Module S

Mitigating System Performance Index (MSPI)

Mitigating System Performance Index

- Purpose: Provide overview of MSPI, with special emphasis on its PRA basis
- Objectives: At the conclusion of this section, students will understand :
  - What is MSPI
  - Why MSPI was developed
  - How MSPI is related to ΔCDF
  - How MSPI includes both unavailability and unreliability
  - How MSPI uses importance measures
- References
  - NEI 99-02, Rev. 4, August 2006
  - NUREG-1816, February 2005

What is MSPI?

- **MSPI is the numerical sum of the deviation between a system's actual unavailability and unreliability values for a calendar quarter and the established baseline values.**
- **MSPI takes into account plant specific risk importance measures in the calculation.**
- **MSPI = Unavailability Index + Unreliability Index**

MSPI – Systems Monitored/Aspects

- **MSPI monitor four front-line systems and support system (e.g., emergency AC power, high pressure injection, secondary cooling, long-term heat removal, service water, etc.).**
- **Definitions/Aspects monitored:**
  - **Unavailability -** the ratio of the hours that a train was out of service for planned or unplanned maintenance or testing during the previous 12 quarters while critical, to the number of critical hours during the previous 12 quarters.
  - **Unreliability -** the probability that a component (failure modes) would not perform its monitored function (defined by PRA success criteria and mission time) when required during the previous 12 quarters.

Why Was MSPI Developed?

- Problems identified with safety system unavailability (SSU) performance indicator
  - Uses short-term unavailability to approximate unreliability
  - Uses same performance threshold regardless of risk significance
  - Potential for double-counting support system failures
  - SSU inconsistent with Maintenance Rule definition of unavailability
  - Inconsistent with indicators promulgated by World Association of Nuclear Operators (WANO) and Institute of Nuclear Power Operations (INPO)
    - Requires plant personnel to track plant data three different ways

Development Timeline

- NRC initiates Risk-Based Performance Indicator program
  - NUREG-1753 issued in 2002
    - Proposed indicators that incorporated risk significance, as measured by SPAR models
    - Plant-specific thresholds for indicators
- MSPI Pilot Program initiated in Summer 2002
  - 20 plants participated
  - Provided V&V of
    - Baseline data
    - Current performance data
    - Importance measures
    - Spreadsheet calculations
    - Overall MSPI results
- NRC gave NEI agreement to proceed with MSPI in August 2004

MSPI Objectives

- **Provide a risk-informed, plant specific, indication of mitigating system performance.**
  - **Reflect risk impact of system availability and reliability at each plant**
  - **System performance requirements based on PRA system success criteria rather than design basis criteria**
  - **Monitor most risk significant components**

How To Calculate MSPI

- Includes unavailability and unreliability in single risk measure
- MSPI = UAI + URI
  - UAI is Unavailability Index
  - URI is Unreliability Index
- MSPI = $\Delta CDF = CDF_1 - CDF_o$
  - CDF_1 is actual plant performance
  - CDF_o is industry baseline performance
- Because MSPI = ΔCDF can apply “colors” from SDP
  - MSPI $\leq 10^{-6}$ GREEN
  - $10^{-6} <$ MSPI $\leq 10^{-5}$ WHITE
  - $10^{-5} <$ MSPI $\leq 10^{-4}$ YELLOW
  - MSPI $> 10^{-4}$ RED

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Calculating UAI

- **UAI is sum of contributions from each train of a monitored system:**

$$UAI = \sum_{j=1}^{n} UAI_{tj}$$

- **UAI_{tj} is unavailability index for each train**

Calculating UAI_t

- $UAI_t = I_B(UA_{PRA}) \quad \Delta UA$

  $= I_B(UA_{PRA}) \quad (UA_t – UA_{BLt})$

where:

UA = train unavailability

UA_t = observed train unavailability

UA_{BLt} = baseline train unavailability

$I_B(UA_{PRA})$ = Birnbaum importance of PRA basic event representing unavailability of train

