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From Field Data to Reliability Optimization, a Navy LCAC Application

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Presented in:

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From Field Data to Reliability Optimization, a Navy LCAC Application

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From Field Data to Reliability Optimization: Navy LCAC Application

MORS Symposium
June 2007

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Systems Sustainment and Readiness Technologies
Sandia National Laboratories
Outline

- Navy’s Needs

- Approach: Overview & Details
  - 1) Analyze Field Data
  - 2) Create Baseline Model
  - 3) Optimize Over Improvements

- Summary

*Disclaimer: Data and logic used in this presentation are for example purposes only. They are not, and should not be treated as, real LCAC data and information.*
Navy Needs

- Navy needs “a model to perform analyses of current and future LCAC maintenance and support operations”
  - How will funding changes (up or down) impact fleet readiness?
  - How will planned upgrades improve fleet readiness?

- Navy will run what-if scenarios to optimize over
  - Budget
  - Maintenance
  - Operations & Support

Translate $$$ into Readiness
Approach – Overview

Maintenance Records (Unscheduled, Inspections, …)
Cost Information
Operating Hours

Craft Configurations
Updated Data

Planned Upgrades

Performance Objectives
Constraints/Requirements

Analyze
Field Data

Create Baseline
Model

Predict
Impact

Optimize Over
Improvements

RESULTS & DECISIONS

Annual Cost Reduction

$700
$600
$500
$400
0 50 100 150 200 250 300
Estimated RECAP Cost
Millions

Sandia National Laboratories
Approach – Overview

- **Analyze Field Data**
  - Investigate existing failure & maintenance data sources
  - Recommend improved data collection process

- **Create Baseline Model**
  - Populate with existing failure & maintenance data (updated data, if necessary)
  - Capture component redundancy for various craft configurations
  - Analyze current system performance (Readiness, Annual Costs, …)

- **Predict Impact**

- **Optimize Over Improvements**
Approach - Overview

- Predict Impact (optional)
  - Predict impacts of current planned changes in maintenance, supply, and budget policies
  - Evaluate other cost and availability drivers identified by the baseline model

- Optimize Over Improvements ("best bang for the buck")
  - Examine improvement options
  - Optimize to select best improvements
  - Incorporate user-defined constraints
Analyze Field Data

● Goal

  − Assessment of “As-Is” Performance

● Inputs

  − Basic Maintenance and Logistical Data
    ● Machine ID
    ● Failure Mode: Code & Name
    ● Failure Date & Time
    ● Total Downtime
    ● Event Type (Failure, Preventative Maintenance, ...)
    ● Costs
    ● Operating Hours

<table>
<thead>
<tr>
<th>Assigned Names</th>
<th>Linked</th>
<th>Pro-Opta Fields</th>
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<tbody>
<tr>
<td>Code</td>
<td>&lt;=&lt;&gt;</td>
<td>FailureCode</td>
</tr>
<tr>
<td>Date</td>
<td>&lt;=&lt;&gt;</td>
<td>FailureDate</td>
</tr>
<tr>
<td>Name</td>
<td>&lt;=&lt;&gt;</td>
<td>FailureName</td>
</tr>
<tr>
<td>Time</td>
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<td>FailureTime</td>
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<tr>
<td>Machine ID</td>
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<td>MachineID</td>
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<tr>
<td>Downtime</td>
<td>&lt;=&lt;&gt;</td>
<td>TotalDowntime</td>
</tr>
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</table>
Analyze Field Data: Data Analysis Process

1. Collect Field Failure Data / Maintenance Records
2. Clean Data Records – Interact with Data Provider
3. Analyze Data – Generate Results
4. Validate Results
5. Report Results
Analyze Field Data

● Description
  – Calculates “Nominal” Output
    ◆ Calculated directly from data
    ◆ Example Questions Answered:
      » What was our largest Downtime driver last year?
      » Which craft had the best Availability this quarter?
  – Calculates “Statistical” Output
    ◆ Uses randomness from raw data to provide distributional assessments
      » Information about variability is gathered from the deterministic historic data
    ◆ Example Question Answered:
      » Which failure modes contributed the most to variability in Maintenance Cost over the past 2 years?
Analyze Field Data: Sample Output

- **Availability: Numerical Summary**
  - Nominal Value, Mean, Median, Percentiles, Standard Deviation

![Summary Statistics Table]

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Availability</th>
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<tbody>
<tr>
<td>Mean</td>
<td>0.61088</td>
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<tr>
<td>Nominal</td>
<td>0.62979</td>
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<tr>
<td>Std. Deviation</td>
<td>0.1493</td>
</tr>
<tr>
<td>1st Percentile</td>
<td>0.17621</td>
</tr>
<tr>
<td>5th Percentile</td>
<td>0.30478</td>
</tr>
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<td>10th Percentile</td>
<td>0.38984</td>
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<td>20th Percentile</td>
<td>0.50066</td>
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<td>30th Percentile</td>
<td>0.55182</td>
</tr>
<tr>
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<tr>
<td>50th Percentile</td>
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<tr>
<td>60th Percentile</td>
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</tr>
<tr>
<td>70th Percentile</td>
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<td>80th Percentile</td>
<td>0.73729</td>
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<td>90th Percentile</td>
<td>0.76401</td>
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<tr>
<td>95th Percentile</td>
<td>0.78787</td>
</tr>
<tr>
<td>99th Percentile</td>
<td>0.80895</td>
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</tbody>
</table>
Analyze Field Data: Sample Output

