JENSEN HUGHES

Advancing the Science of Safety

Economic Enterprise Risk: Protecting the Value of the Nuclear Investment

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Topics of Discussion

- Issues and Objectives
- Generation Risk Assessment – Technical Description
- Applications and Benefits
- Fleet Wide Application
- Conclusions

(1)

ISSUE AND OBJECTIVES

Background

- Market Drivers
  - Regulated plants[1] = regulated rate of return provides predictability in economic performance
    - Costs, not revenues, are primary decision driver
  - Merchant market plants[2] = more control but greater uncertainty in economic performance
    - Risk management crucial for success
- Generation Risk Assessment provides engineered approach to support improved economics / performance
  - Reduction in plant trips and down-power events
  - Improved capacity / availability factors
  - Quantification of lost generation due to system and component failures
  - Reduced costs through optimized equipment maintenance
  - Input to asset management / life cycle management plans

1. Regulated power plants are built and operated by regulated utilities, with rates negotiated between the utility and relevant State Utility Commission, and set at levels designed to fund the plant's maintenance and operating costs, plus a return.
2. Unregulated – or merchant – power plants, on the other hand, sell power into the competitive market, with no guaranteed return.

What Is Unacceptable Risk?

- Assessed and defined by plant / corporate decision-makers
- Different organizations have different levels of risk aversion
- Risk to plant generation may be dependent on:
  - Plant / site conditions
  - Time of day
  - Season
  - Operating status of electrical grid / other generation facilities
- Risk management evaluations provide insights to support operational and maintenance decision making

GRA model developed to support risk tolerance and defined plant / corporate objectives

Key Drivers

- Ability to supply energy to the regional transmission organization / independent system operator (RTO / ISO) while simultaneously meeting the plant's planned earnings contribution
- Delivery on its commitment to meet capacity factor / power quality goals
- Ensuring ability to produce power during periods of peak demand and transmission system instability
- Providing high value production at minimal cost while ensuring compliance with all regulatory requirements (e.g. emission controls)

GRA model can provide quantitative evaluations to support meeting these objectives

(2)

GENERATION RISK ASSESSMENT

What Is Generation Risk Assessment?

- GRA is the process of estimating the risk of generation loss during plant operation
  - Combines modeling of probability, magnitude, and duration of plant trip or derate due to postulated equipment failures
- GRA models potential generation and economic impact (MWh/yr) -- similar to modeling of safety impact in probabilistic risk assessment (PRA)
- More robust than simplistic qualitative approaches (e.g. single point vulnerability)
  - Addresses redundancies / interdependences of plant systems and components
  - Provides quantitative estimates to support decision-making.
- Provides importance rankings of critical components in terms of production risk to support effective and efficient resource allocation

