A Low Cost Embedded Instrumentation (EI) Framework for Vehicle Health Management Systems (VHMS)

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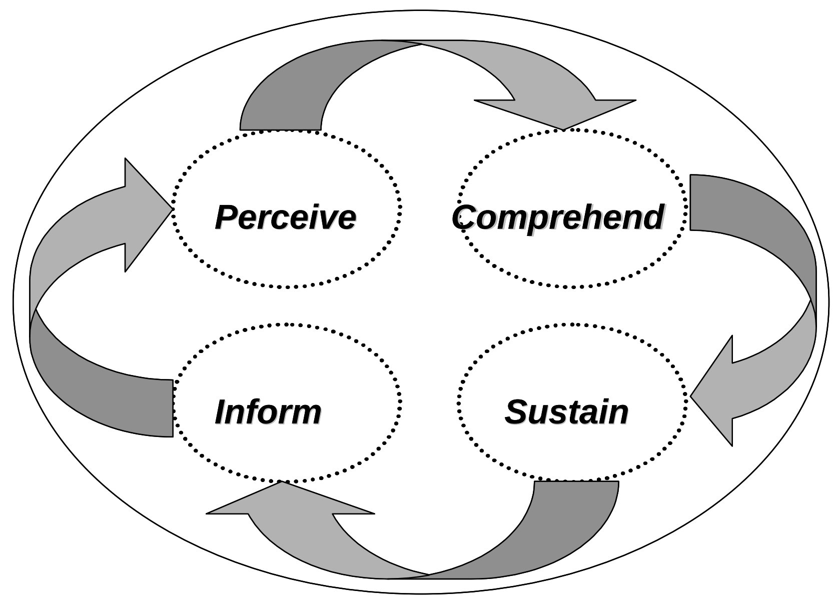


The value proposition

The purpose of using EI for diagnostics and prognostics is to provide an affordable solution with early detection that enables a lower cost pro-active corrective action preempting a higher cost situation.

To be cost effective, any diagnostic and prognostic system must itself Be worthwhile.

Simplistic approaches of adding of a bunch of sensors, and a data acquisition unit adding weight and offloading data to a remote data centers is a very hard sell these programs suffer from high infrastructure costs, long procurement cycles,

A compelling return on investment is a key factor in any EI solution !!

Barriers

Getting EI for CBM, PHM, training etc. into service is a function of cost. Some major cost factors are:

- Weight
- Non-recurring engineering (redesign)
- Wiring, data acquisition units, sensors and hardware
- Millions of lines of software
- Reliability and effects on platform safety
- Ineffective reaction time by off-platform analyses

History of “Smart Wiring”

The Joint Strike Fighter (JSF) contract requirements included use of on-vehicle (embedded) CBM/PHM to increase operational availability, shrink the logistics footprint, and reduce total life cycle costs.

