An Investigation of MSPI* Optimization to Improve NPP Safety and Efficiency

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*MSPI stands for Mitigating System Performance Index.

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Outline

- MSPI Overview
- MSPI Optimization Methodology
- MSPI Calculation Tool
- Conclusions and Future Work

MSPI Overview (1/3)

- Mitigating System Performance Index (MSPI) is one of the risk-informed, plant-specific performance indicators of the Nuclear Regulatory Commission (NRC) Reactor Oversight Process (ROP)
- MSPI replaced previous performance index (PI) indicators, such as safety system unavailability (SSU) PI and Risk-Based PI
- Used to monitor and assess the performance of nuclear power plant (NPP) mitigating systems

Index	PWR Systems	BWR Systems
MS06	Emergency AC (EAC) Power Systems	EAC Power Systems
MS07	High Pressure Injection (HPI) System	HPI System
MS08	Auxiliary Feed Water (AFW) System	Reactor Core Isolation Cooling (RCIC) System
MS09	Residual Heat Removal (RHR) System	RHR System
MS10	Cooling Water Support (CWS) System	CWS System

MSPI Overview (2/3)

- MSPI is calculated for each monitored mitigating system as the sum of the Unavailability Index (UAI) and the Unreliability Index (URI)

$$MSPI = UAI + URI$$

$$UAI = CDF_P \left(\sum_{i=1}^{n} \frac{FV_P}{UA_P} \right) (UA_C - UA_B)$$

$$URI = CDF_P \left(\sum_{j=1}^{n} \frac{FV_P}{UR_P} \right) (UR_C - UR_B)$$

CDF_P = Plant-specific core damage frequency

FV_P = Fussell-Vesely importance measure of a train or component

UA_P = Plant-specific train unavailability

UA_C = Current train unavailability

UA_B = Baseline train unavailability

UR_P = Plant-specific component unreliability

UR_C = Current component unreliability

UR_B = Baseline component unreliability

MSPI Overview (3/3)

- A performance color is assigned to the MSPI results for each mitigating system according to its numerical value and the Performance Limit (PL)

Condition	Performance Color
MSPI ≤ 10^{-6} and $F_a \leq F_m$	GREEN
MSPI ≤ 10^{-6} and $F_a > F_m$	WHITE
10^{-6} < MSPI ≤ 10^{-5}	
10^{-5} < MSPI ≤ 10^{-4}	YELLOW
MSPI > 10^{-4}	RED

F_a = Actual number of failures F_m = Maximum number of failures

MSPI Optimization Methodology (1/5)

- MSPI program needs considerable resources from NPPs to maintain along with the concerns on potential elevated MSPI colors and associated costs

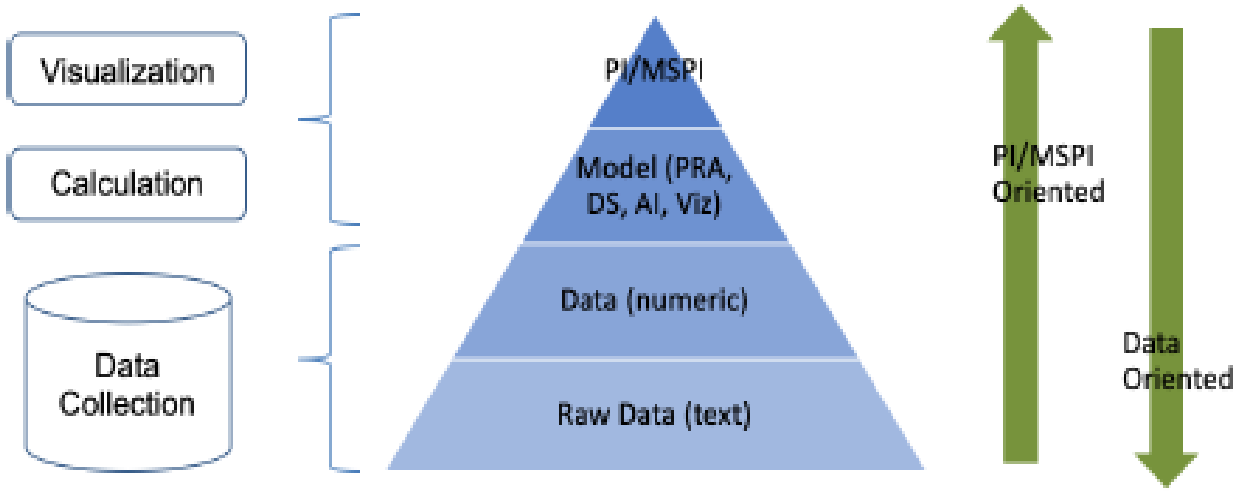
- Can these resources be better utilized with an optimized MSPI process to improve both plant safety (better performance) and economics (cost efficient)?

