Condition Based Maintenance, the Maintenance Execution Process and the Open Systems Standards

An Overview of Activities at Penn State

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Ed Crow  
814/863-9887

ecc1@psu.edu
## Common, Joint Needs to Transform Enterprise Processes

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>Measures</th>
<th>Needs</th>
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<tbody>
<tr>
<td>-Collect &amp; Share Data</td>
<td>-Effective</td>
<td>Architecture</td>
</tr>
<tr>
<td>-Have Visibility</td>
<td>-Speed</td>
<td>Interoperability</td>
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<tr>
<td>-Work Together</td>
<td>-Time</td>
<td>Technology</td>
</tr>
<tr>
<td>Off a Common</td>
<td>-Safety</td>
<td>Infusion</td>
</tr>
<tr>
<td>Operating Picture</td>
<td>-Cost</td>
<td>Common Standards</td>
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<td></td>
<td>-Mass</td>
<td>Path to Implementation</td>
</tr>
<tr>
<td></td>
<td>-Volume</td>
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<td></td>
<td>-Manpower</td>
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What is Our Involvement Developing and Maturing Logistics and Supportability?

**DEVELOP:**
Sensor Systems that report status and health of combat critical items
Message and IT linkages from tactical units into Global Combat Service Support

**MATURE:**
Pilot buildout of Log Operational Architecture(s)
Championing Open Standards
Standardized Engineering Methodology for Implementation
Further the Metrics & Business Case Analysis

Doing demonstrations to show organizational and technical interfaces, gaps and overlaps, challenges and benefits

**NEED**
Concepts
Products
Solutions
Technologies
Processes
Trials & Evaluation by a Non-Vested Party

**DO TMLPF**
Doctrine
Organization
Training Materiel
Leadership Education
Personnel Facilities

**Acquisition**

**Standards**
Value Added: End-to-End Prototyping from Vehicle to Enterprise

**Data Requirements**
- Situational Awareness & Situational Understanding for Commanders in Mission Planning
- Critical platform data for planning and execution
- Reach as required

**Off-Platform Architecture**
- **5** ERP

**Commonality & Interoperability**
- **4** Interoperability
- **3** Commonality

**On-Platform Architecture**
- **2** Integration
- **1** Synchronize

**GCCS**
- Commanders
- S2
- S3

**GCSS MC**
- S4
- Maintainers
- PM’s

**Common Standards, Specifications, Protocols**
- Synchronize & Reduce redundant efforts
- Establish Configuration Control of Architecture
- Business Process baseline for Autonomic Logistics
- Provide Adaptable Technologies

**Embedded Health Management System**
- Research
- Design
- Develop
- Test
- Implement

**Network Enabled**

**Distributed Processing**

**Sensor Based & Linked**
Apply appropriate sensors (data), analysis (knowledge), and reasoning (interpretation) to provide system level health assessment.

- Detect and isolate component degradation and incipient failure
- Give appropriate alerts to operator, maintainer, log/supply and C2

Platform “Sensors”
the Key Enabler- get data flowing

Earlier Notification Buys Time

Failure Prevention

Normal Operation
Fault Initiation
Functional Failure

Failure Response

Collapse

Prognostics-
Very High Tactical Value

Return to Service

Diagnostics- High Supportability Payoff
Platform Status and Health Reporting Architecture

Knowledge

Data

Knowledge

Platform Status and Health Reporting Architecture

- **Planner / Logistics**
- **Operator / Commander**
- **Diagnostic/Prognostic Unit**

Subsystems:
- **Subsystem Monitor**
- **Engine/Motor**
- **Drive Train**
- **Generator Alternator**
- **Batteries**
- **Fuel, Lube H2O**
- **Ammo**

Sensors:
- **Mobility**
- **Electrical Power**
- **Combat Resources**

Data

Knowledge

- **Diagnostic/Prognostic Unit**

**ARL**
Penn State
USMC Autonomic Logistics Request Management Process

Battalion S4 (RM) — Order Manager (OM) — Command & Control (C2)

Work package for platform fault/failure repair action

Log Status

Parts

Transport

Skills / Tools

Distribution Capacity Manager (DCM)

Inventory Capacity Manager (ICM)

Maintenance Capacity Manager (MCM)

AL Demand Message
Condition-based demand triggered by sensors on platform

Focused & Tailored Response

Automated Demand Flow

Platform

Mobile Contact Team (ME)
Demo- Relation of individual maintenance action to Combat Readiness and Capability

Vibration Management Enhanced Program
US ARMY
Show HEMTT Maintenance Demonstration Here
## Championing Open Standards

