The Synergies of PLiM, PLEX, and Power Uprates: Lessons Learned From Recent BWR Experience

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The Synergies of PLiM, PLEX, and Power Uprates: Lessons Learned From Recent BWR Experience

- Business Case
- Key Lessons from Implementations
  - Vibration
  - Plant Reliability & Maintenance
  - Implementation Strategy
- Conclusions

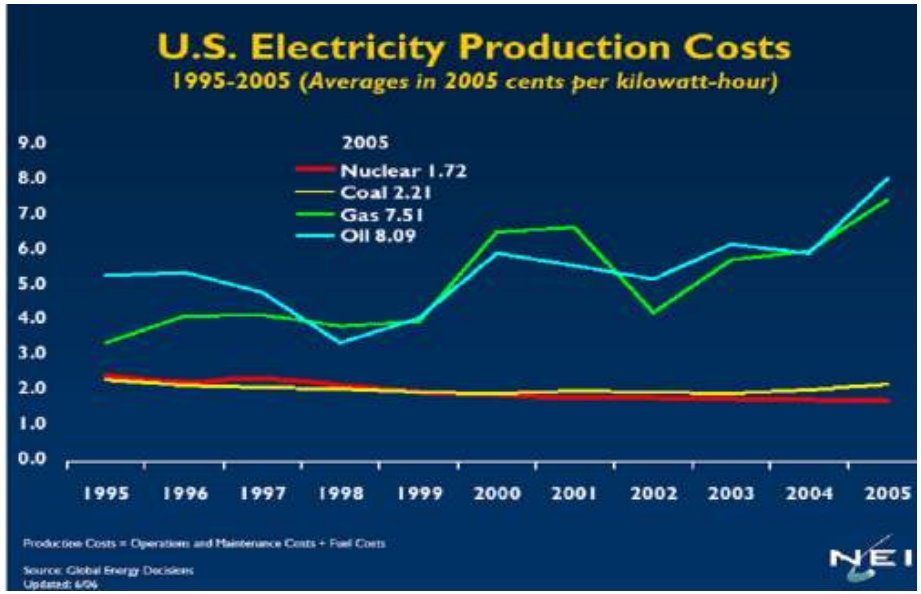
Business Case – Synergies

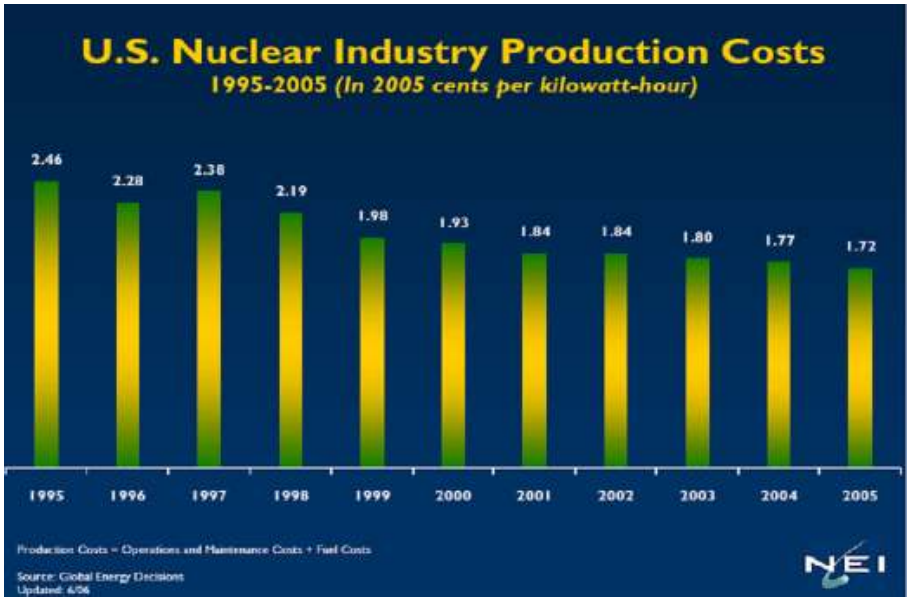
Operations

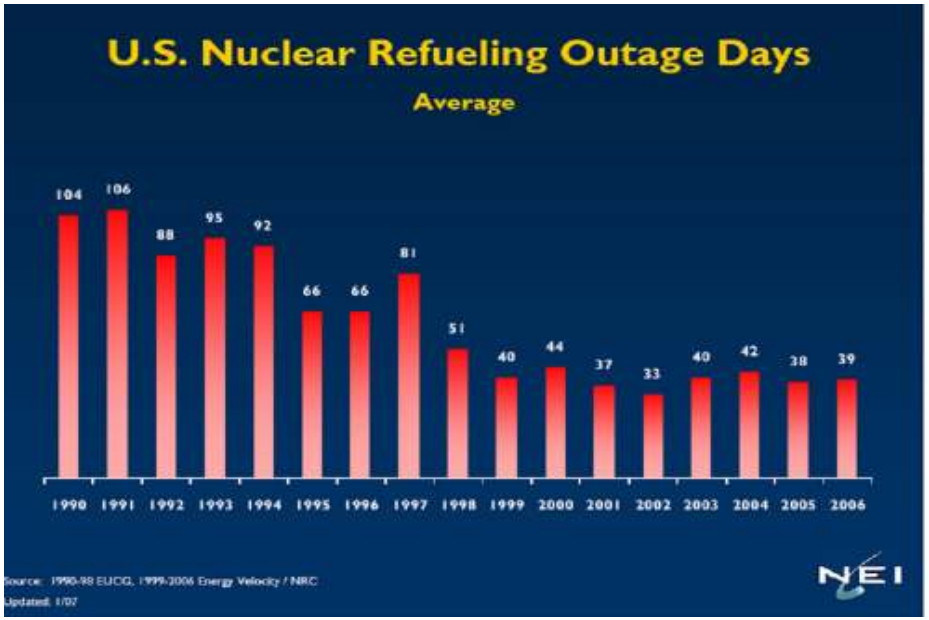
Safety, Capacity Factors, Cost Reduction

Life Extension

Power Uprates – Extended Power Uprates







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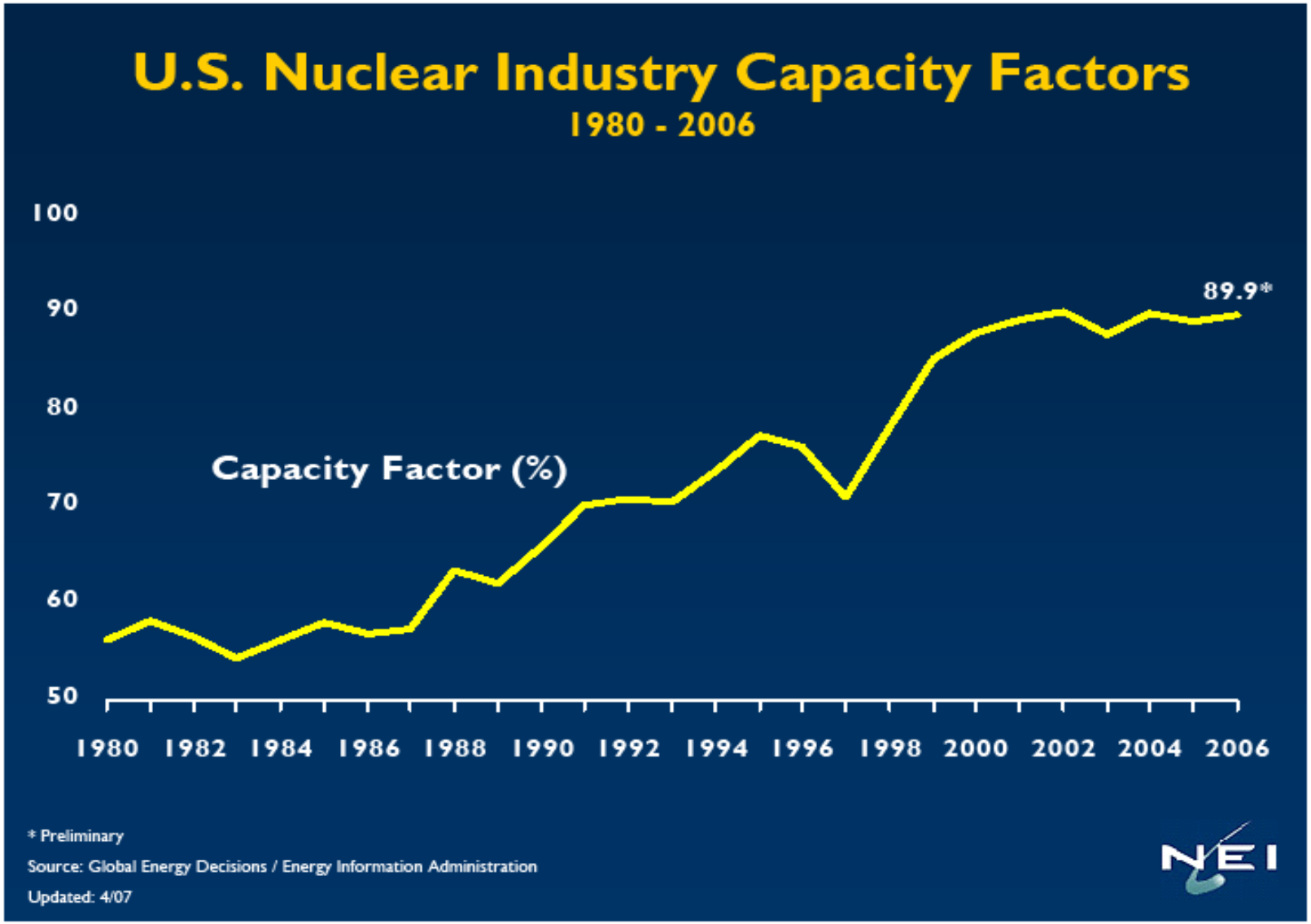
Courtesy of NEI Website