- The purpose of this investigation is to develop a process to optimize MSPI with the data-based reasoning to:

  - Address the off-normal equipment conditions
  - Utilize the ranking of the root causes and potential resolutions to find the best option of economically reducing MSPI value
  - Facilitate and simplify the risk-informed and reliability-related decision-making for continuous improvement

MSPI Optimization Methodology (2/5)

- PI/MSPI-oriented approach: developing MSPI optimization process based on data, PRA model, and plant operation inputs, with three stages: Data collection, calculation and visualization stage.
- Data-oriented approach: developing MSPI optimization process by starting from a target PI, diving into the database to identify the contributing events and find the root causes from the data analysis of the numeric and text data, and finding the resolutions



MSPI Optimization Methodology (3/5)

- **MSPI optimization is an interdisciplinary effort**
  - PRA modeling
  - Data science techniques (e.g., big data, statistics and probability, data mining techniques)
  - Artificial Intelligence (AI) and Machine Learning (ML) techniques, including natural language processing (NLP), decision trees, and visualization

- **Three major tasks in developing the MSPI optimization process**
  - Develop MSPI system objective functions
  - Extend MSPI system objective functions and fuse with AI techniques
  - Develop MSPI plant objective function

MSPI Optimization Methodology (4/5)

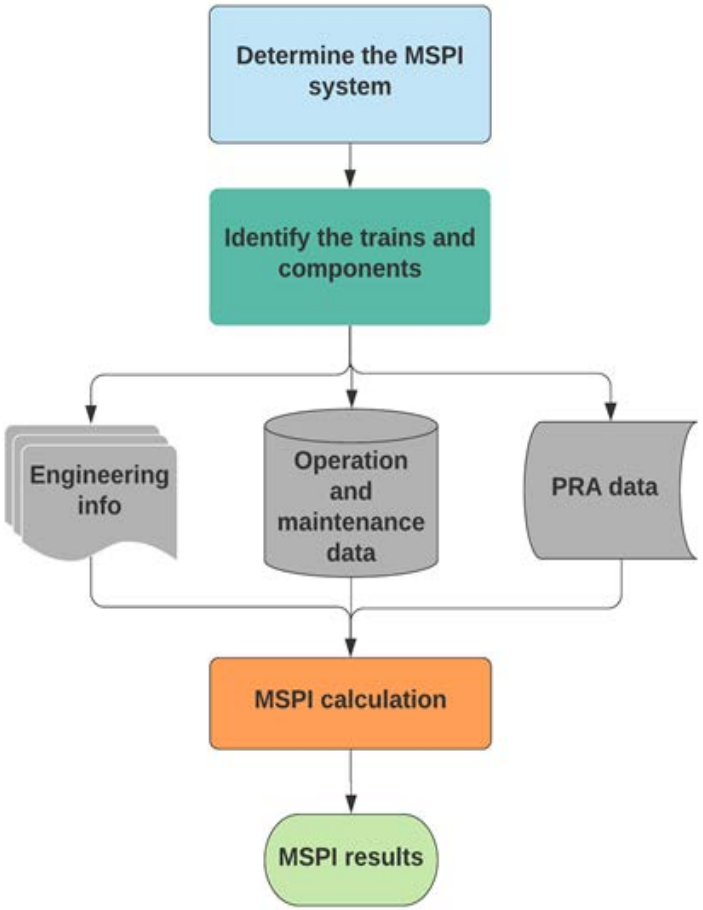
- **Task 1 - Develop MSPI system objective functions**
  - Derive and implement system objective functions in existing MSPI program
  - Pre-define the maximum allowed combinations of UA time and UR values for each system and closely monitor low-margin MSPI systems
  - Monitor the MSPI margin and risk to keep MSPI green
- **Task 2 - Extend MSPI system objective functions and fuse with AI techniques**
  - Find out the root cause of risk-significant contributors like initiating event frequency, equipment failure probability or rate, or operator action
  - Develop a method to balance maintenance cost/frequency and reliability improvements for risk significant equipment

MSPI Optimization Methodology (5/5)

- **Task 3 - Develop MSPI plant objective function**
  - System-level MSPI margin management in Tasks 1 and 2 can be extended to plant level by aggregating the MSPI system objective functions into one MSPI plant objective function
  - Plant can focus its resource and efforts on the risk-important structures, systems, and components efficiently

MSPI Calculation Tool

- MSPI calculation in the industry is performed by the Institute of Nuclear Power Operations (INPO) Consolidated Data Entry web-based tool
- Other MSPI calculation tools developed by various companies are available for purchase
- We developed an MSPI calculation tool using the Python programming language by incorporating the plant operation data, PRA data, and industry baseline values to automate the calculation process of MSPI and generation of the report
- The tool was verified with example data sets



Conclusions and Future work

- This paper provides an overview of MSPI and describes how MSPI is evaluated in the current MSPI program.
- Two proposed MSPI optimization approaches as well as the three major tasks for developing the MSPI optimization process are introduced.
- An integrated MSPI calculation tool was developed by integrating plant operating data, PRA data, and industry baseline values to automate the MSPI calculation process and report generation.
- The three tasks in the MSPI optimization process will be carried out in the next step.

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Thank you!

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