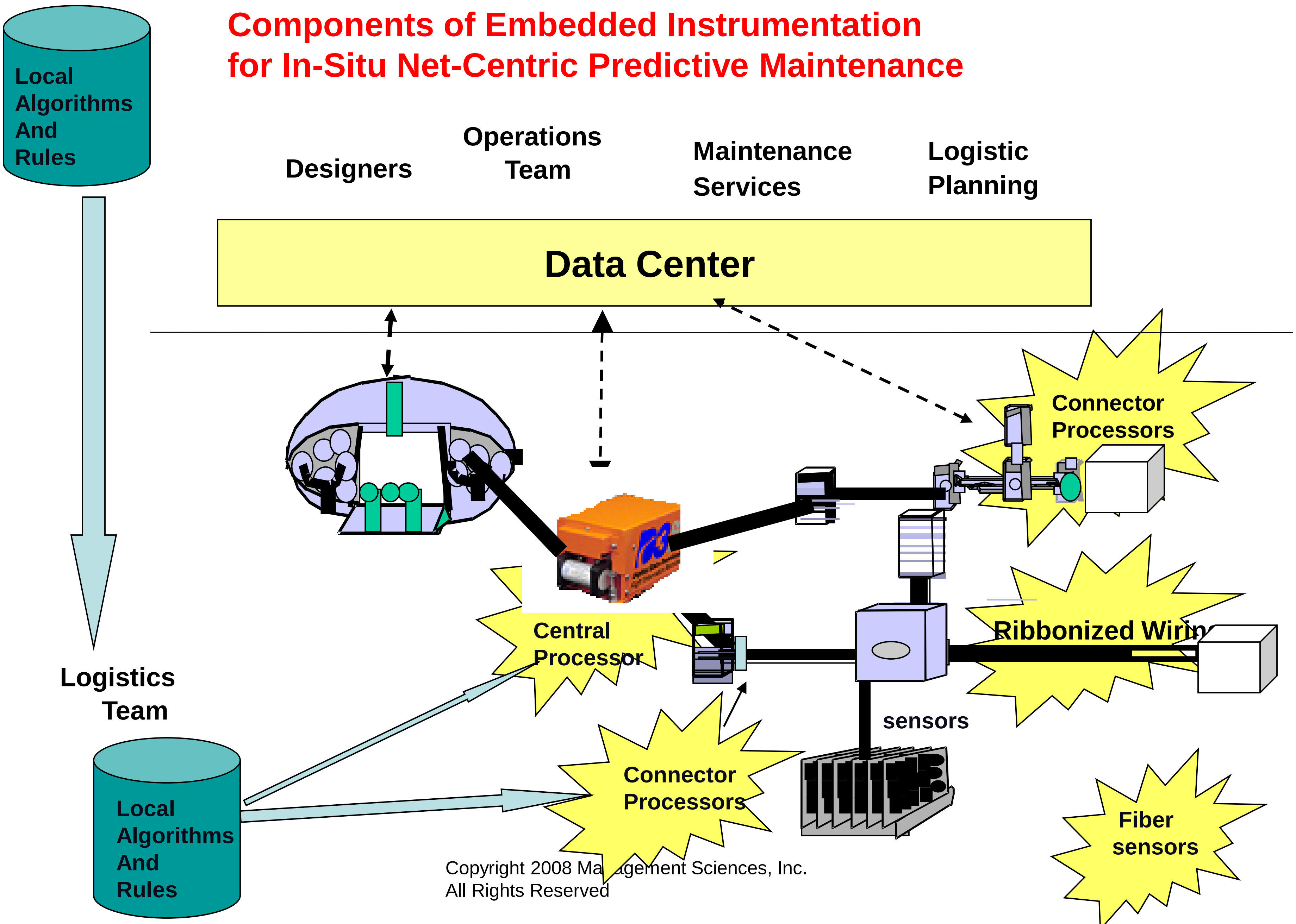
The Smart Wiring project to develop instrumented harnesses for embedded health monitoring was first funded by JSF in a 1997 DARPA program.

Since 1997 funding has been provided by Navy, Air Force and Army programs.

The Concept

- A distributed web of instrumentation is hosted by the existing platform wiring
- Microsystems in connectors perform data collection
- Distributed processors monitor environmental and operational stresses needed to perform structural and other failure physics health/damage assessments.
- Use publish and subscribe network to send data to network centers and respond to queries

Components of Embedded Instrumentation for In-Situ Net-Centric Predictive Maintenance



Benefits of an EI Framework

Less weight: EI implemented with microprocessors can actually reduce weight over larger on-board computers

Less cost:

- Less-Weight = $$$ Fuel savings
- Processors in connectors eliminates costs for changing the design of hundreds of units to facilitate health management.
- Eliminates wiring ambiguity which results in quicker repairs as maintainers would be directed to remove or repair only components requiring service

(Fewer “no fault found” situations reduces logistic costs)

Increased Safety

- Real time assessments can save lives as well as systems

Wiring-Based EI Objectives

Open architecture
Maximum use of COTS components
Plug and play certifiable installation
Reduce need for equipment unique software
Reduce installed weight penalty
Perform distributed processing
Event and baseline monitoring
In mission diagnostics and prognostics
Store backup data
Form sensor webs
Perform networked communication functions
Perform wiring health integrity tests
Reduce fault ambiguity
Interface sensors (e.g. to sense fires, corrosion, fluids, wiring damage

