Advanced Infotronics Technologies for Smart Life Cycle Support

A Closed-Loop Acquisition

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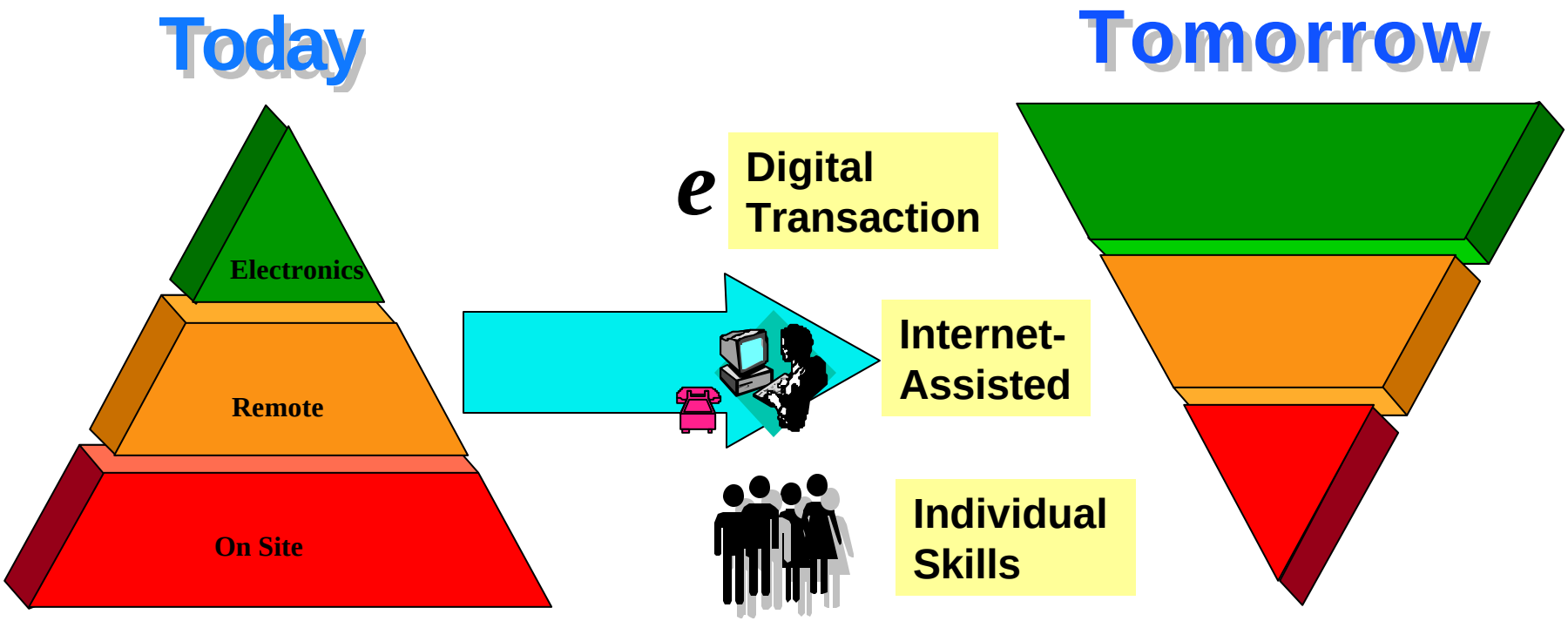
Intelligent Maintenance Systems (IMS)