Courtesy of NEI Website

Strategic Projects

Power Uprate

- Cost effective additional generation
- Economics dictate limits to uprates
  - System and component limits can be increased
  - Analytical limits (technical/licensing approaches)

Plant Life Extension

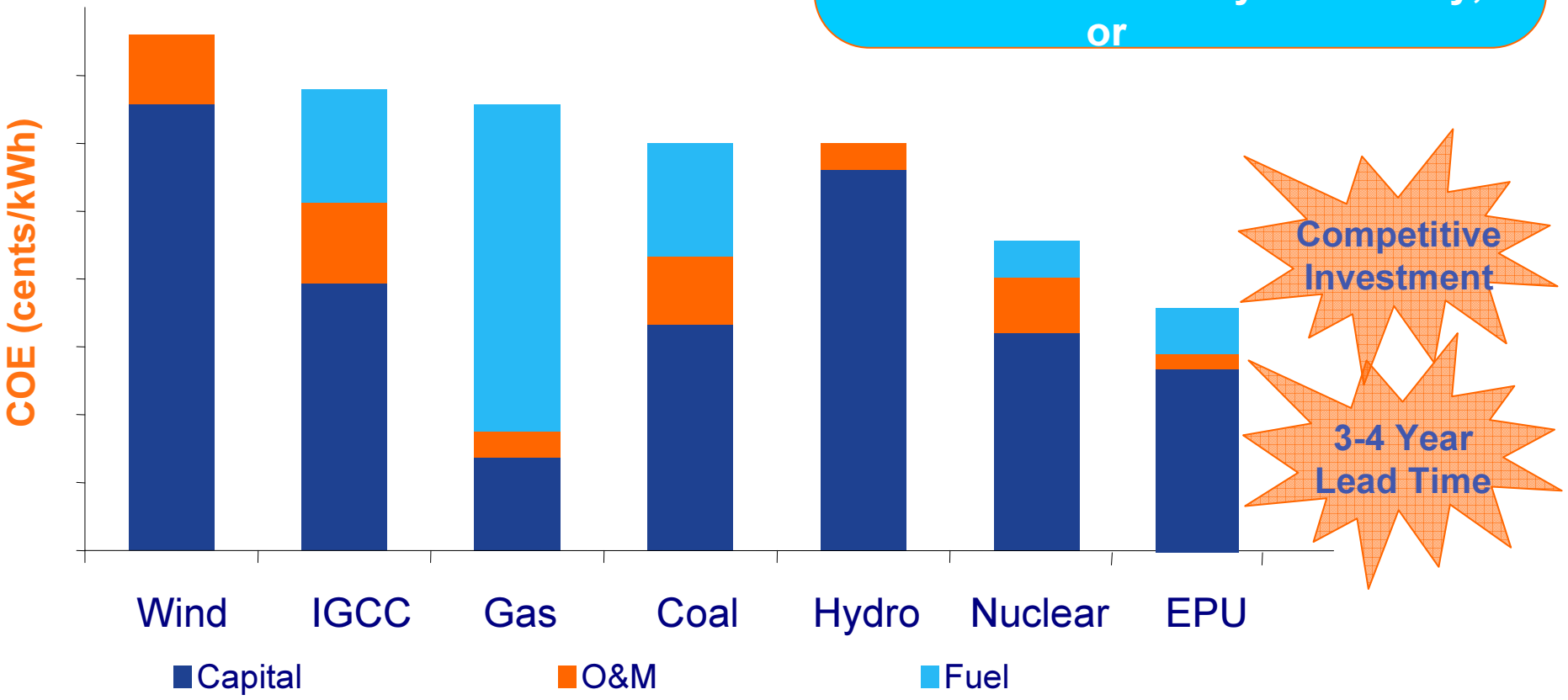
- Regulatory process straight forward
- Requires economic planning for equipment life
- Many of the same issues as power uprate planning

"In my view, the vast majority of nuclear power plants in the US could be serious candidates for license extension for up to 80 years of operation, and I believe the NRC must prepare itself to consider that question." – USNRC Commissioner

Why EPU?

- NRC approved 108 uprates since 1977, ***or***
- 4,600 additional MWe, ***or***
- Equivalent of 4 to 5 reactors

