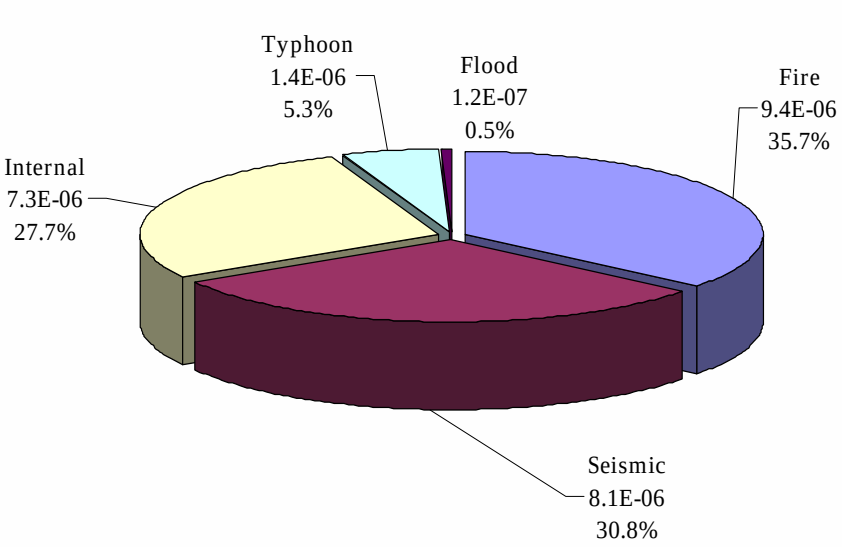
Total CDF = 3.8E-5

Before follow-on review

Total CDF = 2.6E-5

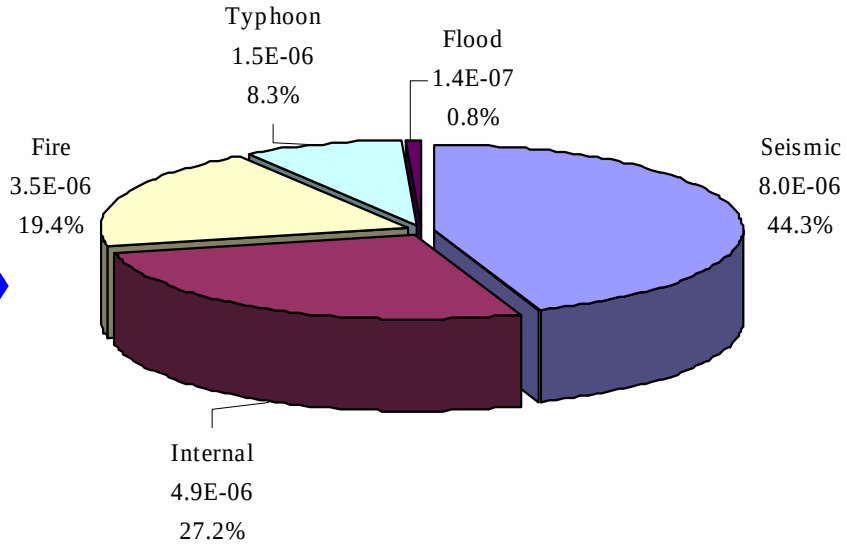
After follow-on review

CDF Results (Maanshan)