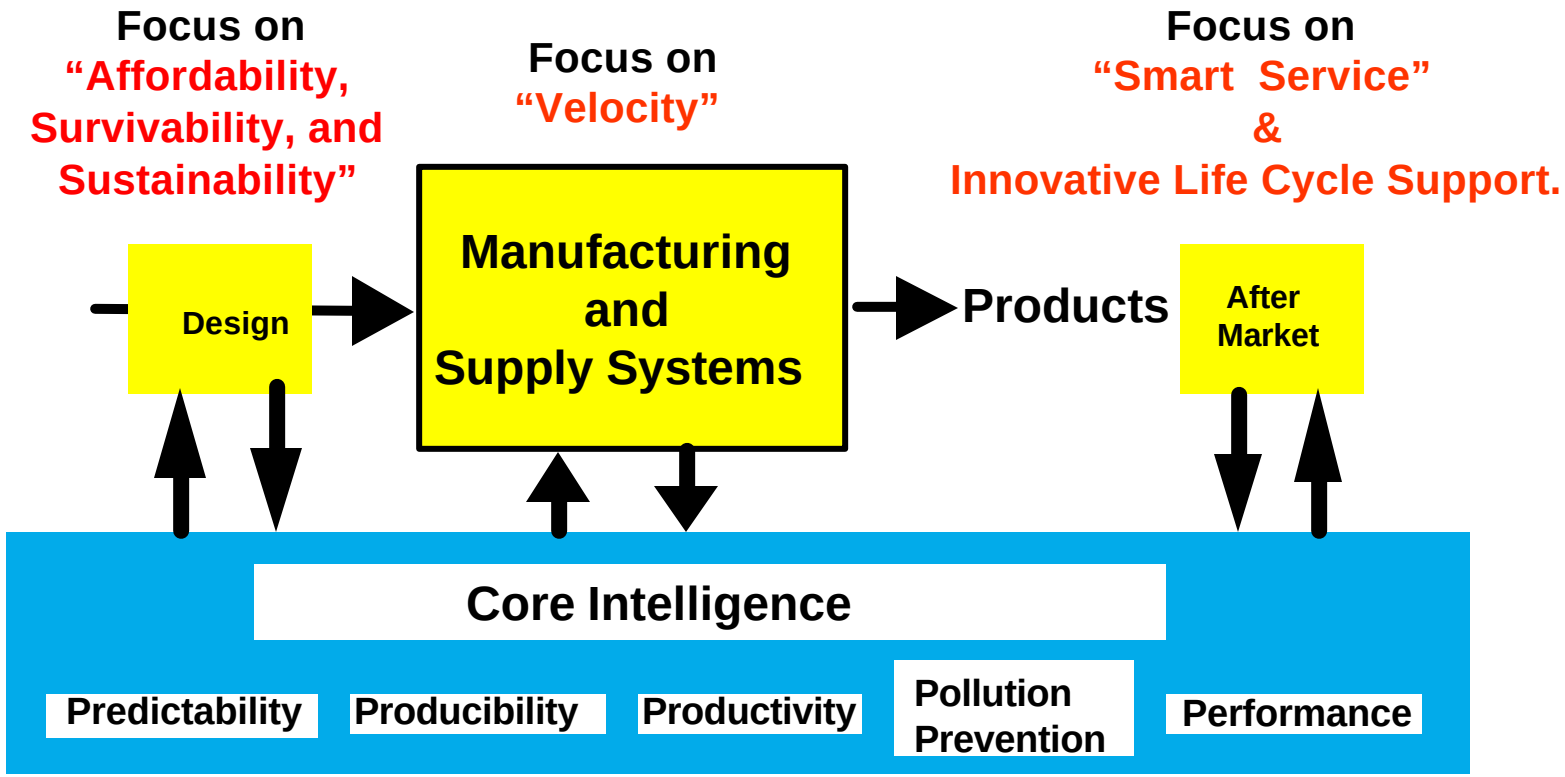
A National Science Foundation (NSF) Industry/University Cooperative Research Center (I/UCRC)

