

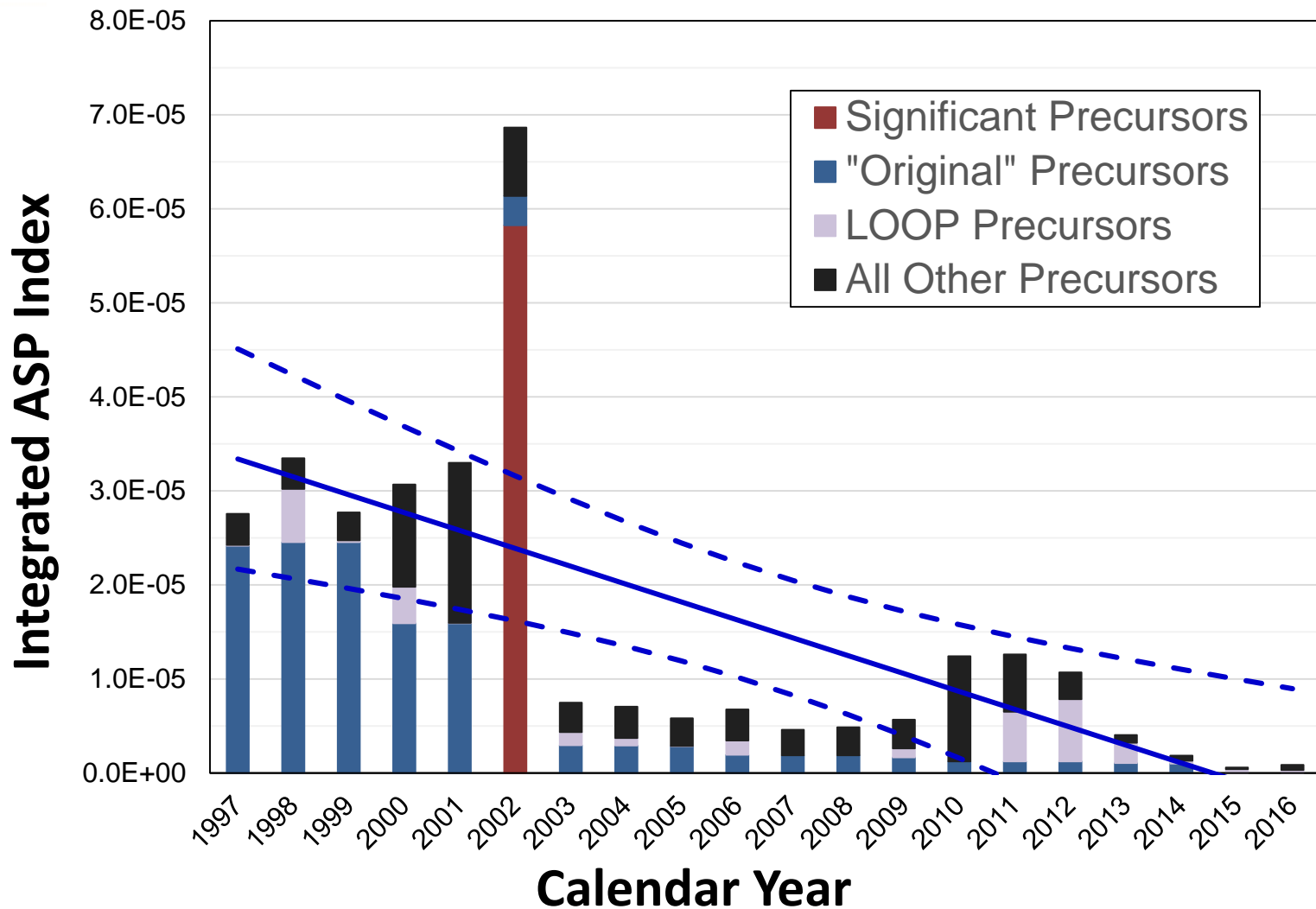
# Accidents, Near Misses, and Probabilistic Analysis: On the Use of CCDPs in Enterprise Risk Monitoring and Management

