

PENNSTATE



**ARL**

Applied Research Laboratory  
The Pennsylvania State University

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

## **An Overview of Activities at Penn State**

**Defense Maintenance Conference**

**Ed Crow**

**Reno, Nevada October, 2006**

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## Capabilities

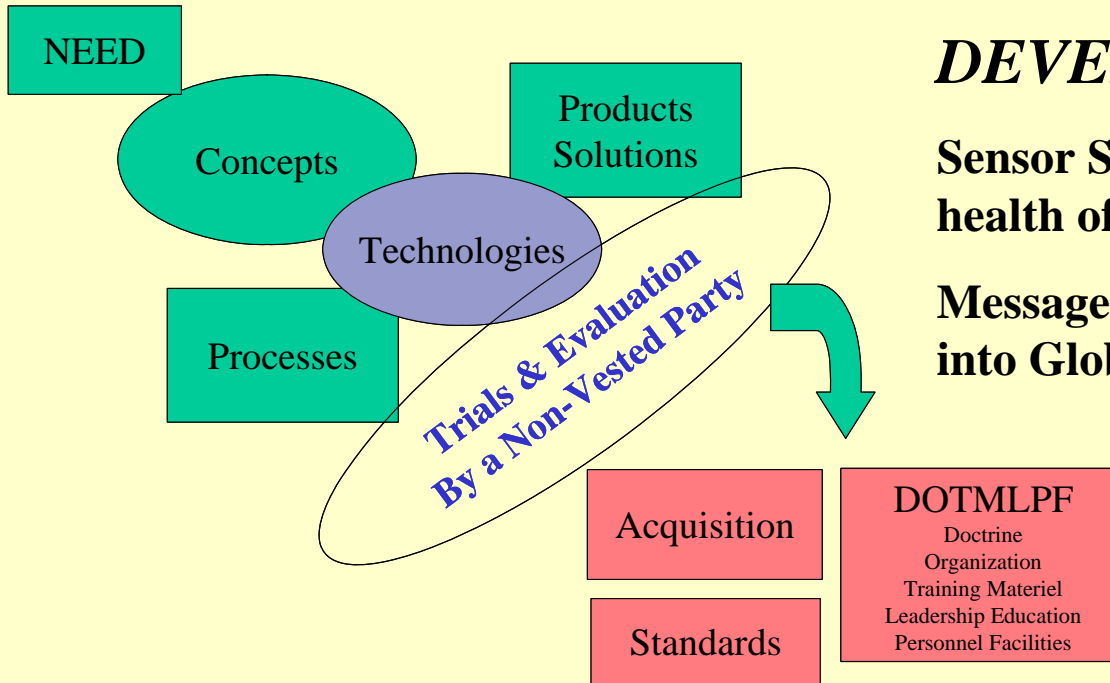
- Collect & Share Data
- Have Visibility
- Work Together Off a Common Operating Picture

## Measures

- Effective
- Speed
- Time
- Safety
- Cost
- Mass
- Volume
- Manpower

## Needs

- Architecture
- Interoperability
- Technology Infusion
- Common Standards
- Path to Implementation



## ***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*

# 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

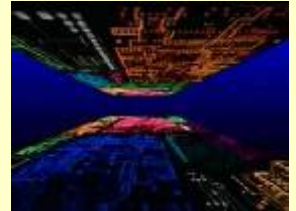
### GCCS

- Commanders
- S2
- S3

### GCSS MC

- S4
- Maintainers
- PM's

*Network Enabled*



## Common Standards, Specifications, Protocols

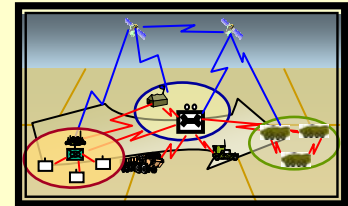
Commonality & Interoperability

**4**  
Interoperability

**3**  
Commonality

- Synchronize & Reduce redundant efforts
- Establish Configuration Control of Architecture
- Business Process baseline for Autonomic Logistics
- Provide Adaptable Technologies

