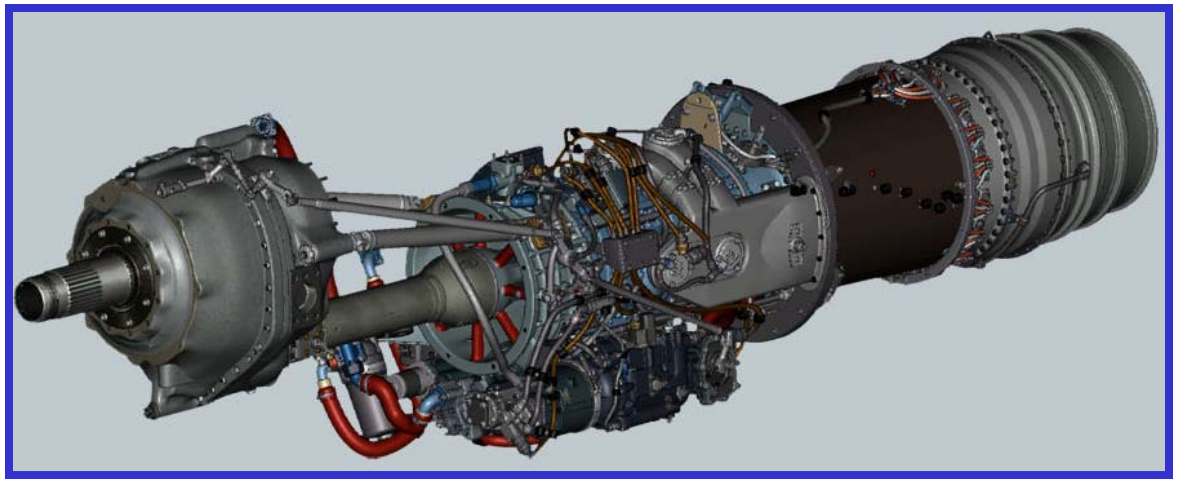
Reliability Modeling & Workscope Optimization for Gas Turbines

Jim Henry
VP Technology Development



2nd Wind Turbine Reliability Workshop

17 September 2007

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Outline

- Standard Aero at a Glance
- Reliability and Standard Aero
- Workscoping & Modeling
- Case Studies
- Conclusions

Standard Aero at a Glance

Overview

- **Large, independent overhauler of gas turbines**
- **Approx $800 M in Annual Sales**
- **2,500 Employees**
- **ISO 9001 & ISO 14001 Registered Facilities**
- **Facilities in USA, Canada, Europe, Australia**

Airlines

PT6A

PW100

AE3007

CF34

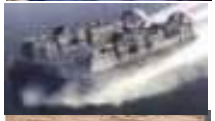
Military

T56/501 Props

AE2100

Industrial/Heli

Model 250



TF40/50

LM1600

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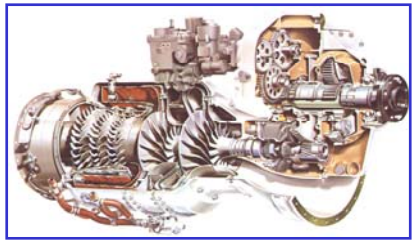
Why Standard Aero and Reliability?

- Competitive advantage:
  - Optimize cost and reliability for our customers
  - Secure lasting customer relationships

Standard Aero Technical Services IMX (TM)

- Manage cost per hour programs:
  - Quantify future risks
  - Understand future cash flows
  - Long term management of programs
  - Leases: revenue recognition

Why Is Standard Aero Here?



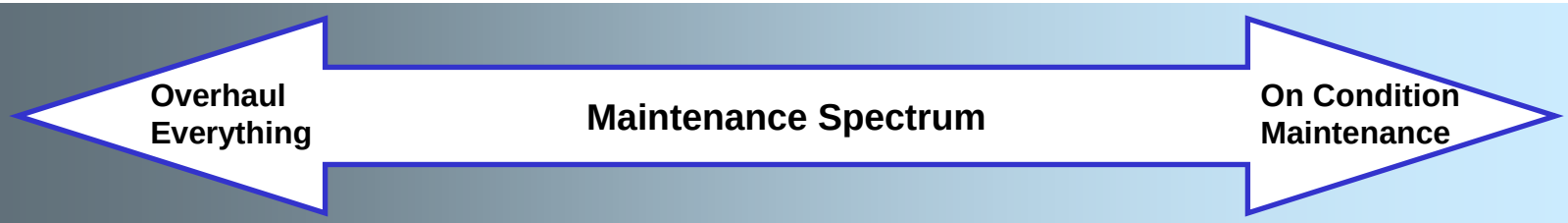
?

Gas Turbines and Wind Turbines are similar in some respects:

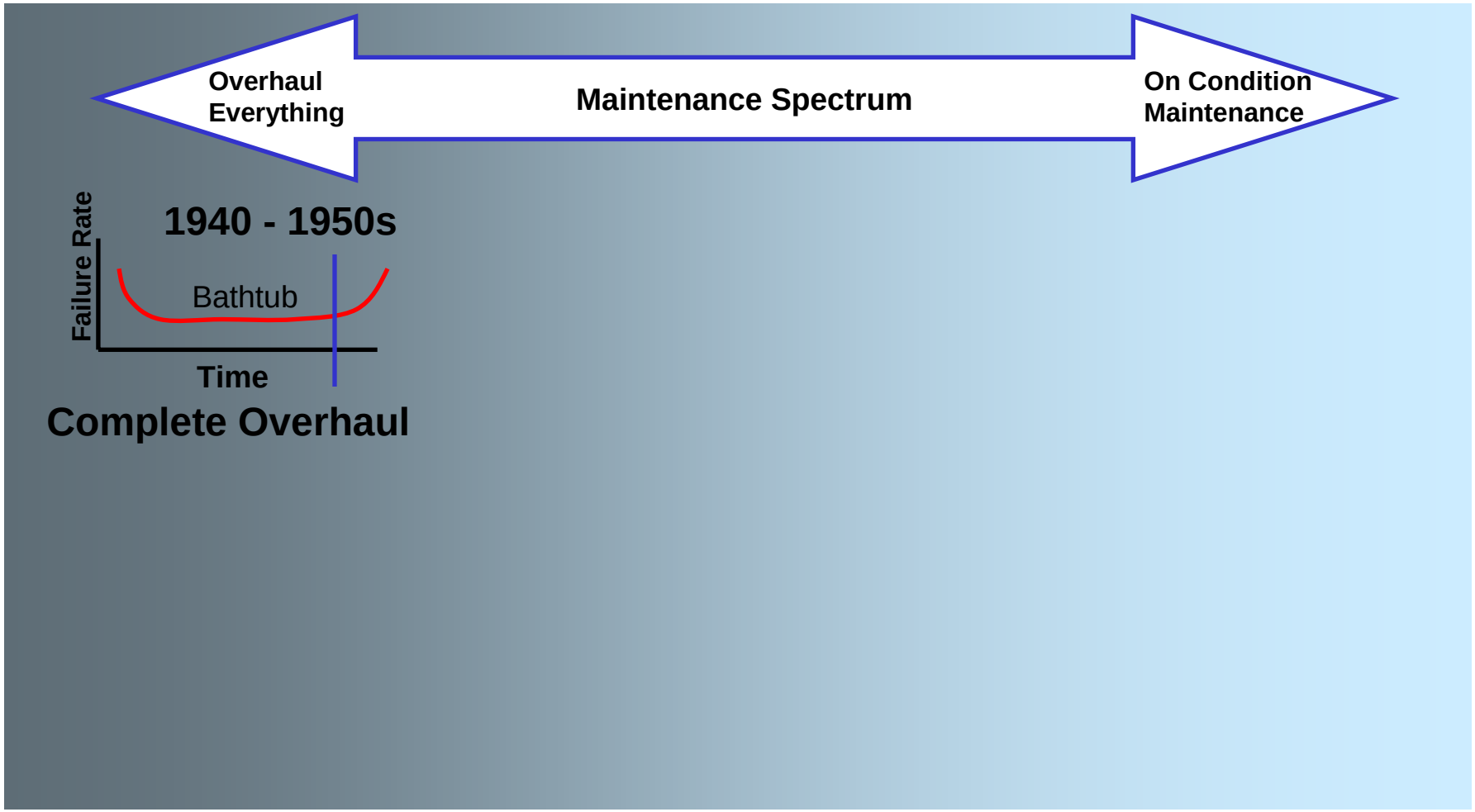
- High cost assets
- Long life cycles
- High maintenance cost
- Significant lost revenue when unavailable
- Maintenance costs increase with time
- System reliability will decrease over time unless proactive workscoping is performed

Perhaps the Wind Turbine Industry can learn from our mistakes...