Smart Wiring Systems

Branches for sensors

Embedded Sensors

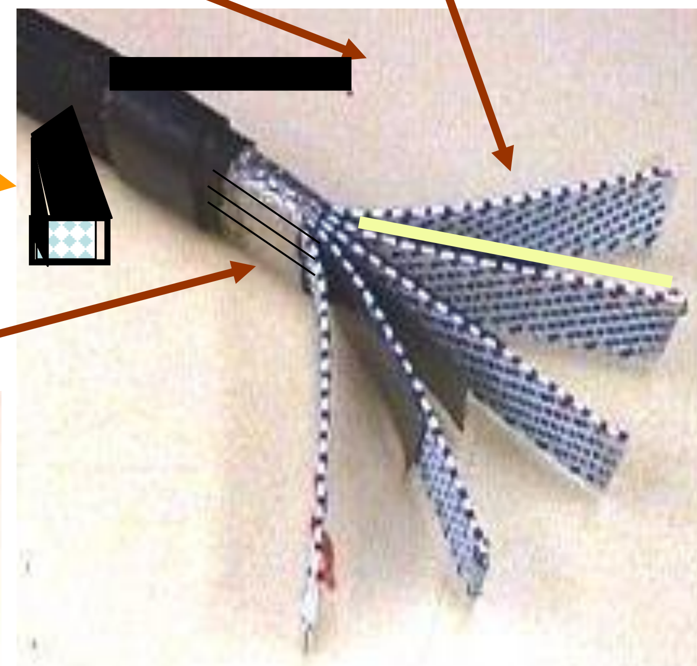
Embedded Data Buss Copper/Fiber Optic

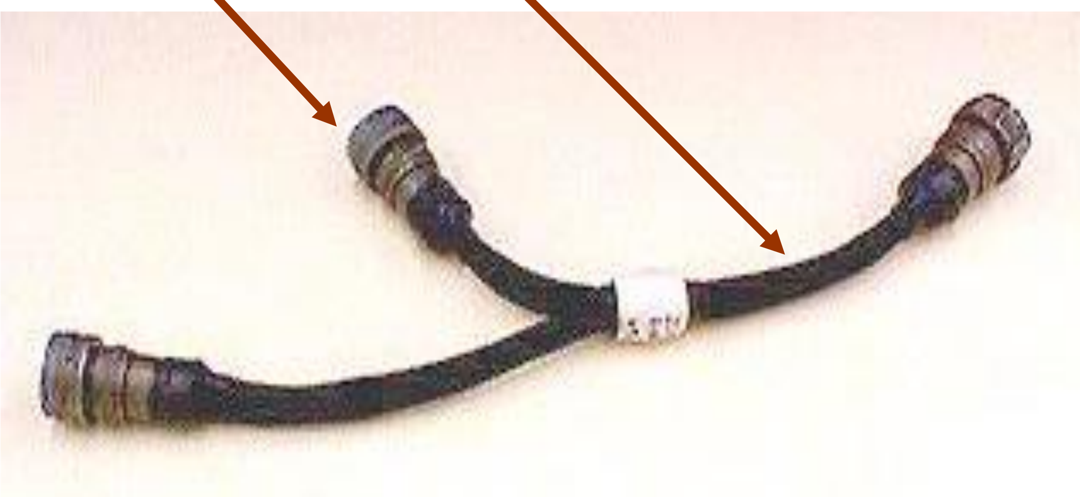
Data Port

Standard Connectors

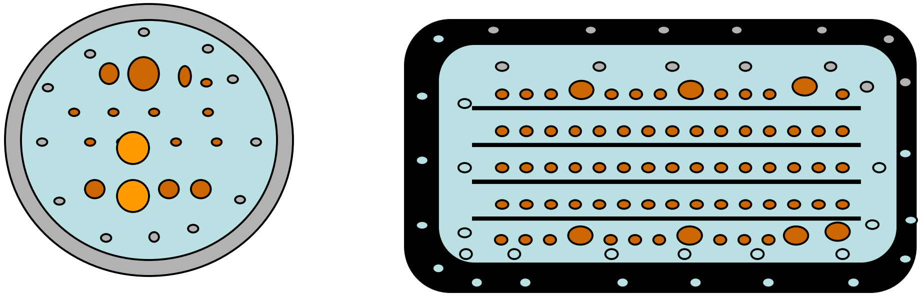
EMI Shielding

Ground Planes





Guardian Sensors



Integral Sensitized Strands and Strips

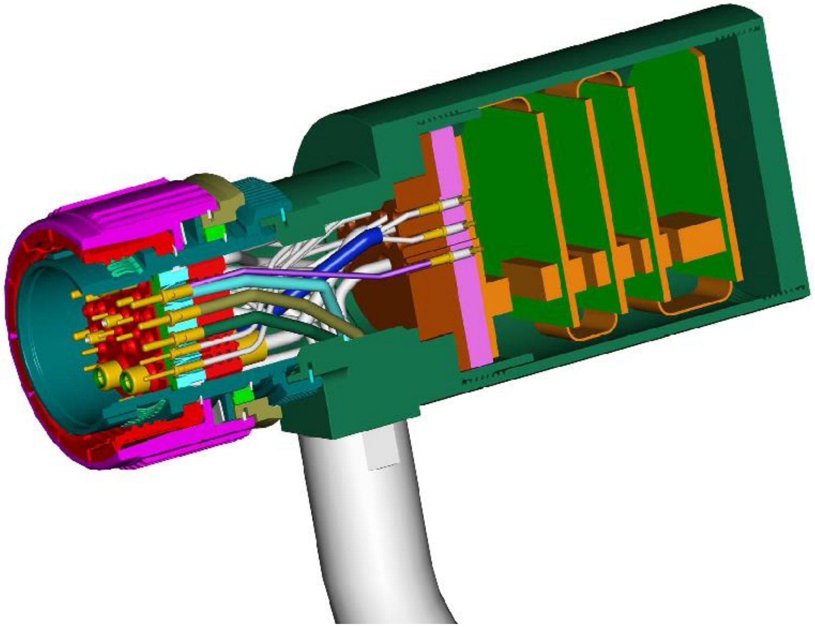
Provide data used to detect and locate points of stress and rate of damage