N. Siu, K. Coyne, J. Nakoski, and C. Hunter  
Office of Nuclear Regulatory Research  
U.S. Nuclear Regulatory Commission

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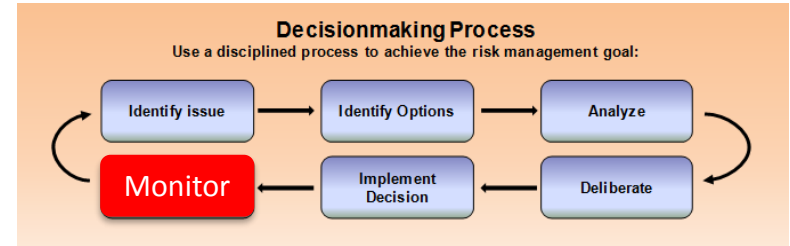
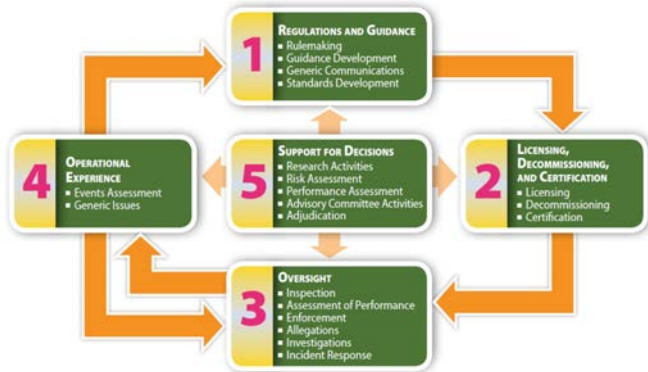
Adapted from: I. Gifford, C. Hunter, and J. Nakoski, "U.S. Nuclear Regulatory Commission Accident Sequence Precursor Program: 2016 Annual Report," May 2017. (ML17153A366)

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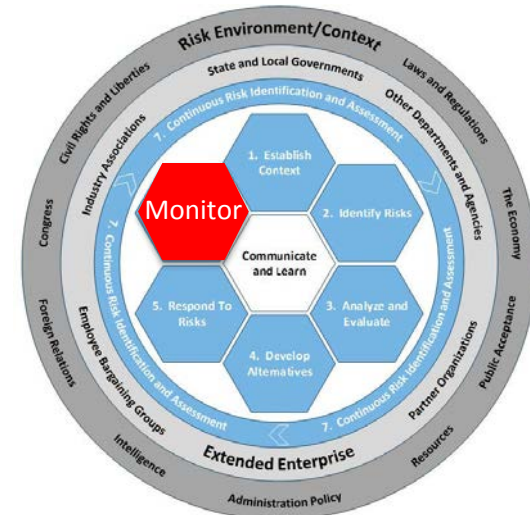
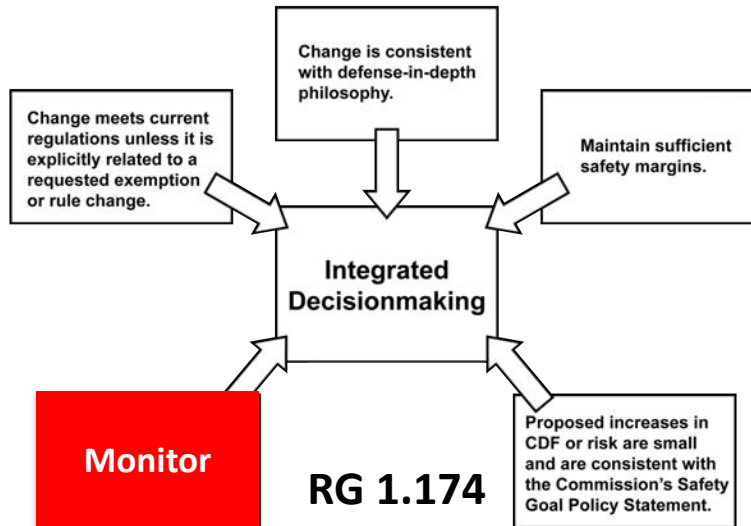
# Presentation Scope

- Presentation discusses the Integrated ASP Index (IAI)
  - Definition
  - Connection with total fleet CDF
  - Attributes for Enterprise Risk Management
  - Alternatives to IAI
- Full paper provides additional discussion
  - Exchangeability and use of accident data in estimating plant CDF
  - Other enterprise-level performance indicators used by NRC and OGAs
  - History of IAI

# Monitoring in Risk-Informed Decision Making



**NUREG-2150**



**OMB A-123**

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# IAI Overview

- Concept
  - Use numerical results of ASP analyses to indicate fleet performance
  - Increases with number of precursors
  - Increases with severity of precursors
- Definition

$$IAI = \frac{1}{T_{CY}} \left( \sum_{j=1}^{M_I} CCDP_j + \sum_{k=1}^{M_C} \Delta CDP_k \right)$$

$T_{CY}$  = total calendar years  
 $M_I$  = # initiating event precursors  
 $M_C$  = # degraded condition precursors  
 $CCDP$  = conditional core damage probability  
 $\Delta CDP$  = change in core damage probability