The Evolution of Engine Maintenance



The Evolution of Engine Maintenance



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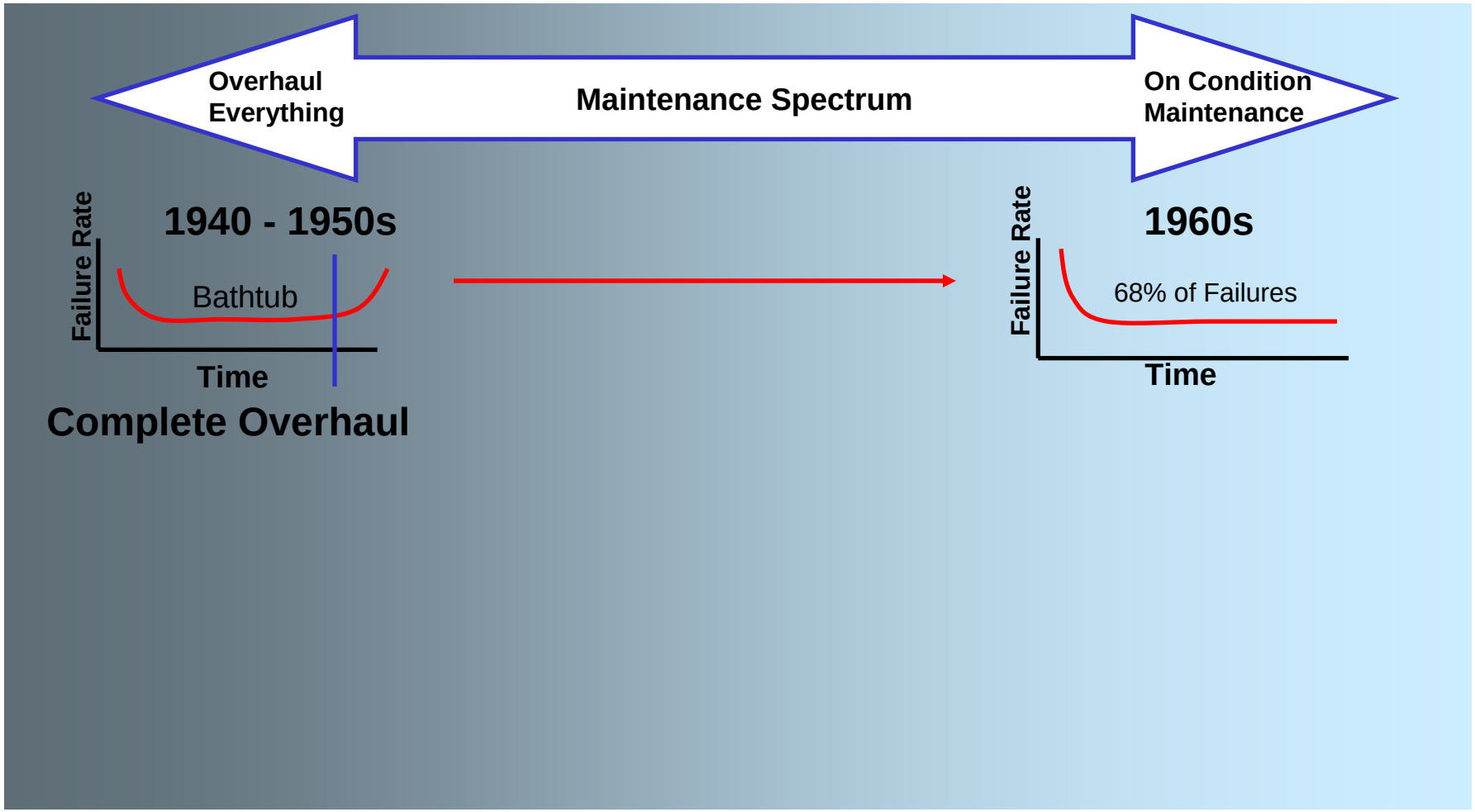

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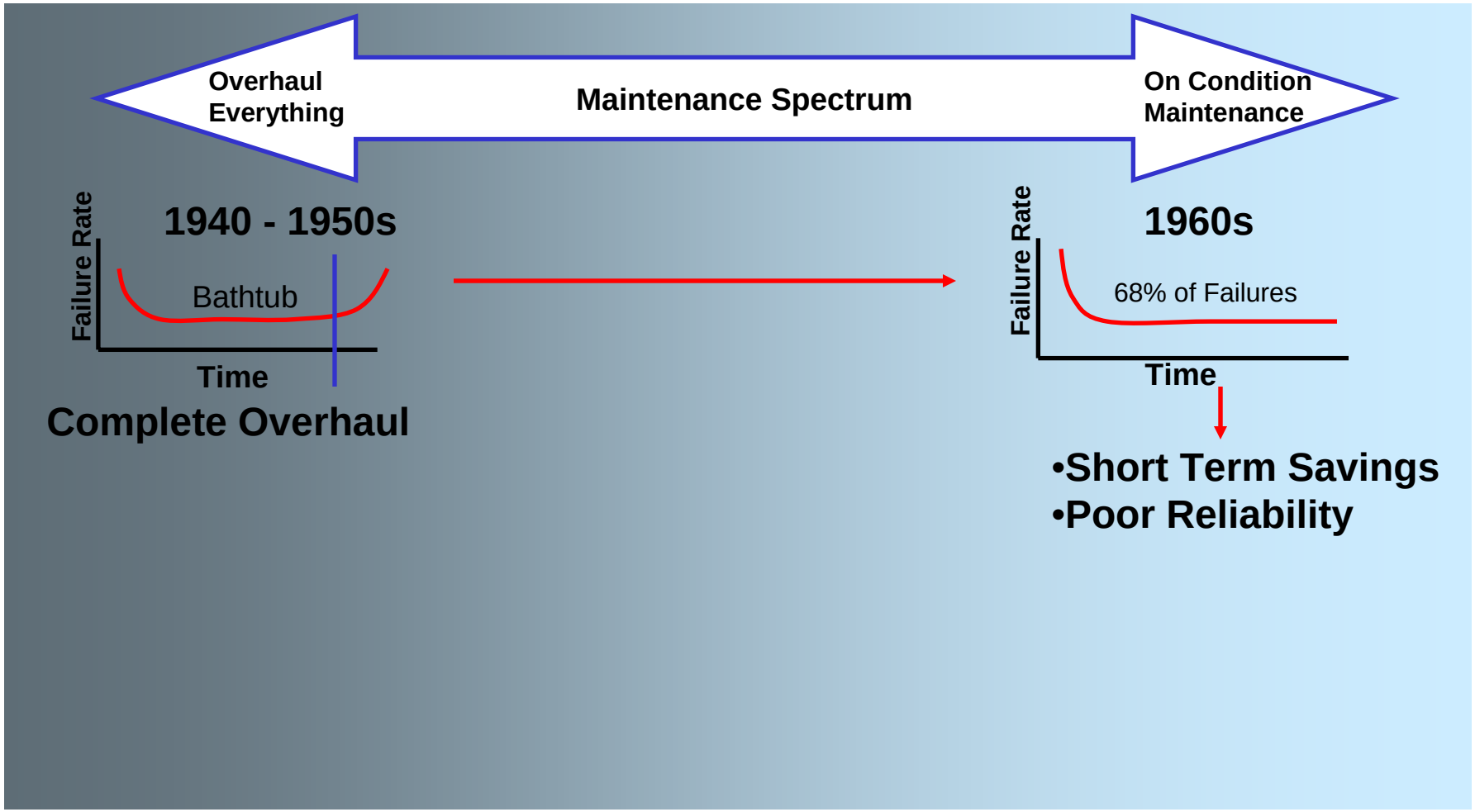
The Evolution of Engine Maintenance



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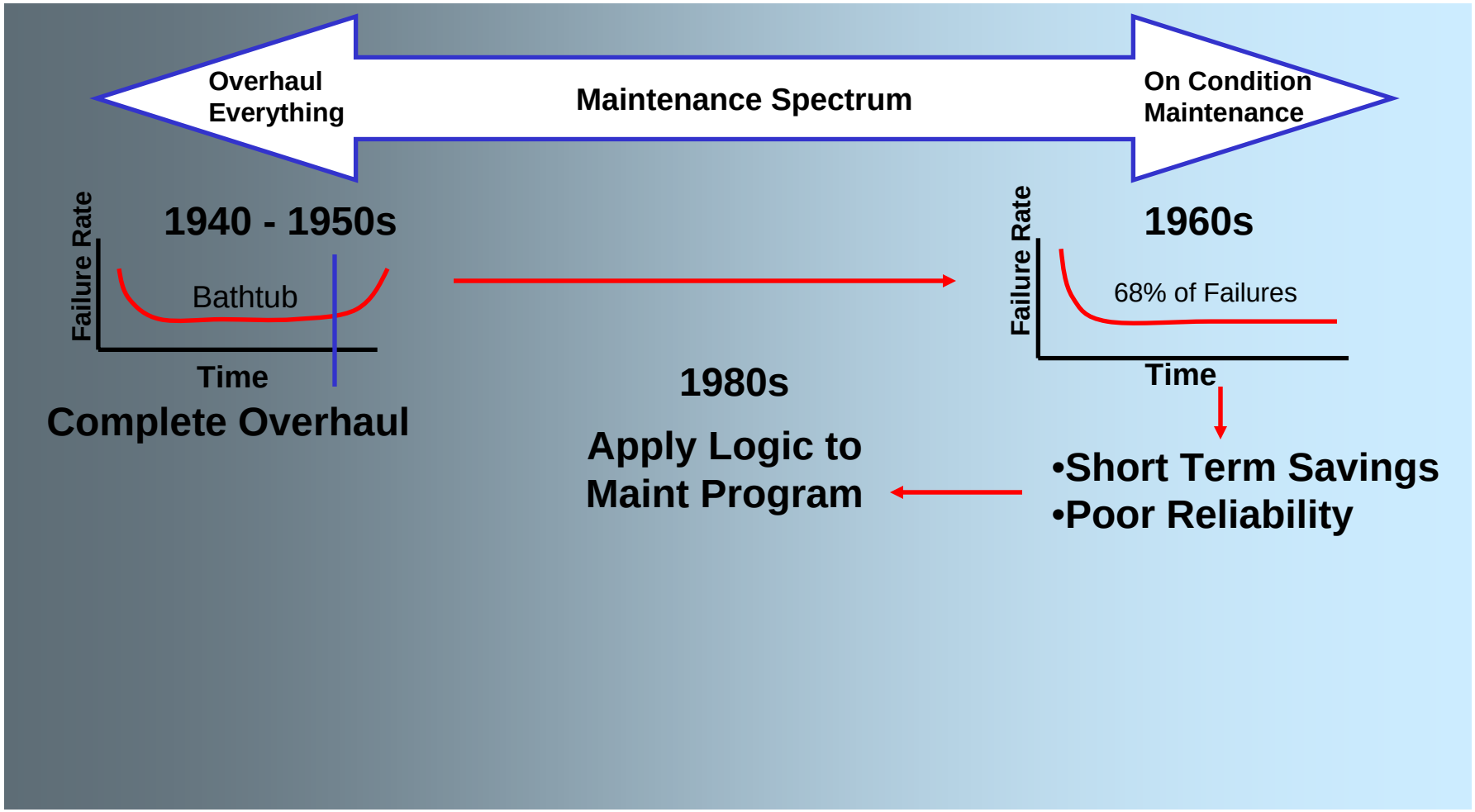