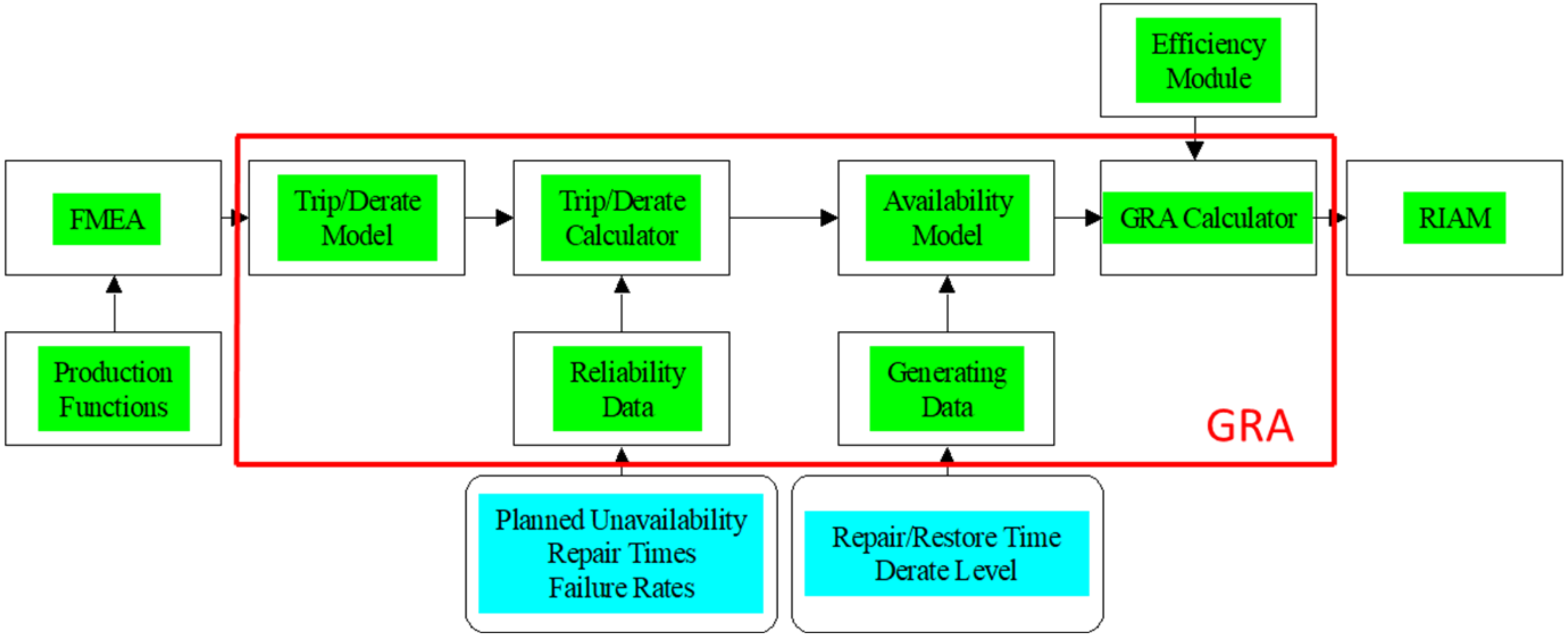
GRA Objectives

- Reduce plant trips and power reduction events
  - Evaluate real time conditions and provide operating guidance on how to restore margin
- Improve plant capacity factors
- Quantify lost generation due to system / component failures for improved asset management
  - Reduce costs through more focused equipment maintenance
  - Optimized maintenance scheduling and capital improvements
- Identify personnel safety concerns
  - Superheated steam leaks, turbine missiles, etc.
- Capture knowledge of plant engineers
- Support engineering and economics decision-making
  - Capability to conduct proactive “what if” scenario analysis to support risk / benefit tradeoffs
  - Support maintenance optimization

Technical Elements of GRA

- Specify business objectives of GRA study.
  - Comprehensive plant trip / derate model.
  - Specific application / business decision support models.
- Select applicable modeling approach.
  - Qualitative methods
  - Quantitative methods
- Obtain necessary information.
- Build model / analyze results / develop recommendations.
- Obtain management approval.
- Implement approved recommendations / monitor results.

Typical GRA Flow Diagram



Consequences

- To obtain accurate picture of risk need to consider impact of generation loss.
  - The level of derate (i.e. magnitude of power reduction) associated with the failure (Trip = 100 % derate)
  - The duration of the load reduction (total downtime)
    - Depends on time to repair and time to return to power
  - Cost of repair
  - Price of electricity at the time of failure
    - Not constant over time
  - Other factors
    - Test and maintenance unavailability
    - Common cause failures
    - Environmental impact
    - etc.

Risk = Magnitude of Consequences ($) x Likelihood of Occurrence

GRA Outputs

- Identification of equipment failures that can result in plant shutdown / power reduction
  - Single Point Vulnerabilities (SPVs) – individual failures resulting in plant trip or significant power reduction
  - Combinations of component failures that can lead to plant trip or power reduction
- Frequency of occurrence of failure events or combinations of failures
- Consequences (in units of Megawatt-hours (MWh) lost or Equivalent Full Power Hours (EFPH) lost)
- Prioritized rankings of component failures in terms of contribution to lost generation
- Uncertainty distributions for the frequencies and consequences of events for each system modeled

Product

- Delivered product is model of plant generation that permits quantification of likelihood of lost generation
  - Can be modified to incorporate changes in economic conditions or plant / corporate objectives
  - Can be modified to assess impact in postulated changes in plant design, operation, or maintenance strategies
  - Can provide estimates of uncertainties in outcomes and their likelihoods
  - Can be expanded to provide a Trip Monitor for continuous risk assessment
- Supports broad range of potential applications
  - Cost / benefit assessment for capital improvements
  - Maintenance optimization strategies
  - Operational / configuration risk management

