20th SYMPOSIUM ON INDUSTRIAL APPLICATIONS OF GAS TURBINES

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MAXIMIZE YOUR ASSETS OPERATIONAL VALUE BY FOCUSING MAINTENANCE ON RELIABILITY THROUGH UTILIZATION OF CONDITION ANALYSIS AND PREDICTIVE ANALYTICS

by

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Optimized Systems & Solutions

Presented at the 20th Symposium on Industrial Application of Gas Turbines (IAGT)
Banff, Alberta, Canada - October 2013

Quick Introduction to OSyS

- OSyS is short for Optimized Systems and Solutions
- We are a wholly owned subsidiary of Rolls-Royce Group
  - Rolls-Royce is a major innovator and supplier of power systems and services to marine, oil and gas, defence, aerospace & industrial customers
- OSyS' role in Rolls-Royce group is to deliver high value data services within the group and directly to operators with particular focus on machinery risk
- Our solutions enable sustainable, safe, and profitable operations for complex equipment centric businesses in multiple markets
  - 83% of the US nuclear capacity, 62% of US refining capacity, and more than 300 airlines amongst many others use OSyS risk solutions

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'If I have seen further, it is by standing on the shoulders of giants'

~Sir Isaac Newton

We are taking risk prediction techniques and strategies developed by great thinking in other industries and making them applicable here

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Why predict machinery risk?

The primary drivers predicting machinery risks are:

- Work scope optimization
  - Reduces maintenance downtime
  - Maximizes component life
  - Avoids unnecessary waste
  - Makes best use of resources
  - Captures knowledge
- Reduction of preventive maintenance
  - Proof of good condition can be as valuable as detecting failure
- Detection and prevention of exceptional events
  - Reduce ‘surprises’
  - Does not directly increase reliability, but can increase availability, safety, compliance, and profitability

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Benefits Realizable with Risk Insight

- Safer Operations
  - Risk analysis highlights non obvious risks
  - Analysis reveals risk multipliers before they occur
- Reduced (Optimal) Maintenance Costs
  - Move items from the preventive scope to the predictive
    - Only fix what is presenting an increased risk
    - Don’t maintain items that do not present a risk
    - Lower labour and facility requirements
    - Reduce preventive spend
- Higher availability, potential for higher production
  - Total availability is increased through
    - Ability to maintain safely whilst online
    - Shorter turnarounds due to reduced scope

