



# PHM-RIAM Tools and Future Directions

September 2024

*Changing the World's Energy Future*

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# **PHM-RIAM Tools and Future Directions**

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**September 2024**

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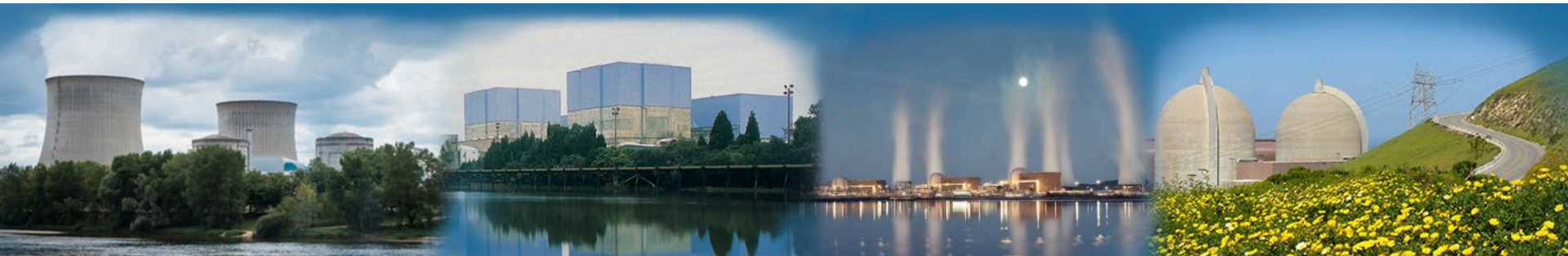
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# PHM-RIAM Tools and Future Directions



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## System Risk Analysis Platform

- Development focuses on general purpose capabilities rather than specific use cases
  - Models
  - Quantitative methods
- From tradeoff analysis to trade-space exploration
- Development agenda can easily change/update depending on project needs
  - Costs can be shared among other internal projects
- Development goals: Increase models/methods
  - Pedigree
  - Credibility

# System Risk Analysis Platform: Overview

## Objectives:

- Automate plant operations
- Enhance system performance
- Reduce operational costs
- Inform plant performance
- Integrate safety and economic risk

### Plant, fleet and industry data



### Analysis engines

- Reliability model updating
- Resources optimization algorithms
- Analysis of plant data (sensor data, failure reports, maintenance reports)



## Applications:

- Optimize plant resources allocation
- Optimize system maintenance operations
- Schedule component replacement
- Monitor economic risk

## System Risk Analysis Framework

System models

System simulators

### System digital models

Plant availability profile

Plant ops

Procurement

Maintenance

Lifecycle mgt

Plant risk profile

## Methods:

- Machine learning
- Data mining
- Optimization

## Tools:

- Open source model libraries
- Open source system analysis codes
- Plant existing PRA tools