Trends in Maintenance



Ref: IBM

Competitive Intelligence



Evolution in Product, Manufacturing, and Quality

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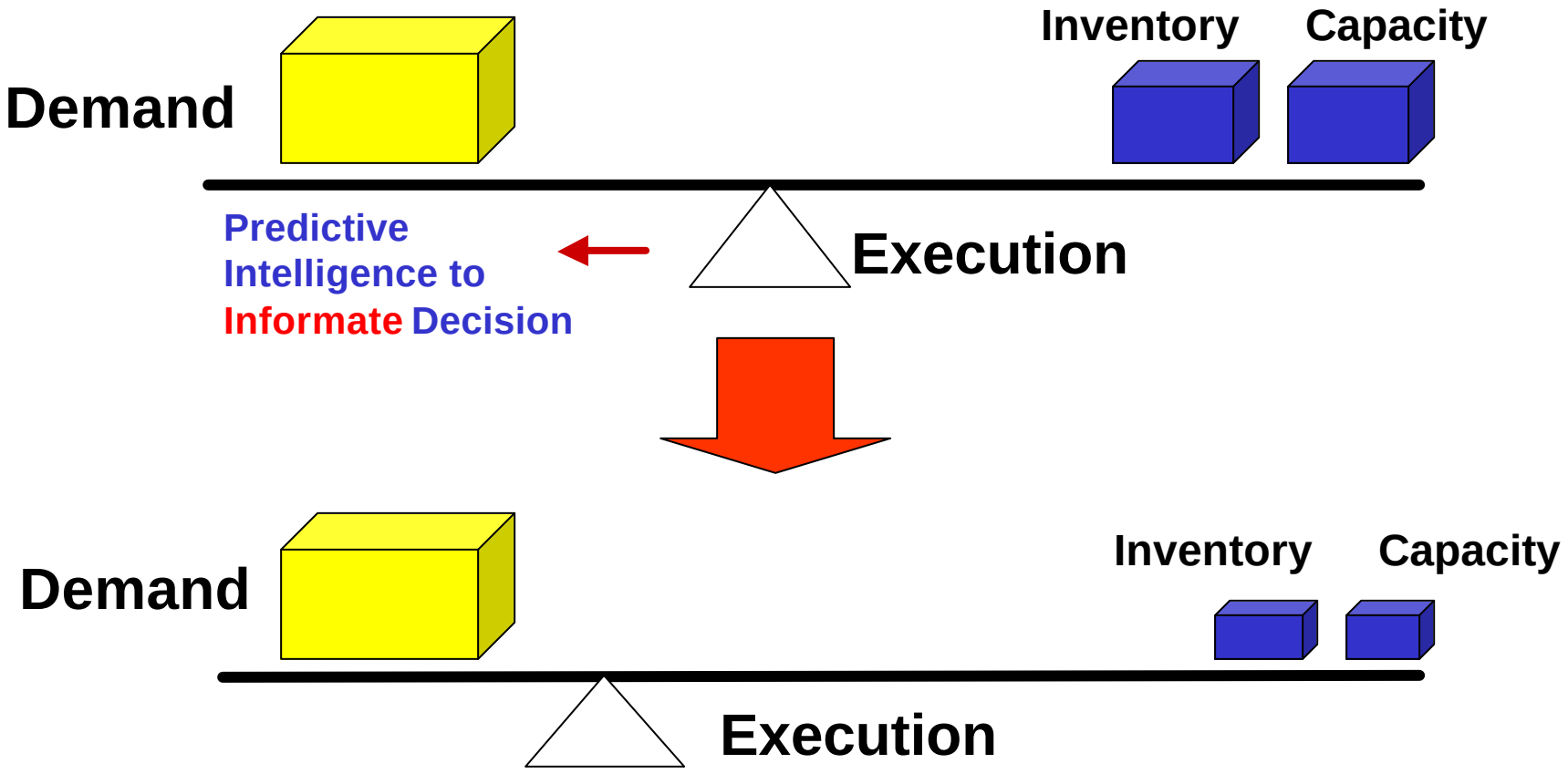
	1980	1990	2000	→ 2010
Product Focus	Intelligent Mechatronics *(data & control intelligence)*	Product That Thinks and Links *(information & computer intelligence)*		Products That Learn, Grow, Reconfigure, and Sustain *(knowledge & distributed Intelligence)*
Manufacturing Focus	Factory Automation *(flexibility)*	Enterprise Integration *(agility)*		E-Logistics & E-Manufacturing *(velocity)*
Quality Focus	SPC, TQM, TPM for Manufacturing Process *(factory)*	Six-Sigma For Business Process *(enterprise)*		Near-Zero-Downtime & Sustainability and Asset Optimization *(customers)*

The Business Model



Infotronics Technologies ?

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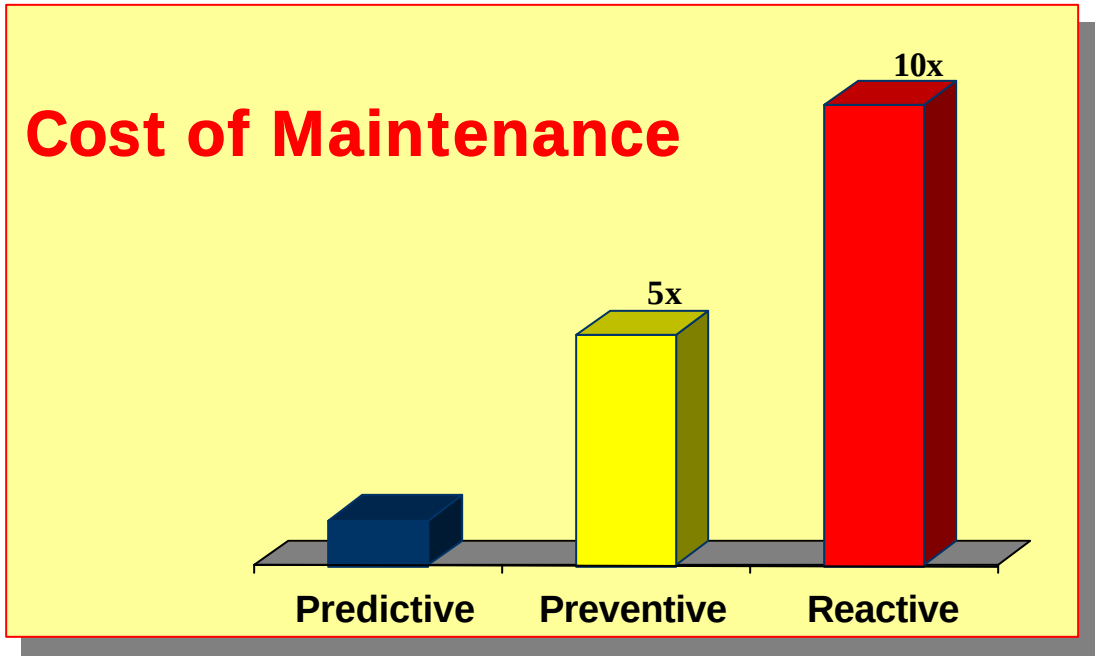
Infotronics Technologies **intertwine advanced information and electronics systems intelligence and enable autonomous business functions and objectives through the use of internet and other tether-free technologies (i.e. wireless, web,…)**