Total CDF = 2.6E-5

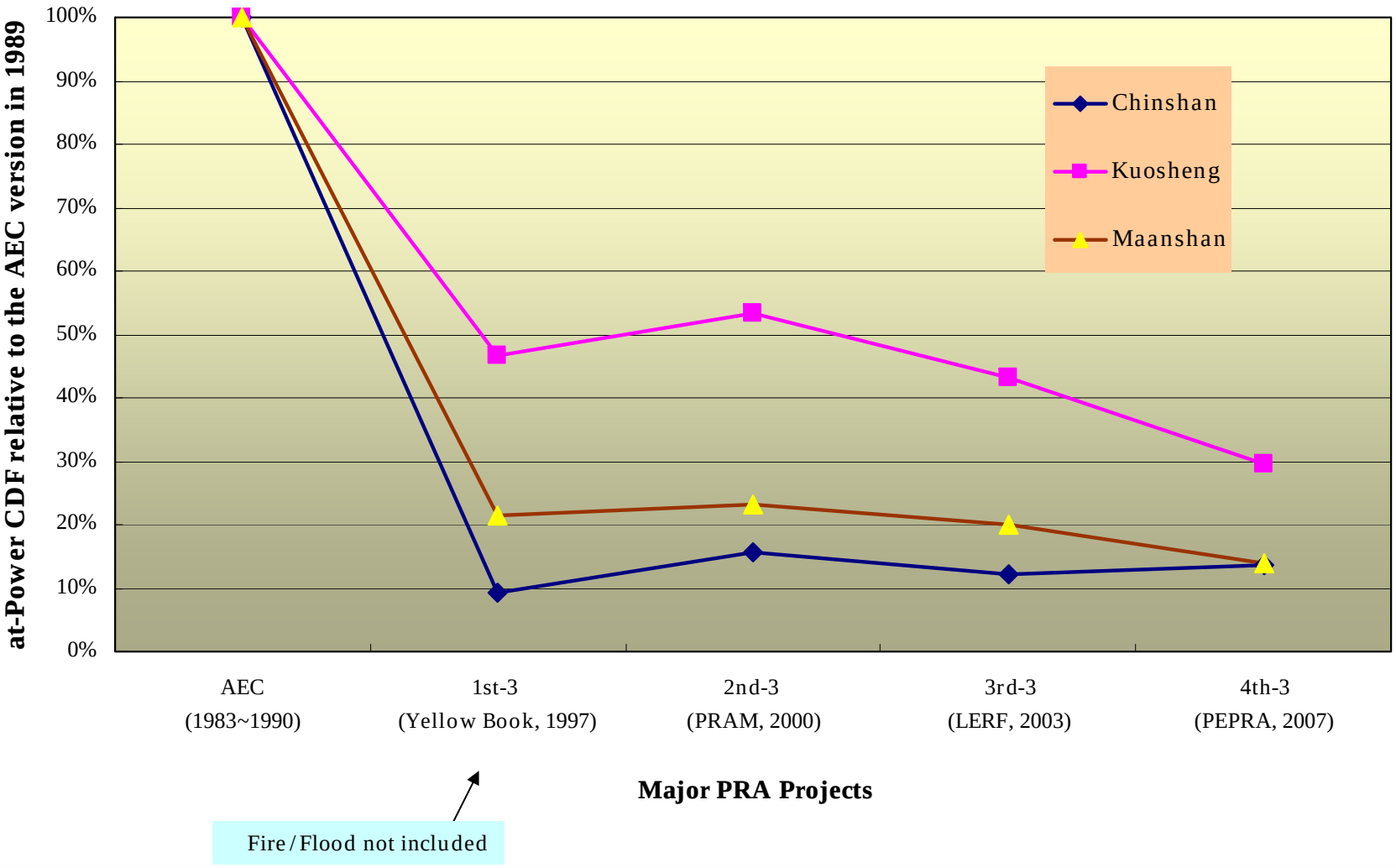
Before follow-on review



Total CDF = 1.8E-5

After follow-on review

Calculated Risk Variation



Reviewers' Recommendations of Further Enhancements

- **Can be more realistically reflect the risk characteristics of the plants**
  - Incorporate into PRA models the more recent generic data and new failure modes in conjunction with collected plant-specific operation experience
- **Some initiating events need more rigorous presentations**
  - The impact of HE events on CDFs under LOOP
  - Consideration of accident mitigation of LOIA events
  - The impact of HE events on LERF under SGTR
  - The recovery operation of feedwater under general transients
- **Consider the updates of Seismic and Fire PRAs**