*Distributed Processing*



## Embedded Health Management System

On-Platform Architecture

**2**  
Integration

**1**  
Synchronize

- Research
- Design
- Develop
- Test
- Implement

*Sensor Based & Linked*

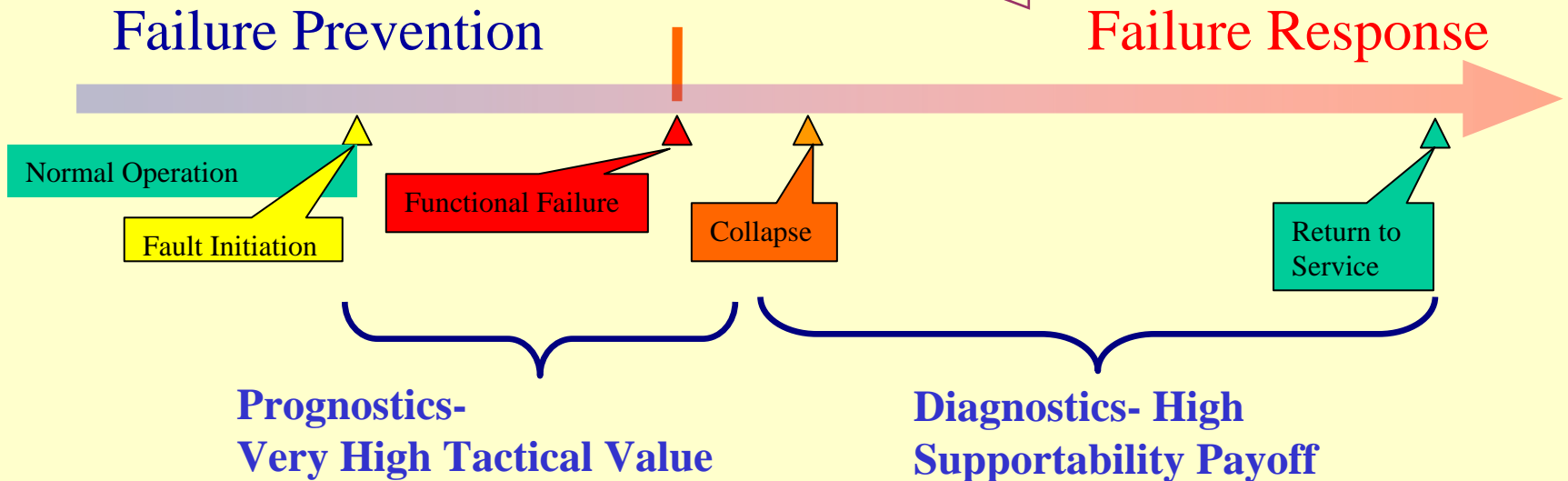


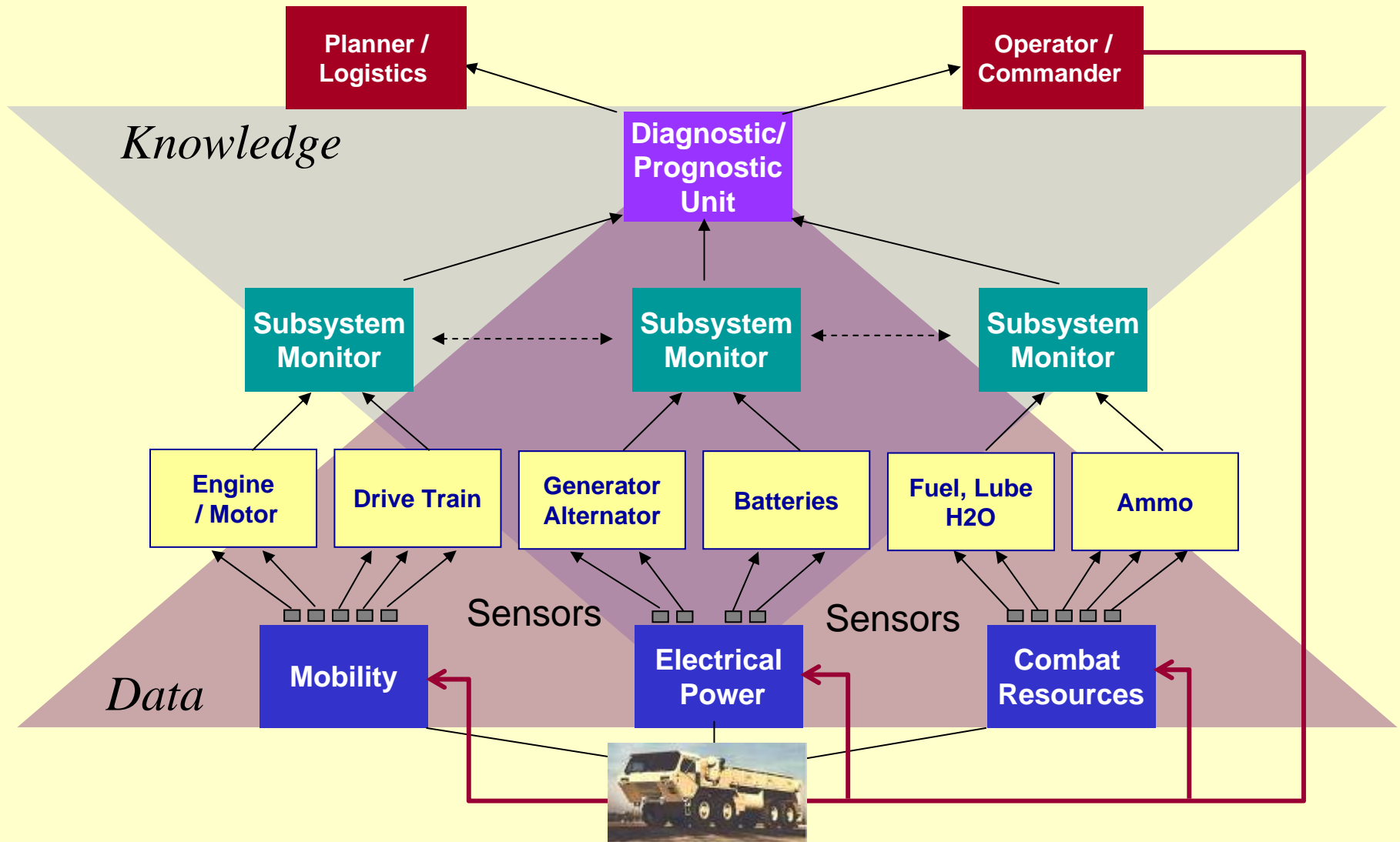
**Apply appropriate sensors (data), analysis (knowledge), and reasoning (interpretation) to provide system level health assessment.**