- Historical purpose: provide order-of-magnitude comparisons with industry-average CDFs

# Relationship with Fleet CDF?

$$CDF_{fleet} = \sum_{i=1}^{N_{fleet}} CDF_i$$

A simple estimator, following Apostolakis and Mosleh (1979):

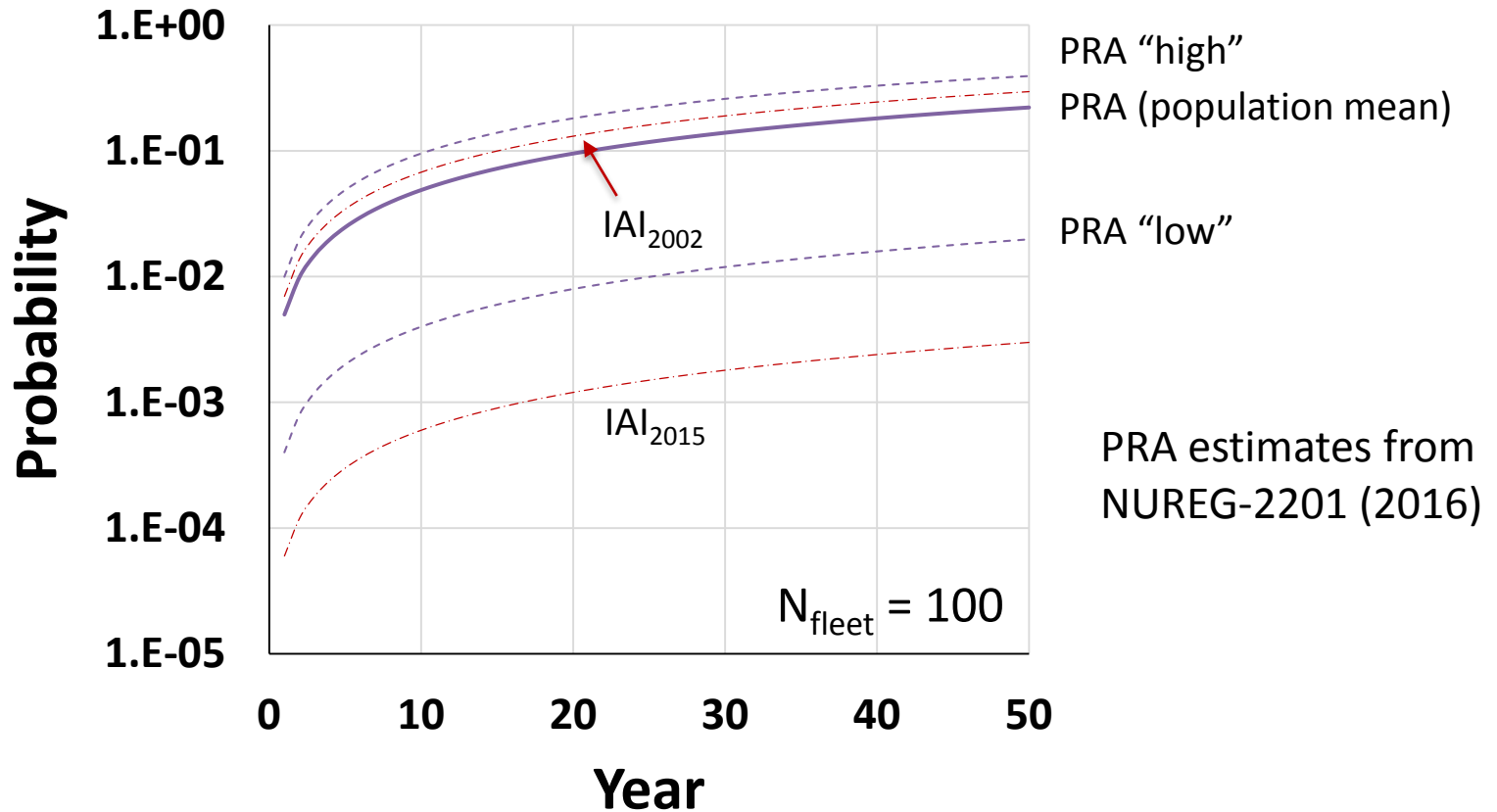
$$\widehat{CDF}_{fleet} = \frac{1}{T} \left[ \sum_{i=1}^{N_{fleet}} \sum_{j=1}^{N_{event,i}} X_{ij} \right] = \frac{1}{T} \left[ \sum_{k=1}^{N_{event}} X_k \right]$$

$$X_m = \begin{cases} 1 & \text{Proposition } m \text{ is true} \\ 0 & \text{Proposition } m \text{ is false} \end{cases}$$

$$E[\widehat{CDF}_{fleet}] = \frac{1}{T} \sum_{k=1}^{N_{event}} E[X_k] = \frac{1}{T} \sum_{k=1}^{N_{event}} P\{X_k = 1\}$$