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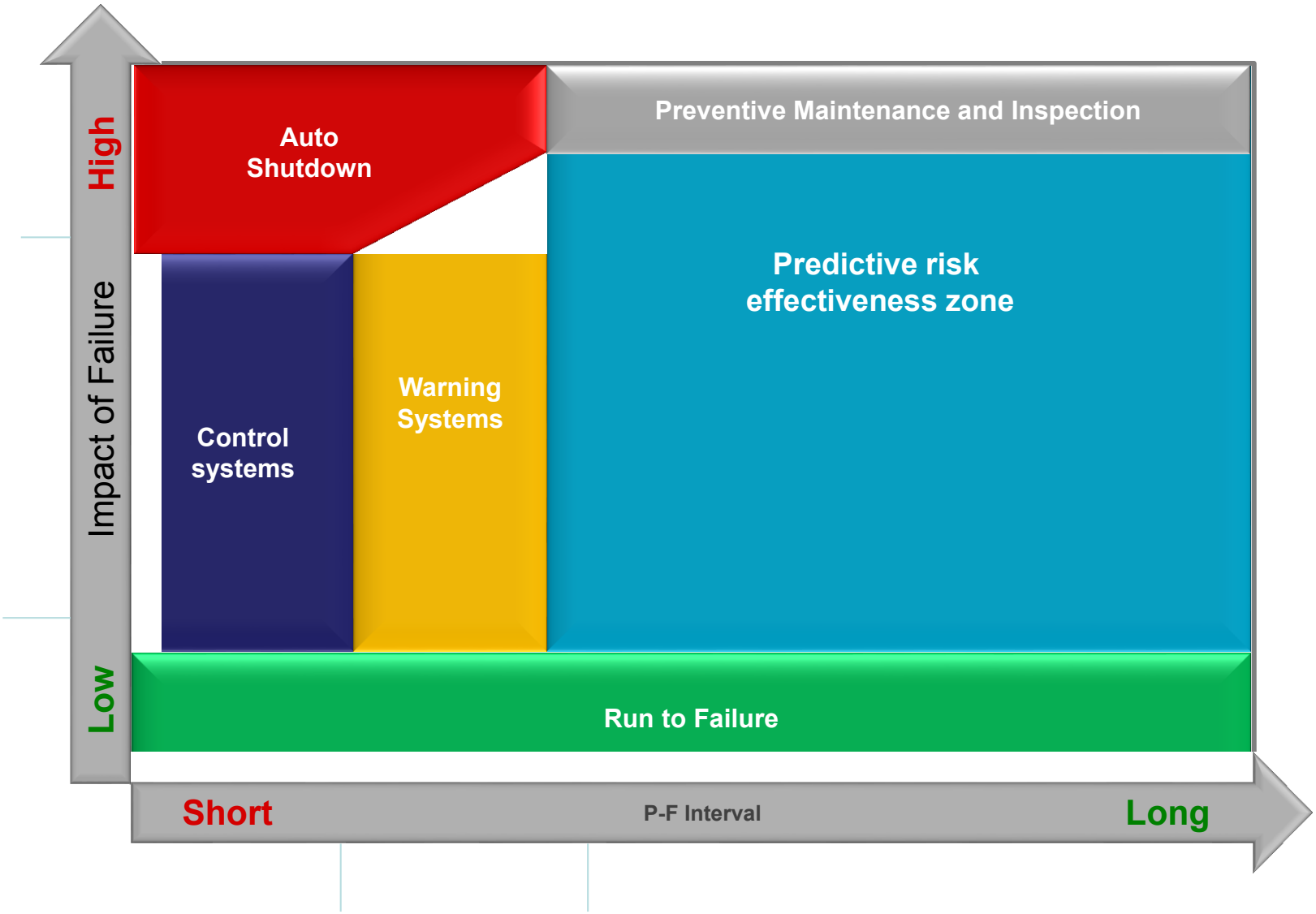
Predictive Risk Applicability



Key Challenges For Improving Risk Prediction

- The degree of reliability of risk predictions must be high to be valuable
  - The key valuable attributes are timeliness and accuracy
  - Only a reliable diagnosis of risk can lead to effective prognosis, essential for informed decision making
- Reliable predictions require knowledge and insight hidden within data
- Data is proliferating, truth and knowledge less so
- Risks are diverse, complex, numerous, and not all of them can be predicted
- Many risks are not easily identified by human observation, and some are in fact caused by the human observers themselves

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Examples of what can be achieved?

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Nuclear Generation Risk Transformation

Improvement Objectives

- Establishment of sound operational & safety fundamentals
- Increased focus on equipment & activities that have safety & reliability implications (RCM)
- Manage reduction in staffing levels
- Reduction in outage length & outage frequency
- Exploit advances & adoption of new technologies
- Adoption of process management concepts

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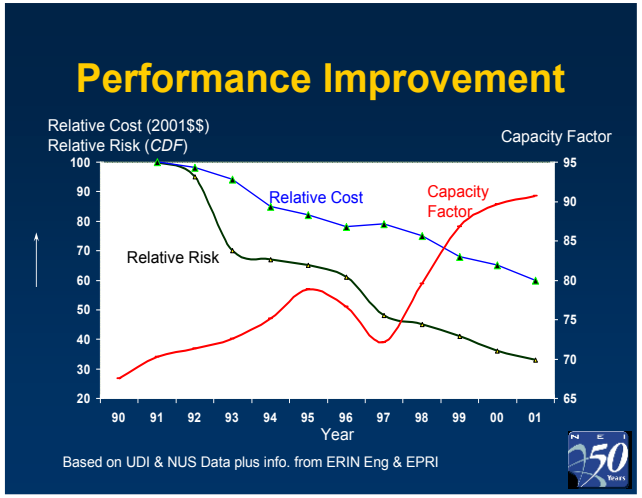
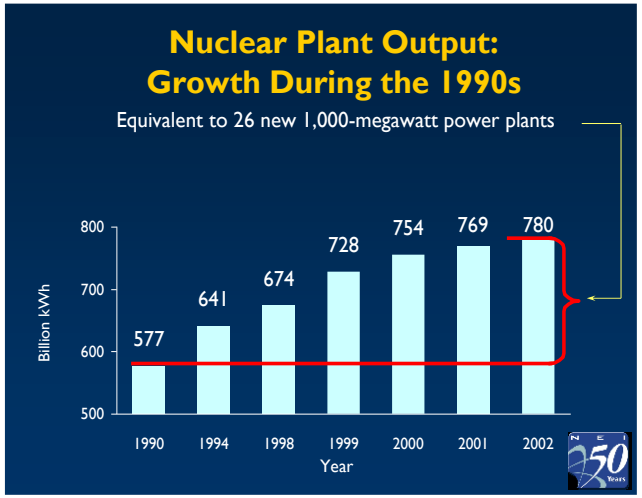
Nuclear Generation Risk Transformation

