



# JENSEN HUGHES

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## **EXELON ECONOMIC ENTERPRISE RISK MODELING OF A BWR**

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# TOPICS FOR DISCUSSION

- ② Concept
- ② Overview of approach
- ② Insights



# THE CONCERN

- PRA 'SUCCESS' or 'OK' sequences may avoid core damage but could have significant economic impact on plant assets:
  - PWR Feed & Bleed
  - BWR Containment venting
  - Some FLEX strategies



# RISK

Public  
Risk

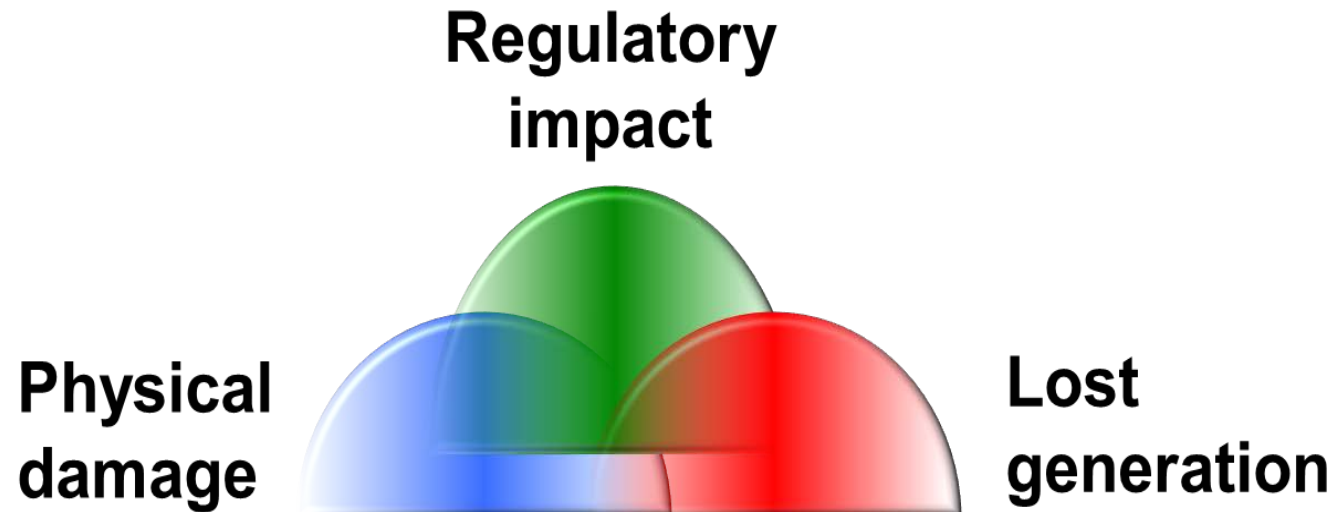
- **Probability of core damage x consequences**

Economic  
Risk

- **Probability of loss of asset x consequences**



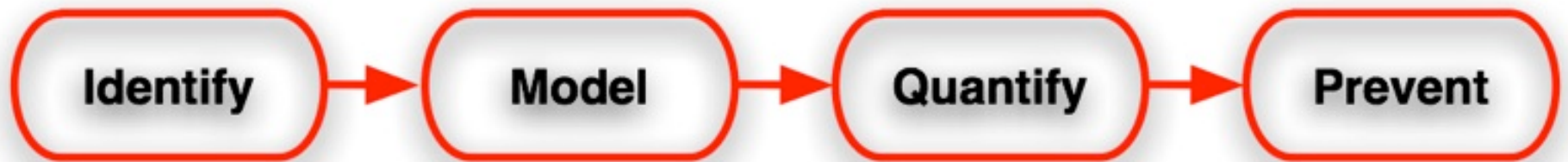
# ECONOMIC ENTERPRISE RISK\*



**\* Stopping short of core damage**



# OVERVIEW OF APPROACH



# NRC MANAGEMENT DIRECTIVE 8.3

Estimated Conditional Core Damage Probability (CCDP)				
CCDP < 1E-6	1E-6 – 1E-5	1E-5 – 1E-4	1E-4 – 1E-3	CCDP > 1E-3
No additional inspection				
	Special inspection			
		AIT		
			IIT	