- Addresses aleatory uncertainty
- Same mathematical foundation as basic PRA (Barlow and Proschan, 1965)

# Fleet Accident Probability Implications



# Considerations

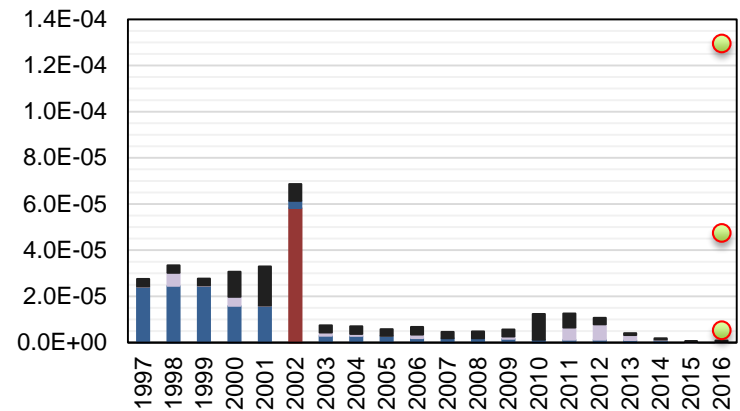
- Use of “partial data” broadly consistent with general Bayesian approach to uncertain evidence

- Addresses epistemic uncertainty
- Used in CCF analysis (“impact vectors”)
- Precursor evidence > CCDP, ΔCDP numerical values

$$\pi_1(\lambda|\underline{E}) = \sum_k \pi_1(\lambda|E_k)P(H_k)$$

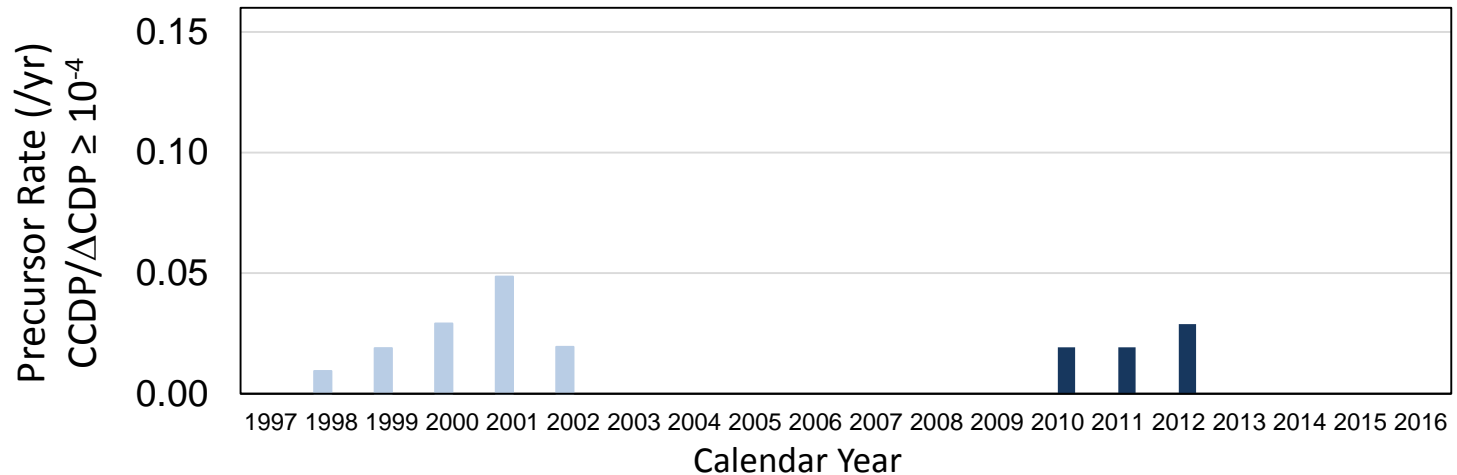
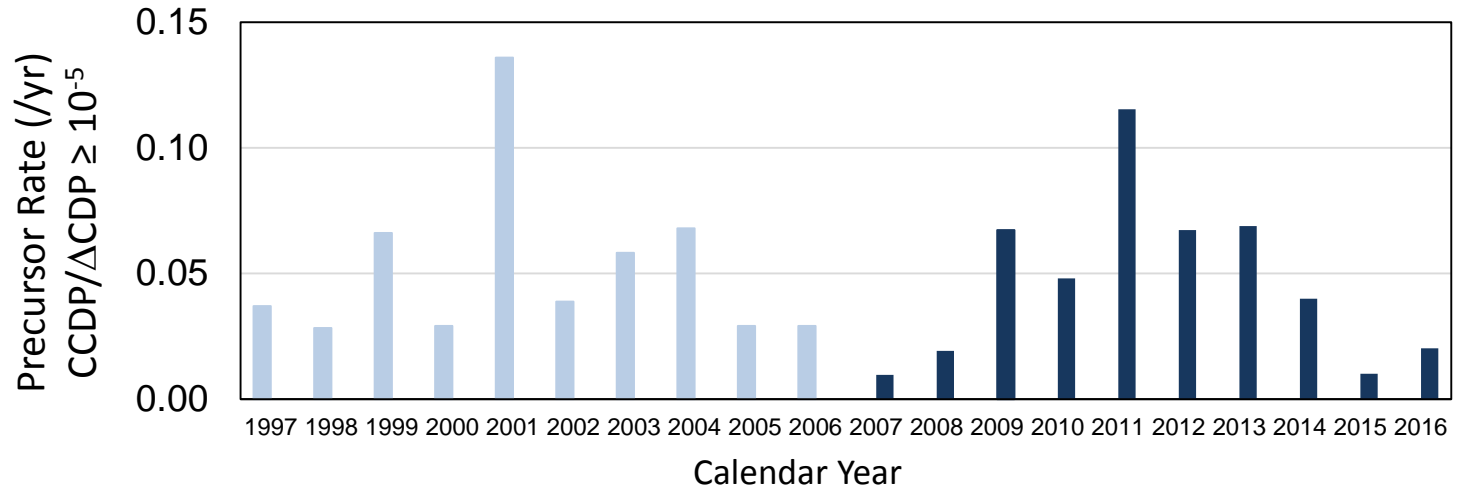
- Practical concerns as fleet CDF estimator