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

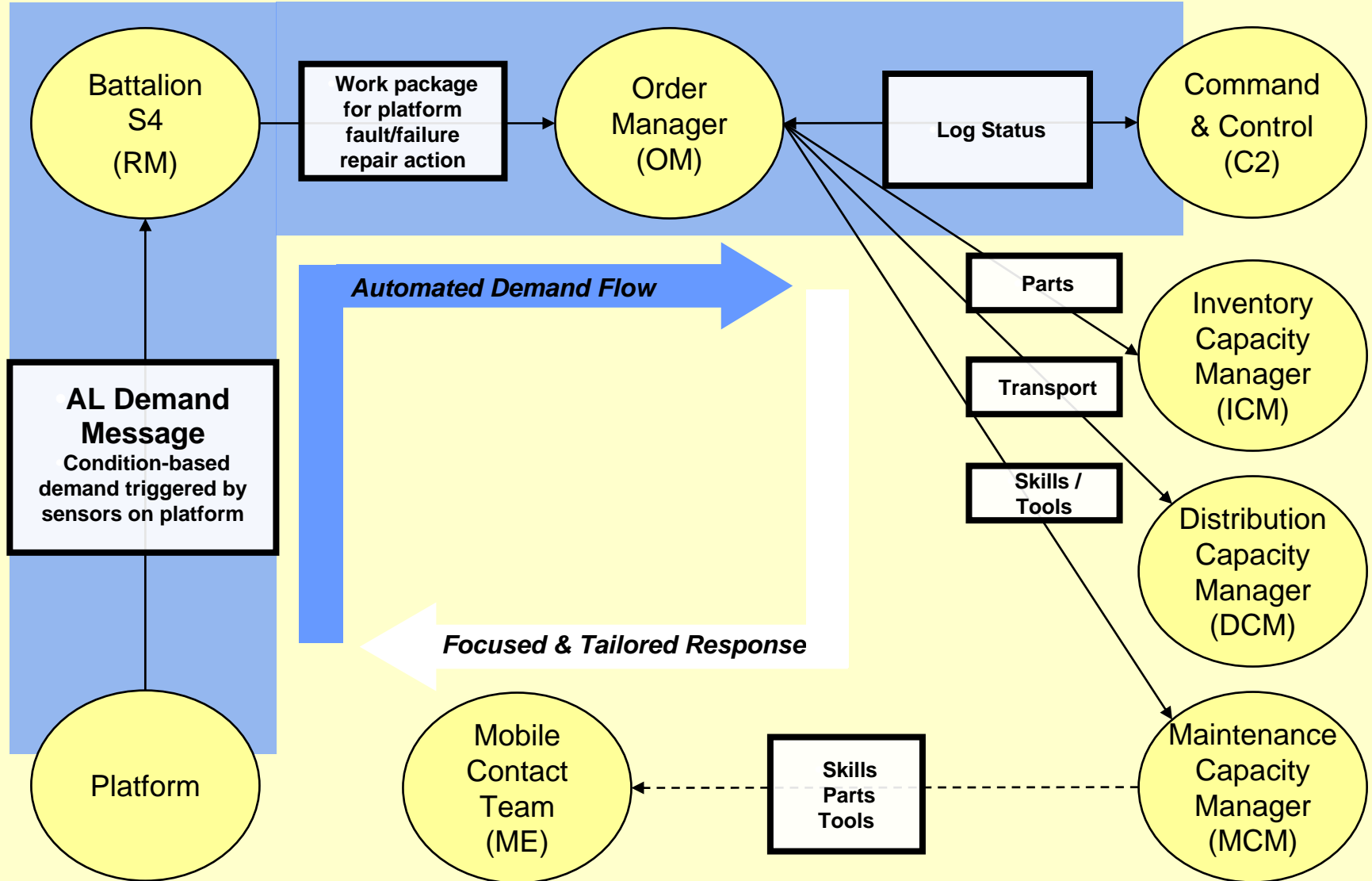


Earlier Notification Buys Time





# USMC Autonomic Logistics Request Management Process



Demo- Relation of individual  
maintenance action to Combat  
Readiness and Capability

Vibration Management Enhanced Program  
US ARMY

Show HEMTT Maintenance  
Demonstration Here

## **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**

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

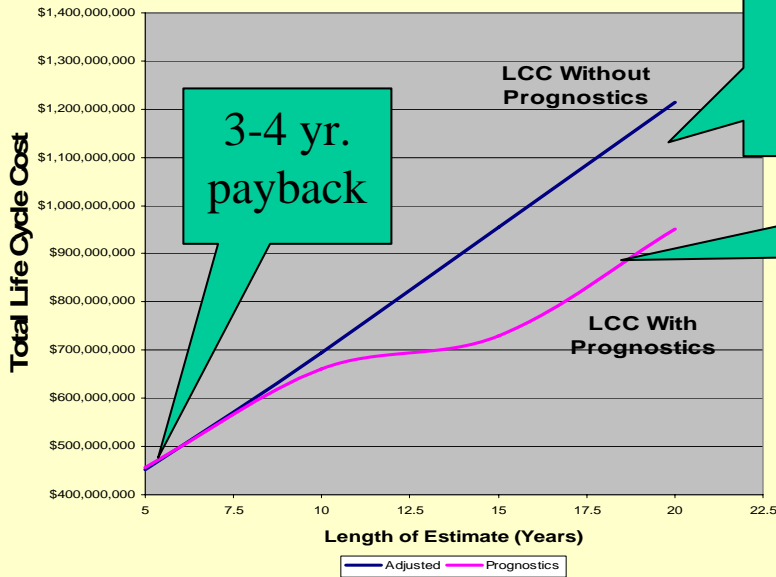
## **THE CHALLENGE**

- **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**

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

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

Prognostics/CBM Effect on LCC



Benefits increase as service life is extended

“s” shape effect due to deferred depot overhauls

Benefits can either be:  
increased Ao;  
decreased life cycle cost  
or reduced number of  
assets for same total  
operational availability

AAV RAM/RS Data (Hours)	W/O Prog	W/Prog
Mean Time Between Failures	64	73.6
Mean Time To Repair	0.87	0.87
Mean Logistics Delay Time	5.4	2.7675