1 EPU ~ = 1 150 MW Wind Farm, or 1 Heavy Duty Simple Cycle Gas Turbine, or 1 Small Hydro Facility, or



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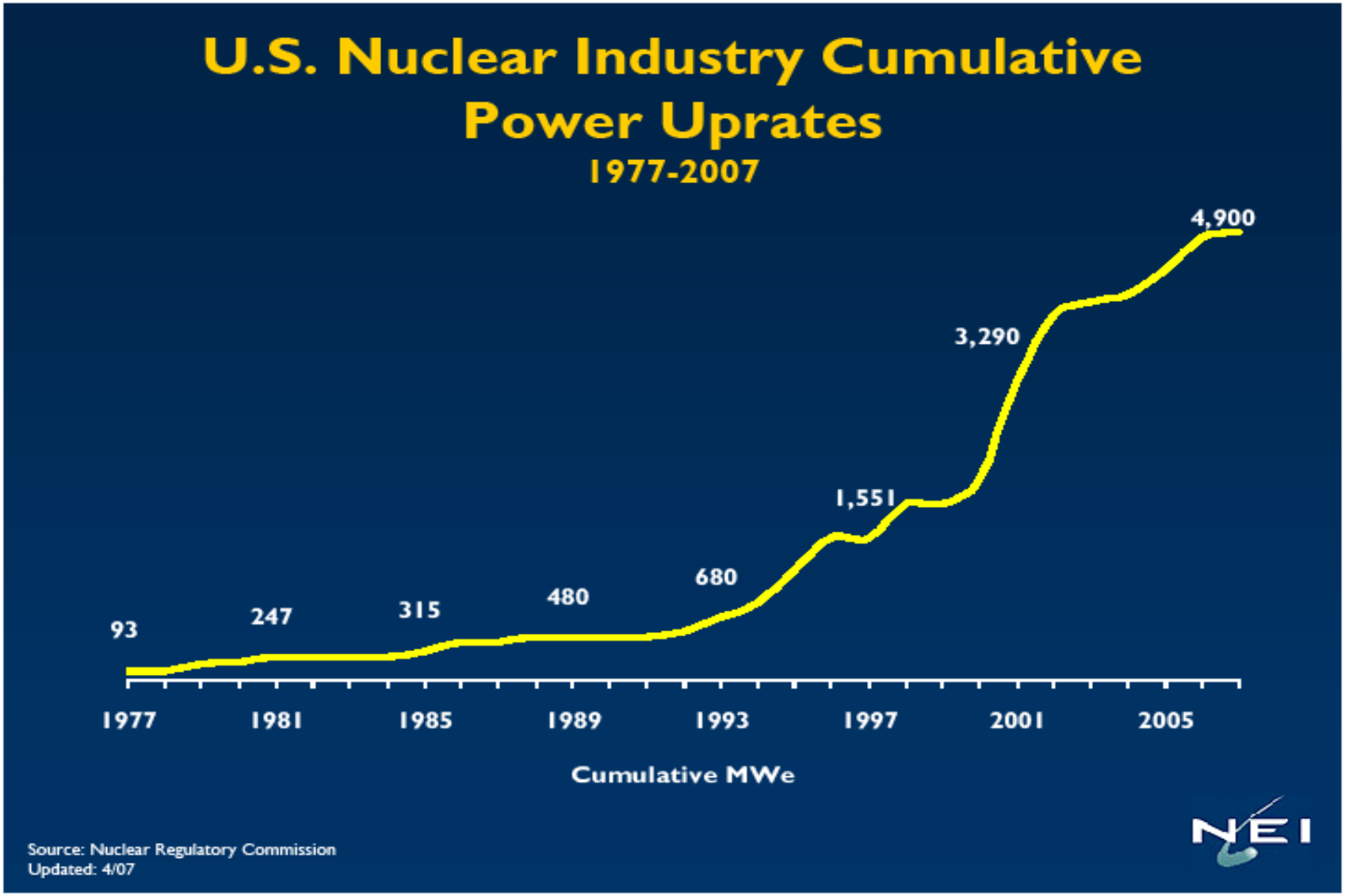
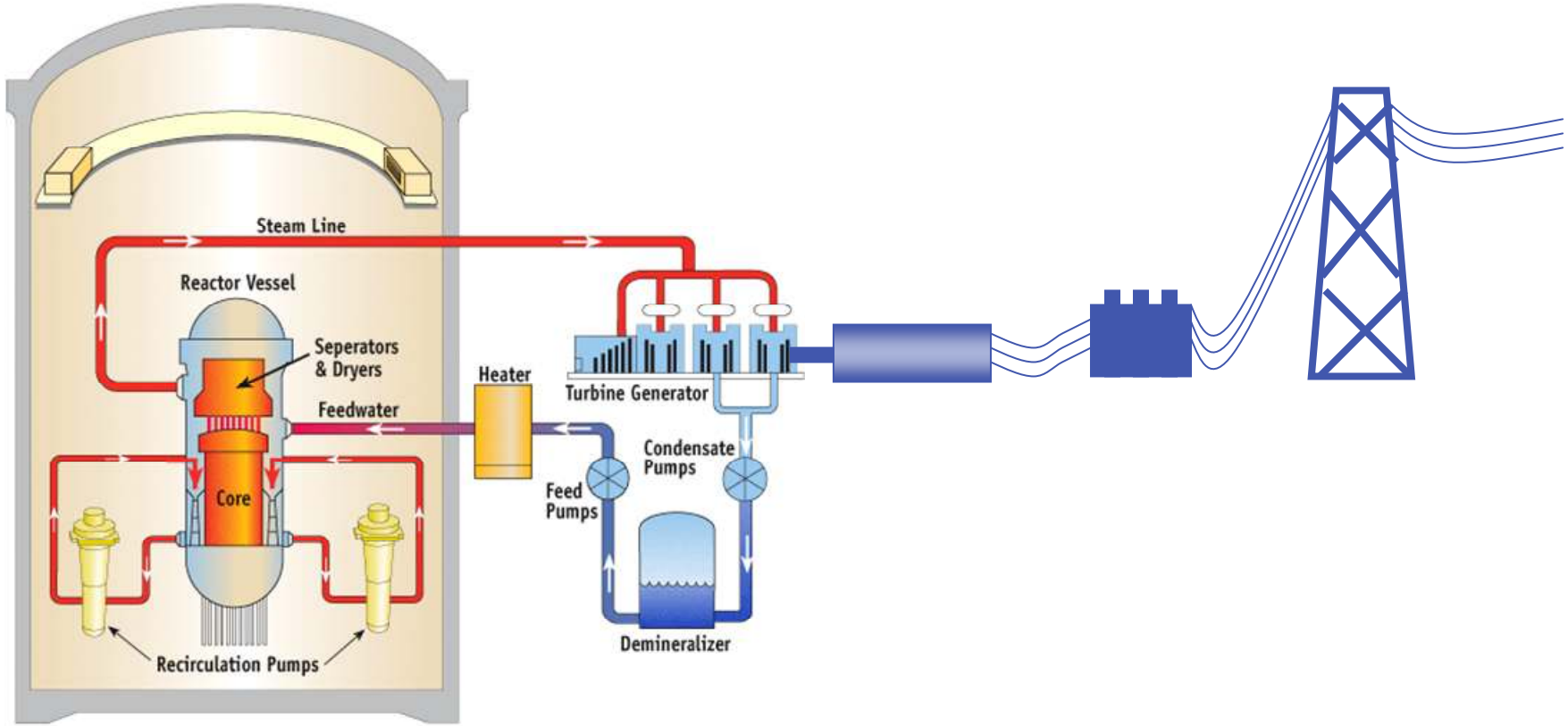


Courtesy of NEI Website

BWR / Uprate Schematic

- Increased steam flow requires upgrade of key equipment
- Balance of plant including turbine/generator modifications and increased fuel cycle costs are all incremental with power level



Source: Nuclear Regulatory Commission

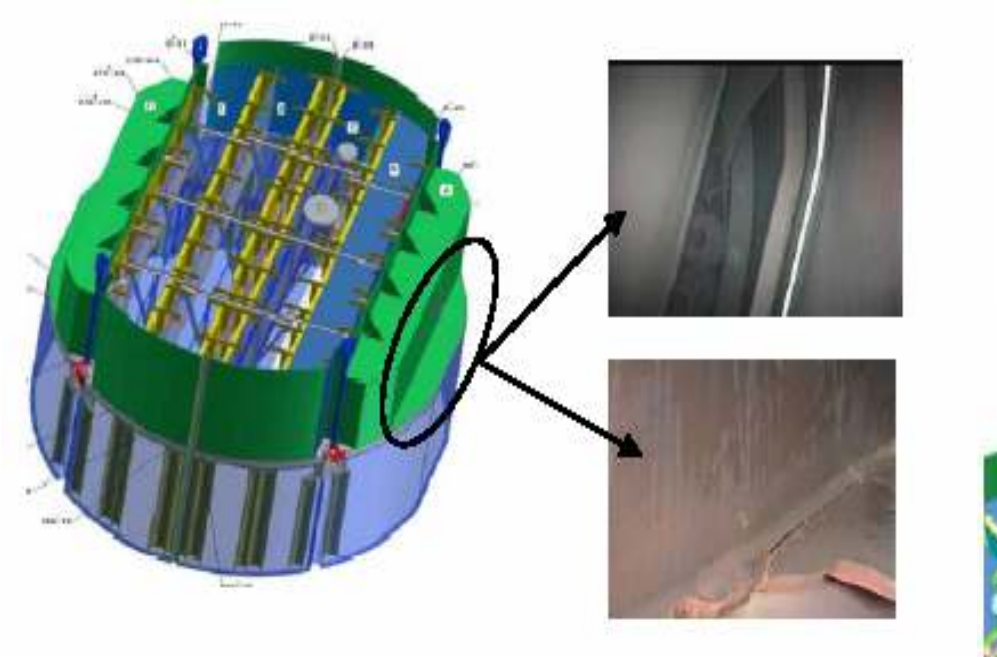
Key Lessons from Implementations

Lesson: Vibration

Steam dryer cracking and flow-induced vibration damage on components and supports for the Main steam and Feedwater lines.