Due to:

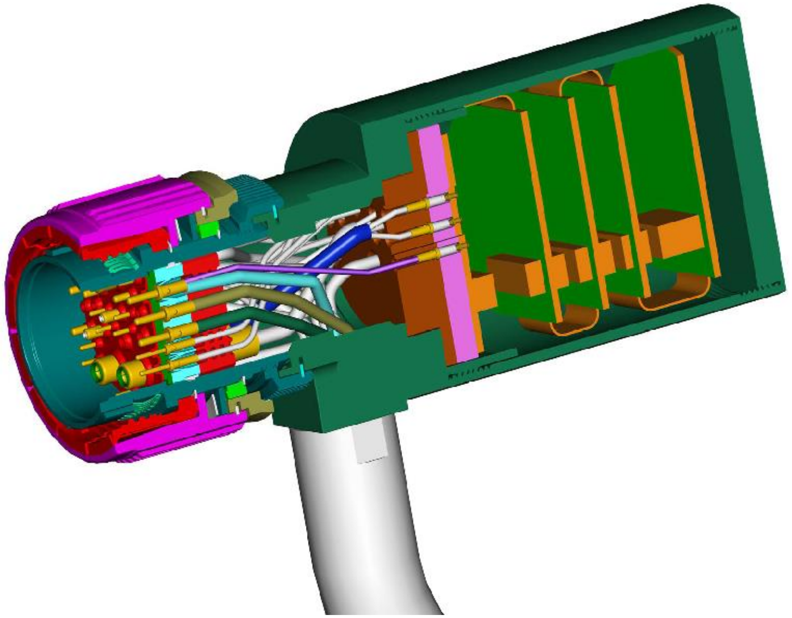
- **incisions**
- **crimping bends,**
- **internal / external heat,**
- **incisions and abrasion,**
- **corrosion,**
- **invasive fluids, etc.**
- **incision**
- **loss of EMI shielding**

Smart Connectors

A specially configured mil-spec wiring connector with an integral circuitry including
- processor,
- gigabits of non volatile memory,
- data acquisition,
- communication and options i.e. control, wiring health monitoring, troubleshooting circuit



Circuits in connector backshell housing
Health monitor signatures of subsystems
Collect sensor and LRU data
Use the rules and agents to fuse data into information
Transmit data packets to subscribers



Example:

Cable with J1760 connector
With chipset in backshell

Embedded Reasoning

Smart Wiring uses of autocoding to construct fast, adaptive and statistically accurate situation specific cognitive algorithms ”on the fly”.

Fast – “just in time” building of situation specific algorithms and models

Adaptive - continuously improves by parameter and model structure learning

Situation specific – changes with context

Statistically accurate – known confidence factors

Cognitive – derives an understanding of causal relationships and future impacts.

Communications

Fault reporting capabilities with connectivity (including network or data centric) capabilities can be readily included in the overall system capabilities and the information is readily accessible within the EI subsystem.

EI For the New Systems

For new systems the concept is to use distributed EPIC located in connectors of wiring harnesses.

This EI concept is being applied to:

- intelligent power management and control in Army vehicles
- data driven condition based tactical vehicle maintenance and troubleshooting
- Data driven diagnostics and prognostics for aircraft health management.

EI For the Legacy Platforms

For legacy platforms like the USMC AV-8B Harrier the concept is to build a replacement of an existing avionics box through the addition of additional sensors and processors. But the embedded processing architecture is a variant of the processing architecture of the distributed EPIC functionality.

This approach is currently a risk reduction effort to add EPIC capability Which is initially applied to ground vehicles to develop an experience base to allow future airborne flight certification in a broad range of platforms.

Conclusions

A system engineered approach is appropriate for maximizing adding of connector and wiring based Embedded Instrumentation into new platforms for integrated vehicle and wiring health management.

Even for legacy platforms this wiring-based EI approach can perform cost effective subsystem diagnostics, prognostics and fault isolation.

Wiring Based EI is Pro-Active

Wiring Based EI Provides Significant weight and life cycle cost reductions