AAV RAM/RS Calculations	W/O Prog	W/Prog
Forecasted Op Availability	91.08%	95.29%
Increase in Op Avail w/Prog		4.21%
Increased AAVs Mission Capable w/Prog		29
Total LCC Costs per AAV w/Prog		\$973,504

<b>Operational Availability</b>		
<b>Opportunity Benefit of Prognostics</b>		<b>\$27,890,754</b>



Future  
Combat  
Systems

Sea  
Basing

HQ I&L Log  
Modernization

ELog 21

LTA- Common Logistics  
Operating Environment

Sea Based  
Sense &  
Respond  
Logistics

MCSC GCSS



HBCT- Vehicle Health  
Management CBM+

MCSC Autonomic  
Logistics, EMSS

KSC, JSC &  
MSFC

FCS- LDSS, P/SMRS  
Analysis

Ship CBM

MCSC  
Platforms- LAV,  
MTVR, Howitzer,  
HWMV

TWV- HEMTT, FTTS

Joint ARMY/USMC AL

ONR S&T

# 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

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**Bob Walter, Head**

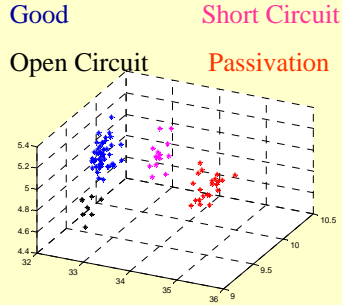
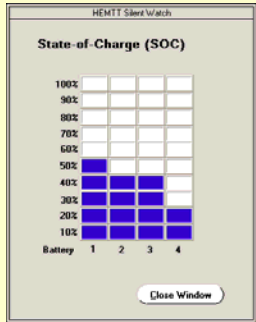
**Enterprise Systems**

**Dept.**

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# "Sensors" at the Platform Level- Batteries

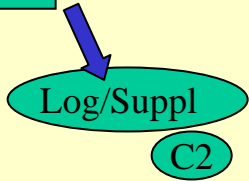


Battery has failed- passivation  
Battery is healthy, but low charge  
Battery is healthy

Need Battery

Demand  
Capability

Will need Battery



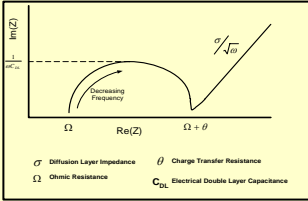
Health

HEMTT Battery Progression System - Saber DATA

Battery	SOC	Conf	SOH	SEV	Conf	Vbattery
1:	83	89	0	0	100	12.22
2:	88	84	0	0	100	12.36
3:	87	91	0	0	100	12.33
4:	54	90	1	6	100	11.18