Current Industry Maintenance Practices

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



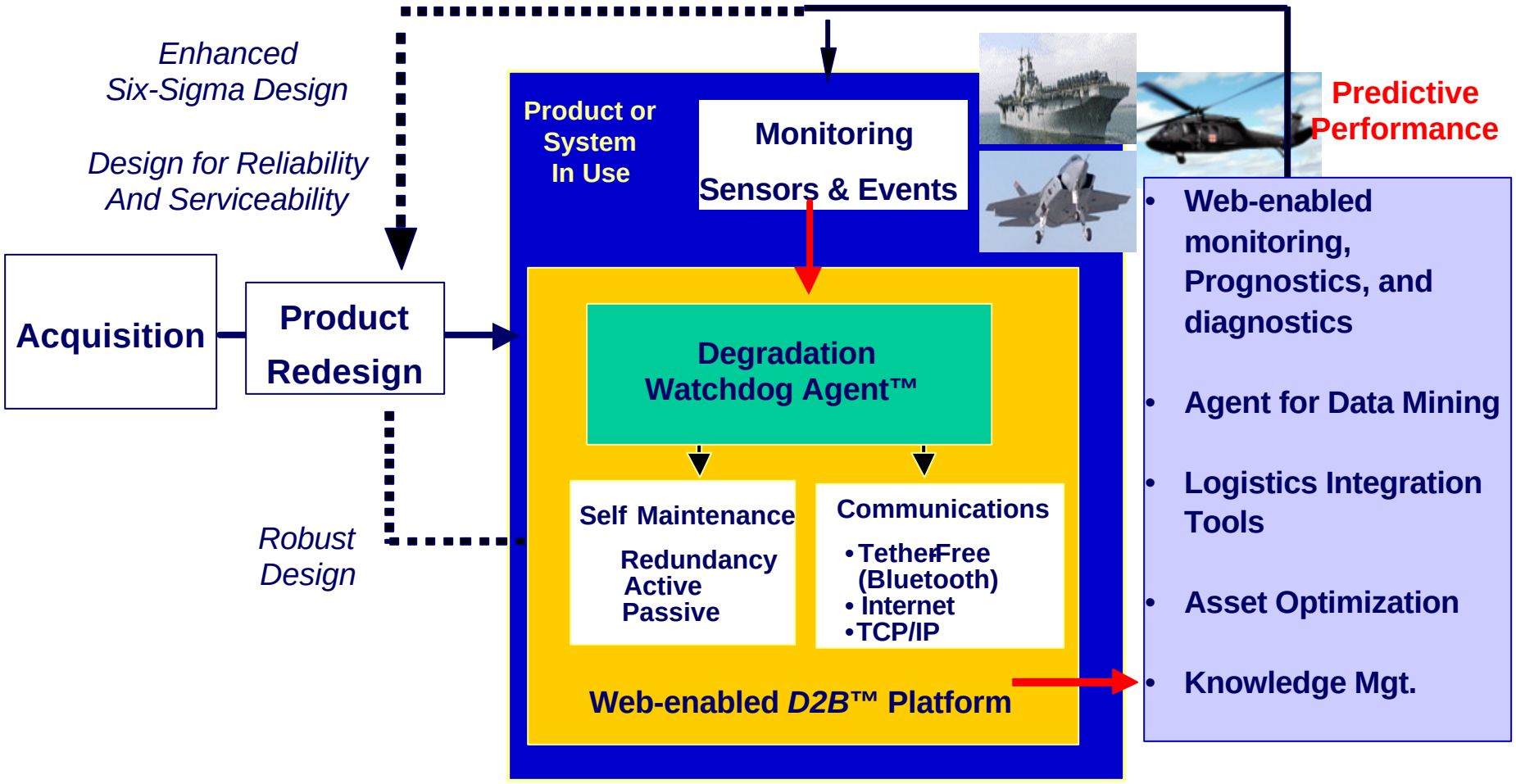
" 60 %

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
• Tether-Free
(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

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- ***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)

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Need for Prognostics

Degradation Process

?

Signal Processing

Need On-Site Experts

Diagnostics

Sensors

Monitoring

?

MODEL

?