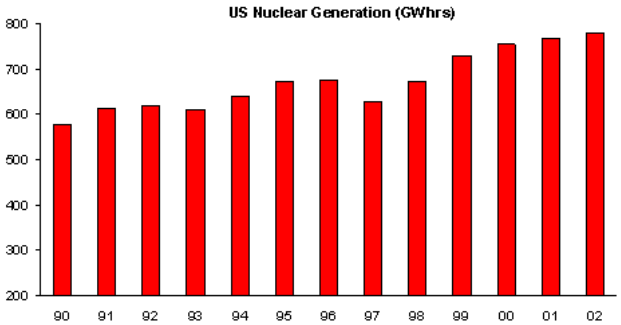
Metrics (1990-2002)

- Production Costs decreased by 45%
- Capacity Factor increased from 75% to 92%
- Refueling outages reduced from 105 to 37 d
- Safety reportable events reduced by > 80%



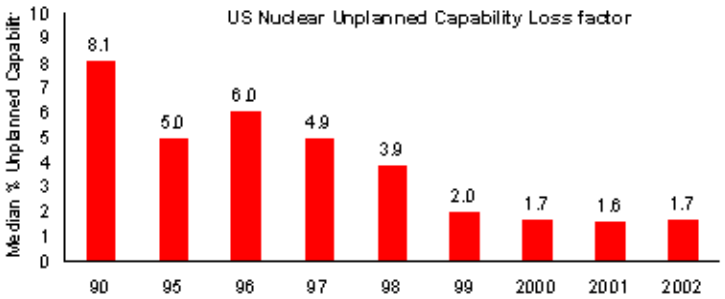


US Nuclear Fleet Performance Improvement (1990-2002)



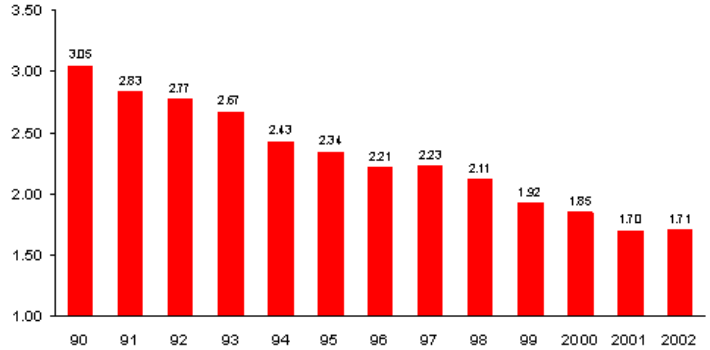
Source: NEI/EUCG

Power Generation Increase +25%



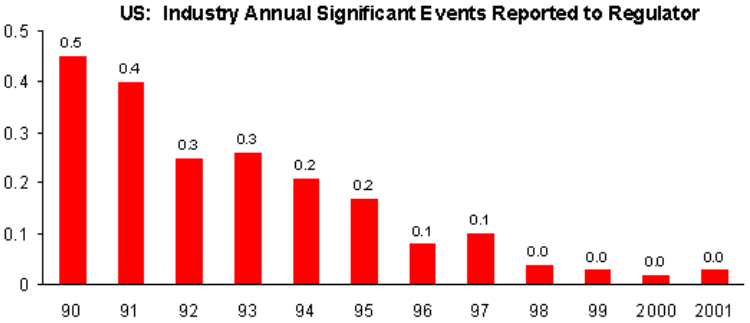
Source: WANO

High Unit Reliability is Expected



Source: NEI/EUCG

Production Cost Decrease -45%



Source: US NRC

Threats to Nuclear Safety Maintained

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Nuclear Evolution to Risk-informed, Performance-based Regulatory Process