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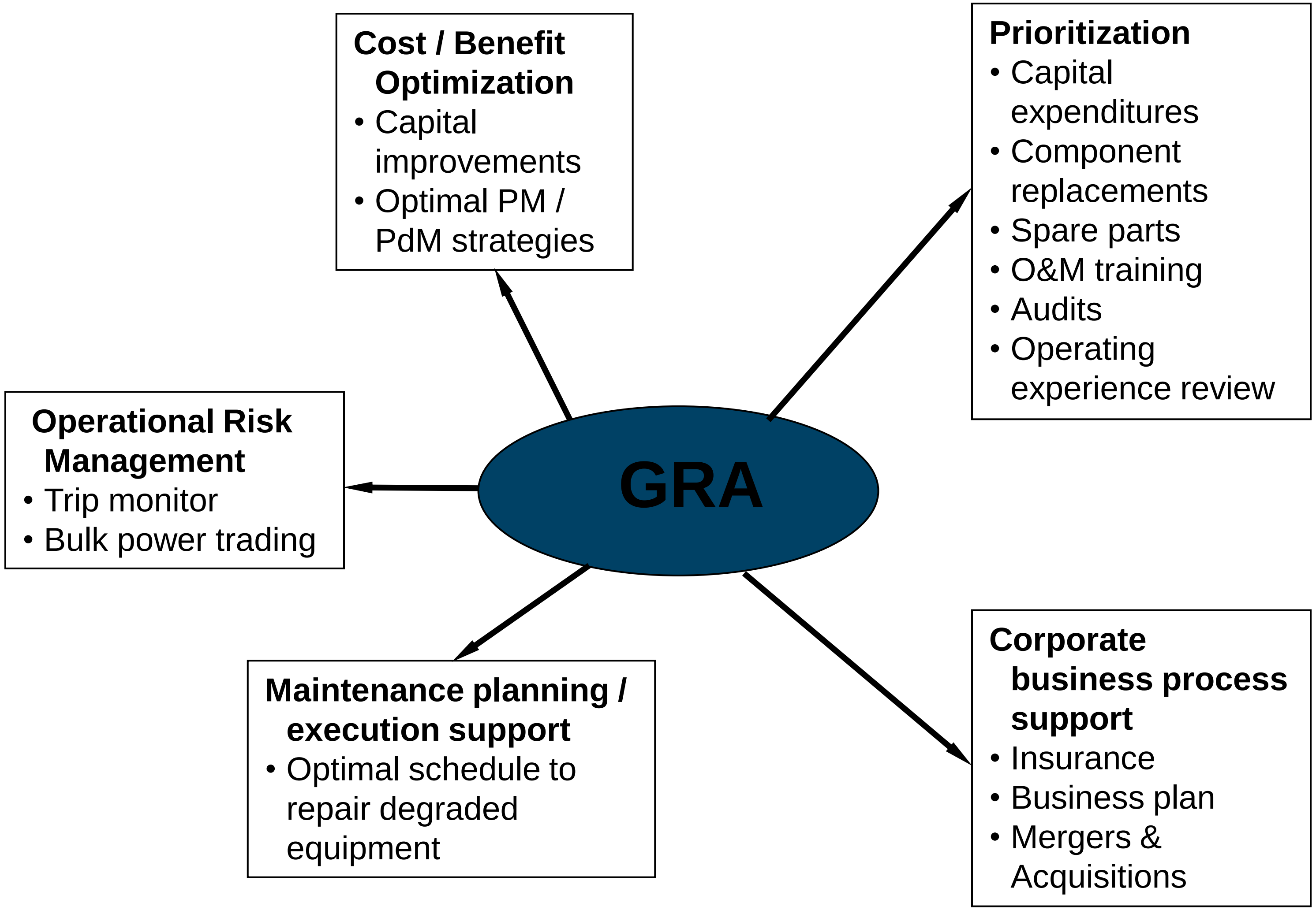
APPLICATIONS AND BENEFITS

EER Applications



Immediate Payback for Plant Staff

- Support for maintenance and operational planning
  - Support integrated preventive and predictive maintenance scheduling optimization
- Support operational risk management
  - Current and planned status of key systems and equipment
  - Current and planned status of critical plant functions
  - Visual support for daily review meetings and shift turnover
  - Permits “what if” analyses to understand implications of emergent issues
- Model can be used as a training tool for new staff