Close Window

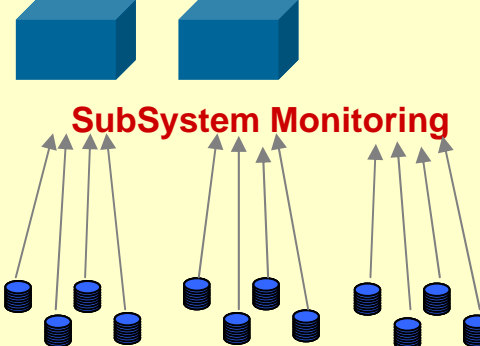
Condition



Signal

System Monitoring

Determination of State  
-State of Charge  
-State of Health  
-State of Life



Feature determination:  
-signal processing  
-models  
-automated reasoning

Sensors  
• impedance sensor

Component Monitoring



Targeted Degraders  
• Charge  
• Cold Cranks  
• Cycle life

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:**

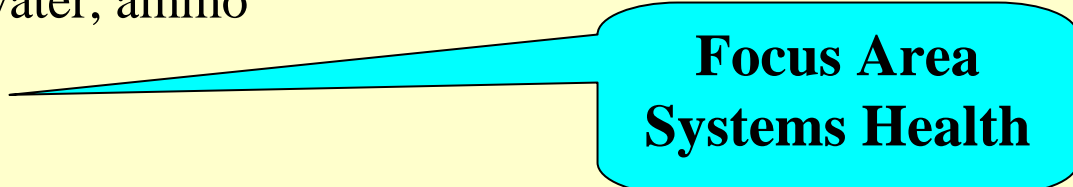
Consumables: fuel, water, ammo

*System Health*

*-failure (diagnostics)*

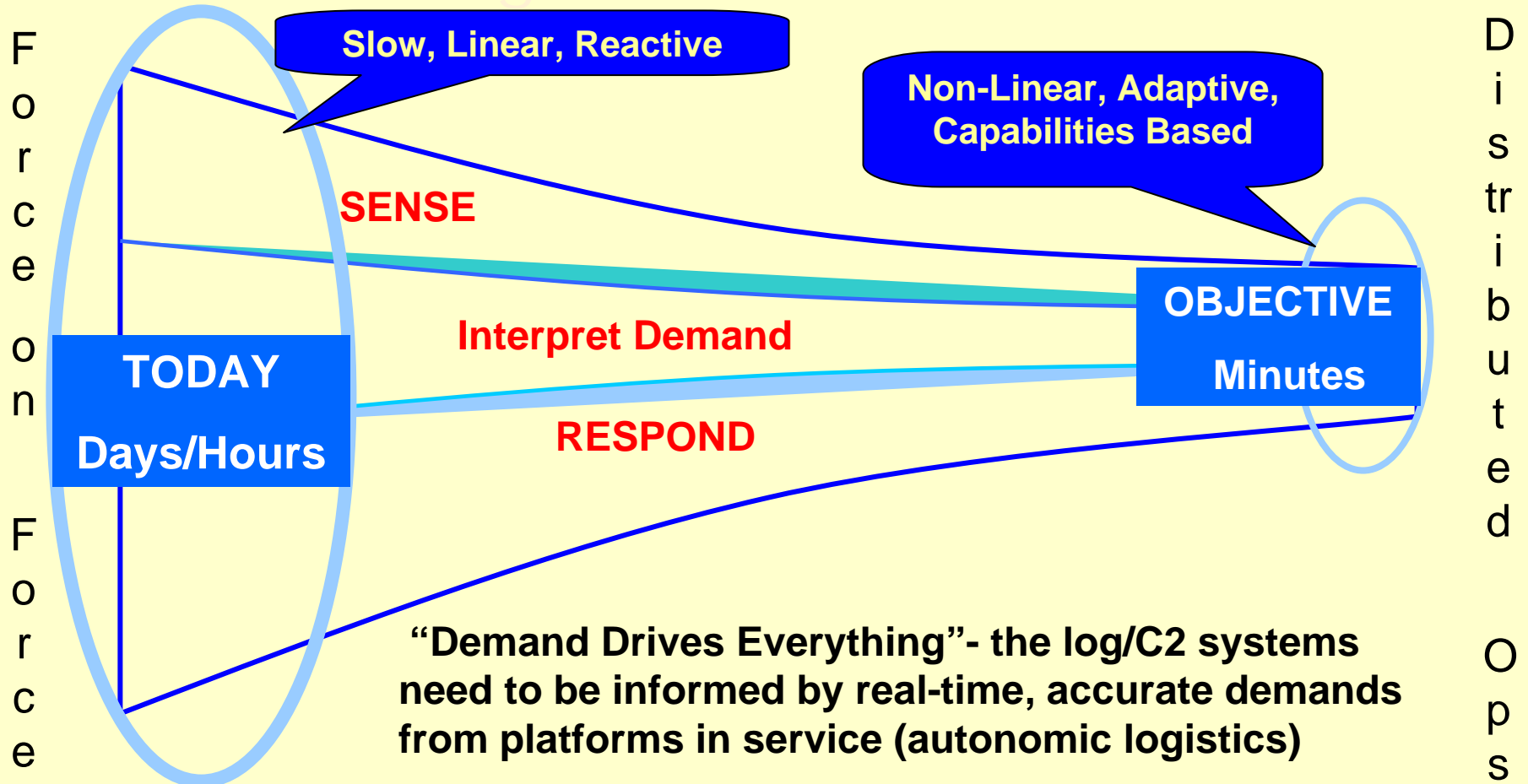
*-fault localization (adv. Diagnostics)*

*-fault initiation and remaining useful life (prognostics)*



**Focus Area  
Systems Health**

# Logistics & Maintenance Transformation Needs a New LogC2 Calculus



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