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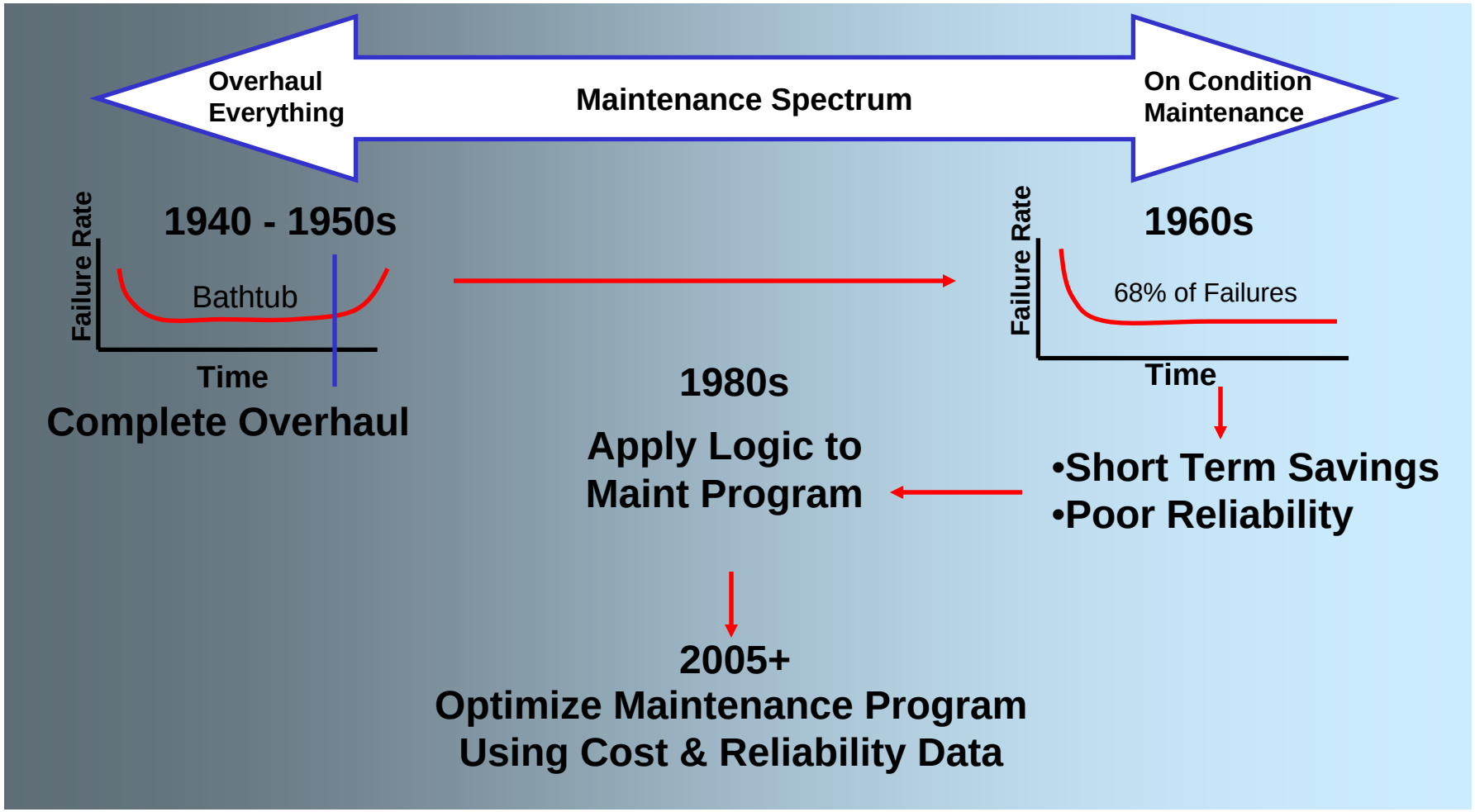

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Workscoping & Modeling

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Standard Aero Technical Services IMX (TM)

A Systematic Methodology to Optimize Reliability & Operating Cost

Step 1

Gather Data, Analyze and Model
Find Opportunities for Improvement

Step 2

Gather Detailed Data
Build Tools

Step 3

Implement Tools/ Improvements

Step 4

On-going Reliability
Program Management

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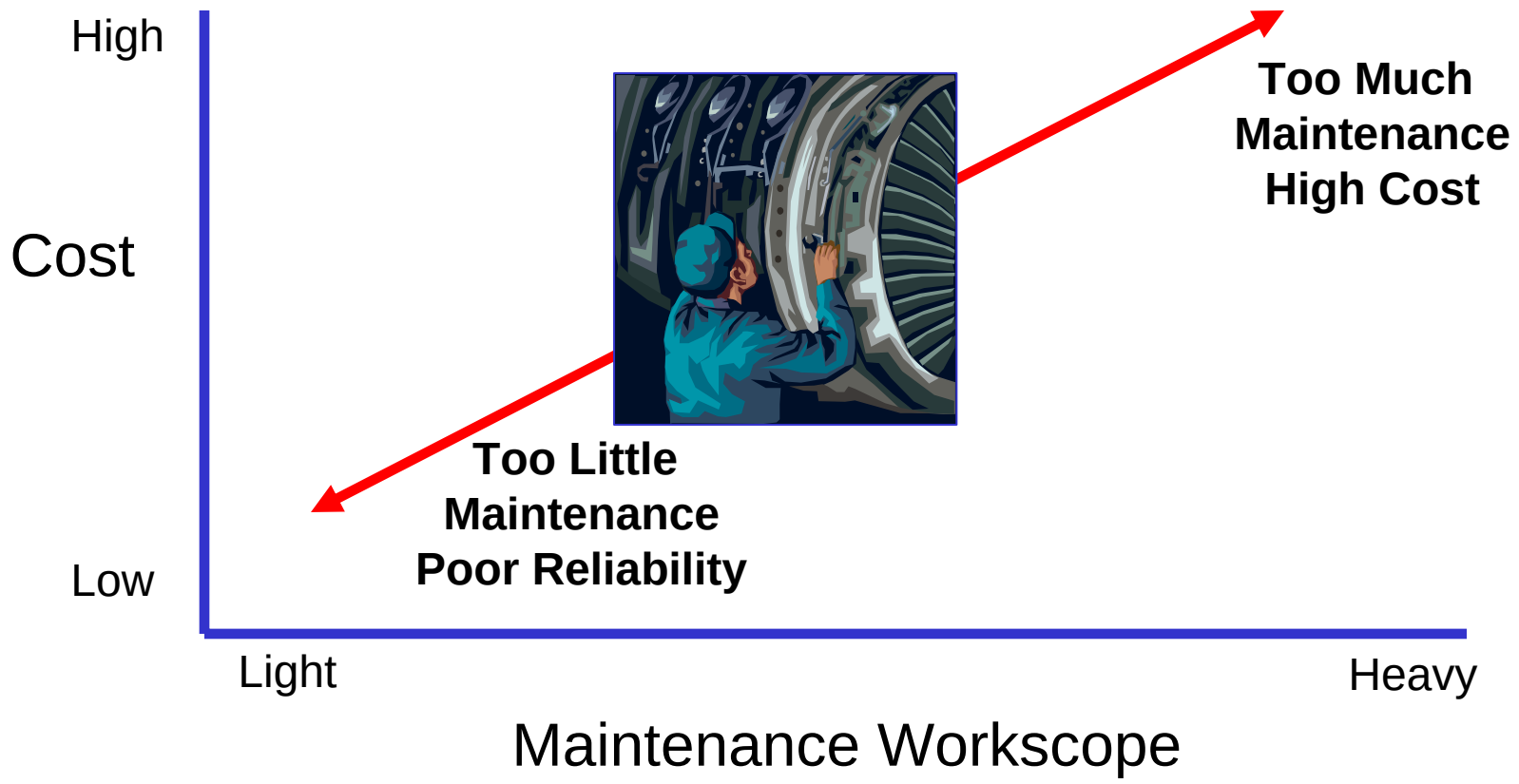
Workscoping: The Maintainer's Dilemma



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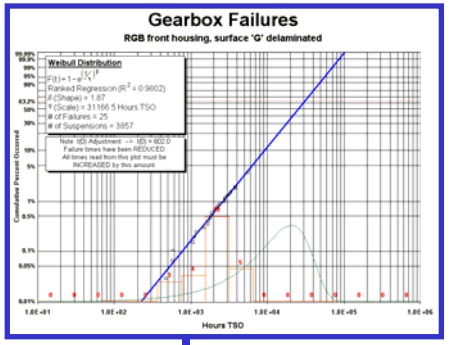
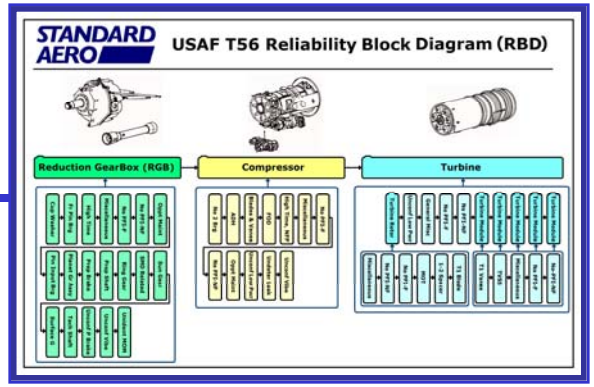
Predicting Engine Reliability