# REGULATORY IMPACT – RULES OF THUMB

$$\Delta\text{CDF} > 1 \text{ E-}4$$

Red: \$100 million

$$1 \text{ E-}5 < \Delta\text{CDF} \leq 1 \text{ E-}4$$

Yellow: \$30 million

$$1\text{E-}6 < \Delta\text{CDF} \leq 1 \text{ E-}5$$

White: \$10 million

$$\Delta\text{CDF} \leq 1 \text{ E-}6$$

Green: Nominal

“Dark” Red (CCDP >  $10^{-3}$ ): > \$300 million



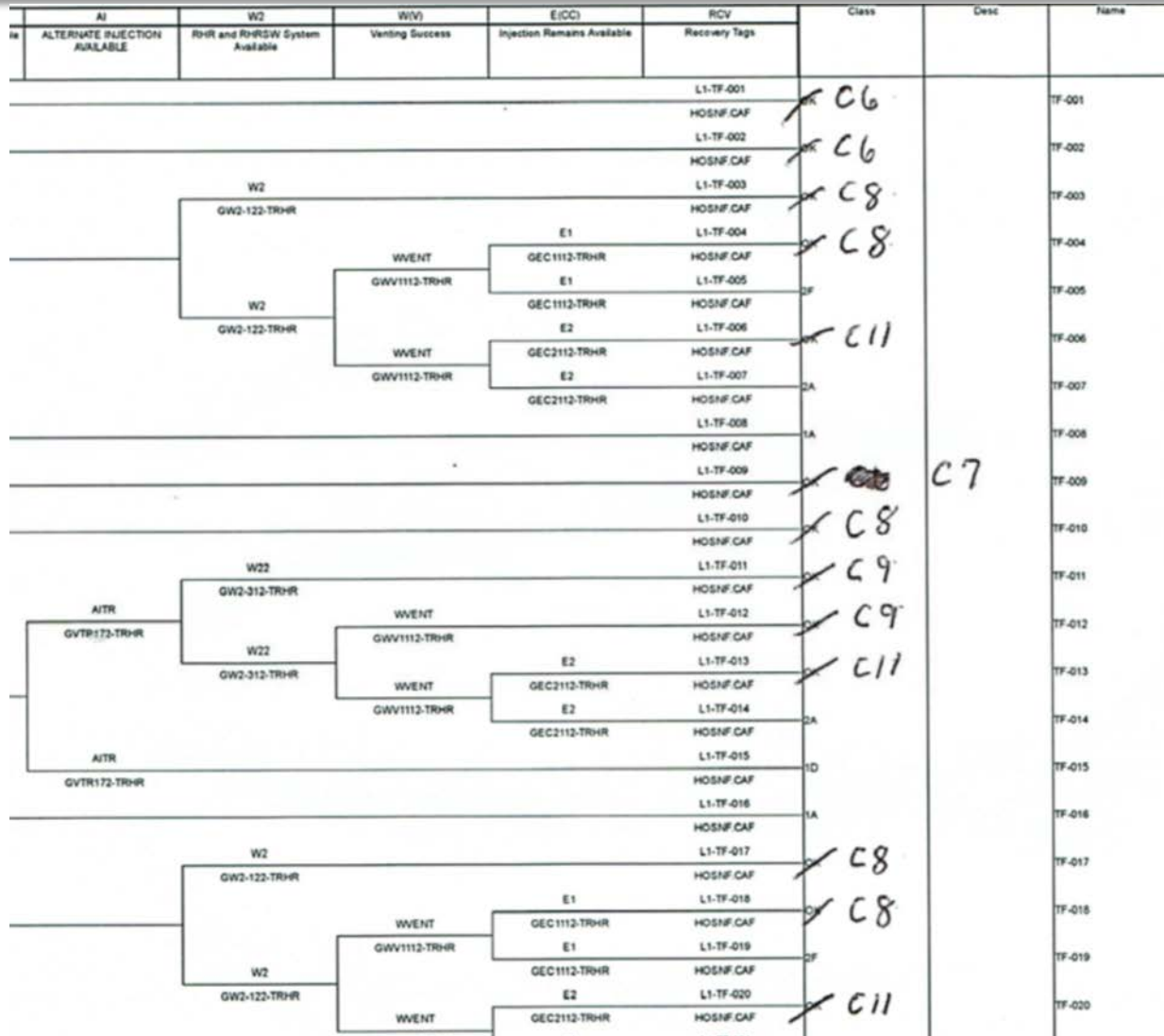


# SAMPLE EVENT CASUALTY DATA

Event	Plant Impact State	Nominal Outage Duration	Median Cost Bin	Comment
Uncomplicated reactor trip	PI6	Days to 1 week	C6	Event data
Loss of offsite power	PI7	2 weeks	C7	Event data
Fire in main transformer	PI8	10 weeks	C8	STP fire, Perry replacement
Steam generator tube rupture	PI9	1 year	C9	IP-2 event
PWR feed & bleed – long duration through recirculation	PI9	1 year	C9	Judgment, pairwise comparison
Medium LOCA	PI10	> 2 years	C10	Judgment, pairwise comparison