- "Risk-informed" Regulatory Process Established 2000
  - Industry collaboration / Oversight Process / Working Groups
  - Blend of PRA, Operating Experience & Design enhancements based on advances in technology
  - PRA technical adequacy
  - Increase in safety by focus on matters that have safety significance
  - Gaining a better understanding of design margins
- Today, Risk-Informed Applications are widely applied in industry
  - PRA Quality Standards
  - Integrated Safety Management Specifications (Tech Specs)
  - In-Service Inspection and Testing Programs
  - Graded Quality Assurance Programs

Probabilistic Risk Assessment (PRA) a key driving factor

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Case Study – Civil Aviation

- Prior to early 1990s Rolls-Royce was a government owned marginal provider of aviation gas turbine engines
- Engine sale then parts and maintenance supply chain model
- Operations and maintenance risk sat with the airline operators
- RR market share of the key large engine market for long haul airliners ~5%

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RR TotalCare Transformation

- In the 1990's RR changed to TotalCare where airlines pay for flying hours rather than purchasing assets directly
- OEM takes on the maintenance & reliability risk contractually
- RR had to deliver higher reliability at lower cost by moving maintenance from preventive/detective strategies to predictive
  - Design modifications to eliminate the causes of failure based on fleet-wide reliability data
  - Analytics to detect, diagnose, and predict specific failures, moving maintenance items to an on-condition basis
- Specific diagnoses enabled planners to make risk informed decisions about which maintenance actions need to be:
  - executed now
  - deferred to the next overhaul
  - monitored for further development

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Rolls-Royce Transformed

- Risk based maintenance, underpinned by analytics, diagnostics and risk optimization solutions transformed Rolls-Royce
- Today RR has 50% of the civil aviation large engine market
- Best performing FTSE 100 share - 2000% increase in 15 years

Applicability to Oil and Gas

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Oil and Gas Industry Challenges

All major independent and state-owned OG&P companies are facing a number of key challenges:

- The ability to obtain consistently manufactured quality process equipment from suppliers worldwide
- Applications are pushing proven design envelopes
- Infrastructure is aging
- Companies are faced with having to operate equipment longer and with less resources
- Major accidents are increasing a push for governmental regulation or, at the least, industry self-regulation
- Tighter health, safety, and environmental (HSE) regulations
- The lack of information sharing throughout the lifecycle

Very similar to the nuclear and aviation industry challenges solved

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API-691 - Tackling the oil and gas risk challenge

- Define requirements to deliver RBMM for API Machinery to ensure its safe and efficient operation through the lifecycle:
  - Manufacturers, purchasers and users within OG&P
  - Supply Chain Manage machinery risks
  - Manufacturing quality, robust designs and verification
  - Risk based maintenance strategies
  - Deliver Safe, Reliable and Efficient Operation
- In alignment with existing industry standards for reliability and safety of production systems

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API-691 Risk Competencies and Tools

FMEA
- Failure Mode & Effect Analysis
- By Vendor during FEED
- By Owner in Detailed Design

RAM
- Reliability, Availability & Maintainability
- Reliability Block Diagram
- Monte Carlo Simulation
- Sys (FEED) & Eq. (D. Eng)

TRL
- Technology Readiness Level
- By Vendor
- Validated by Owner
- Technology Qualification
- Risk Factor

LOPA
- Layer of Protection Analysis
- Technical Safety
- Based on IEC60511
- Used to define barriers to Failure Modes (Threats)

CBM
- Condition based Monitoring
- By Vendor
- Validated by Owner
- Used to detect and diagnose incipient failure

METRICS
- Key Performance Indicators
- Drive process improvement
- Used to identify design changes

MOC
- Management of Change
- Component of process safety
- Ensure that any change is documented, evaluated and analyzed against hazards

RCA
- Root Cause Analysis
- Find causes at the System level (Latent)
- Used as a proactive tool to improve process and design

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Truth or Data?

"All truths are easy to understand once they are discovered; the point is to discover them."

Galileo Galilei 1564-1642

"The truth is rarely pure and never simple."