Watchdog

Prognostics

Assessment

Remote Experts

Action

Watchdog Agent

Controller

Machine

Actuators

Sensor

External Sensor

Human Observer

TCP/IP - Wireless

WATCHDOG AGENT

(Prognostics on a chip)

BEHAVIORAL LEARNING

PERFORMANCE ASSESSMENT

HASHING

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

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

IF CV(t) < CV(threshold)

Watchdog IMS

Degradation

X

R

EMBEDDED STATISTICAL PROCESS CONTROL(SPC)

Maintenance Management

Remote Diagnostic

Preventive Maintenanc

Remote Services

Intranet/Internet

Correlation of multiple signals into Performance Prediction- CV

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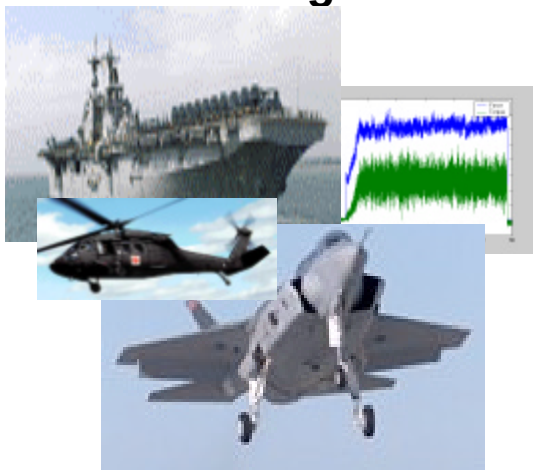
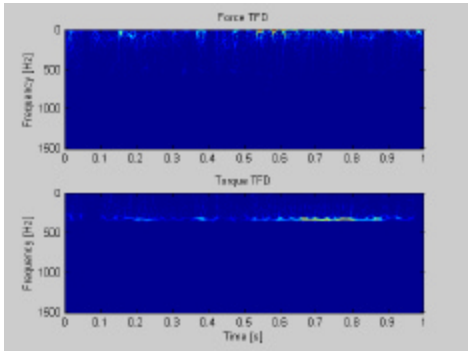
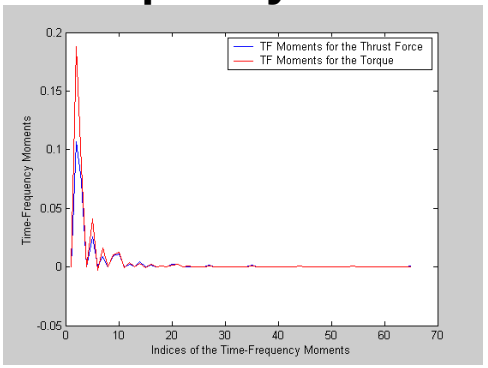
Sensor signals



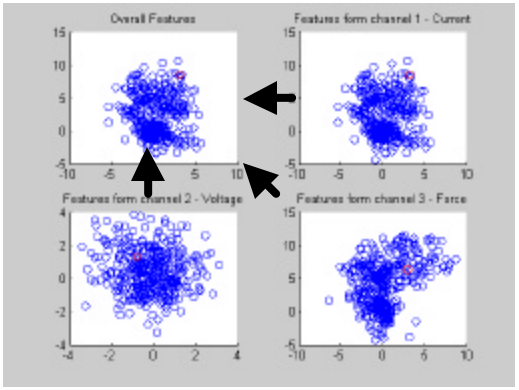
Time & Frequency Domain



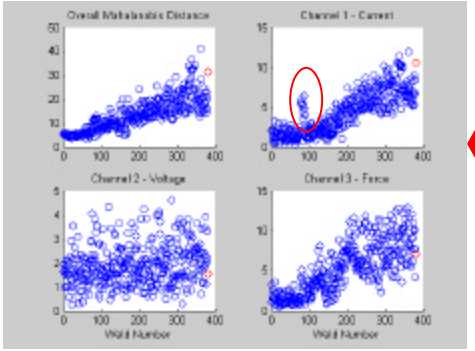
Time-Frequency Moments



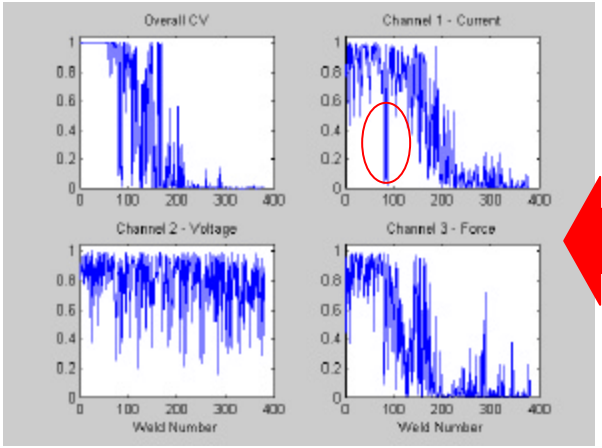
Principal Components



Mahalanobis Distances



Confidence Value- CV



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Performance Index Model Based Prognostic Approach