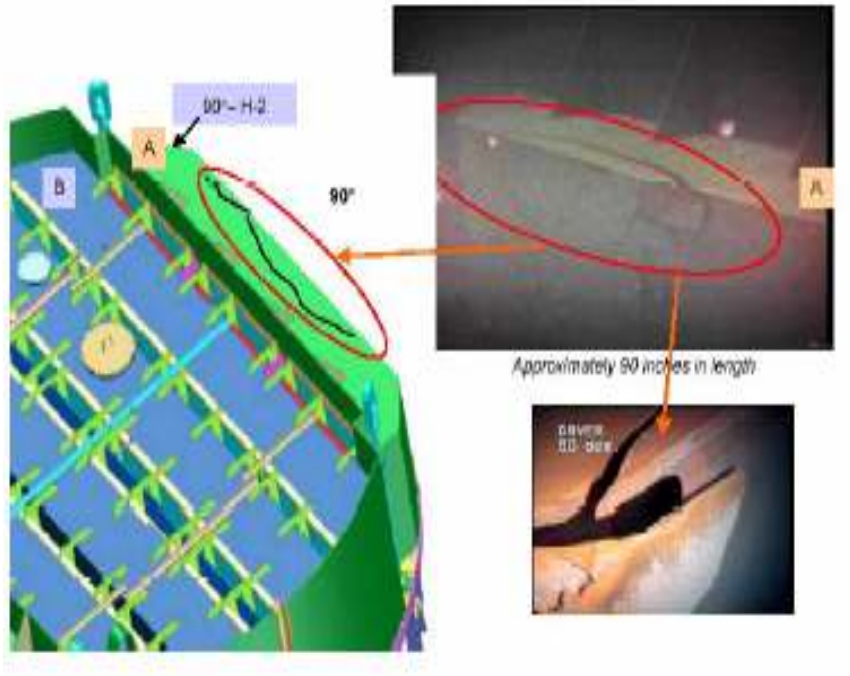
Actuators for the Electromatic Relief Valves (ERVs) experienced significant fretting and wear.

Steam Dryer EPU Experience



Event 1 - Lower Cover Plate

Event 2 - Outer Hood



Current State of Knowledge

- Recent Experience - Curved Hood Dryers
  - Hydrodynamic loads more consequential
  - Peak stresses are in internal areas making modifications more difficult
  - Current load definition tools do not adequately address in-vessel sources
  - USNRC requiring large margin to account for load definition uncertainty
- Replacement can be cost effective option
  - Reduced outage duration and worker dose offset higher capital cost. Supports life extension
  - Improved regulatory certainty

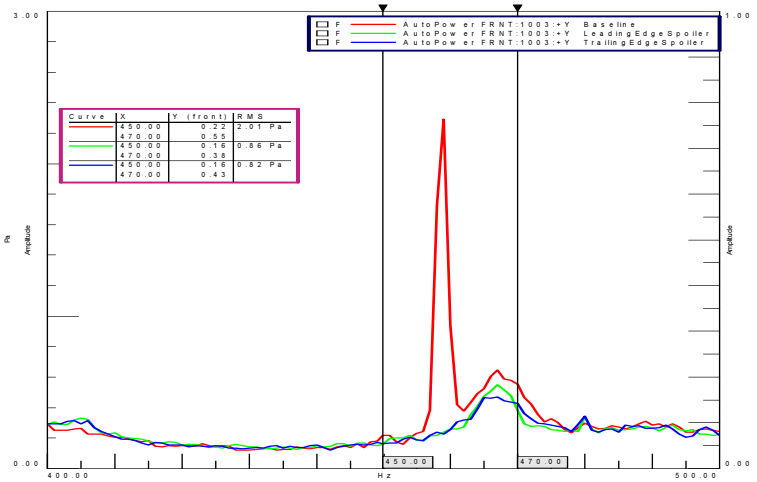
Dryer Program (NRC RG 1.20

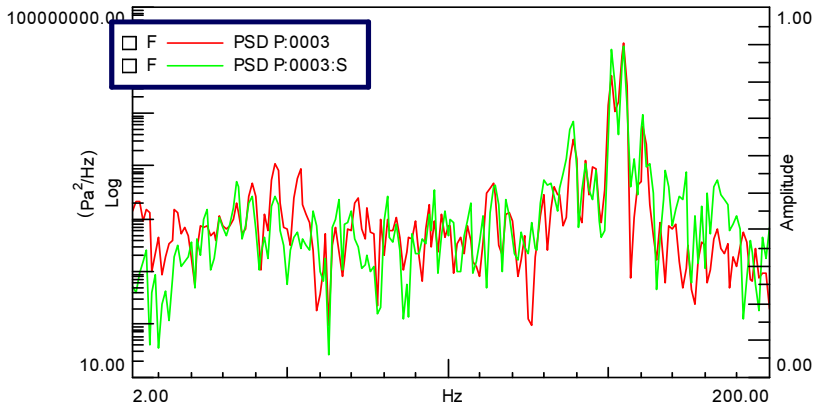
- Calculation of expected excitation sources
- Comprehensive and conservative dryer analysis including uncertainty assessment with a benchmarked model
- Evaluation of dryer acoustic and hydrodynamic loads at CLTP with margin for EPU using steam line measurements
- Monitoring and evaluation of dryer loads with plant instruments during power ascension with licensed limits
- NRC review/acceptance at each stage of power ascension
- EPU License Condition for dryer and piping FIV issues
- Long term commitment to follow-on inspections

Steam Dryer Innovations

Load Definition - PBLE

- ✓ No plant-specific tuning required… eliminates constant model revisions
- ✓ Reduces singularities present in other methods
- ✓ Solves both in-vessel and MSL loads
- ✓ Benchmarking with QC2 data complete
- ▪ LTR expected in 2007





Load Mitigation

- Addressing MSL and in-vessel sources
- Retrofit option for operating plants
- Incorporate into new plant /dryer design
- Does not impact plant operation/ maintenance
- Scale model testing progressing
- Provides plants with options for EPU, LCM, and PLEX
- Available 2008

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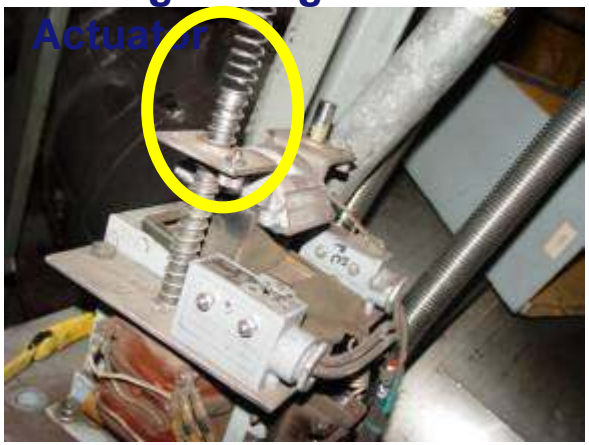
P20- ERV Performance

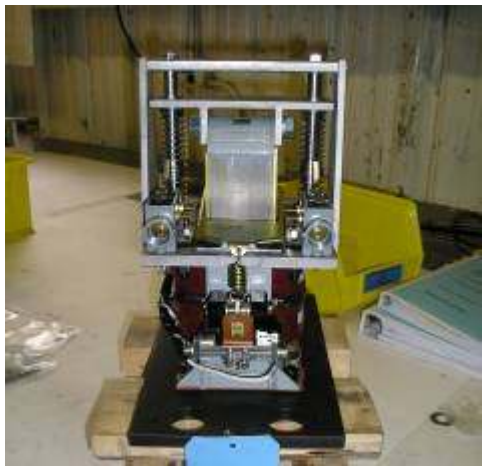
Damaged Original Actuator



Original actuator failed due to excessive wear

- Guide Bushings wore sufficiently to allow springs to slide thru
- Guide rods jammed in bushing due to wear
- Plunger jammed in solenoid due to loss of alignment
- Actuator life was less than 24 months

Modified



GE modified existing actuator to withstand high frequency vibration.