Oscar Wilde 1854-1900

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Extracting truth from data

- Proactively search for known valuable truths related to prioritized risks
- Understand the correlating factors in those truths from a sound engineering basis
- Apply appropriate technologies to observe the occurrence of those correlations
- Eliminate the inevitable false positives and missed detections through application of advanced analytical techniques

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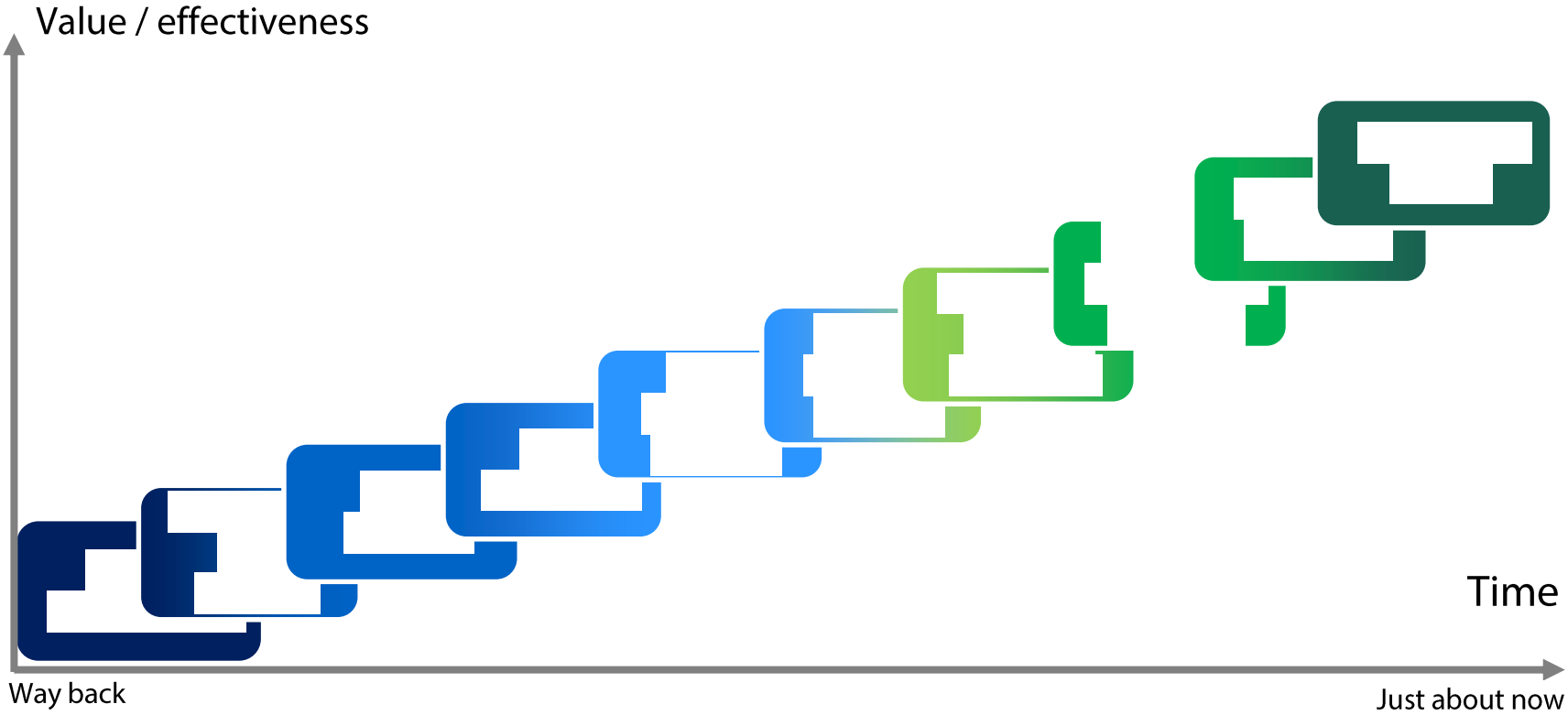
Diagnostics Evolution – Getting Truer