Step 1: Performance index modeling

Using history data:

Normal data + Failure data

⇩

Probability of failure:

$$\Pr\{1|\vec{\mathbf{x}}\} = f_1(\vec{\mathbf{x}})$$

Using parameters fixed after each maintenance:

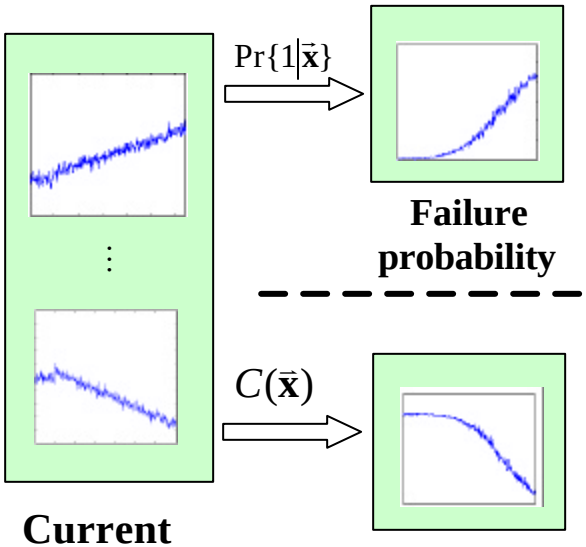
Beginning setting + Acceptable level

⇩

Confidence:

$$C(\vec{\mathbf{x}}) = f_2(\vec{\mathbf{x}})$$

Step 2: Current performance calculation



Step3: Degradation tendency prediction

Determine model structure of probability or confidence curve

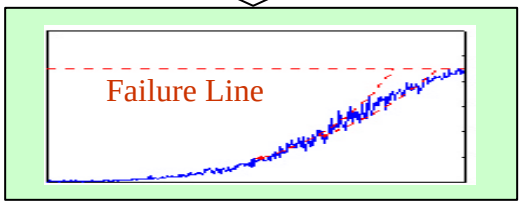
$$y(k) = f_1 y(k-1) + \cdots + f_p y(k-p) + e(k) - q_1 e(k-1) - \cdots - q_q e(k-q)$$

With Box-Jenkins method

⇩

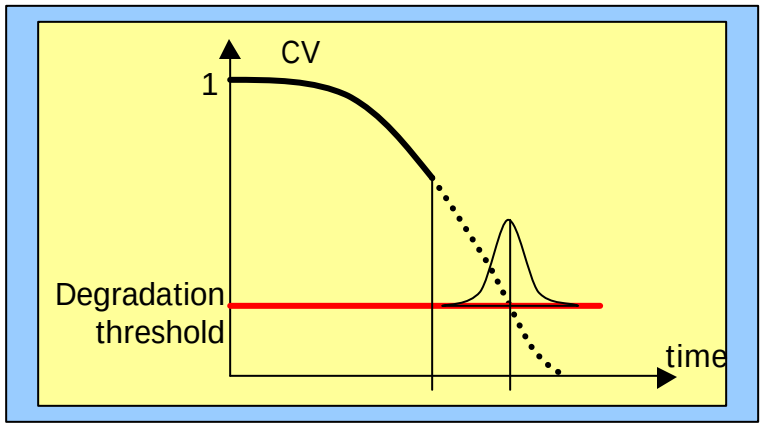
On-line parameters (q_i, f_i) identification, then predict

