Advanced Infotronics Technologies for
Smart Life Cycle Support

A Closed-Loop Acquisition

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A National Science Foundation (NSF) Industry/University Cooperative
Research Center (I/UCRC)

www.imscenter.net
Trends in Maintenance

Today

- Electronics
- Remote
- On Site

Tomorrow

e
- Digital Transaction
- Internet-Assisted
- Individual Skills

Ref: IBM
Competitive Intelligence

Focus on “Affordability, Survivability, and Sustainability”

Focus on “Smart Service” & Innovative Life Cycle Support.

Focus on “Velocity”

Design → Manufacturing and Supply Systems → Products → After Market

Core Intelligence

Predictability  Producibility  Productivity  Pollution Prevention  Performance
Evolution in Product, Manufacturing, and Quality

**Product Focus**
- **1980**: Intelligent Mechatronics (data & control intelligence)
- **1990**: Product That Thinks and Links (information & computer intelligence)
- **2000**: Products That Learn, Grow, Reconfigure, and Sustain (knowledge & distributed intelligence)
- **2010**: Products That Learn, Grow, Reconfigure, and Sustain (knowledge & distributed intelligence)

**Manufacturing Focus**
- **1980**: Factory Automation (flexibility)
- **1990**: Enterprise Integration (agility)
- **2010**: E-Logistics & E-Manufacturing (velocity)

**Quality Focus**
- **1980**: SPC, TQM, TPM for Manufacturing Process (factory)
- **1990**: Six Sigma For Business Process (enterprise)
- **2010**: Near-Zero-Downtime & Sustainability and Asset Optimization (customers)
The Business Model

Demand

Inventory Capacity

Execution

Predictive Intelligence to Informate Decision

Demand

Inventory Capacity

Execution
Infotronics Technologies intertwine advanced information and electronics systems intelligence and enable autonomous business functions and objectives through the use of internet and other tether-free technologies (i.e. wireless, web,...)
Current Industry Maintenance Practices

- **Reactive** >50-60 %  → Fail & Fix
- **Preventative** >40-50 %  → Routine maintenance
- **Predictive** <5%  → Fix before Fail

“60% of all planned maintenance is unnecessary.”
ARC Advisory Group
Vision

Enhanced Six-Sigma Design

Design for Reliability And Serviceability

Acquisition

Product Redesign

Robust Design

Product or System In Use

Monitoring Sensors & Events

Degradation Watchdog Agent™

Self Maintenance

Redundancy

Active Passive

Communications

• TetherFree (Bluetooth)
• Internet
• TCP/IP

Web-enabled D2B™ Platform

Predictive Performance

• Web-enabled monitoring, Prognostics, and diagnostics
• Agent for Data Mining
• Logistics Integration Tools
• Asset Optimization
• Knowledge Mgt.
IMS Core Technologies

- **Watchdog Agent™** for Predictive Prognostics

- Web-enabled **Smart D2B™ (device to business)** Platform and Tools for Data Transformation, Optimization, and Synchronization

- **Applied Wireless Technologies**

4. **Logistics Infotronics Agent (LIA)**
Need for Prognostics

Degradation Process

Signal Processing

Sensors

Monitoring

MODEL

Prognostics

Assessment

Watchdog

Need On-Site Experts

Remote Experts
Watchdog Agent

WATCHDOG AGENT
(Prognostics on a chip)

BEHAVIORAL LEARNING

PERFORMANCE ASSESSMENT

MEASURE CONFIDENCE VALUE (CV) AT t1, t2, t3, ...

IF CV(t1) > CV(t2) > CV(t3) > ...

IF CV(t) < CV(threshold)

DEGRADATION

REMOTE DIAGNOSTIC

PREVENTIVE MAINTENANCE

REMOTE SERVICES

MACHINE

SENSOR

EXTERNAL SENSOR

HUMAN OBSERVER

TCP/IP - WIRELESS

REMOTE MAINTENANCE

MAINTENANCE MANAGEMENT

EMBEDDED STATISTICAL PROCESS CONTROL (SPC)
Correlation of multiple signals into Performance Prediction - CV

Sensor signals

Time & Frequency Domain

Time-Frequency Moments

Confidence Value - CV

Mahalanobis Distances

Principal Components
## Performance Index Model Based Prognostic Approach

### Step 1: Performance index modeling
- Using history data:
  - Normal data
  - Failure data
- Probability of failure:
  \[ \Pr[I|x] = f_1(x) \]
- Using parameters fixed after each maintenance:
  - Beginning setting
  - Acceptable level
- Confidence:
  \[ C(x) = f_2(x) \]

### Step 2: Current performance calculation
- Current inputs \( x \)
- Current probability \( \Pr[1|x] \)
- Confidence \( C(x) \)

### Step 3: Degradation tendency prediction
- Determine model structure of probability or confidence curve
- \[ y(k) = \phi_1 y(k-1) + \cdots + \phi_p y(k-p) + \epsilon(k) - \theta_1 \epsilon(k-1) - \cdots - \theta_q \epsilon(k-q) \]
- With Box-Jenkins method
- On-line parameters \( (\theta, \phi) \)
- Identification, then predict
- Failure Line
- Predict failure probability or confidence continuously
Mean Time Between Degradation

\[ \text{MTBD} = \int_0^\infty t \cdot P(t) \, dt \]
Example
Hybrid Prognostics and Diagnostics

Virtual Instruments

Hashing

Degradation (Prognostics)

Product Nervous Systems

Performance Measure

Look up tables

when

Performance Status
When degradation occur

signal for degradation

Production System/Machine

Fusion

Neural Network
Genetic Algorithm
Statistic Computing
Fuzzy Logic.....