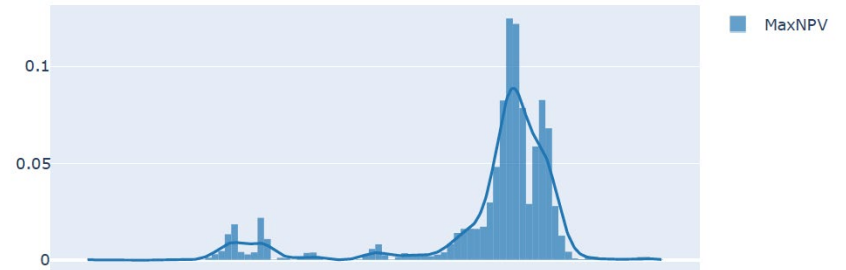
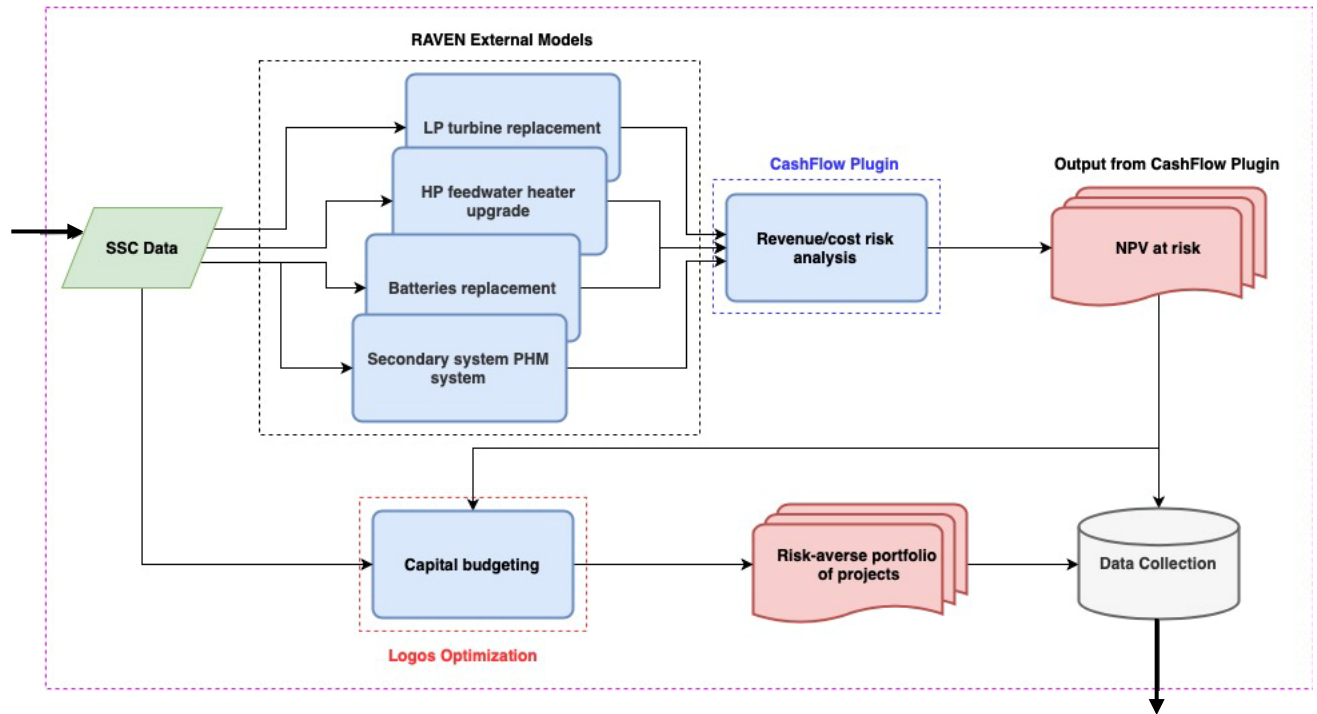
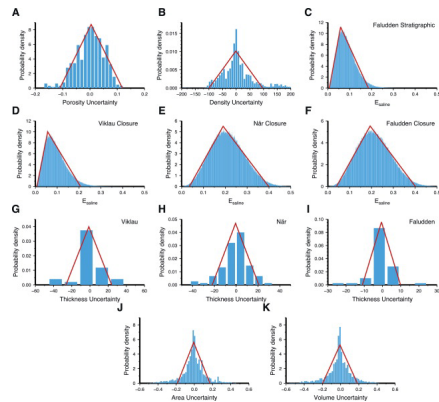
## **System Risk Analysis Platform: Under the Hood**

- RAVEN: Statistical analysis platform
  - Link models together in a single ensemble model
  - Optimization algorithms
  - Propagation of uncertainties
  - Analysis of complex datasets
    - Sensitivity analysis
    - Data mining (e.g., clustering)
- LOGOS
  - Basic discrete optimization classes
  - Optimization models for budgeting (capital and stochastic)
- SR<sup>2</sup>ML
  - SSC reliability models
  - Maintenance unavailability models
  - GRA models
- CashFlow
  - Economic models
- [SRAW]
  - Templated inputs for PHM and RIAM analysis