Calculating UAI_t

- **Relationship to Fussell-Vesely importance**

$$I_{F-V}(x) = \frac{p_x I_B(x)}{CDF}$$

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Calculating UAI_t

- **Substitute into equation for UAI_t**

$$UAI_t = CDF\left[\frac{I_{F-V}(UA_{PRA})}{UA_{PRA}}\right](UA_t - UA_{BLt})$$

where:
CDF = Plant core damage frequency
$I_{F-V}(UA_{PRA})$ = Fussel Vesely value from plant specific PRA
UA_{PRA} = Plant specific unavailability (probability of being unavailable due to being out for planned or unplanned maintenance)
UA_t = actual unavailable of train t = $\frac{\text{[Unavailable hours (planned and unplanned) during previous 12 quarters]}}{\text{Critical hours during the previous 12 quarters}}$
UA_{BLt} = historical baseline unavailability value for the train (industry average)

Birnbaum Importance and ΔCDF

- **More on Birnbaum importance**

$$I_B(x) = \frac{\partial(CDF)}{\partial p_x} = CDF(x=1) - CDF(x=0)$$

- **$\Delta CDF \approx \Sigma I_B(x) \Delta p_x$**
- **Thus UAI is approximately the increase in CDF caused by increase in unavailability of monitored systems**

Calculating URI

$$URI = \sum_{j=1}^{n} I_{B,\max} (UR_{PRA,j})(UR_{BC,j} - UR_{BL,j})$$

$I_{B,max}$ = maximum Birnbaum importance of all basic events for given component

UR_{PRA} = unreliability from PRA

UR_{BC} = Bayesian-corrected unreliability (plant-specific)

UR_{BL} = Industry baseline unreliability

Calculating URI

- **Using relationship between Fussell-Vesely and Birnbaum importance gives**

$$URI = CDF \sum_{j=1}^{n} \left\{ \left[\frac{I_{F-V}(UR_{PRA,j})}{UR_{PRA,j}} \right]_{\max} (UR_{BC,j} - UR_{BL,j}) \right\}$$

- **URI includes both demand failures and running failures**
  - **Details can be found in App. F to NEI 99-02**

Calculating URI

Where:

CDF = Plant core damage frequency

$I_{F-V}(UR_{PRA})$ = Fussel-Vesely value from plant specific PRA (component's failure modes [i.e., MDP fails to run])

UR_{PRA} = Plant specific unreliability (probability of component's failure modes [i.e., MDP fails to run])

UR_{BC} = Bayesian corrected plant-specific value for the component's specific failure modes [i.e., MDP fails to run]

$UR_{BC,d} = (N_d + a)/(a + b + D)$

N_d is the total number of failures of on demand during previous 12 quarters
D is total number of demands during the previous 12 quarters
a and b are parameters of the industry prior, derived from industry experience (Appendix F NEI99-02)

$UR_{BC,r} = [(N_r + a)/(T_r + b)] * T_m$

N_r is the total number of failures to run during previous 12 quarters
T_r is total number of run hours during the previous 12 quarters
T_m is mission time for the component based on PRA model assumption.
a and b are parameters of the industry prior, derived from industry experience (Appendix F NEI99-02)

UR_{BLt} = historical baseline values of unreliability for the component's failure modes [i.e., MDP fails to run]

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Color Scale for MSPI

- MSPI = UAI + URI
- MSPI is calculated for each monitored system and compared to risk thresholds
  - $MSPI \leq 10^{-6}$ GREEN
  - $10^{-6} < MSPI \leq 10^{-5}$ WHITE
  - $10^{-5} < MSPI \leq 10^{-4}$ YELLOW
  - $MSPI > 10^{-4}$ RED

MSPI Front-Stop

- Don’t want single failure to result in MSPI being WHITE
- For example, expected to see three failures over a three year period. Due to variability, it can be expected to see 2 or 4 failures in three year period.
- It is not appropriate a system should be placed in WHITE band due to expected variation.
- Avoid this by capping most risk-significant failure at 5 10^{-7} (from risk-informed Tech. Specs.) (This ensures one failure beyond expected alone doesn’t result in MSPI > 1.0 10^{-6}

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MSPI Back-Stop

- **For systems with low Birnbaum importance, performance could degrade significantly without MSPI crossing WHITE threshold**
- **To prevent this, a maximum number of failures is determined as the threshold to the WHITE band, even though the calculated MSPI < 1.0 10^{-6}**
- **Appendix E to NUREG-1816 or Appendix F of NEI99-02 gives formula for finding maximum allowed failures, even if MSPI is still GREEN**