- **Downtime: Failure Mode Pareto**
  - Failure Types Driving Downtime

![Graph showing contributors to mean downtime with bars for each failure mode and a list of failure modes driving downtime.](image-url)
Cost: Variability Quantification

- Failure Types Driving Cost Variability
Analyze Field Data: Sample Output

- **Cost: Craft Details**
  - Monthly Costs for a single Craft
Analyze Field Data

- **Output Metrics/Values**
  - Availability
  - MTBF
  - Downtime
  - Cost
    - *Both Built-in and User-defined version of the above*
      - *Example: Readiness*
  - Failure Mode Summary
    - Downtime Distributions
    - Failure Rate Distributions

- **Output Types/Formats**
  - Numerical Summary
    - Nominal Value
    - Mean, Median, Percentiles, Standard Deviation
  - Paretos of Failure Modes with the most impact
  - Variability Quantification
  - Data by Fleet or by Craft
Create Baseline Model

● Goals
  – Create sophisticated model of fleet and craft configurations
  – Ability to assess planned component & design changes
   ✦ Ability to answer “What If …” questions
  – Update Failure Mode Data, if necessary

● Inputs
  – Failure Modes: Failure Rate, Downtime, and Cost Distributions
   ✦ Combination of field data and info from other sources
  – Craft configurations with component redundancy
  – Sub-system hierarchy
Create Baseline Model

● Description
  - Fault Tree solver
  - Capability to model a family of Fault Trees
    - Multiple Configurations
    - Some shared failure modes
    - Different redundancy structures
Create Baseline Model

**Outputs**

- A set of output for each Configuration
- Very similar to “Analyze Field Data” output
Optimize Over Improvements

- **Goal**
  - Select Improvements for max Availability, min Costs
    - While incorporating user-defined constraints

- **Inputs**
  - Baseline Model: Single configuration OR *multiple* configurations
  - Potential Improvements
    - Benefits to Failure Rate, Downtime. Impact to Constraints.
  - Goals & Limitations
    - Acceptance criteria for “good” solutions
    - User-Defined constraints (Development Cost, Weight, Firepower, ...)

- **Flow**
  - Analyze Field Data
  - Create Baseline Model
  - Predict Impact
  - Optimize Over Improvements
Optimize Over Improvements

- **Description**
  - Optimization – can choose between
    - Weighted-Objective Genetic Algorithm
    - Multi-Objective Genetic Algorithm
    - Full Enumeration (no heuristic or algorithm)
  - Simultaneously Maximizes Availability, Maximizes MTBF, Minimizes Annual Cost, and/or Minimizes Annual Downtime
    - All while incorporating user-defined constraints

- **Sample Input: Improvement Tradeoffs**

<table>
<thead>
<tr>
<th>Component</th>
<th>Observed MTBF</th>
<th>% MTBF Improvement</th>
<th>Development Cost</th>
<th>Weight</th>
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<tr>
<td>Skirt System</td>
<td>2103</td>
<td>10%</td>
<td>$30M</td>
<td>+500lbs</td>
</tr>
<tr>
<td>Skirt System</td>
<td>2103</td>
<td>15%</td>
<td>$35M</td>
<td>+1000lbs</td>
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<td>20%</td>
<td>$42M</td>
<td>+2500lbs</td>
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<td>Skirt System</td>
<td>2103</td>
<td>25%</td>
<td>$59M</td>
<td>+4000lbs</td>
</tr>
<tr>
<td>Radio / Communications</td>
<td>982</td>
<td>5%</td>
<td>$3M</td>
<td>+0lbs</td>
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<td>Radio / Communications</td>
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<td>$20M</td>
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<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
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</tbody>
</table>
**Optimize Over Improvements: Output**

- Value attained for each Performance Measurement & Constraint
  - Values available for top 25 solutions

### Summary Information

<table>
<thead>
<tr>
<th>Performance Measure/Constraint</th>
<th>Baseline</th>
<th>Limit</th>
<th>Objective</th>
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<td>Fitness</td>
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<td>0.108</td>
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<td>Availability</td>
<td>0.616</td>
<td>0.650</td>
<td>0.750</td>
<td>0.661</td>
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<tr>
<td>Annual Cost</td>
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<td>1.61E+06</td>
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<td>100,000</td>
<td>204,000</td>
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<td>Strength</td>
<td>0</td>
<td>15.00</td>
<td>30.00</td>
<td>20.40</td>
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</table>
Optimize Over Improvements: Output

- Improvement Options to Implement

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<th>Level</th>
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<tr>
<td>Total</td>
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<td>20.40</td>
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Optimize Over Improvements: Output

- Graphical Histories of Optimal Solution
Summary

- **Analyze Field Data**
  - Assess current conditions for components, craft, fleet

- **Baseline Model**
  - Understand craft design & configurations
  - Examine planned changes
    - Mix of historical field data and info from other sources

- **Optimize Over Improvements**
  - Consider multiple configurations together
  - Select best improvements for Availability, Cost, User Requirements simultaneously
  - Incorporate additional feedback and “fuzzy” constraints by selecting among top solutions