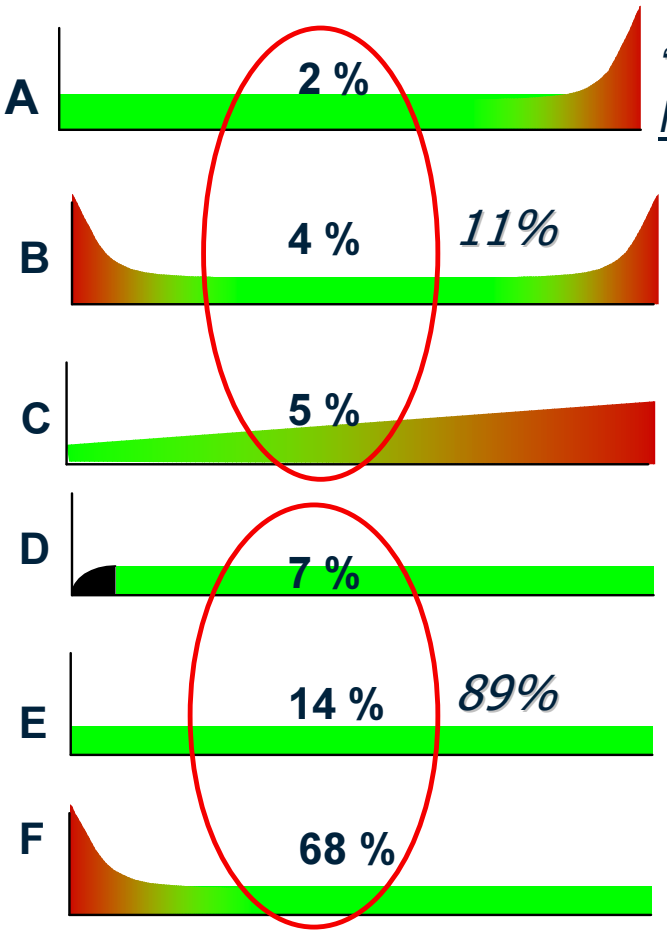
- Hardened guide posts and guides
- More stable guide support assembly centers motion
- Dampened input into base
- Controlled tolerances on interface parts reduces lateral movement
- Engineered springs for consistent load

Electromatic relief valves (ERV)

Plant Reliability and Maintenance

Majority of the problems attributed to EPU are in the Balance-of-Plant (BOP) area and involve pre-EPU plant component deficiencies or minimal operating margins

Failure Patterns



"Traditional View"
Random Failure then a wear out zone

"Bathtub Curve" - High infant mortality, then a low level of random failure, then a wear out zone

"Slow Aging" - Steady increase in the probability of failure

"Best New" - Sharp increase in the probability of failure then random failure

"Constant Random Failure"
Random - No age related failure pattern

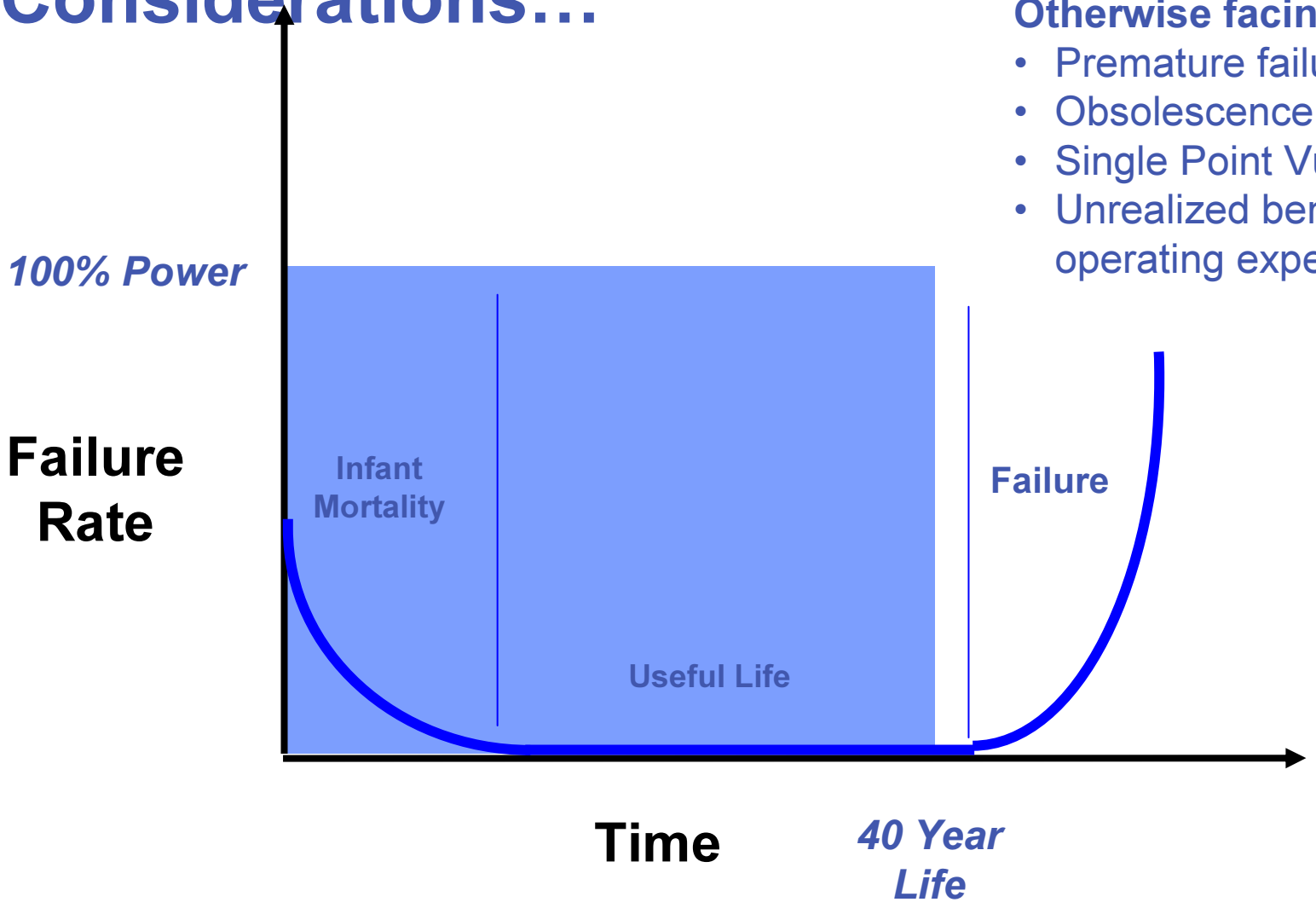
"Worst New"
High infant mortality then random failure

Because 89% of failures are not age related, Condition-Based Maintenance is more effective than relying on Time-Based Maintenance for these failure modes.

Existing Reliability Considerations…

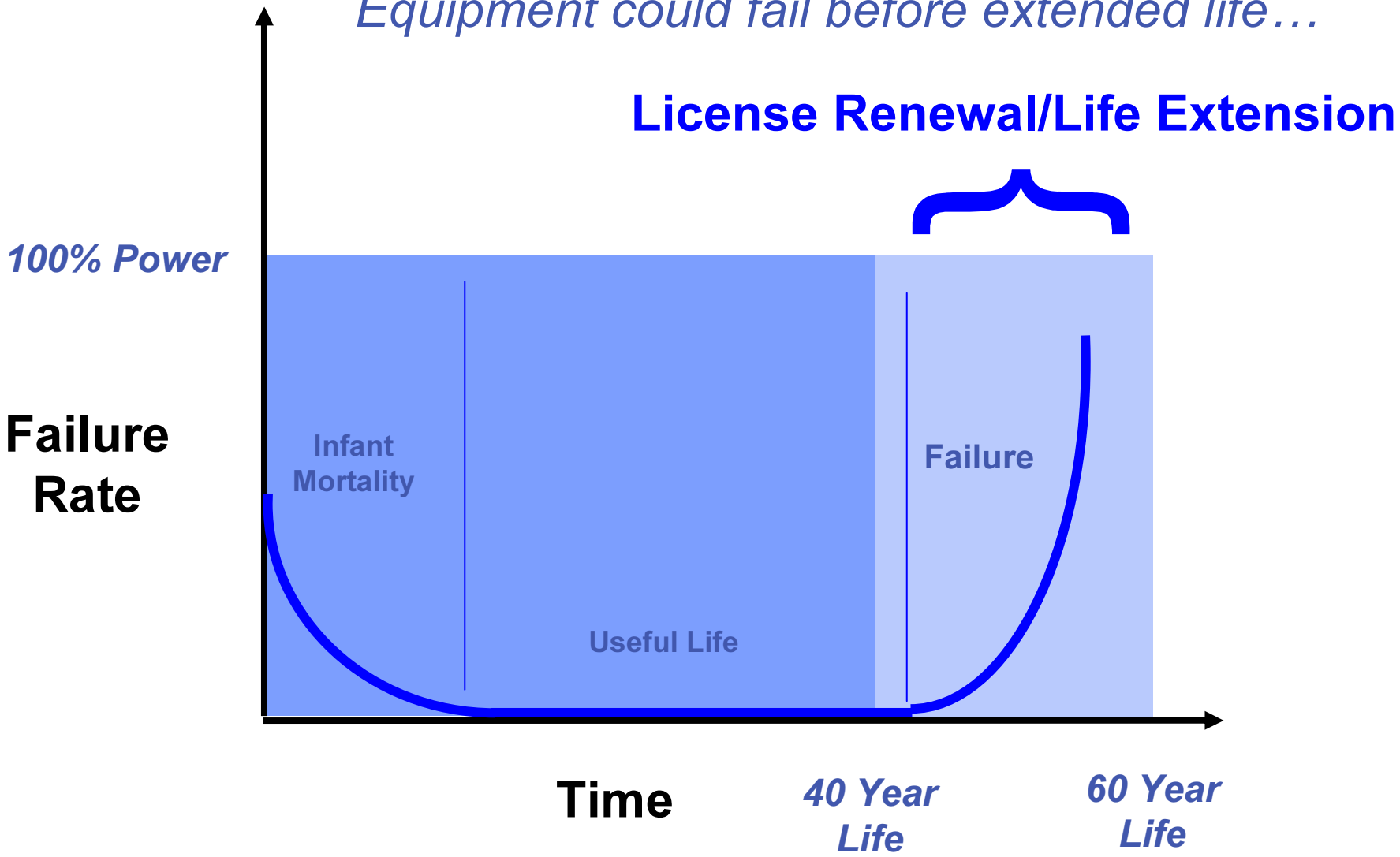
Otherwise facing:

- Premature failures
- Obsolescence
- Single Point Vulnerabilities
- Unrealized benefits of operating experience

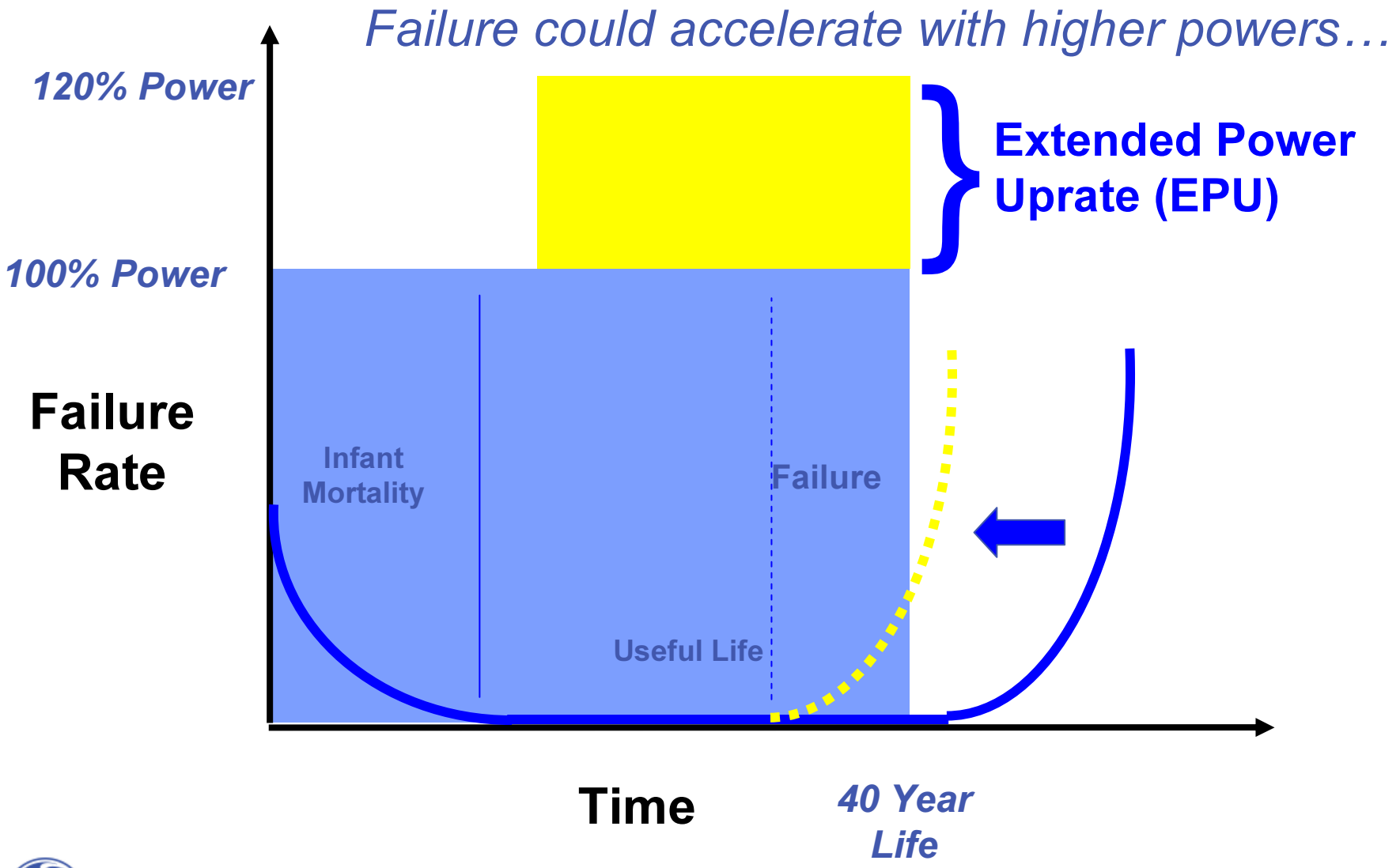


Life Extension Reliability Impact

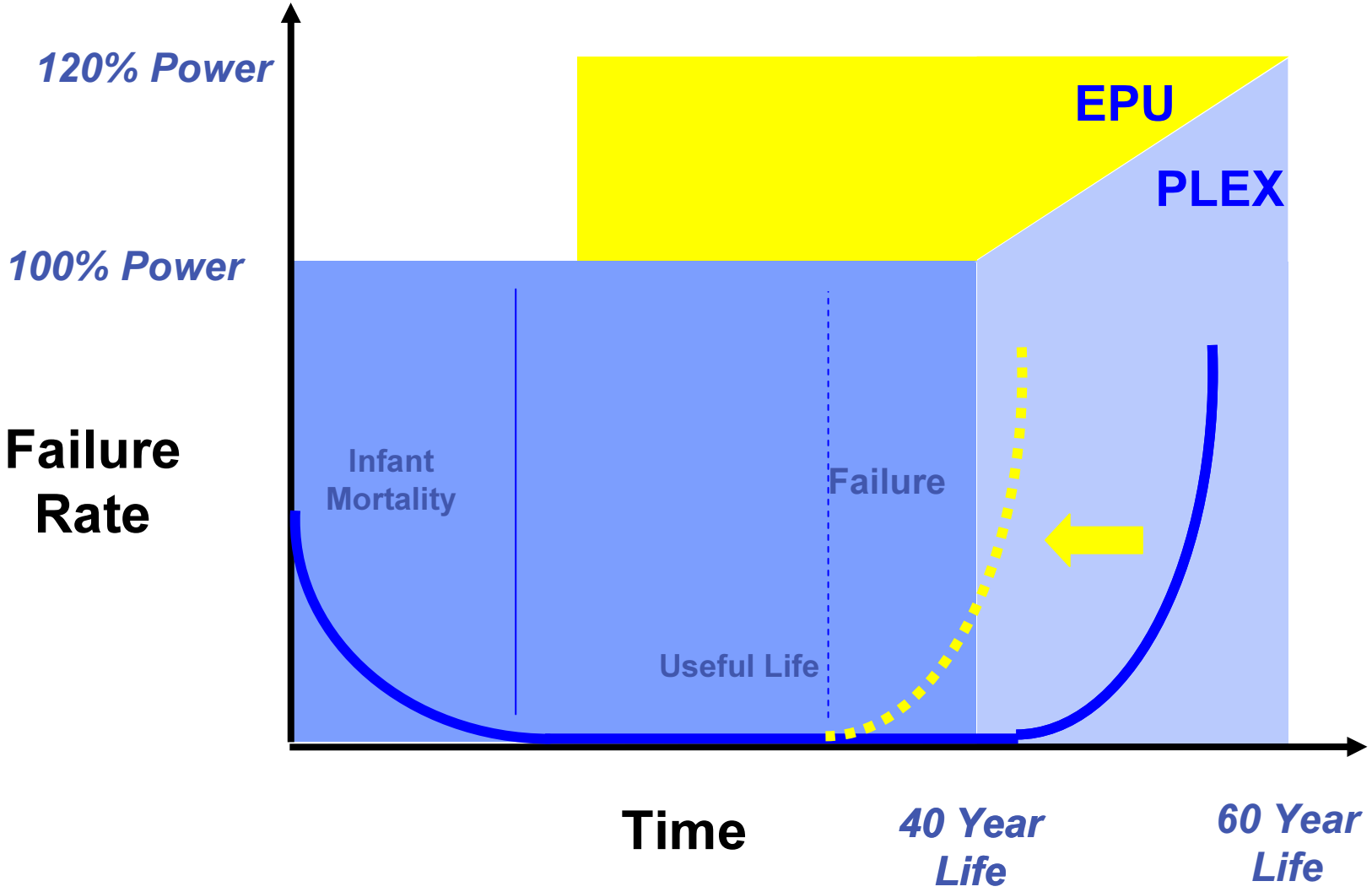
Equipment could fail before extended life…