# MODIFY EXISTING PRA MODEL



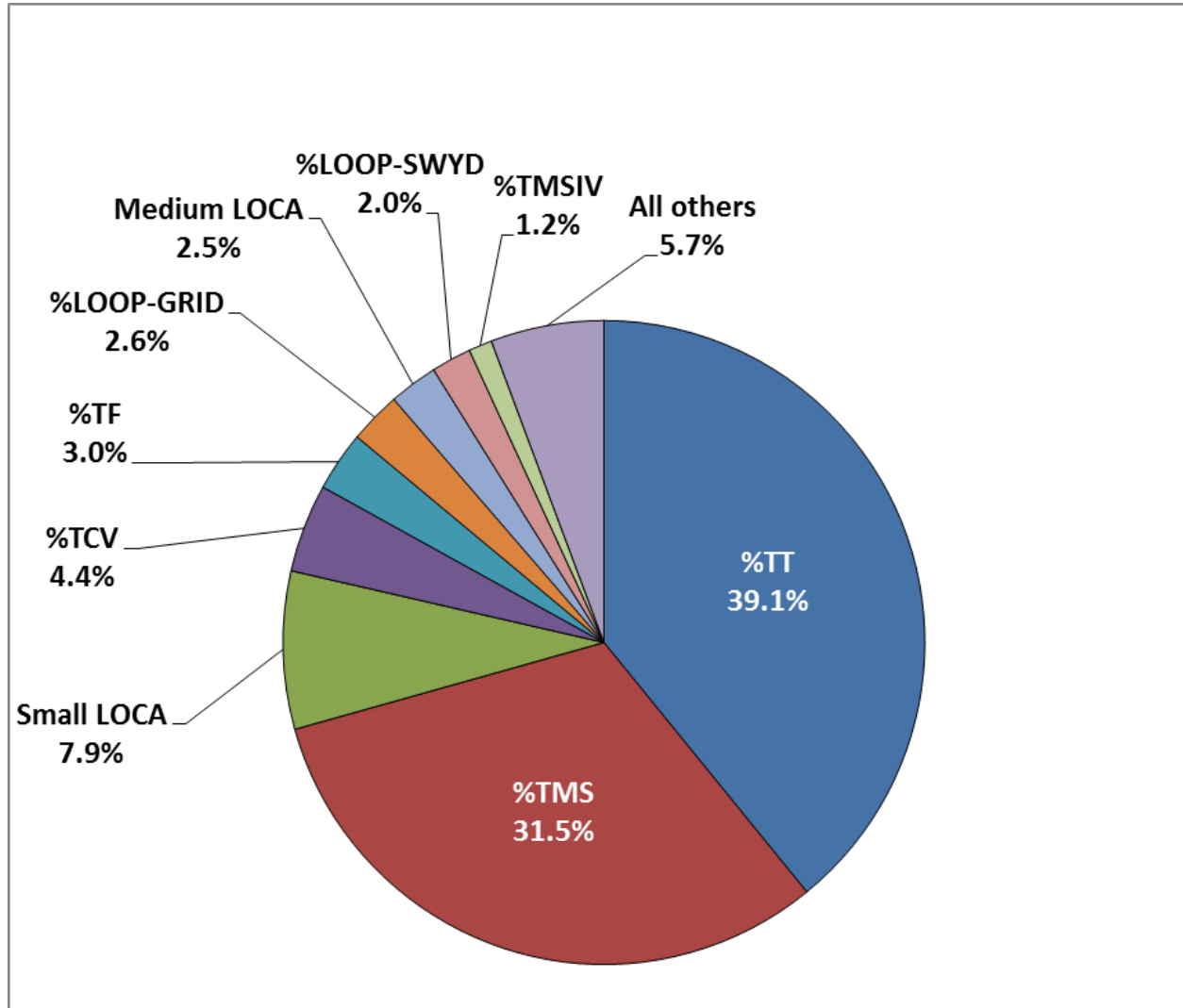
# BASELINE RESULTS FOR BWR PILOT

## ECONOMIC RISK

- Small fraction of the total value of electrical production, but
- Significantly greater than maximum averted cost risk (MACR) from severe accident mitigation alternatives (SAMA) assessment under license renewal



# RISK BY INITIATOR (FPIE, NON-FLOOD)



# FPIE INSIGHTS

- Risk driven by Turbine Trip and unplanned manual shutdown (about 70% of total economic risks).
- Address single-point vulnerabilities resulting in reactor/turbine trip
  - Acquisition of portable compressor and dryer for use during maintenance on an installed instrument air (IA) compressor
  - Avoidance of main steam isolation valve closure



# INSIGHTS FOR INTERNAL FLOODING

- About 73% of economic risk from IF is due to moderate-to-high consequence events (\$30 million - \$100 million)
- PRA model for CDF calculation may be inappropriate for best-estimate economic risk assessment
  - Reconsider assumptions regarding equipment damage
  - Adjust some human error probabilities (HEPs) on isolation



# STUDY REINFORCED GOOD PRACTICES

- Expansion joints on the circulating water pumps are inspected every refueling outage. Furthermore, the outside of the expansion joints can be observed for gross leakage during shift rounds.
- Expansion joints are replaced at the rate of 5-out-of-35 every refueling outage.