- Git repository for each software package
  - RAVEN open source
  - Plant to release the other packages open-source as well
- Release of new feature/capabilities:
  - Development phase
    - Code development
    - Coding standard
    - Documentation development
    - Regression tests
      - Analytical tests (if possible)
  - Review phase
    - Code review (peer)
    - All tests are required to pass
  - Merging into main repository
- Additional documentation:
  - Training material (workshops)
  - Peer review publications
  - Benchmarking with literature test cases

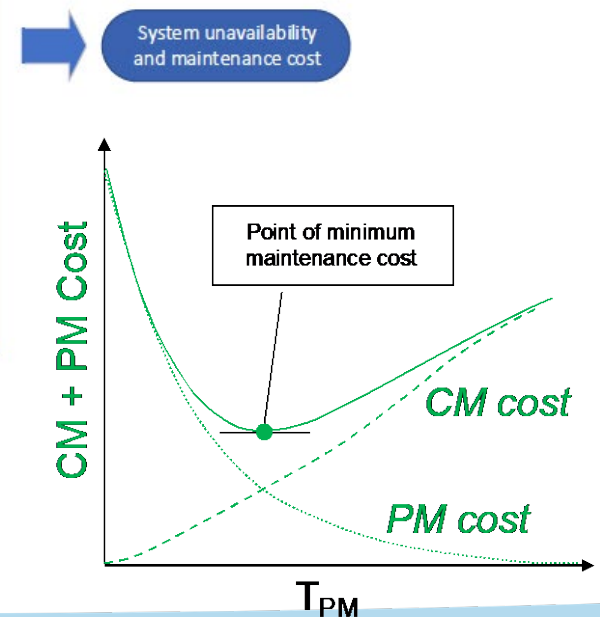
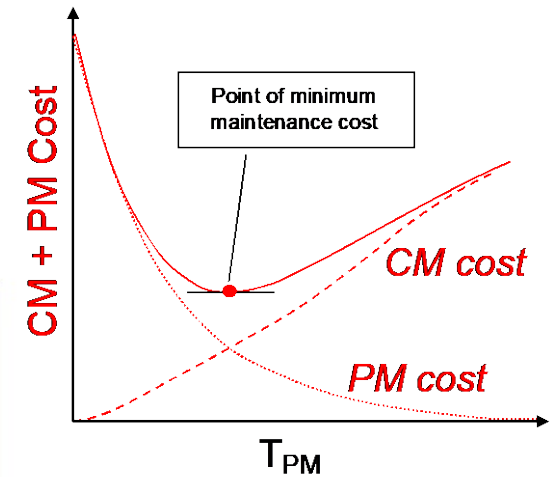
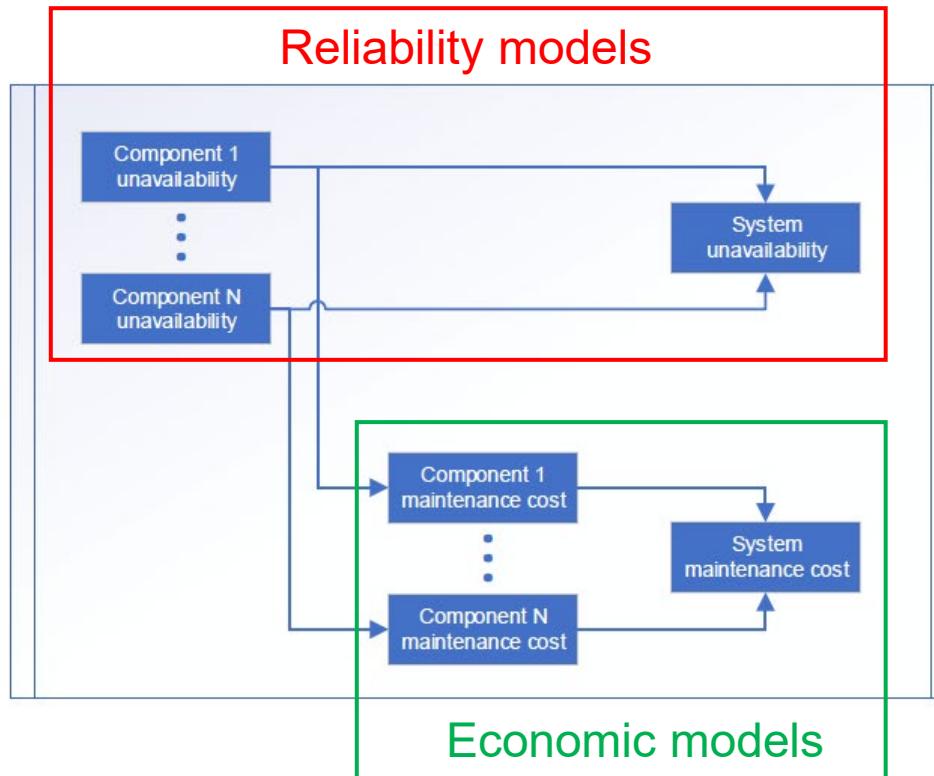