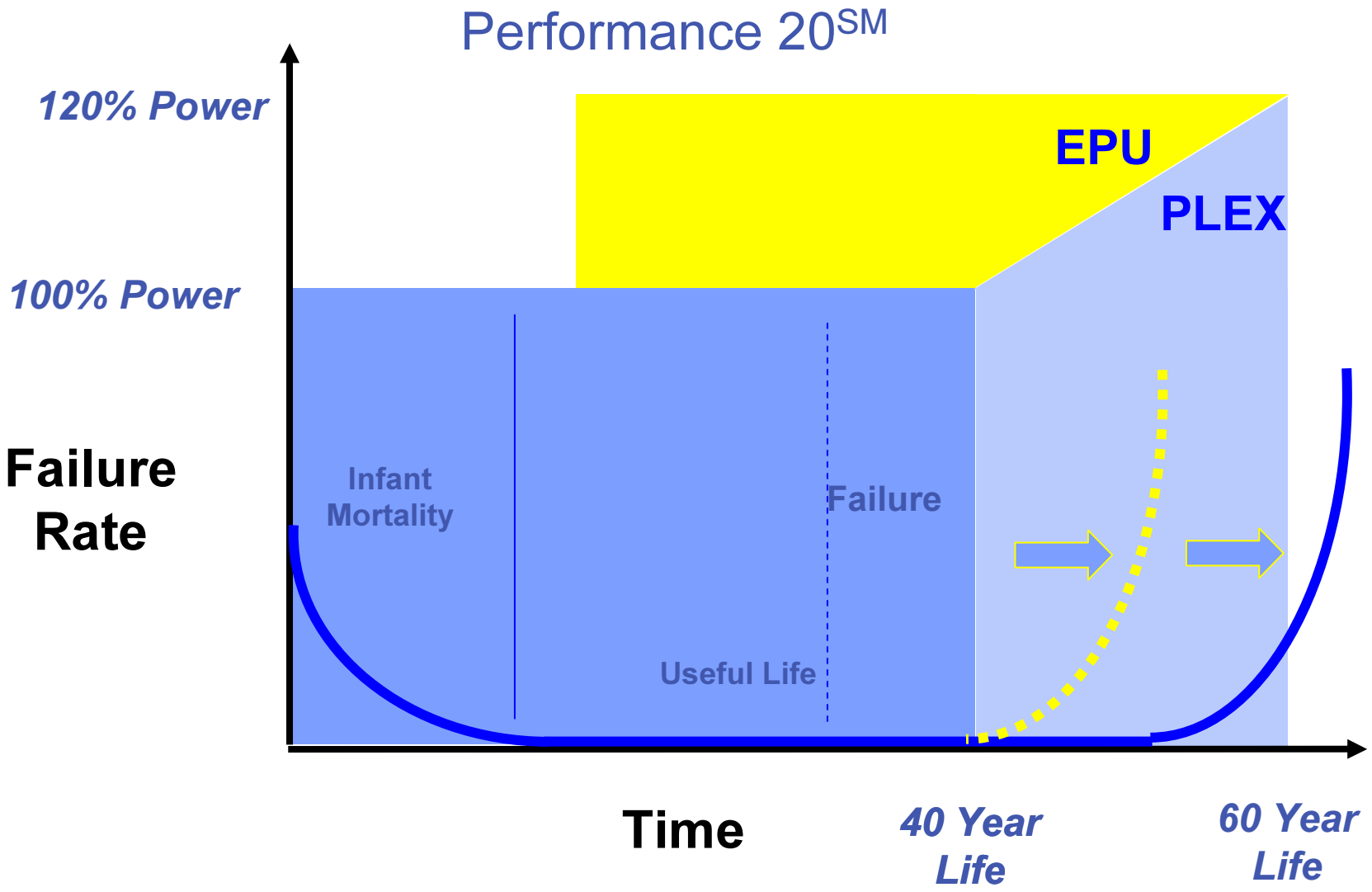
Power Uprate Reliability Impact



Combined PLEX and PU Reliability Impact



Reliability & Margin Enhancement



Asset Condition Monitoring

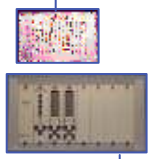
Online - continuous
monitoring & protection

Online – periodic
(scanning) monitoring

System 1®
Optimization and Diagnostic Platform

Switch/Hub

3500 & TDI



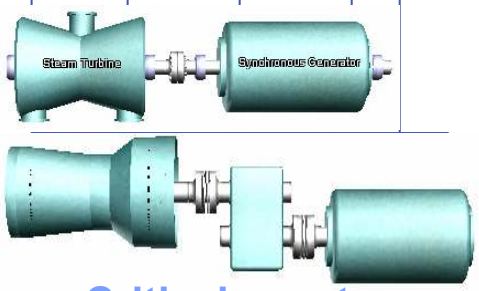
3300 & TDXNet™ or TDE

Trendmaster® Pro

Motor Management Relays

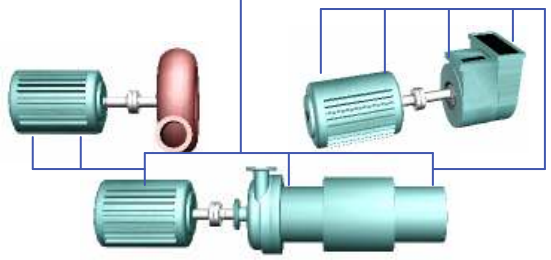
Snapshot™ for Windows® CE

BOP assets



Critical assets

- Steam Turbines
- Compressors
- Main line Pumps
- Recip Compressors



Essential assets

- Fans
- Pumps
- Blowers
- Etc…

GE Energy
Bently Nevada

Offline – portable
Lube oil
Thermography, etc…

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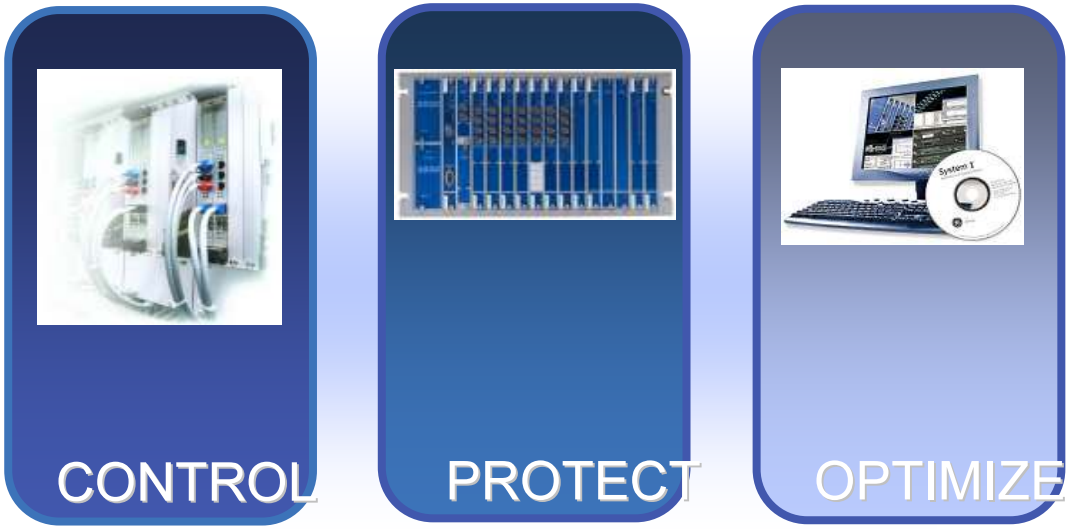
Synergy: PLiM, PLEX, EPU Instrumentation & Control