Diagnostics

Internet

Diagnostics + Prognostics

where
what
why

identify reasons
### Similarity Matrix for Performance Comparison

#### MACHINE 2

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Simulation of Throughput Response Surface Between Parameters

Sensitivity

Degradation of (X1 & X2)
Watchdog Toolbox

CMAC Learning Method

Joint T-F Method

Hybrid Techniques

Applied Statistical Methods
D2B™ Platform

Embedded Monitoring

Prediction & Performance Assessment

Data/Information Transformation

Optimization

Synchronization

Web

e-Business, e-Manufacturing, e-Service Automation

Optimization of Production, Delivery, Maintenance, Human Resources, Logistics Systems etc.

Real Time Decision/Synchronization

Transformation into KNOWLEDGE

DATA/INFORMATION Device/Factory Level
Applied Wireless Issues

- Communication Network
  - Wireline vs. Wireless
  - Performance - Throughput vs. Latency
  - Reliability - Control vs. Monitoring
  - Cost - ISM Band
- Wireless Technologies
  - IEEE 802.11
  - Bluetooth (IEEE 802.15)
  - Proprietary

Radio Propagation Issue

Prof. Ivan Howitt, EE UWM
Tether-Free Embedded Infotronics Agent

HiDRA™ from Rockwell Scientifics

HiDRA™ from Rockwell Scientifics
Remote Monitoring and Prognostics of Defenses Equipment

For short distance transmission:
- 802.11
- Bluetooth
- etc.

Cellular phones or GPS for long range transmission

Alarms
Prognostics
Remote diagnostics
Service Dispatching
Synchronization

Michigan Engineering

UNIVERSITY of WISCONSIN

UW MILWAUKEE
Logistics Infotronics Agent (LIA)

1. Initial product info is written in the product embedded device.

2. Wireless bluetooth connection between mobile device and product embedded device.

3. Wireless Internet connection between mobile device and producer's product life cycle system.


5. Design Innovation through life cycle intelligence.
Logistics Infotronics Agent

(LI A)
Final Product Assembly and Testing
Supplier 1 e-Shops
Supplier 2 e-Shops
Supplier N e-Shops

Customer Needs
Enterprise Database Mgt System (EDMS) (design, manufacturing, suppliers, testing, etc)
Life Cycle Service & Maintenance (LCSM)

Product, Process, and Enterprise Design (PPED)
e-Procurement
Supplier Evaluation & Selection
Decision
Sourcing

Today’s Acquisition and Logistics Systems
Manufacturing Enterprise Execution System (MEES)
Customer Needs

Enterprise Database Mgt System (EDMS)
ADDRESS DESIGN (DFSS)

Product, Process, and Enterprise Design (PPED)

Logistics Infotronics Agent (LIA)

Prediction, Validation & Optimization

Supplier 1 e-Shops

Supplier 2 e-Shops

Supplier n e-Shops

Final Product Assembly and Testing

Data Accessibility & Monitoring

Supplier Quality

Sourcing

Life Cycle Service & Maintenance (LCSM)

Tether-free Interface

Manufacturing Enterprise Execution System (MEES)

Tether-free Interface
Current Members and Sponsors

- Rockwell Automation
- Ford Motor
- GM
- Johnson Controls
- Eaton
- Harley-Davidson
- Xerox
- Wisconsin Electric Power
- United Technologies
- Siebel Systems
- GE Medical Systems
- Toshiba (Japan)
- A.O. Smith
- Intel
- U.S. Postal Services
- National Instruments
- ITRI
- PMC
- Kone Elevator
- API
- Genex Technologies
- ATOP
- Dr. Machine.Com
- Hitachi Seikei
- Velicon
- Eagle Technologies
- Industrial Objects
- InterNext Group
- Citation Custom Products
- DaimlerChrysler
- Lantronix
- Micro Mobio Wireless
- Cognex
- Boeing
- DoD DMSO
- Motorola
- ABB
- Caterpillar
- SEMATECH
Value through Leveraged Partnerships
Why IMS?

Fail and Fix or Fly and Fix

FaF → IMS Methodologies

Predict and Prevent

PaP

Risk Reduction, Technology Readiness, and New Breed of Engineers and Workforce

IMS Testbeds (e-Maintenance/e-Manufacturing/e-Logistics Integration)

Partnerships
Thank You

For More Information

www.imscenter.net