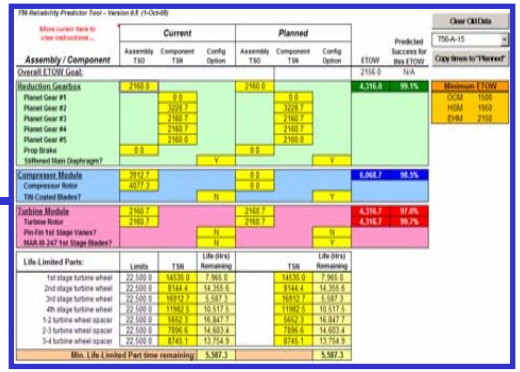
Data Collection

Reliability Analysis





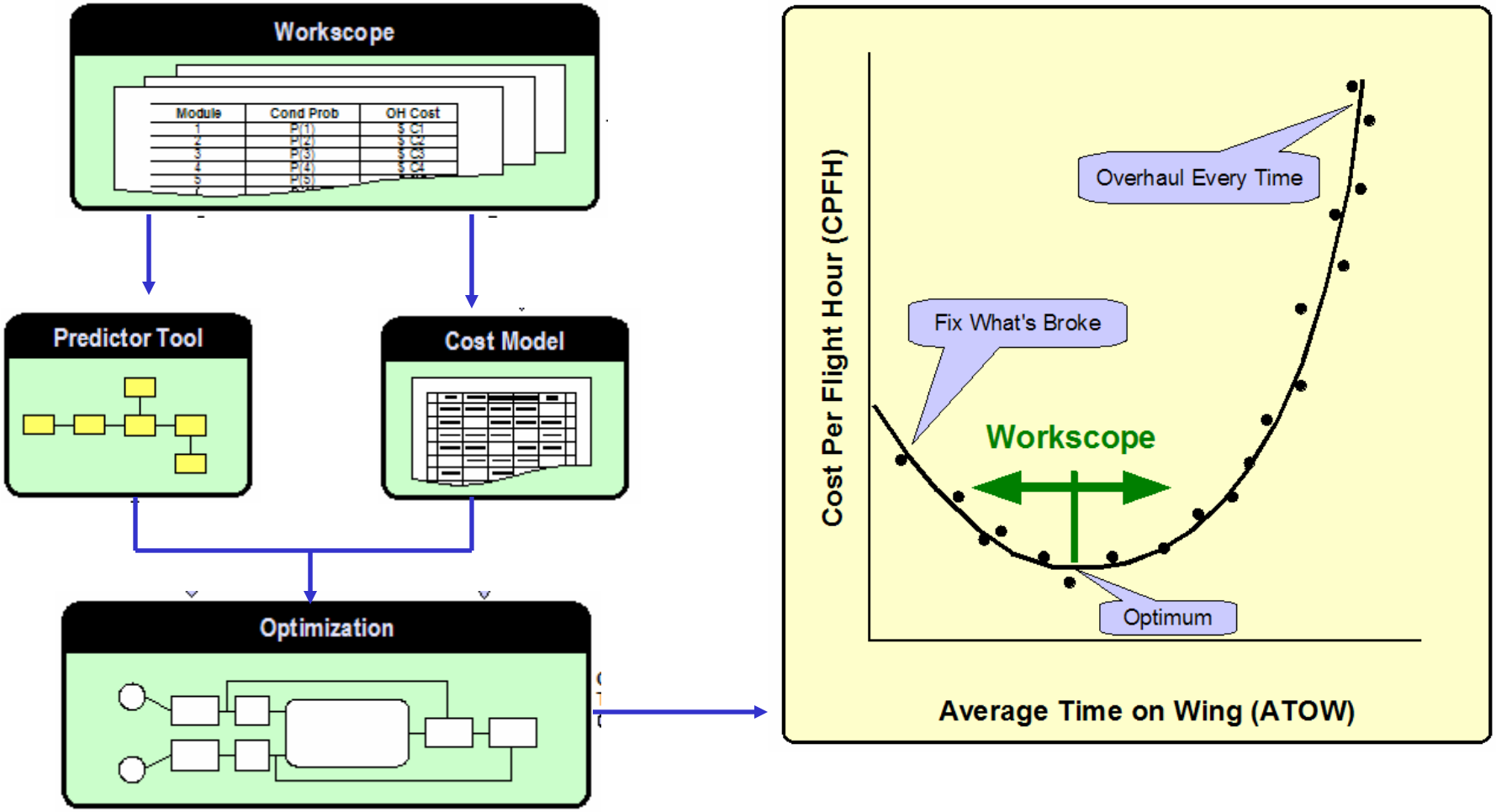
Monte Carlo Simulation



Time On Wing Predictor

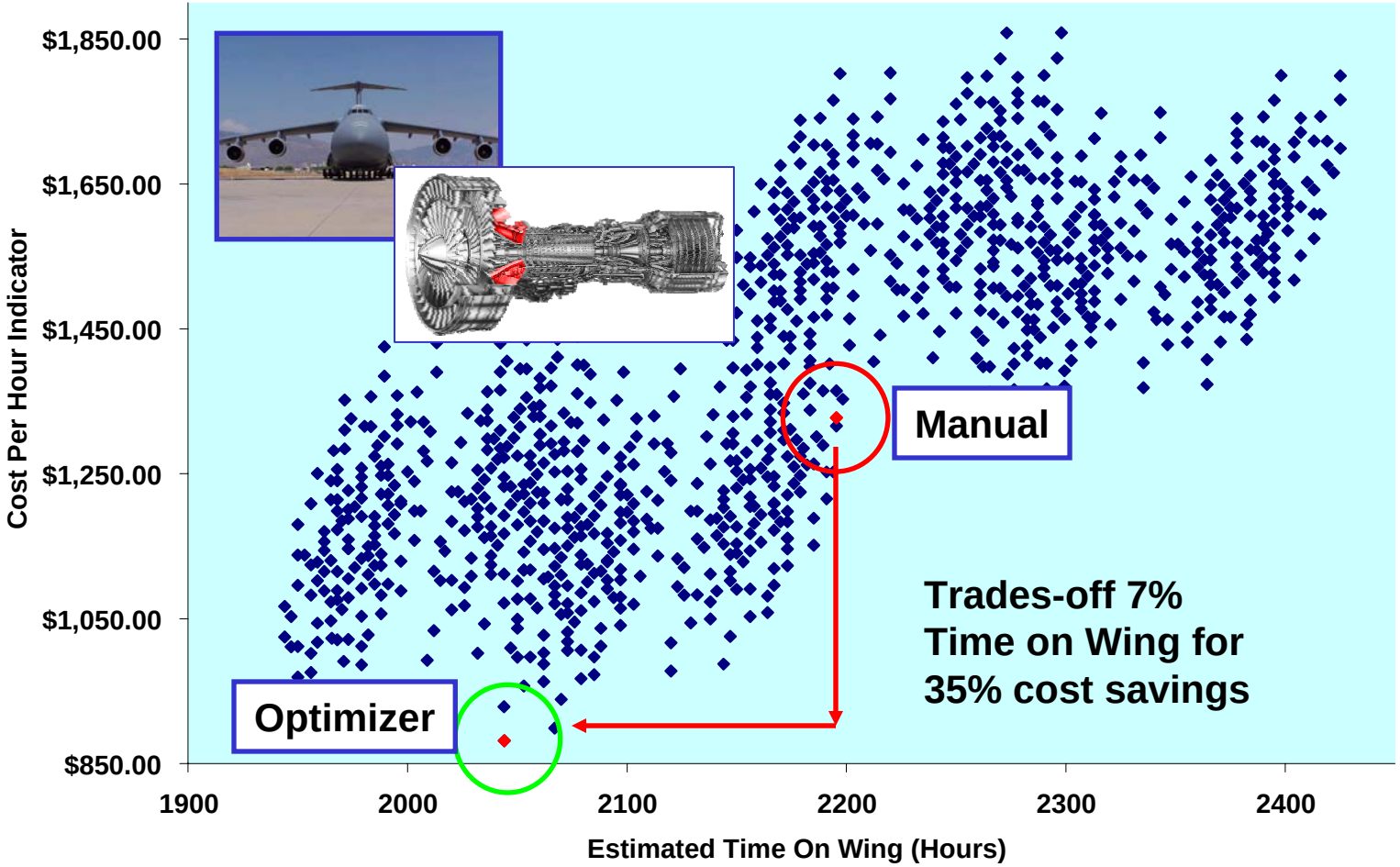
Estimated Time on Wing

Workscope Optimization



TF39 Workscope Optimizer

13 Modules = 2^{13} = 8192 Workscope Options



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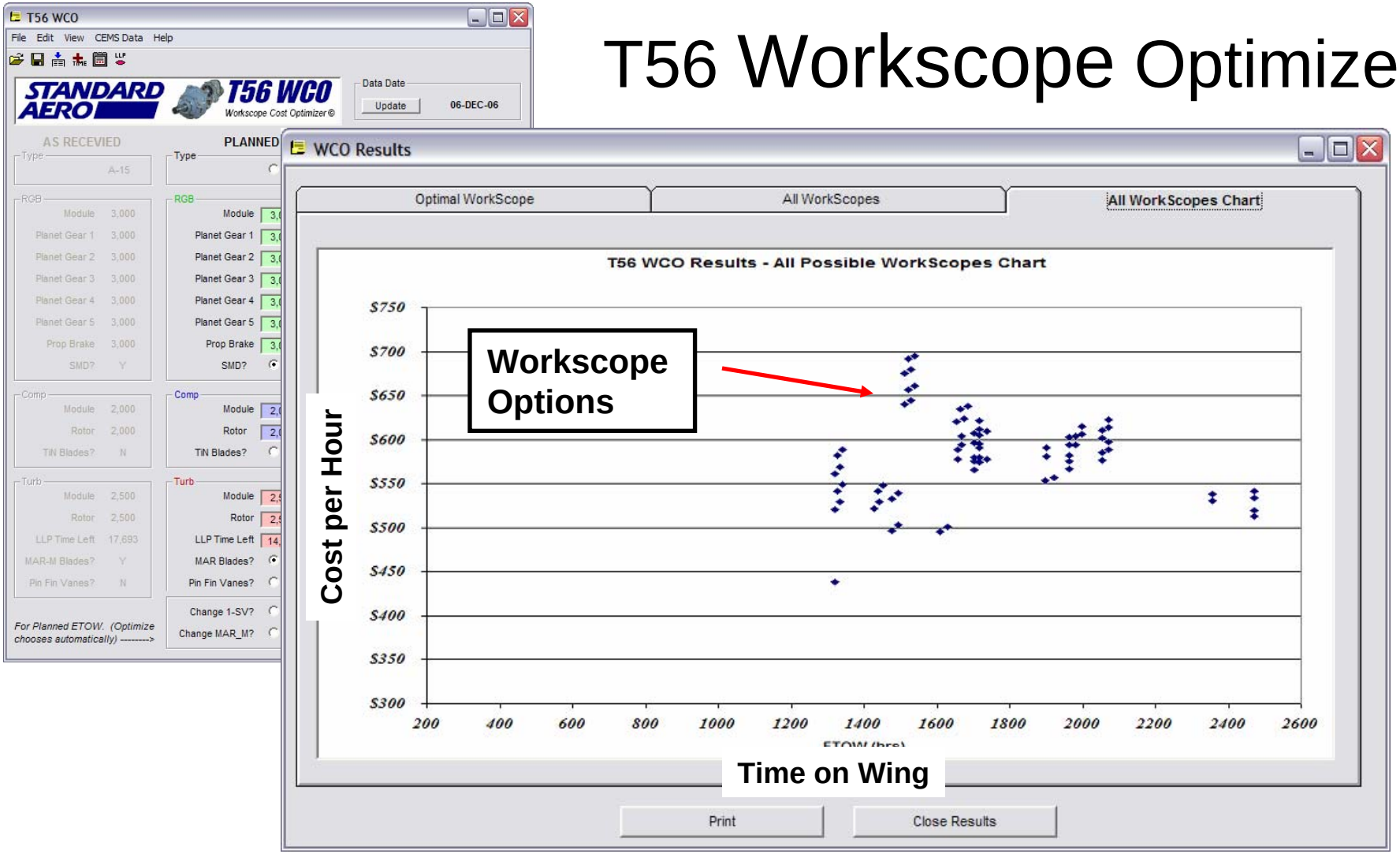
T56 Workscope Optimizer



In use at Dyess, Little Rock and Hurlburt!