- Power Range Neutron Monitoring (PRNM)
- Turbine Control, BOP I&C
- Steam Dryer Instrumentation



Implementation Strategy

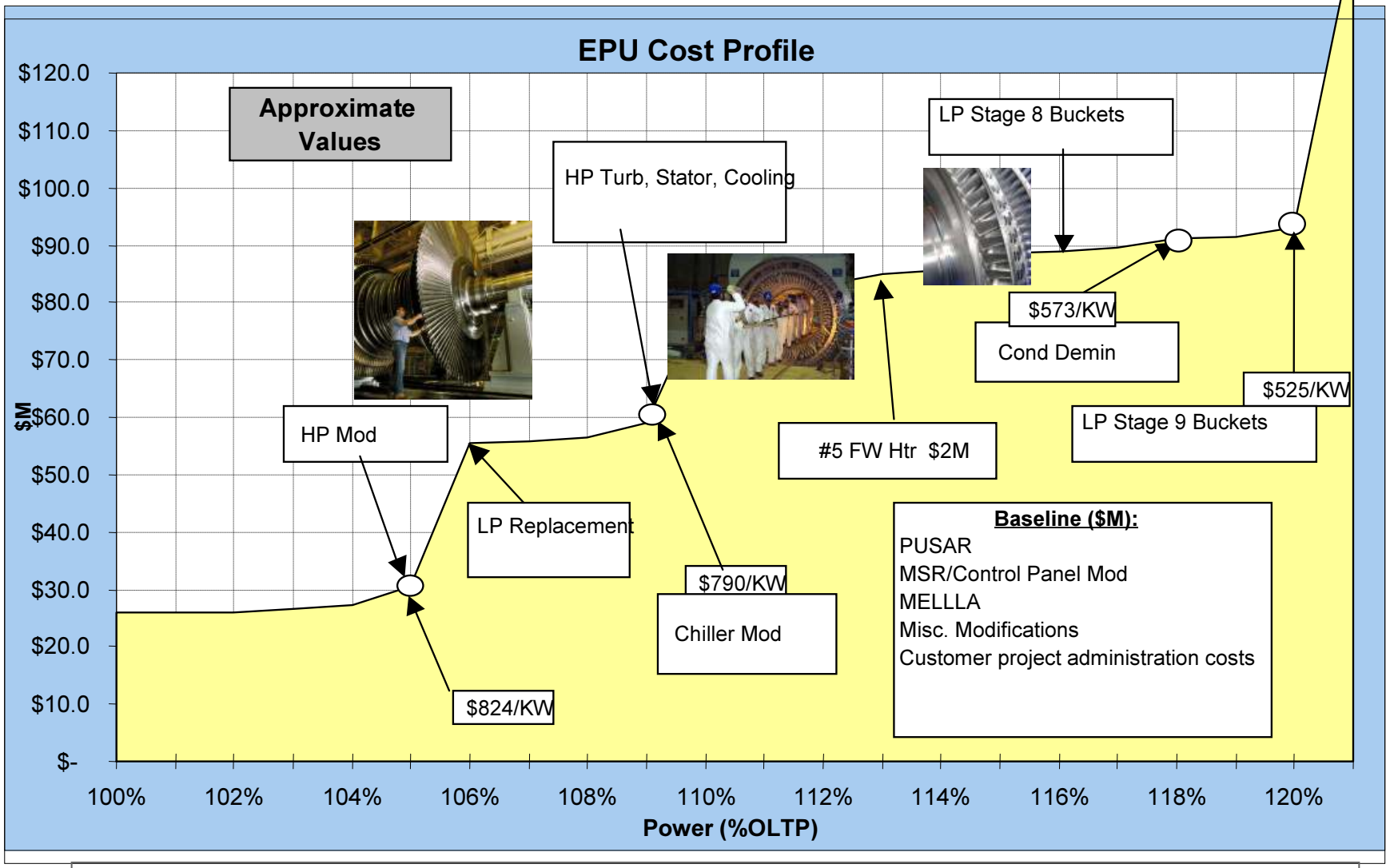
Perform a comprehensive pre-EPU assessment of the plant – AS-IS condition with plant owner collaboration

Evaluate plant procedures for all systems and components that may be affected by EPU and revise appropriately prior to implementation of EPU

Review Main Steam and Feedwater components for potential vibration and wear related degradation

Condition Monitoring and I&C Upgrades as part of evaluation process

EPU feasibility study = decision making information



Pinch Point Map Essential for Long Term Equipment Planning

Recent Examples and Results

Recent North US BWR – 20% power uprate plus modernization and margin recapture

- Uprate capacity factor highest ever – No EPU impacts

MidWest US BWR – Integrated EPU and LCM Plan

- Effective replacements vs. marginal modifications

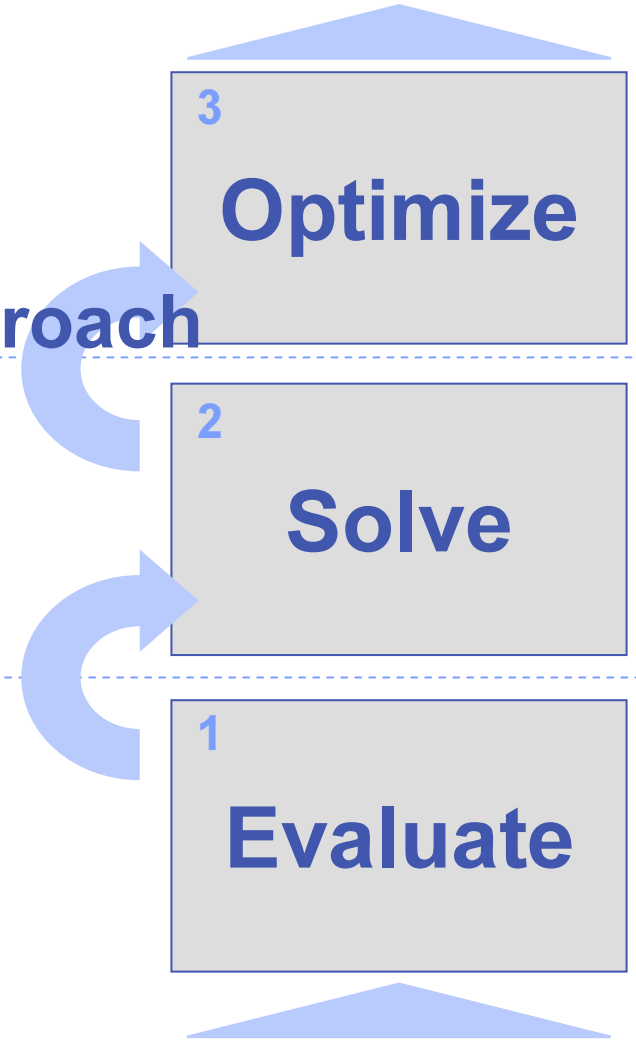
Steam dryer options

- Modify, replace, mitigate
- Instrumentation as needed

Performance 20^{SM} Point of Arrival

Synergistic Approach

- PliM
- PLEX
- EPU



Plant Performance:
- M&D Package
- Performance Guarantees
- Multi-Year Agreement
- Asset Optimization

Plant Improvements:
- Replace
- Repair
- Upgrade
- Uprate

Plant Baseline:
- Business Strategy
- Nuclear Island
- Turbine Island
- Balance of Plant

Fleet • Plant • System • Equipment • Component

Conclusions

Synergies: Power Uprates, Life Extensions, and Plant Life Maintenance are cost effective means to produce additional RELIABLE MW if planned correctly:

- Vibration: Review of Main Steam and Feedwater
- Reliability Studies with Actions
  - Balance of Plant Systems Maintenance and Procedures
- Have upgrade plan for BOP and I&C systems, add Condition Monitoring
  - Do as much prior/coordinated to EPU to minimize risk

Summary

Long-term view - Build in increased margins and reliability for additional operating period of 20 to 40 years during plant modernization and uprate activities.

> Develop a long term strategic plan
> Evaluate best sequence of projects
> Perform overall study (GE version is Performance 20)
> Leverage Best Practice Experience and Regulatory Guidance
> Overall Maintenance Plan and Procedures
> Condition Monitoring and Digital I&C Upgrades