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FLEET WIDE APPLICATION

Generic GRA Model Approach for EER

- Generic Trip Model
  - Develop customizable “template” GRA model based on pilot plant characteristics with capabilities to modify for application across the fleet
    - Provide streamlined “plug and play” system models based on typical plant designs
    - Include lessons learned from industry experience & other info sources
  - Desired Characteristics
    - Broad and comprehensive; easily customized
    - Screening guidance to limit model size and manage cost & scope
    - Define system boundaries to support plant-specific adaptation
- Trip Model Systems
  - Identify (only) systems that should be modeled based on plant & industry experience
  - Use appropriate level of modeling detail
  - Model generation critical systems first

Fleet Wide Implementation of EER

- Perform a risk assessment for each plant to assess identified critical operational risks
  - partial derates (i.e. runback)
  - forced shutdown conditions
  - plant trip
- For each end-state, assess relevant items (maintenance activities, etc.) that may impact the end-state (e.g. single / double point vulnerabilities)
- Produce a final risk matrix to guide operational decisions that can be applied across the fleet
- Develop basis automated support tools (Trip Monitor)

Implementation can be performed in stages based on economic importance of individual assets and annual corporate budget limitations

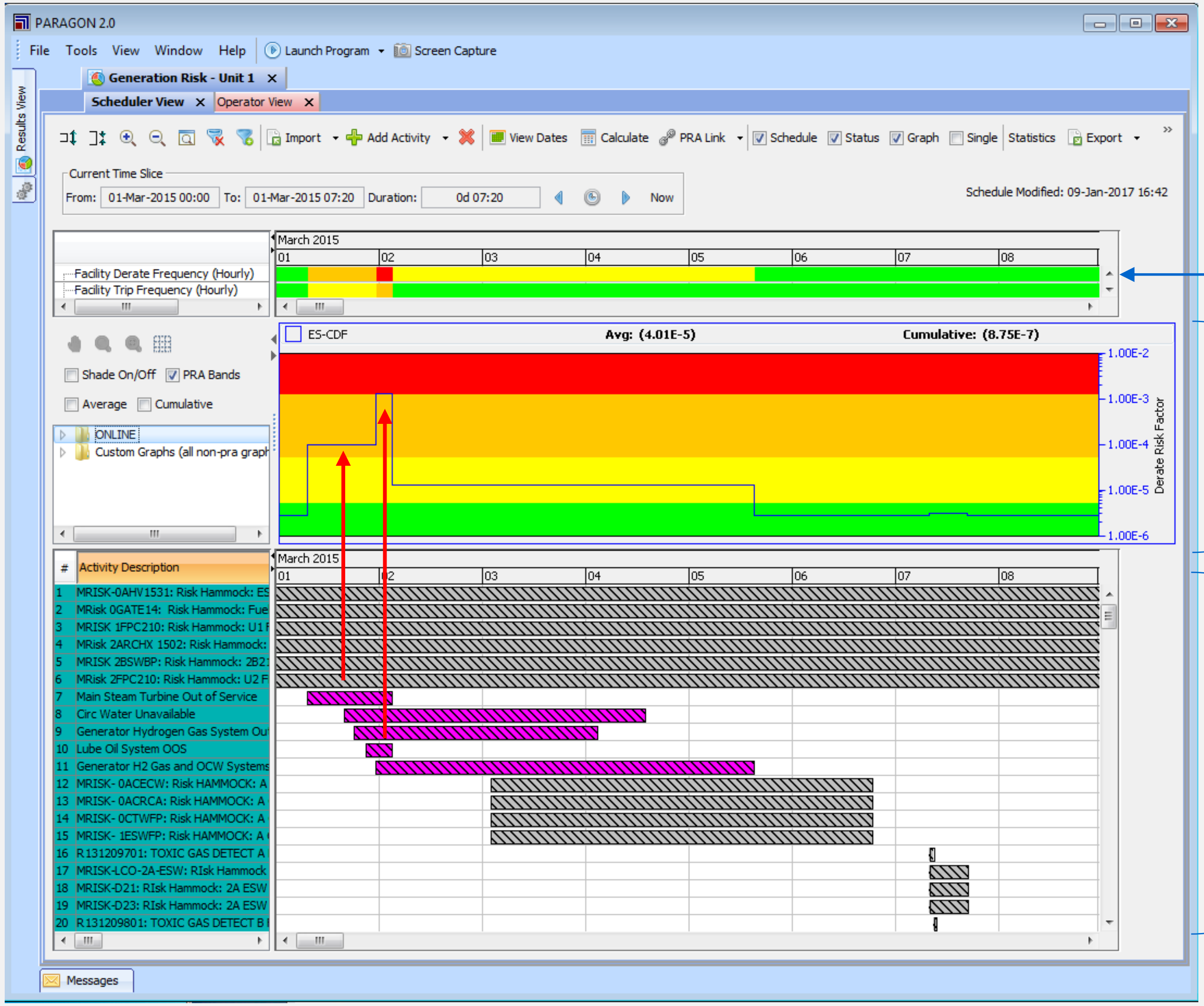
Trip Monitor

- A trip monitor is a tool to estimate the likelihood of an unplanned plant trip or significant power derate.
- Purposes for developing trip monitors.
  - ECONOMICS: The potential for an unplanned plant trip or derate can be lowered in periods where production is essential for the reliability of the grid and at times of peak electric power prices.
  - GRID STABILITY: Understanding and controlling the potential for unplanned plant trip or derate can increase grid stability and lower the potential for other grid disturbance events.
  - SAFETY: Improvements in safety are achieved through lowering the probability of the potential for events that can impact personnel safety or result in environmental consequences.

Trip Monitor

- Operates in real time and evaluates risks as plant equipment configuration changes
- Evaluates frequency of trip and derates given configuration changes
- Provides single point vulnerabilities with component out of service to support maintenance risk management
- Extends reliability models to generation critical systems
- Requires
  - Simplified templates
  - Modular construction
  - Appropriate data