# Uncertainties Propagation

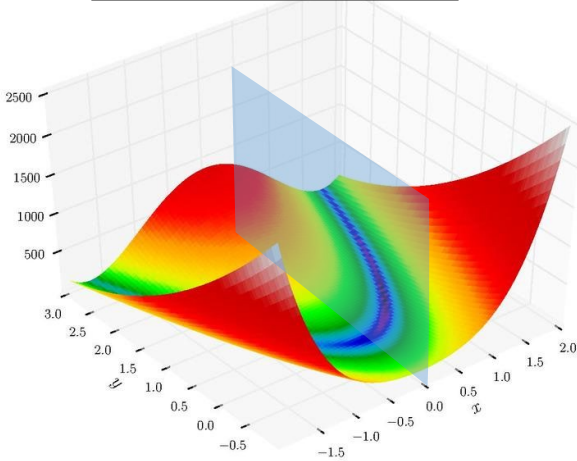
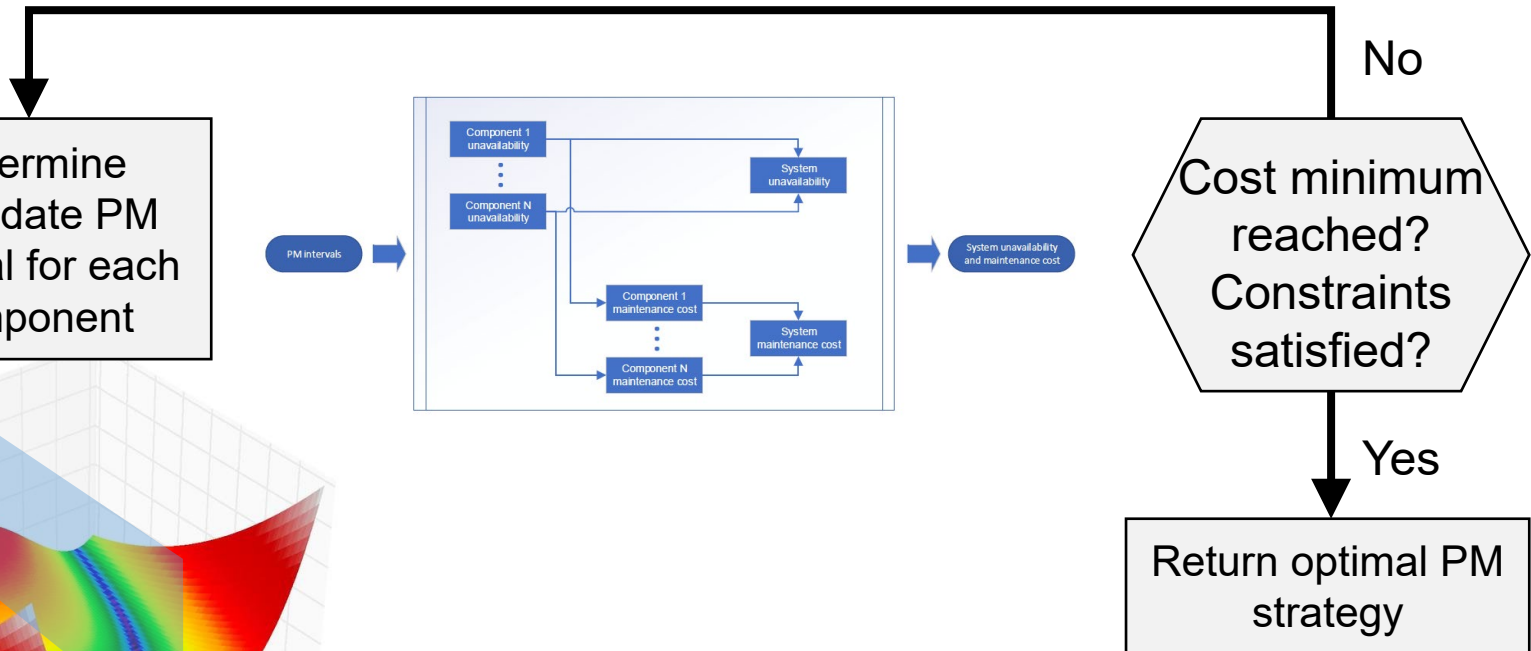