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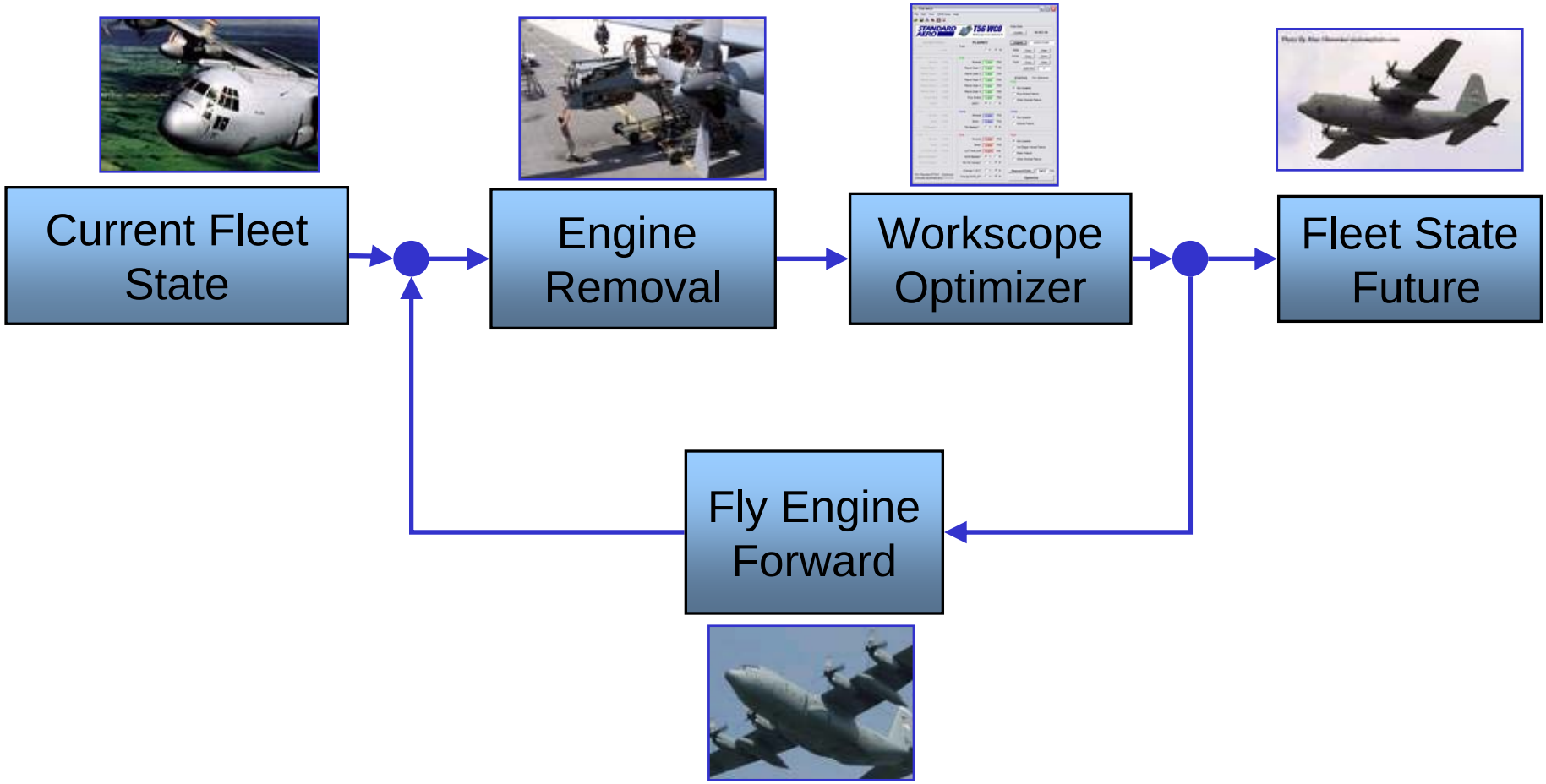
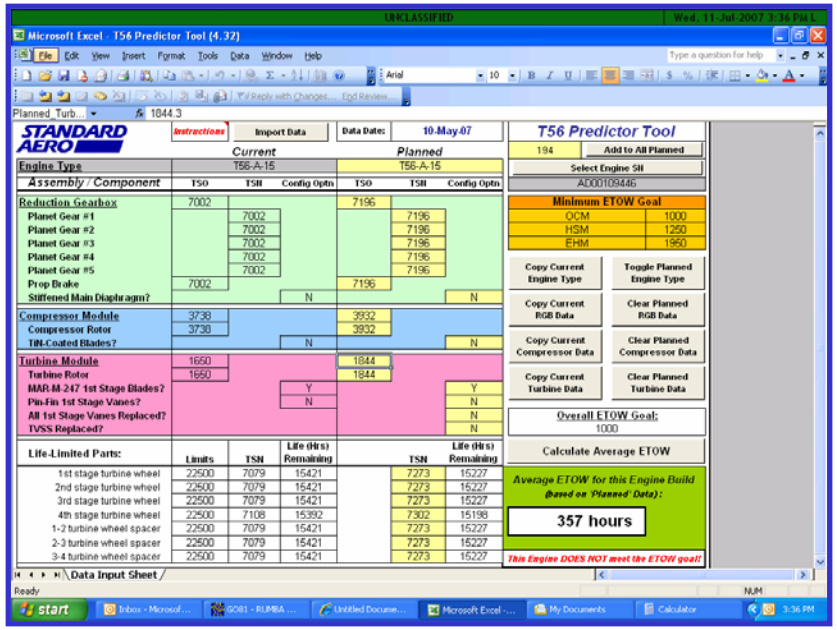
Fleet Simulation



Case Studies

Example - T56 Workscope Optimizer

12 July 2007, Dyess AFB



- Ran optimizer on T56 engines on C130 aircraft undergoing annual inspection prior to deployment
- Optimizer showed ETOW of just 357 hrs for # 1 engine
- USAF elected to change engine to avert possible failure in AOR
- Practical use of predictive maintenance tools

"Thanks for the insight. Your actions possibly prevented an unscheduled engine change during austere conditions (AOR)."

Michael Woodward, SMSgt, USAF

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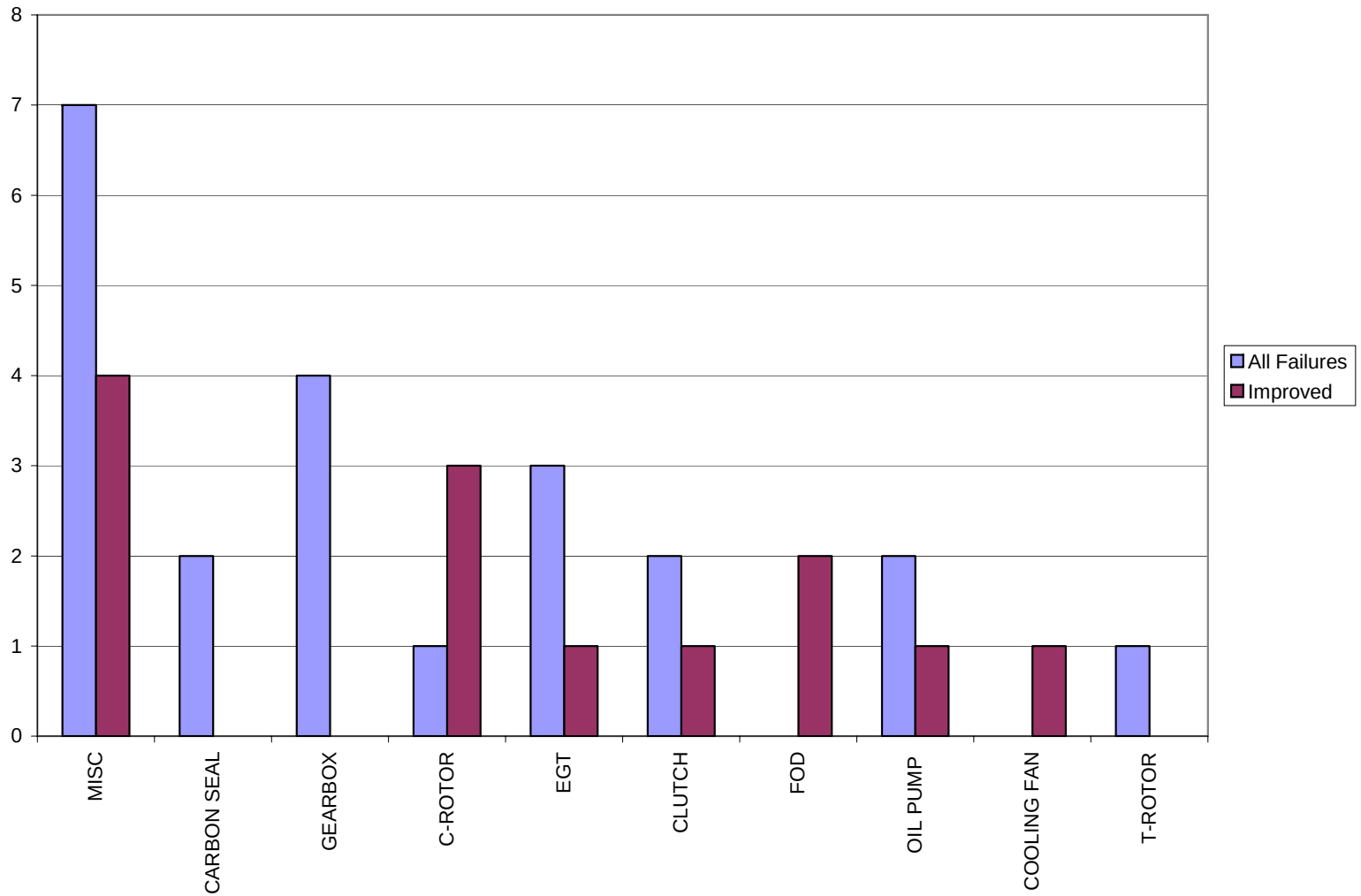
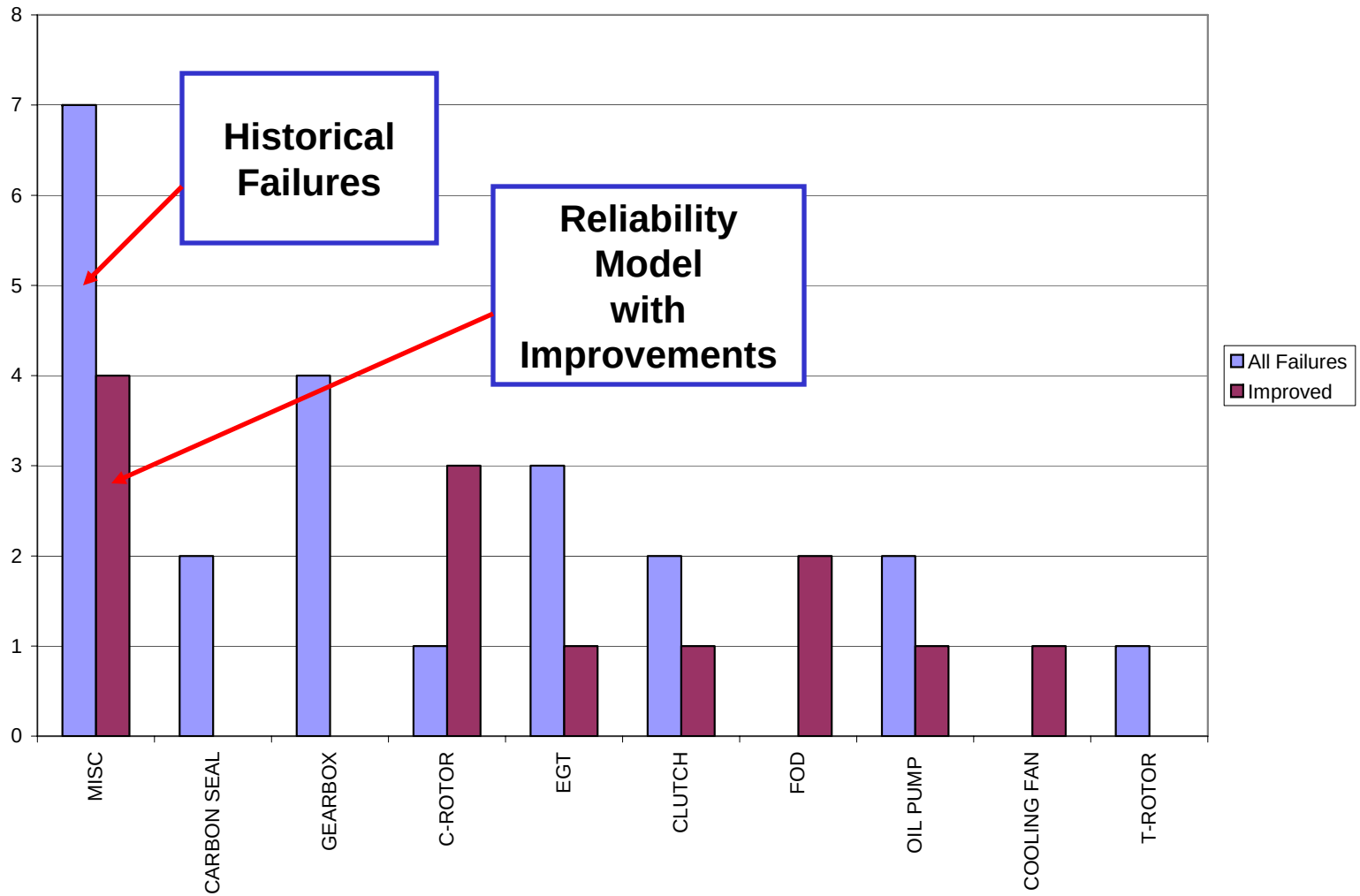
Example - Auxiliary Power Unit (APU) Reliability