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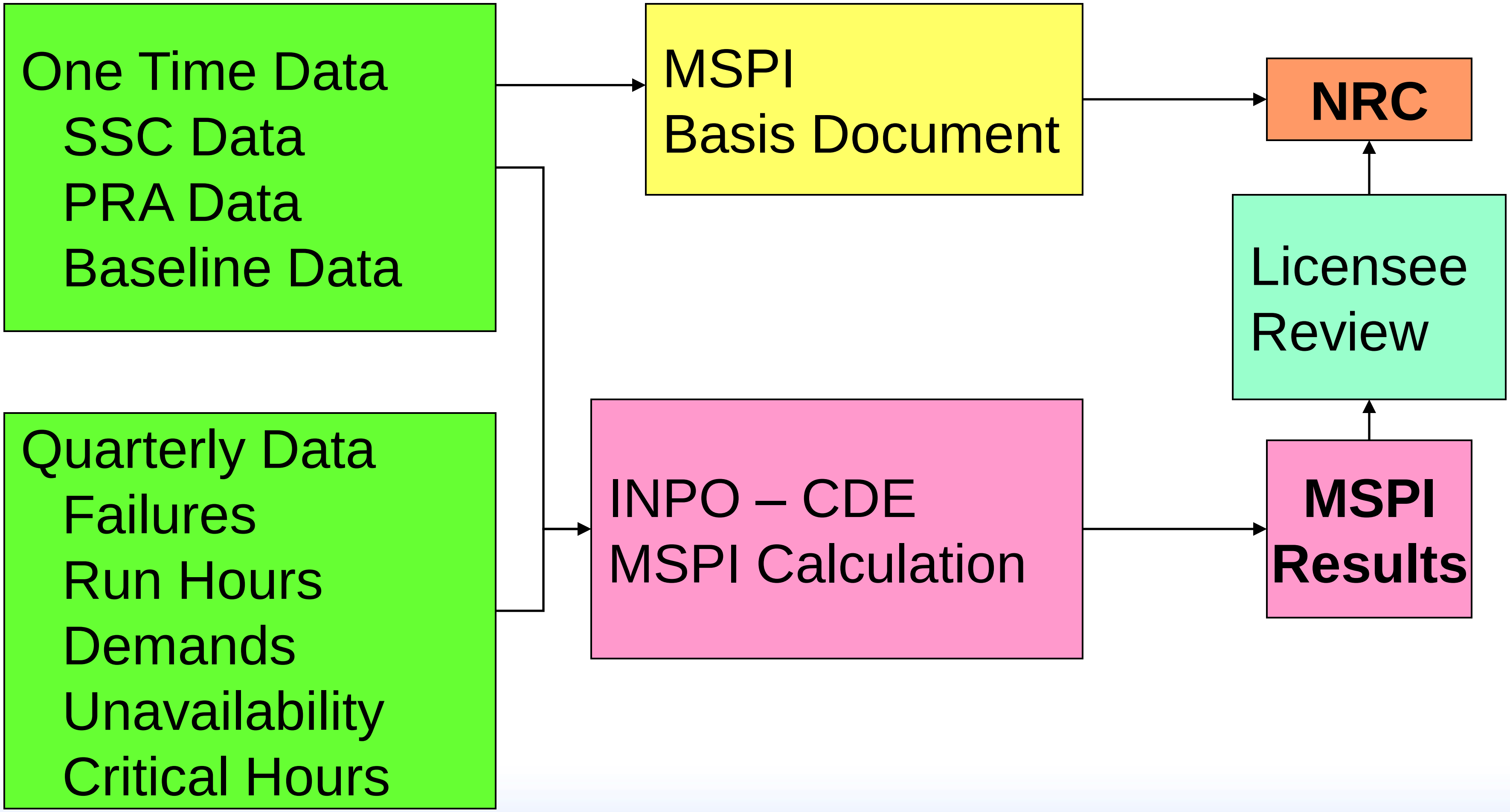
MSPI Overall Process



Guidance Documents

- NEI 99-02 Section 2.2
  - Basic Definitions
- NEI 99-02 Appendix F
  - Details of Calculation Methods
  - Detailed Definition of Inputs
- NUREG-1816
  - Technical bases
  - Description of pilot program
  - Recommended enhancements
  - MSPI limitations