## Optimization Analysis

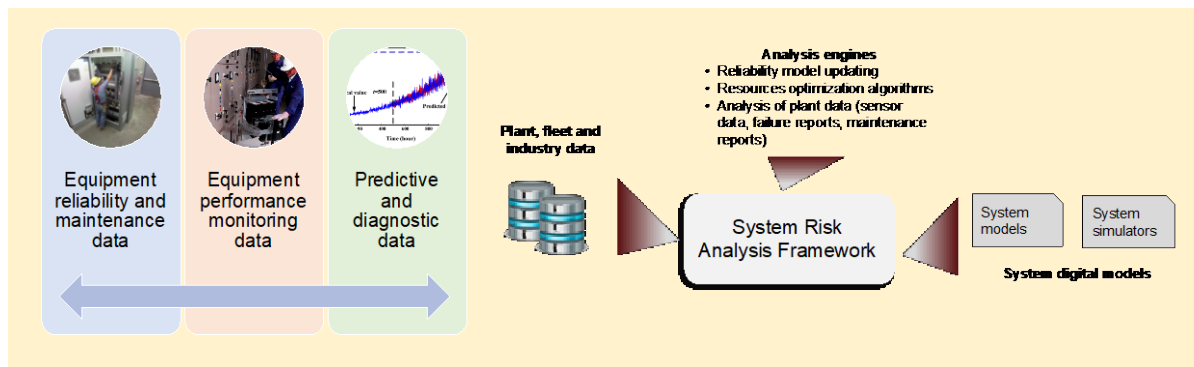
- Example: safety-economic maintenance optimization



- Example: safety-economic maintenance optimization
  - Optimization problem
  - Constraints (e.g., system availability)
  - Under uncertainties

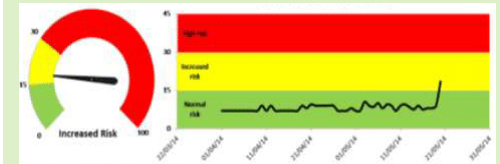


- Release all software packages Open-Source
- Short term development plan:
  - Smart optimization algorithms (e.g., genetic algorithms)
  - Regulatory risk models
  - Bayesian updating [TBD]
- Long-term plan
  - Integrate plant data sources to decision making in a complete, automatic and self-consistent analysis platform



### Plant Risk Monitors

- Safety: CDF, LERF
- Economic: Loss of MWe
- Regulatory: SDP, MSPI



### Actions

- PM scheduling
- Surveillance frequency updating
- Set replacement date
- Procurement scheduling



# Sustaining National Nuclear Assets

*<http://lwrs.inl.gov>*