Modeling and Simulation (M&S) Impact on Reliability
Basic Thoughts

Briefing for:

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Emerging data shows that a significant number of US Army systems are failing to demonstrate established reliability requirements during operational testing and many of these are falling well short of their established requirement.

In recent years, there has been an increasing trend within the Department of weapon systems not achieving the required reliability during development testing and subsequently being found unsuitable during Initial Operational Test and Evaluation. Also, higher than anticipated ownership cost points to insufficient reliability engineering activities and logistics planning during the program acquisition phase. This trend indicates that RAM was not adequately designed into systems.
Consider the Use Physics of Failure (PoF) in Materiel Design

The ultimate long term goal is for DoD system developers to consistently predict & design-in reliability at the system and component levels.

Electronic PoF
Proven successful with high Return on Investment

Mechanical PoF
Required for Ultra-reliability required in AAN

Ultra-Reliable System
Increase Reliability
Reduce O&S Costs
Supports RCM
Support CBM+

PoF-Based M&S Analysis Focuses on Fatigue
PoF Design Objective: Identify the fatigue spots on critical components, iteratively modify the design of those components to assure Ultra High Reliability.

Solid Modeling Tool
Examples: Pro/Engineer, I-deas, Solid Works

Dynamics Simulation Tool
Examples: DADS, ADAMS

FEA Tool w/Pre & Post Processor
Examples: NASTRAN, ABAQUS, ANSYS, Pro/Mechanica

Fatigue Analysis Tool
Examples: MSC/Fatigue (N-Code), U.of Iowa DRAW, LMS FALANCS

An integration of these tools
The Focus of Mechanical PoF-based M&S
Predicting early in the design process what testing can not afford to reveal

Reliability testing reveals only a fraction of the failures of the total materiel life cycle

This overlap is where testing can be focused using Mechanical PoF M&S

Mechanical PoF M&S: Main focus is on understanding and predicting wear-out failures throughout the entire materiel life cycle

Mechanical PoF is required to assess life cycle reliability

Main causes of mechanical wear-out:
• Fatigue
• Wear
• Corrosion

Hazard Rate

Time

Failure Curve for Mechanical Equipment

Quality Defects

Wear-out w/ Random Overstress

Testing

Wear-out
The purpose of Reliability Centered Maintenance (RCM) is to formulate Failure Management Strategies that allow assets to continue operating at the users’ desired level of reliability performance as opposed to what the asset was designed to do. The DoD-approved RCM process includes identifying the following items in sequence.

1. Functions
   The desired capability of the system, how well it must perform, and under what circumstances

2. Functional Failures
   The failed state of the system (e.g., the system falls outside the desired performance parameters)

3. Failure Modes
   The specific condition causing a Functional Failure

4. Failure Effects
   The description of what happens when each Failure Mode occurs, detailed enough to correctly evaluate the consequences of the failure

5. Failure Consequences
   The description of how the loss of function caused by the Failure Mode matters (e.g. safety, environmental, mission, or economics)

6. Maintenance Tasks & Intervals
   The description of applicable and effective tasks, if any, performed to predict or prevent failures

7. Other Logical Actions
   Including, but not limited to, run-to-failure, engineering redesigns, and changes/additions to operating procedures or technical manuals

PoF helps in defining maintenance intervals – #6
How can PoF Help RCM
Predicting Failure: On-Condition

On-Condition tasks are performed to identify signs of impending failure and can be performed using:

- Human senses
- Sophisticated monitoring equipment; or
- Continuous monitoring by sensors being applied directly to equipment – **Condition Based Maintenance**

Examples of On-Condition tasks are:

- Performing vibration analysis: detects increased vibration signatures.
- Taking oil samples: Sample results indicate increased water content and additive depletion.
- Measuring brake pads: Identifies how much of the pad is remaining.
- Monitoring # duty cycles endured by key components

The point of an On-Condition task is to identify when action is required **based on the evidence of need** (e.g. detection of the Potential Failure Condition). How often an On-Condition task is performed depends on the **P-F Interval**. Following is a discussion of the P-F Curve and the P-F Interval.

**PoF can help in defining the P-F Interval**
This graph depicts the P-F Curve. The graph below is a typical wear out example such as brake pads. The X axis is “Age”, which can be measured in any number of units such as calendar time, miles, operating hours, cycles, etc. The Y axis is “Resistance to Failure.”

- P is the Potential Failure Condition, defined as evidence of an impending failure.
- F is the Functional Failure, as defined by the user.

Use PoF to define the P-F Curve for Critical Components.
Because of the limitation of sensor sample rates and data storage on in-service vehicles, algorithms and metrics need to be developed that would use simplified counting schemes to compare actual damage cycles on in-service vehicles to pre-calculated damage from various environmental conditions as calculated by PoF failure mechanism models.

**Approach:**
- Categorize mission scenarios (primary, secondary, etc) and run PoF for each
- Initialize damage accumulation model with mission scenario results
- On-board sensors used to determine duration of each scenario
- Transfer sensor data to damage accumulation models
- Damage accumulation models keeps running total % of life is used
- Spare parts ordered and maintenance performed before component failure

Accurately Account for Wear to Check Against the P-F Curve
Use M&S Driven Mechanical PoF
A Helper in Achieving High Reliability

Use M&S driven PoF Design Analysis to:
1) Initially Find the High Reliability Configuration
2) Define RCM P-F Curve to Ascertain When a Critical Component Need to be Replaced
3) Develop Damage Accounting Algorithms for Condition Monitoring of Critical Components

Comments/Questions??