Paragon Risk Monitor - Scheduler



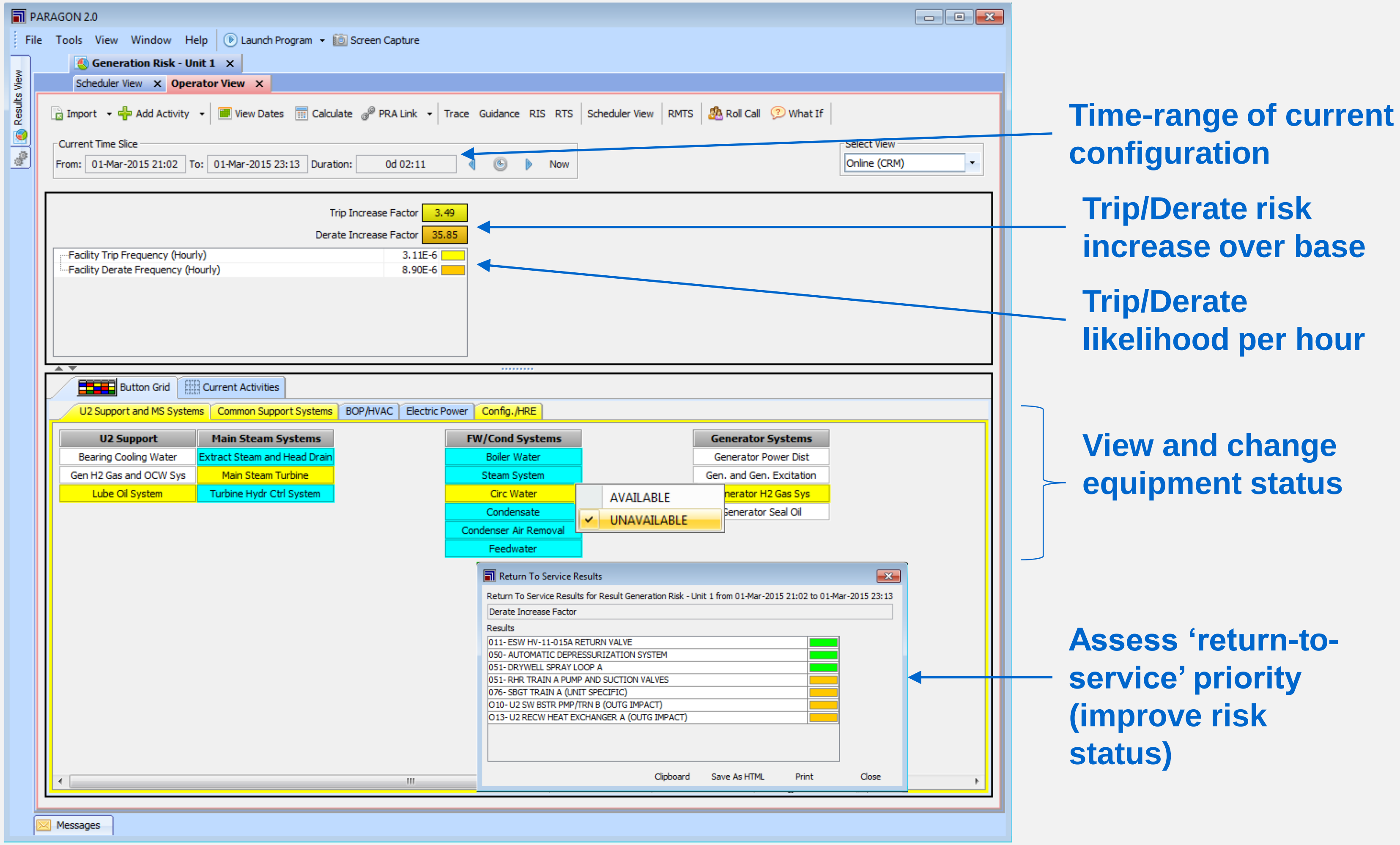
Risk Summary

Risk Profile

Peaks from equipment out-of-service (OOS)

Schedule of planned and modified OOS equipment

Paragon Risk Monitor - Operator



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CONCLUSIONS

Conclusions

- Applying GRA and an EER program to operating nuclear plants
  - For operating nuclear plants have many programs available to optimize maintenance and operation, the EER program can help to better focus those programs to benefit production.
    - Maintenance rule and configuration risk management
    - Equipment reliability (INPO AP-913)
    - Streamline RCM, Single-Point Vulnerability, Value-based Maintenance
    - Risk-informed applications (SFCP (5b), RMTS (4b), Equipment categorization (50.69))
  - For operating nuclear plants that don’t currently have all of these programs, the benefits are greater.