- Regional jet APU
- OEM announces upgrade ‘04
- Must improve reliability to stay competitive
- Created reliability model
- Identified areas for improvement
- Ran model with improvements
- Implemented changes

June 04 Analysis & Simulation



June 04 Analysis & Simulation



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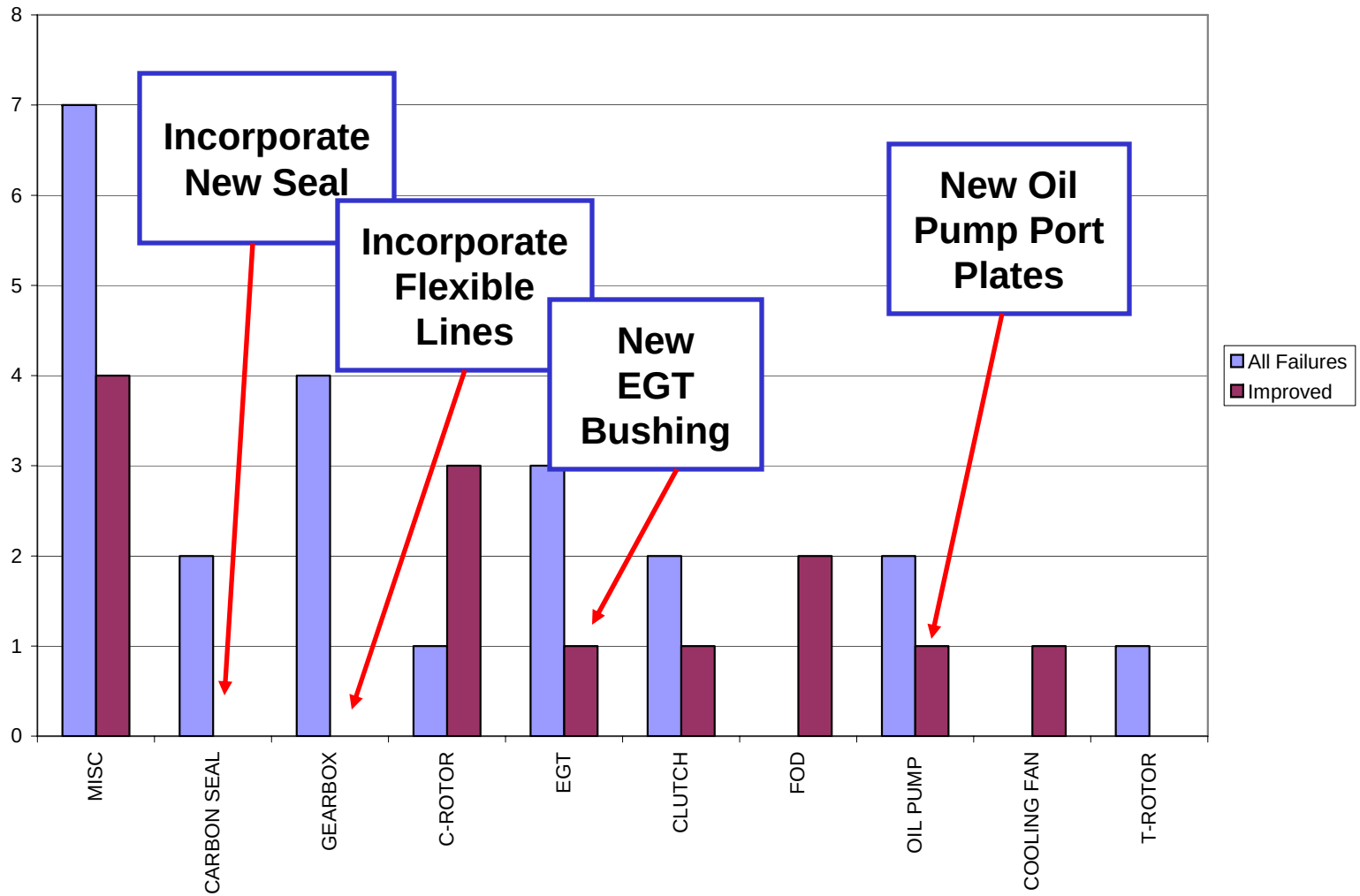

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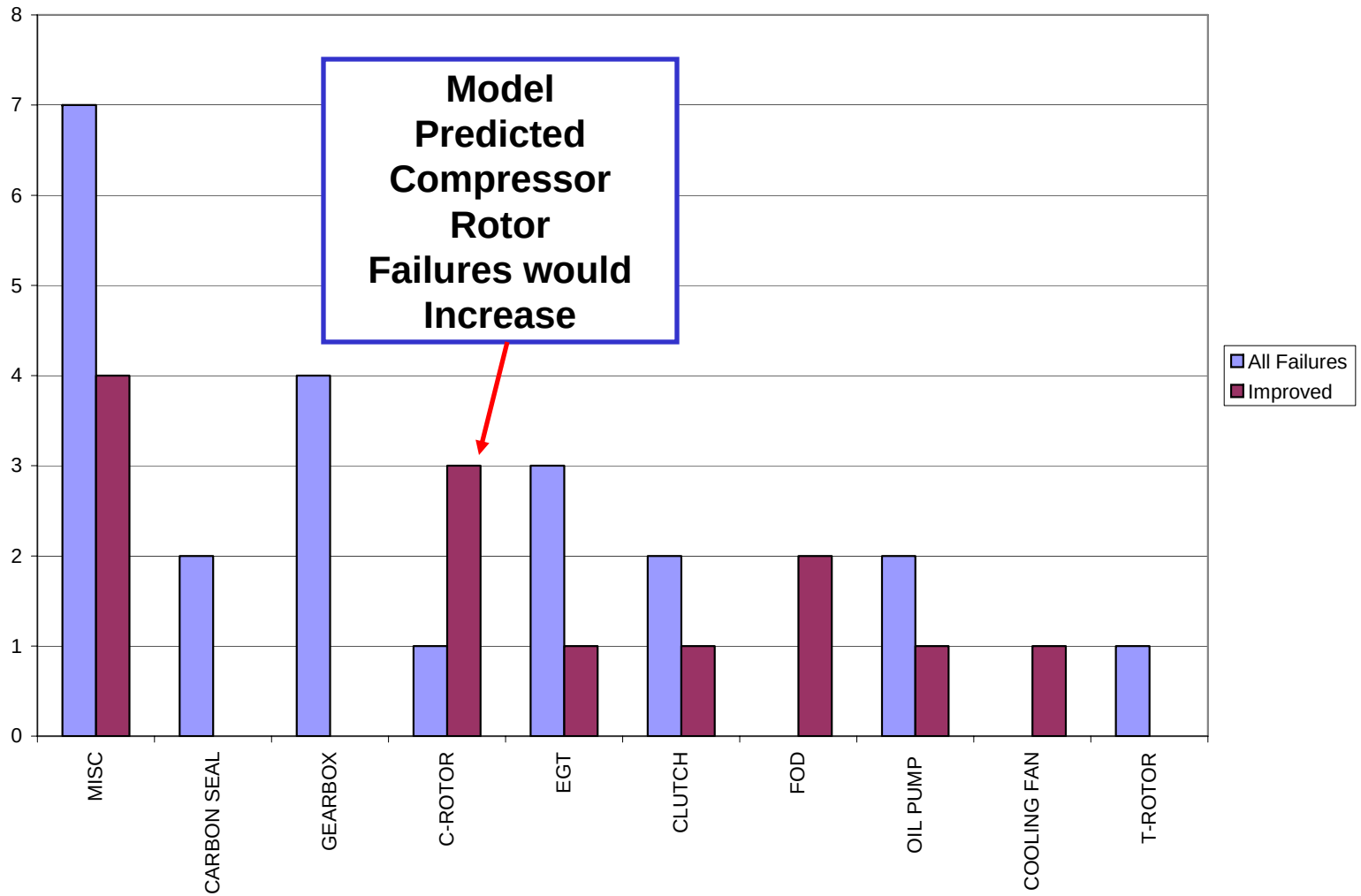

