Selection:
The most critical part of maintenance

N. Hampton & J. Perkel
Acknowledgements

• This material is based upon work supported by the Department of Energy under Award No DE-FC02-04CH1237 and CDFI.

• Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Department of Energy.
Outline

• Motivation
• SAGE
• Selection
  – Choice of when to start
  – Choice of location
  – Choice of action
  – Choice of diagnostic
• Impact of Selection on Benefits / Value
Motivation

• The goal of proactive maintenance is to prevent future service failures
  – Wholesale Replacement
  – Targeted Maintenance

• A Targeted Maintenance program uses diagnostic test(s) to identify the “weak” circuits.

• Program carries upfront costs that must be offset by program benefits.

• The economics of diagnostics are difficult to model and even more difficult to quantify. Must be used to quantify the benefits.
A Useful Way to Visualize this

SAGE

- Selection of circuits
- Actions that might be taken
- Generation of data – including Diagnostics
- Evaluation of the outcome

The name of the herb Sage comes from the Latin salvere or salvation meaning 'to be in good health, to cure, to save.'
Expectations

- Selection
- Action
- Generation
- Evaluation

Failures Increasing

Failures Decreasing

Failures increasing as time passes since test

No. of Failures vs. Time
Selection

Choice of when to start
Choice of location
Choice of action
Choice of diagnostic
When to start?

How to spot the trend
How late can you leave it before it is too late
Falling Reliability

When should we start a program?
Bathtub Curve for Failures

- **Early Failures**: Weibull Shape <1, TBF increases
- **Reliable Operation**: Weibull Shape =1, TBF stable
- **Ageing**: Weibull Shape >1, TBF decreases
Too Soon

Burn-In  
Reliable Operation  
Aging

Failure Rate

Time since Installation

Higher Failure rate for the new component
Too Late

Failure Rate

<table>
<thead>
<tr>
<th>BURN-IN</th>
<th>RELIABLE OPERATION</th>
<th>AGING</th>
</tr>
</thead>
</table>

Failure rate reduced by maintenance action, however, component remains in Aging region.
Just Right...

Failure rate reduced by maintenance action.

Burn-In  Reliable Operation  Aging

Time since Installation

Failure Rate
Sample Circuit Population

Shape 1.419
Scale 748.0
Location

The failure rate is not the same everywhere
Selecting from the Whole Population

Total Component Population

At-Risk Population
Local Failure Rates

![Bar chart showing local failure rates relative to the overall average for different portions of the system.](chart.png)
Local Failure Rates - Importance

![Graph showing relative failure rates](image-url)
Action

How the circuits fail will determine how they are fixed
Age and Type will also determine actions
Failures by Equipment Type

- **Cable**: 100%
- **Unknown Source**: 80%
- **Accessories**: 60%

Percentage of service failures (%)
Length adjusted MV system
Diagnostic

What diagnostic to use for which actions and equipment
Selection of Diagnostic

• Diagnostic technologies are available that provide either localized or global assessments of circuits.

• These techniques should fit with the actions that will be taken.

• Diagnostic should be sensitive to the prevalent failure mechanism.
Failure by Equipment Type

Percentage of service failures (%)

Cable  Unknown Source  Accessories
Economic Benefit
Data for Economics Calculations

Different data are needed before one can begin to compute the economics for diagnostic programs.

- System
- Diagnostic
Diagnostic Program Costs

Cost [$]

Selection
Diagnostic
Maintenance
Consequence
Total Diagnostic Program Cost
System Data

• Failure Rate
  – Global
  – Local
• Maintenance/Replacement costs
  – repair
  – rejuvenation
  – replacement
• Cost of Poor Reliability
  – Reliability indices
  – Customer, regulator, or media intervention
  – Emergency restoration cost
Diagnostic Data

• Selection
• Testing
  – Diagnostic vendor or equipment
  – Switching crew
• Pilot Study data from testing in other areas
  – Percent of tested population requiring each level of maintenance (i.e. percent of segments that needed to be replaced according to diagnostic)
• Percent of tested segments failing on test
• Accuracy (i.e. how often do segments perform as diagnosed?)
Diagnostic Program Costs

Cost [$]

Selection

Diagnostic

Maintenance

Consequence

Total Diagnostic Program Cost
Population Composition

Max. Benefit

Benefit

“Bad” Circuits [%]

?
Summary

• Selecting the right segments to test is key to achieving good performance from the diagnostic program.

• Selection should focus on failure rates and importance of circuits.
  – System cannot be either “too good” or “too bad”.

• Chosen diagnostic technique should match the system characteristics (i.e. failure mechanism) and possible maintenance actions.

• A diagnostic program requires substantial planning to be effective.