- When used during the design process a GRA has significant benefits in supporting design decisions that will support high generation reliability once the plant enters operation. GRA is used to varying degrees by SMR and advanced reactor vendor for this purpose.
- Additionally, EER for operating fossil fuel plants does have significant benefits since these plants do not have the rigorous maintenance and optimization programs of nuclear plants. EER is a lower cost way to achieve similar generation reliability outcomes.

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8. EPRI 1019806, Managing Generation Risk at a Coal-Fired Power Station
9. EPRI 1021084, Program on Technology Innovation: Integration of Degradation Predictions on Generation Risk Assessment

JENSEN HUGHES GRA TEAM MEMBERS CONTRIBUTED TO THESE PROJECTS

Questions?

Thank you!

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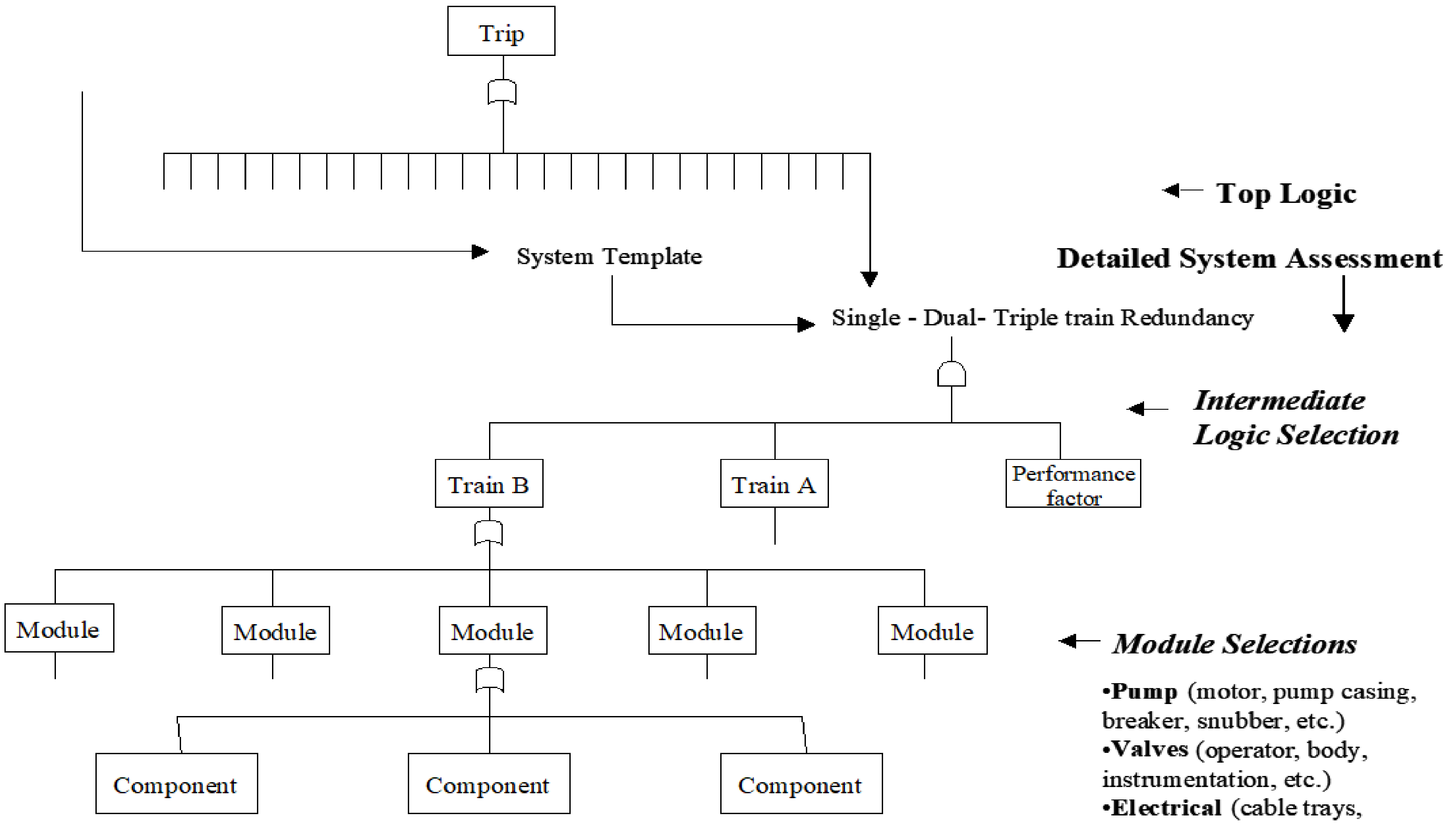
Backup Slides