⇩

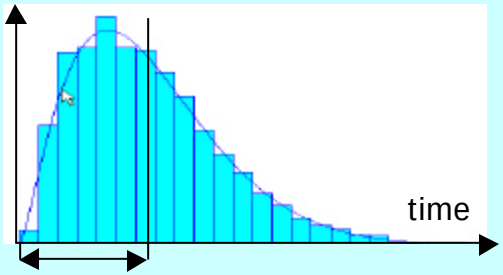


Predict failure probability or confidence continuously

Mean Time Between Degradation



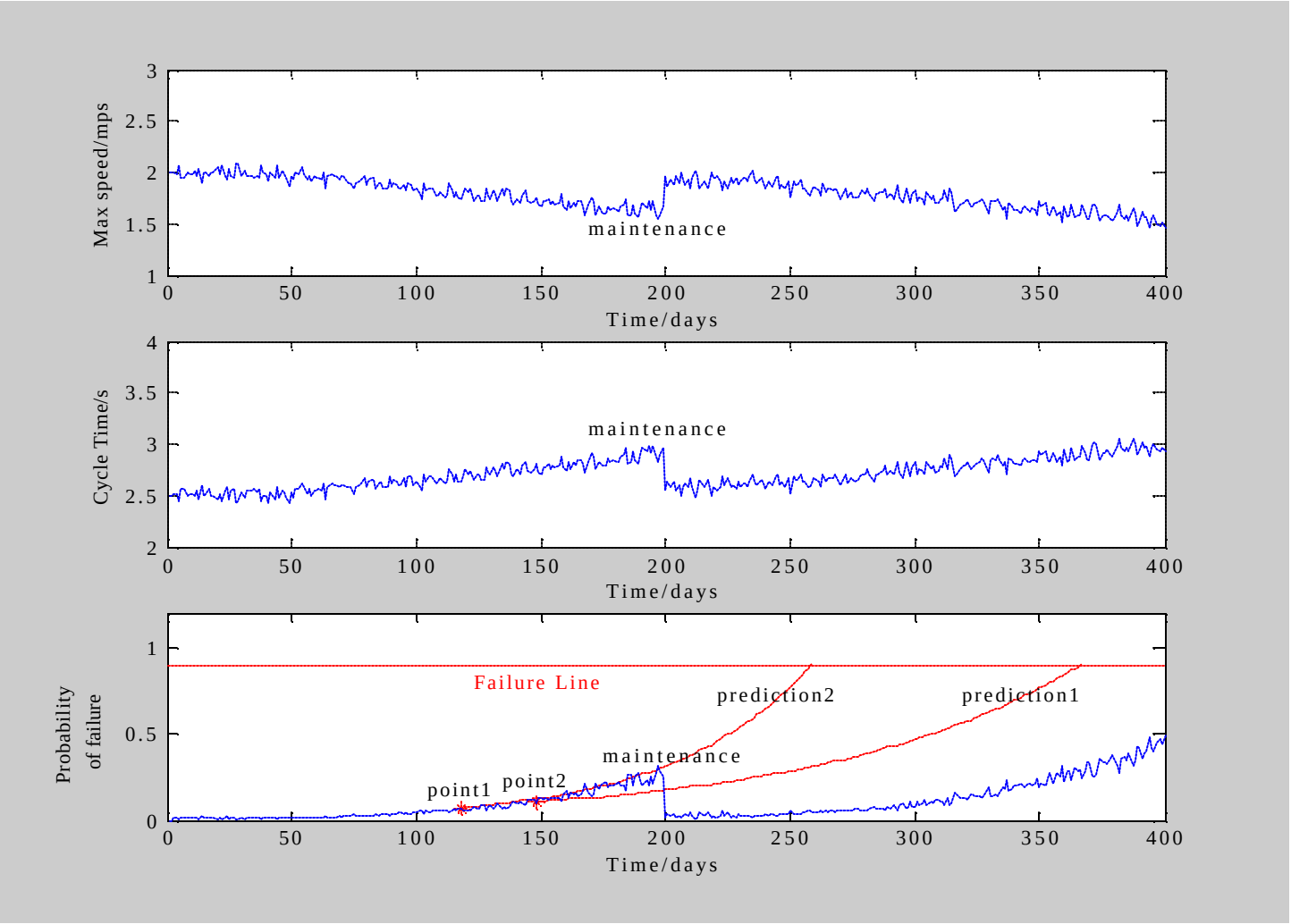
Mean
Time
Between
Degradation



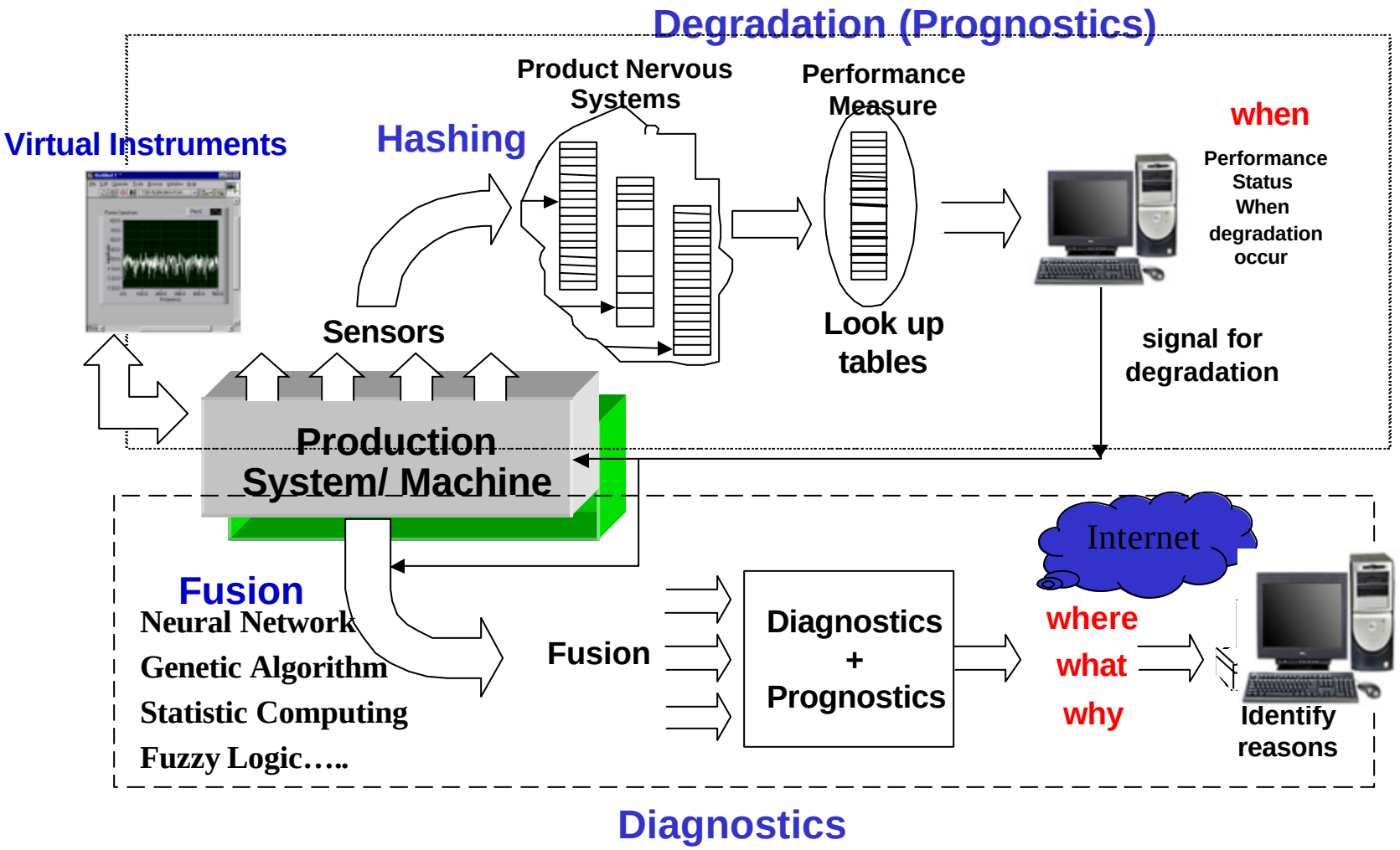
MTBD = $\int_0^\infty t \cdot P(t)\,dt$

Trigger point
Predicted degradation

Example


Max speed/mps
maintenance
Time/days
Cycle Time/s
maintenance
Time/days
Probability of failure
Failure Line
prediction2
prediction1
maintenance
point1
point2
Time/days