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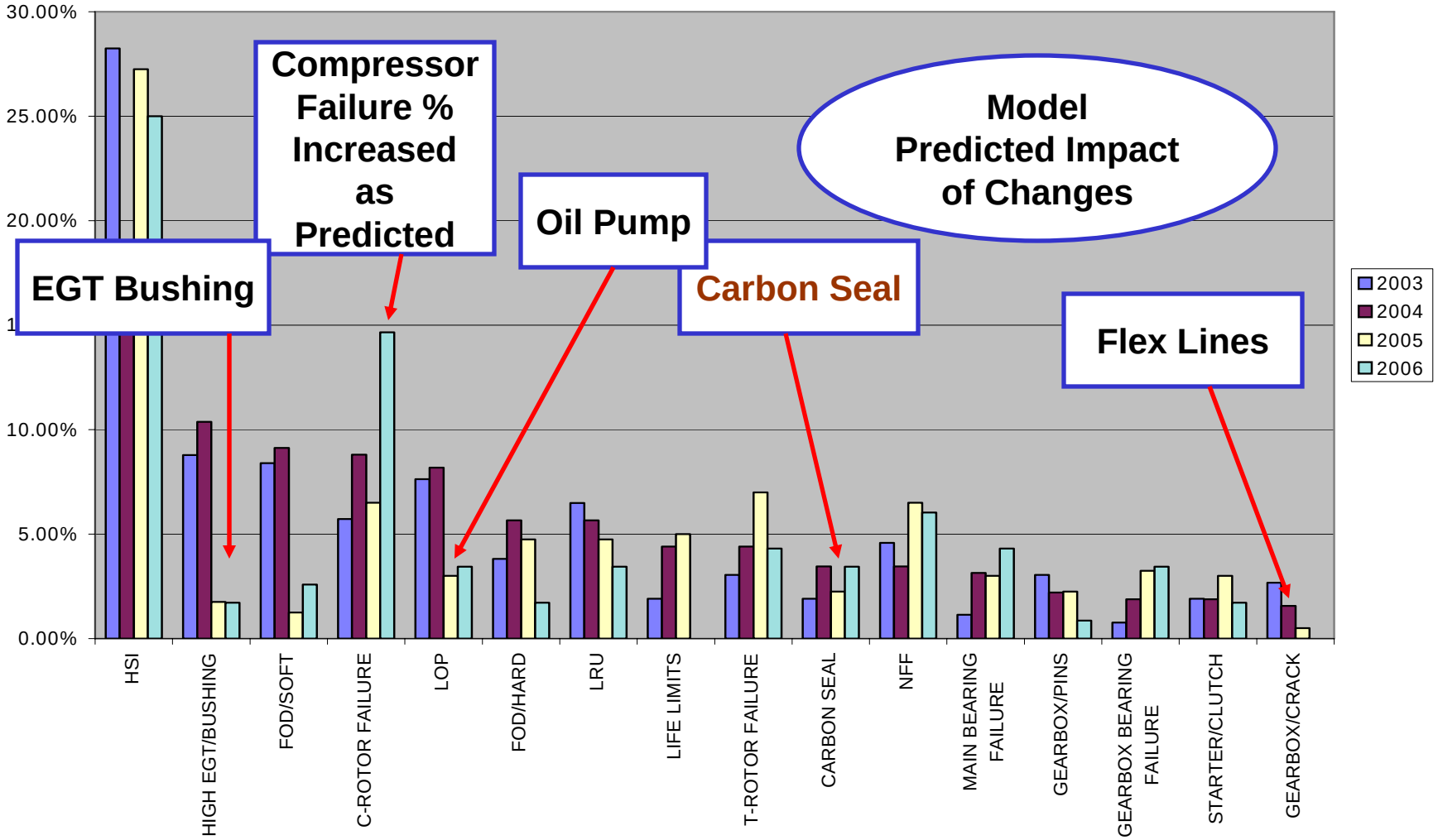
April 07 - Results



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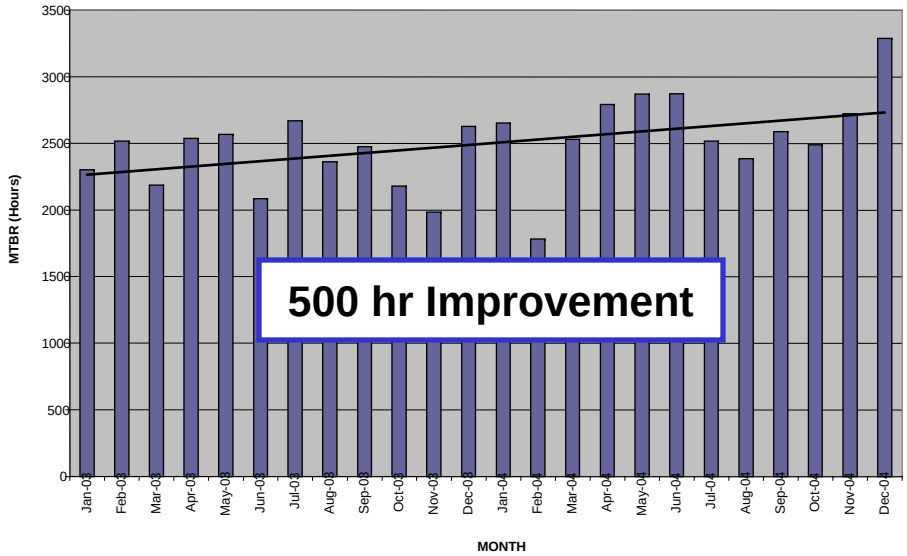
April 07 - Results

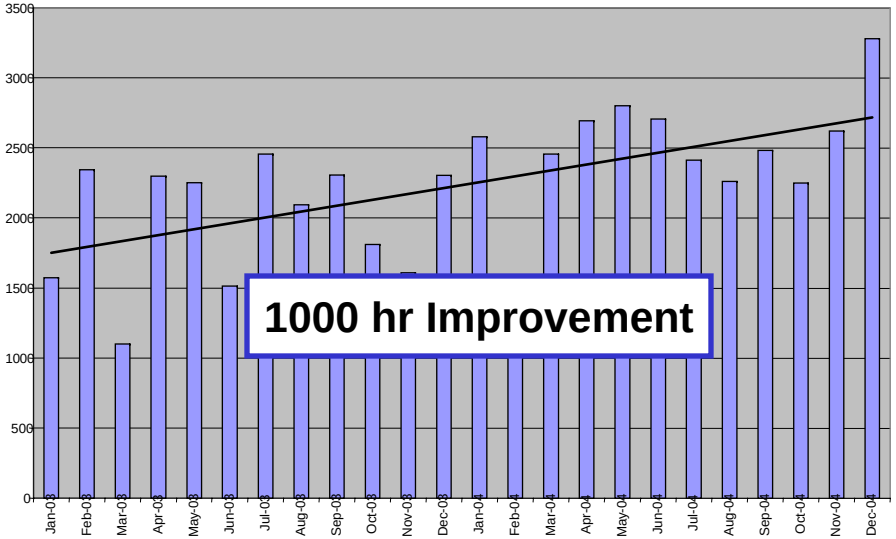
Reliability Improvement through MTBUR increases