GRA Inputs / Information Sources

+ System design and operating documentation
  - Prints (P&ID, electrical single lines, logic diagrams)
  - System Descriptions
  - Operating Procedures
  - Training Manuals
+ Plant operating history / experience
  - Trip / derate data
  - Maintenance history
  - Knowledge from operator interviews
+ Generic industry data sources (NERC/GADS, etc.)

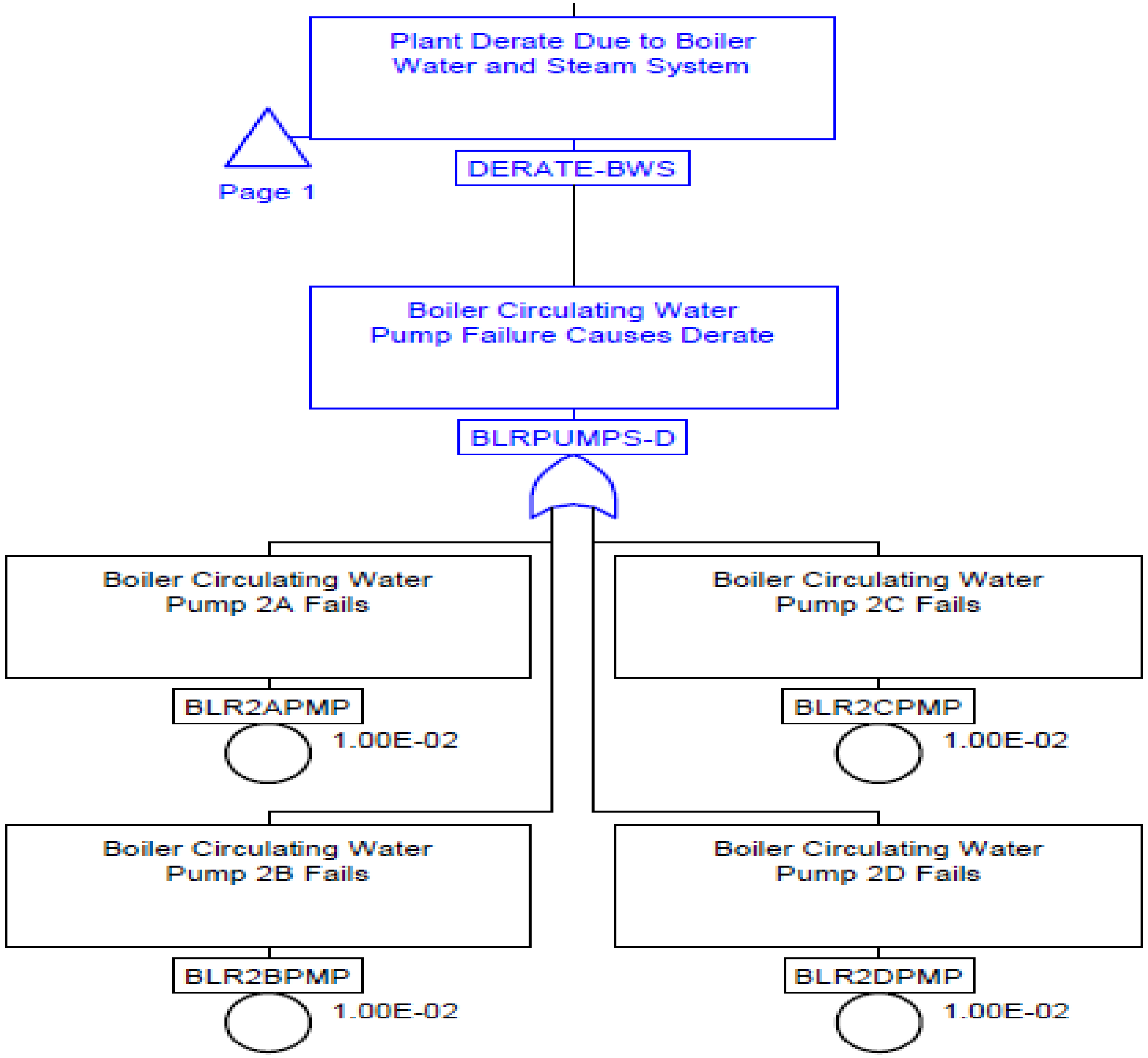
GRA Template Layout



- **Pump** (motor, pump casing, breaker, snubber, etc.)
- **Valves** (operator, body, instrumentation, etc.)
- **Electrical** (cable trays, raceways, etc.)
- **Piping** and appurtenances, snubbers, etc.
- **Structural**

Component failure data
- Screening estimate
- Failure rate / repair time

Example Portion of GRA Fault Tree



Example Functional Importance

Example Criteria for Component Functional Importance	
Level of Consequence	Production Criticality (PC_1, PC_2, or PC_N)
1	Loss of a function of this component will cause: 1) Plant / turbine trip 2) Power reduction >10% 3) Emissions in exceedance of limits Note: This includes Single Point Failure Components
2	Loss of a function of redundant components could cause a plant / turbine trip. Loss of a function of this component will cause: ▪ a small power reduction ▪ significant personal safety impact ▪ significant environmental impact ▪ significant economic consequences
N	Loss of a function of this component will not cause a significant impact on production

GRA model developed to support component functional importance determinations based on plant objectives

How GRA Helps Decision Making (1 of 2)

Prioritization activities		