### THE SITUATION
- Increasingly DOD acquisition programs are requiring availability, readiness, supportability and life cycle cost
- Response is to ambitiously reaching toward prognostics
- Each is developing a unique data architecture
- Vendors want to protect proprietary solutions

### THE CHALLENGE
- Implement a common architecture framework that:
  - Has a foundation in open standards
  - Approaches the goal of plug and play
  - Allows vendors to protect proprietary solutions

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**ISO-13374** Condition Monitoring and Diagnostics of Machines

**OSA-CBM** Open System Architecture for Condition-Based Maintenance

**OSA-EAI** Open System Architecture-Enterprise Application Integration

[www.mimosa.org](http://www.mimosa.org)
Benefits can either be: increased Ao; decreased life cycle cost or reduced number of assets for same total operational availability.

<table>
<thead>
<tr>
<th>AAV RAM/RS Data (Hours)</th>
<th>W/O Prog</th>
<th>W/Prog</th>
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<tbody>
<tr>
<td>Mean Time Between Failures</td>
<td>64</td>
<td>73.6</td>
</tr>
<tr>
<td>Mean Time To Repair</td>
<td>0.87</td>
<td>0.87</td>
</tr>
<tr>
<td>Mean Logistics Delay Time</td>
<td>5.4</td>
<td>2.7675</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>AAV RAM/RS Calculations</th>
<th>W/O Prog</th>
<th>W/Prog</th>
</tr>
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<tbody>
<tr>
<td>Forecasted Op Availability</td>
<td>91.08%</td>
<td>95.29%</td>
</tr>
<tr>
<td>Increase in Op Avail w/Prog</td>
<td></td>
<td>4.21%</td>
</tr>
<tr>
<td>Increased AAVs Mission Capable w/Prog</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Total LCC Costs per AAV w/Prog</td>
<td></td>
<td>$973,504</td>
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**Operational Availability**

**Opportunity Benefit of Prognostics** $27,890,754
Future Combat Systems

LTA- Common Logistics Operating Environment

HBCT- Vehicle Health Management CBM+

FCS- LDSS, P/SMRS Analysis

TWV- HEMTT, FTTS

Joint ARMY/USMC AL

Sea Basing

Sea Based Sense & Respond Logistics

Ship CBM

ONR S&T

HQ I&L Log Modernization

MCSC GCSS

MCSC Autonomic Logistics, EMSS

MCSC Platforms- LAV, MTVR, Howitzer, HWWMV

KSC, JSC & MSFC

ELog 21
Summary

Motive- Measurable benefit to the platform

Means- becoming part of the formal engineering process

Format- Use of open system standards (OSA)

Framework- Joint requirements

• Engineering of Embedded Diagnostics and Prognostics
• Architecture Design for Logistics/Command-Control Systems
• Full Time Dedicated Science & Engineering Staff
• US Citizens, cleared for DoD
• Established Tech Transfer Processes
“Sensors” at the Platform Level- Batteries

**Health**
- State of Charge (SOC)

**Condition**
- Determination of State
  - State of Charge
  - State of Health
  - State of Life

**Signal**
- Feature determination:
  - signal processing
  - models
  - automated reasoning

**System Monitoring**
- Sensing
- Impedance sensors

**SubSystem Monitoring**
- Determination of State
  - State of Charge
  - State of Health
  - State of Life

**Component Monitoring**
- Targeted Degraders
  - Charge
  - Cold Cranks
  - Cycle life

**Battery Status**
- Battery is healthy
- Battery is healthy, but low charge
- Battery has failed- passivation
- Battery needs battery

**Demand**
- Will need battery

**Log/Supply**
- C2
Battery Graveyard... \( \frac{1}{4} - \frac{1}{3} \) of these are still good...
98% of log load by (lift) weight is supply Subsistence (H2O), Fuel/Lube (fuel) and Ammunition*

Class I, III, IV comprise 85% by volume in OEF and OIF**

Class IX Parts (and batteries) next biggest contributor

Op tempo and variations to mission plan outpaces log ability during combat pulse

Suggests prioritized focus for embedded diagnostics and prognostics:

Consumables: fuel, water, ammo

*Ref: Sea-Based Combat Service Support for Ship to Objective Maneuver Center for Naval *Analysis, CRM 95-144, Sept 1995 ** multiple anecdotal sources
Logistics & Maintenance Transformation Needs a New LogC2 Calculus

SENSE

Interpret Demand

RESPOND

OBJECTIVE

Minutes

“Demand Drives Everything” - the log/C2 systems need to be informed by real-time, accurate demands from platforms in service (autonomic logistics)

Thus log response is highly flexible, rather than highly optimized (global combat support system)