Response of the AEC

- **The PRA follow-on peer review results were submitted for record by Taipower and approved docketed by the AEC in February, 2009**
- **Concerns of the AEC**
  - PRA documentation quality control
  - The upgrade and update of seismic PRA models to incorporate advanced methods and more recent earthquake experiences
  - Alignment of the PRA self-assessment and peer review process with RG 1.200
  - Classification and configuration control of PRA models

On-going PRA Applications

- **Supporting Maintenance Rule implementation**
- **Base PRA models enhancement, including the Lungmen NPP, to meet ASME internal events standard**
  - Objective: Capability Category II in general
- **RI-ISI program plan development for the 4-th 10-year operating interval of Kuosheng NPP**
- **SDP tools (ie. PRiSE) kernel update and enhancement to include shutdown events**
- **ASME PRA standard introduction**
- **A fire SDP tool being developed for Chinshan**

PRA Applications in View

- Supporting self management of On-line Maintenance
- SOA fire PRA upgrade in support of NFPA-805 transition
- SDP tools enhancement to include external events (ie. Seismic, Typhoon)
- Tech Spec AOT Extensions
- Risk-informed IST
- Risk-informed Tech Spec

Thank You for Attention

Attachment

Major PRA Modifications (BWR)

- Concerns of steam binding of ECCS pumps during containment venting (AS-2)
- K-LOCA sequences included in SD model
- Treatment of containment heat removal in the success branches of ECCS injection
- Modeling of feedwater recovery
- Calculation of timings in the accident sequences
- Treatment of common-cause failures (DA-9)
- Initiating events data (DA-19)

Major PRA Modifications (BWR) (cont'd)

- Distinguishing human induced events in shutdown IE analysis
- Revisit of the human error probabilities in SD PRA
- The credit of No. 5 diesel in seismic events (SM-2)
- Modeling of piping failure in ISLOCA analysis (ST-3)
- Structure failure of flood barrier (ST-4)
- Failures of temporary pressure boundary during SD
- Enhancement of the fault tree models for some systems

Major PRA Modifications (BWR) (cont'd)

- New failure modes added
- Common-cause failure model expansion
- Comparison of LOOP and LOIA event analysis results between Chinshan and Kuosheng
- Using more recent thermohyraulic code(TH-9)
- Relaxation of conservative assumptions of typhoon-induced LOOP sequences
- Generic data update per NUREG/CR-6928 (2007)

Major PRA modifications (PWR)

- Adoption of new RCP seal LOCA model (AS-18)
- Refinement of calculation of special event probabilities (DA-04)
- MGL modeling of common cause failures and data update per NUREG/CR-5497 (DA-09)
- Refinement of ECCS clogging and intake structure abnormal CCFs (DE-10)
- Verification of COMPBRN results (FR-5)
- More rigorous treatment of human actions dependences (HR-16)
- Sensitivity study of dominant HEPs (HR-06)

Major PRA Modifications (PWR) (cont'd)

- Fault tree modeling of special initiating events (IE-05)
- Refinement of ISLOCA modeling (IE-07)
- Nerw Large LOCA frequency (IE-18)
- Detailed treatment of LOOP initiating events (IE-19)
- Support-system-to-support-system FMEA (IE-25)
- More clear distinction between some human actions in L-1 and L-2 Analysis (L2-04)
- Verification of human dominant cut sets by sensitivity analysis (QU-01)

Major PRA Modifications (PWR) (cont'd)

- Verification of accident sequences with high CCDPs (QU-10)
- Incorporation of gas turbine and other building fragilities into seismic analysis (SM-03)
- Refinement of flood barrier failure modeling (ST-04)
- Thermohydraulic calculation using more recent MAAP 4.04 for LOCAs to validate the adequacy of assumptions and input parameters (TH-09)
- Incorporation of flow diversion failures for various flow systems (SY-03)
- Refinement of equipment restart failure modeling under LOOP conditions (SY-14)