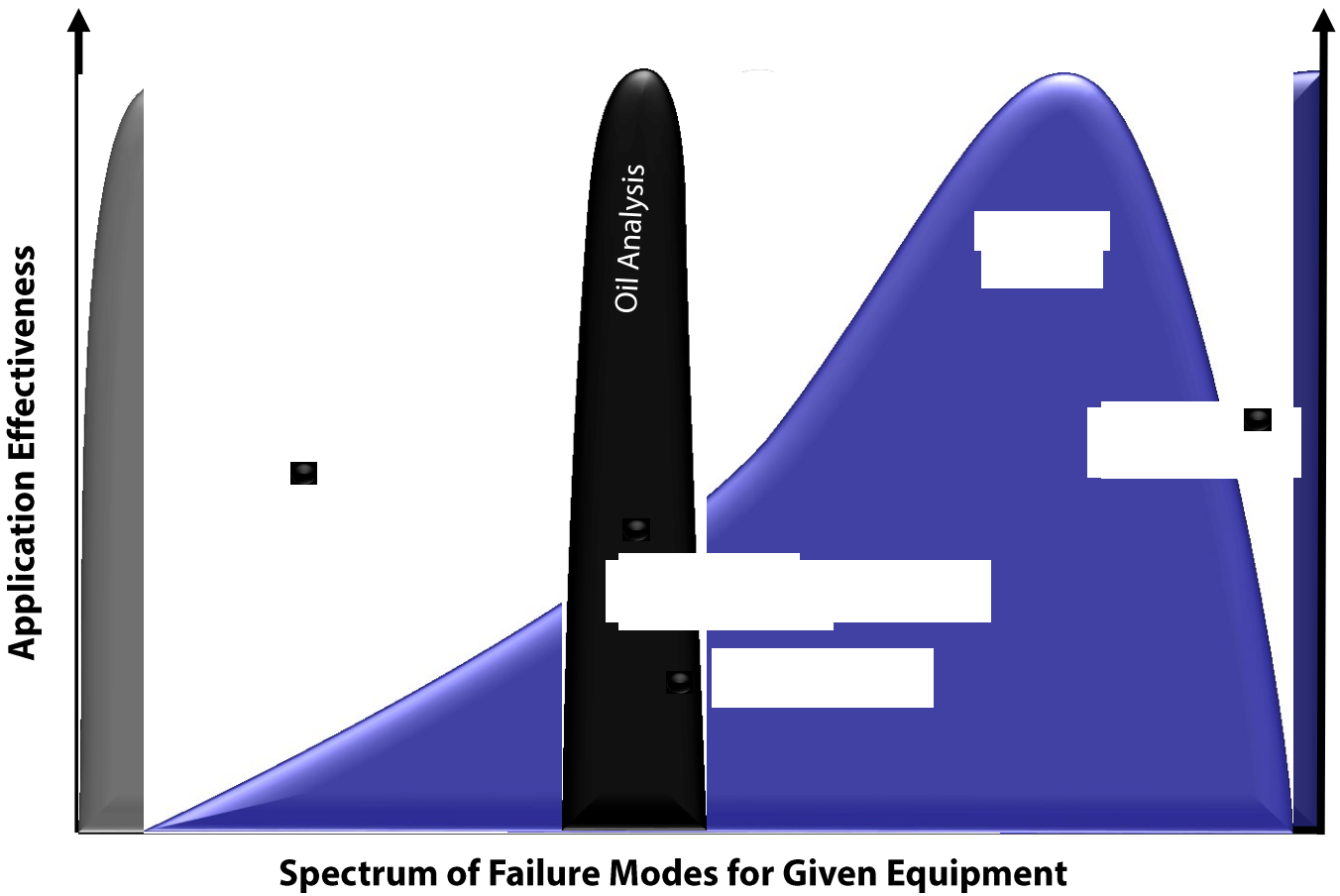


Human dependent

Noisy automated systems

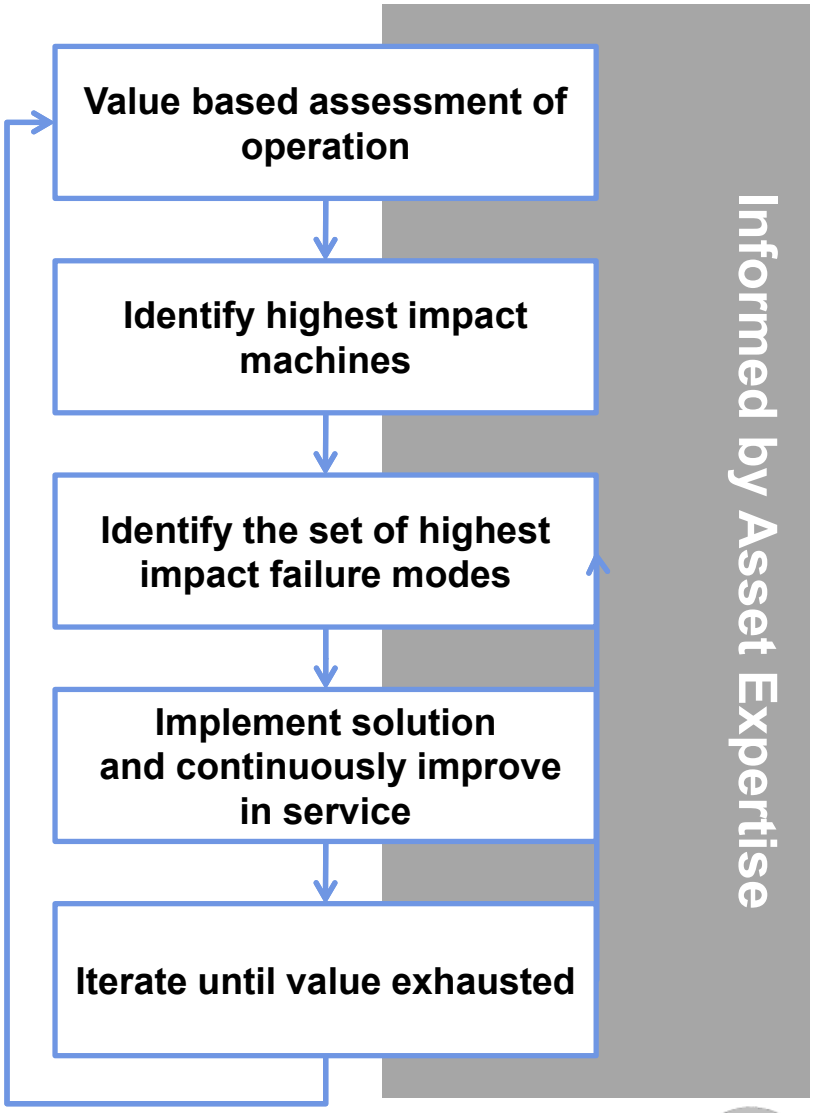
Automated accuracy

Fusion of Diagnostic Techniques



Prioritizing the Value of Risk

- Focus on the key value risk drivers:
  - Production availability
  - Maintenance costs
- Identify the critical issues affecting those risk drivers
  - Machines and failure types
- Implement a solution to predict the occurrence of those issues
  - Diagnose accurately
  - Allow time to mitigate
- Iterate on risk value basis to derive maximum benefit



Wider Risk Value Drivers

Values dependent on criticality and other operational factors

Production Rate

- Maximise production
- Optimise intrinsic reliability
- Ensure utilisation of full performance
- Maximise performance and efficiency
- Mimimise outage duration
- Enable production decision making

Benefit Realization

INCREASED PROFITS

Safety

- Reduce unexpected event frequency
- Inform safety related decision making
- Understand critical dependencies
- Quantify and forecast risks
- Improve awareness
- Avoid fines/penalties

Benefit Realization

REDUCED SAFETY EVENTS

Compliance

- Demonstrate compliance with legislation
- Protect the environment
- Enhance corporate image
- Reduce unnecessary emissions

Benefit Realization

PERMISSION TO OPERATE
BRAND VALUE

Resource Allocation

- Proactively plan resource allocation
- Accurate resource forecasting
- Reduce inventory
- Optimize usage of key resources
- Exploit data, information and knowledge
- Optimize logistics

Benefit Realization

INCREASED EFFICIENCY AND ROCE IMPROVED CASH

Cost Control

- Reduce wasted maintenance
- Reduce insurance costs
- Minimised cost of asset ownership
- Maximise asset life utilization
- Reduce primary and secondary damage costs

Benefit Realization

RELEASED CAPITAL

Business Continuity

- Protect company reputation
- Capture tacit knowledge
- Automate human processes
- Maximize sustainability
- Reduce corporate risk