# INSIGHTS FOR FIRE

- Generally, fair correlation between contribution to CDF and contribution to economic risk from fire events
- Five fire events contribute to 50% of fire CDF and 42% of economic risk
  - However, catastrophic turbo-generator fire is a small contributor to CDF but large contributor to economic risk





# PREVENTION AND MITIGATION



## Incipient fire detection

[www.jensenhughes.com](http://www.jensenhughes.com)



## FLEX equipment



# ALL OTHER THINGS BEING EQUAL...

- Consideration of economic risk in cost-benefit evaluations would tend to shift strategy from one of *mitigation* to one of *prevention*
  - Enhanced pipe inspection over internal flood mitigation
  
- Mitigation strategies need to consider whether in this economic and regulatory environment plant would ever run again
  - PWR non-safety auxiliary feedwater pump preferred over feed & bleed strategy



# FLEX

- Strategy to inject raw water into reactor pressure vessel or steam generators can have economic consequences
- Due to low frequency, economic risk from projected FLEX events is very low
- *Inadvertent* injection due to poor design or error during installation or periodic surveillance could result in significant economic risk



# SUMMARY

- Reduction of economic risk contributors does not come at the expense of CDF reduction
  - Reduction of the one can have the added benefit of reducing the other, and vice versa



# QUESTIONS?

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