Cost Reduction from Reliability Improvement

MTBR Fleet Improvement



MTBUR Fleet Improvement

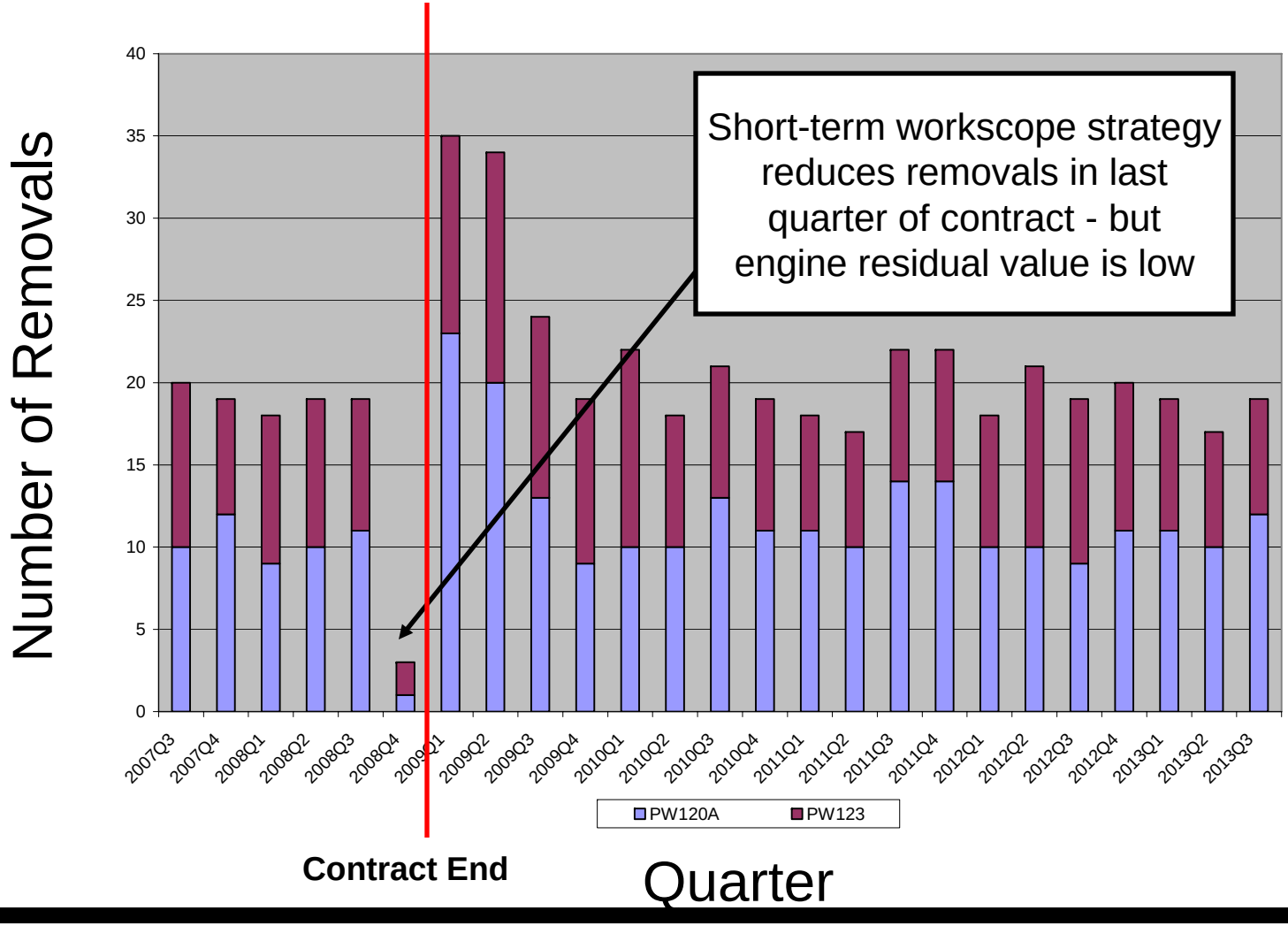


Actual data based on fleet analysis and comparison from before and after Standard Aero began service for current customer base

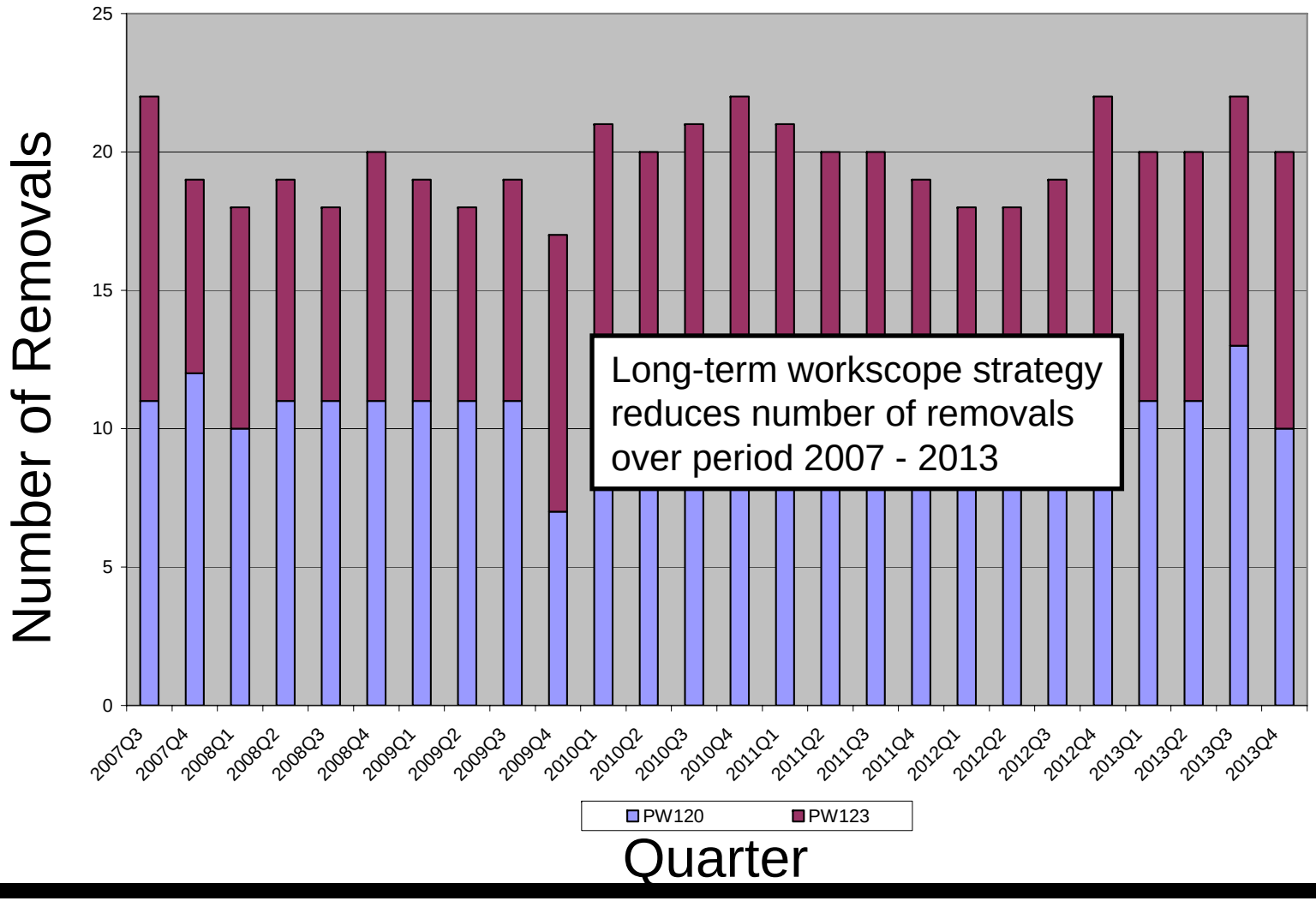
Example - Fleet Simulation

- PW 100 turboprop employed on regional airliners
- Power by the hour contract
- Bid aggressively
- Employed fleet model to provide insight into workscope options
- Evaluated short term and long term strategies

Short Term Strategy - Removals



Long Term Strategy - Removals



Long-term workscope strategy reduces number of removals over period 2007 - 2013

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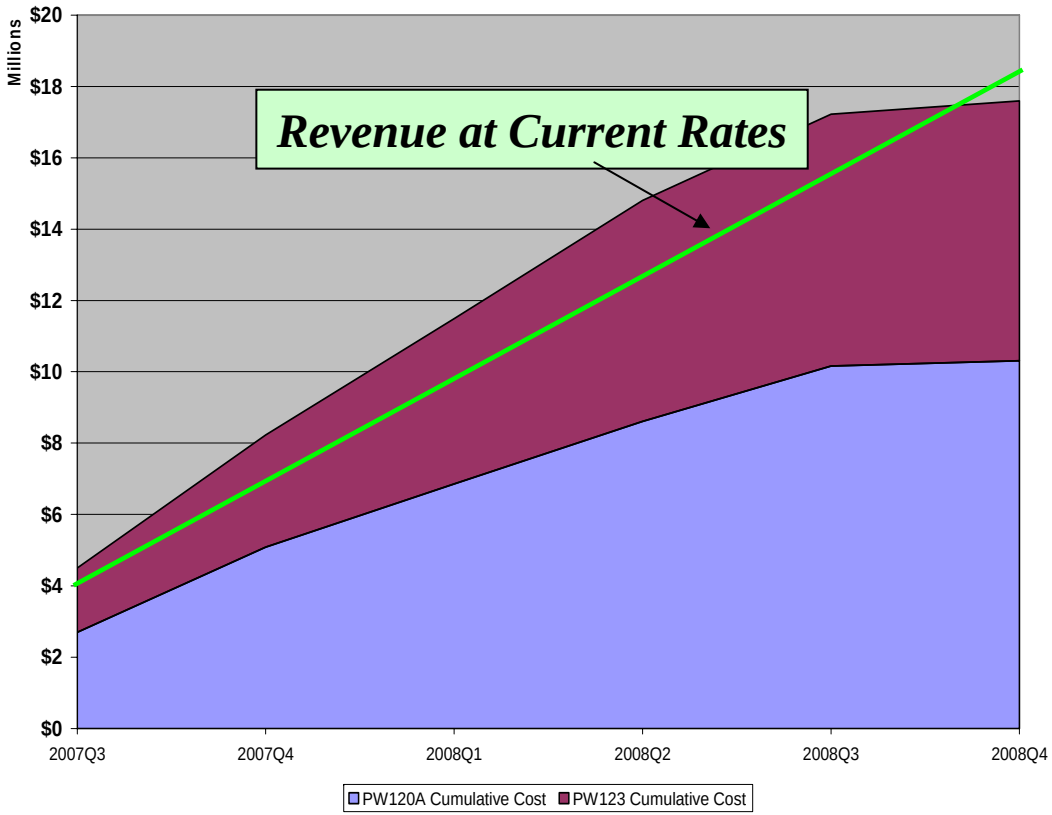
Program Cost Projections



- Project program cost and cash flow over contract life
- Working with customers to optimize the maintenance program on their engines
- Used to capture new work

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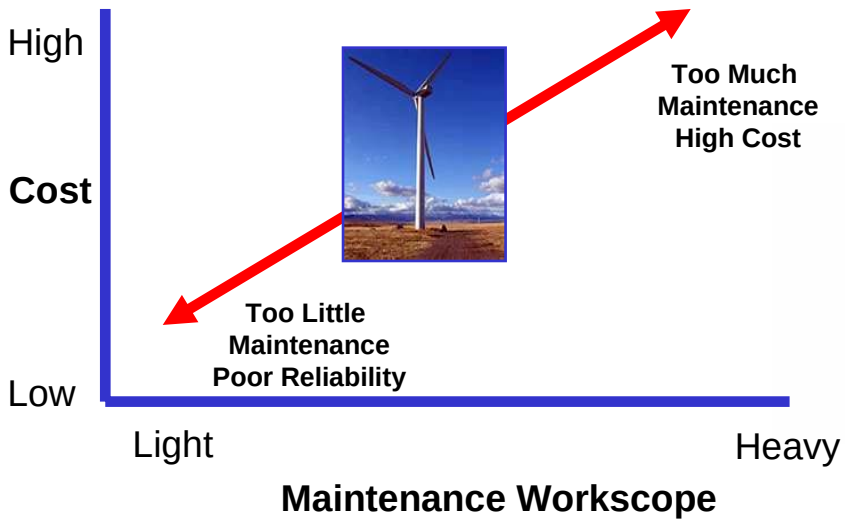
Conclusions

Conclusions



- A data-driven workscoping methodology is key to cost effective operation of aging systems
- Workscoping tools may help reduce Wind Turbine ownership costs
- Workscoping and Fleet Simulation technologies are mature and easily migrated from one system to another

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