- PRA technology limitations
- Variability in representation of actual event
- Lack of uncertainty analysis
- Focus on SSCs
- Failure memory approach
- ***Neglect of risk contribution from unobserved scenarios***





# Baseline Enterprise Risk Monitoring: Example



# IAI for Enterprise Risk Monitoring (Preliminary)

Rating Factor	Δ	Comments
Awareness of current risk levels	Positive	IAI only a partial indicator, but more direct than baseline monitoring scheme. Note: significance of different numerical values needs further discussion. (Should ten events with CCDPs of $10^{-4}$ lead to the same alert level as a single event with a CCDP of $10^{-3}$ ?)
Awareness of current risk profile	None	Both baseline and IAI present summary measures. Specific event reviews and/or additional analyses are needed to identify patterns in contributing plants, hazards, failure modes, etc.
Awareness of changes to risk levels and profile	Positive	See risk levels. Note: under baseline, the identification of important changes might require the decision maker to synthesize and internalize the results of multiple analyses.
Assessment of risk management effectiveness	Positive	See risk levels. Note: since precursor data are sparse and precursor occurrences are influenced by multiple factors beyond agency actions, multiple indicators are needed to assess agency effectiveness.

\*Table compares IAI plus baseline monitoring against baseline reporting by itself.

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# Other Potential Monitoring Improvements

- Improve common understanding of IAI
- Improve correspondence between IAI and  $CDF_{\text{fleet}}$
- Increase emphasis on pre-core damage plant states
- Reduce process inefficiencies in interpreting operational events
- Investigate better integration of full set of performance indicators in to develop clear picture of enterprise risk

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# Closing Remarks and Conclusions

- Presentation includes information published after paper. See I. Gifford, C. Hunter, and J. Nakoski, “*U.S. Nuclear Regulatory Commission Accident Sequence Precursor Program: 2016 Annual Report*,” May 2017. (ML17153A366)
- NRC reports statistics on many risk-relevant abnormal events (see Additional Slides)
- The IAI is not a complete indicator of industry risk but has some useful features
  - Employs scenario-level operational information
  - More sensitive to the occurrence of risk-significant events
- NRC will continue to compute and publish the IAI
- Further exploration of the IAI and its use in enterprise risk monitoring (and management) could be fruitful

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# ADDITIONAL ASP RESULTS

From: I. Gifford, C. Hunter, and J. Nakoski, “U.S. Nuclear Regulatory Commission Accident Sequence Precursor Program: 2016 Annual Report,” May 2017. (ML17153A366)