	Capital spares procurement analysis and optimization Quality assurance audit prioritization Operating/maintenance procedure training prioritization Station major maintenance activity prioritization Project prioritization Component prioritization Preventive/Predictive/Corrective Maintenance prioritization Operating experience review	Order-of-magnitude estimates
Determination of risk tradeoff		
	Trade offs between online and offline maintenance Major equipment refurbishment/replacement/repair decisions & optimization Refueling outage schedule and duration optimization Online/shutdown tradeoffs given equipment degraded performance	Order-of-magnitude estimates Relatively rigorous data
Knowledge of absolute risk		
	Trip monitor Bulk power trading	Order-of-magnitude estimates Relatively rigorous data
Demonstrate cost-benefit		
	Equipment design modification optimization Capital improvement assessment	Moderately accurate data if results are near cost-benefit threshold
Procedures/training activities		
	Treatment of risk from human errors O&M procedure improvement	Order-of-magnitude estimates
Life cycle management		
	LCM planning at the plant level Component aging and aging management Component obsolescence management	Order-of-magnitude estimates
Corporate decision making		
	Insurance Business plan optimization Mergers and acquisitions	Order-of-magnitude estimates

How GRA Helps Decision Making (2 of 2)

Knowledge of absolute risk		
	Trip monitor Bulk power trading	Order-of-magnitude estimates Relatively rigorous data
Demonstrate cost-benefit		
	Equipment design modification optimization Capital improvement assessment	Moderately accurate data if results are near cost-benefit threshold
Procedures/training activities		
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