Benefit Realization

SUSTAINABLE COMPETITIVE BUSINESS

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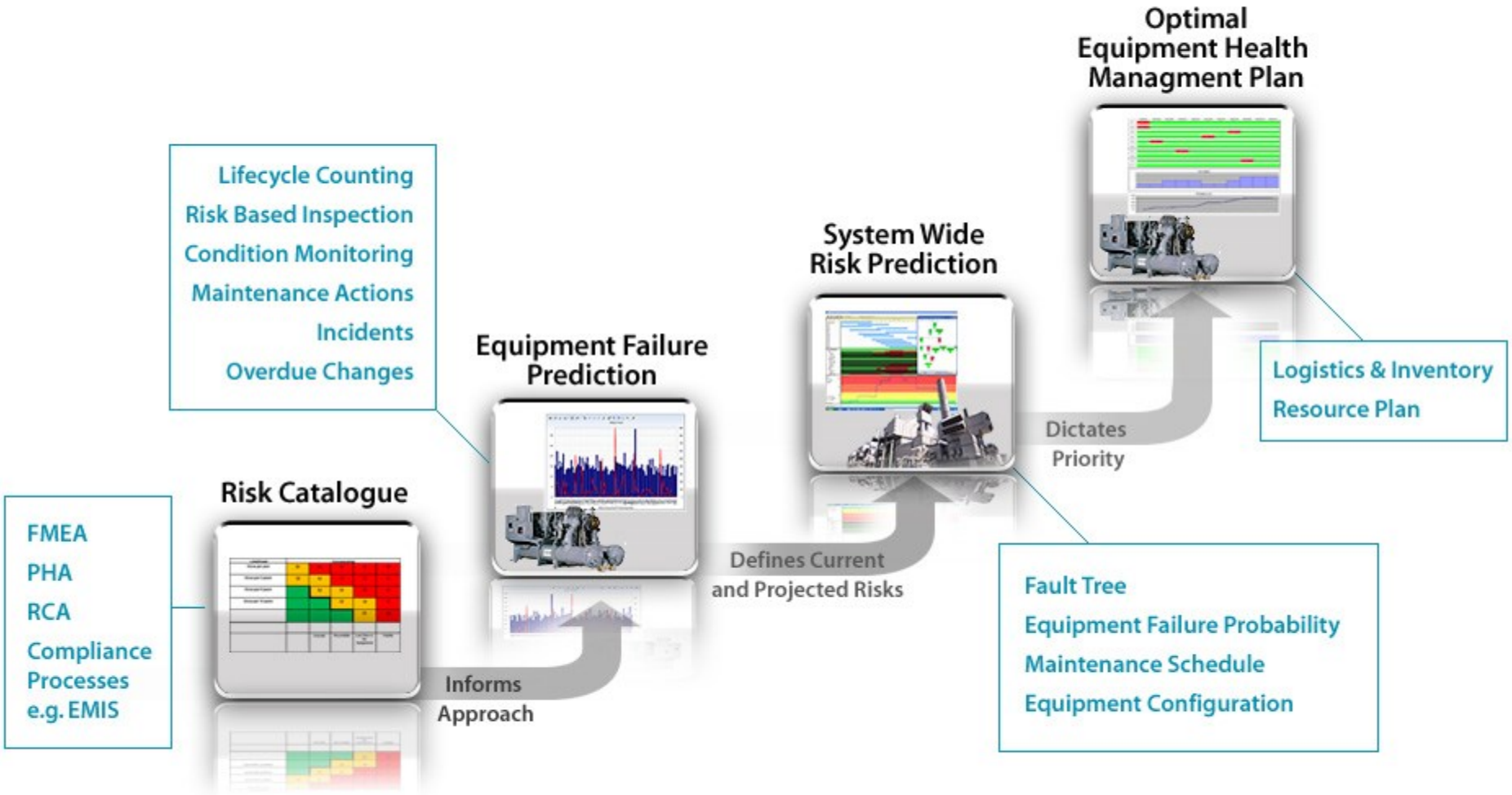
Predictive Risk Optimization



Summary

Risk-based machinery management programs can improve performance while managing costs.

Companies can optimize their operations through a risk-informed approach and predictive analytics which diagnoses the emergence of those risks.

Early adopters have the potential to achieve a market advantage over their competitors, by increasing equipment availably and ultimately production.

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