Hybrid Prognostics and Diagnostics



Similarity Matrix for Performance Comparison

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MACHINE 2

MACHINE 1	A	B	C	D	E	F	G	H
A	--							
B	0	--						
C	0	0	--					
D	.60	.29	0	--				
E	.14	0	.67	.11	--			
F	0	0	1	0	.67	--		
G	0	1	0	.29	0	-0	--	
H	0	.75	0	.14	0	0	.75	--

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Simulation of Throughput Response Surface Between Parameters

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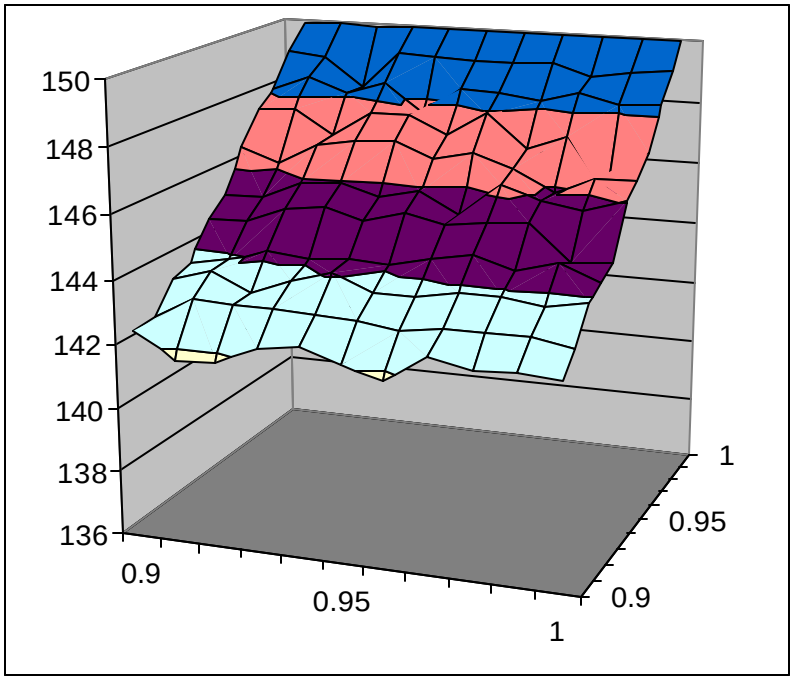
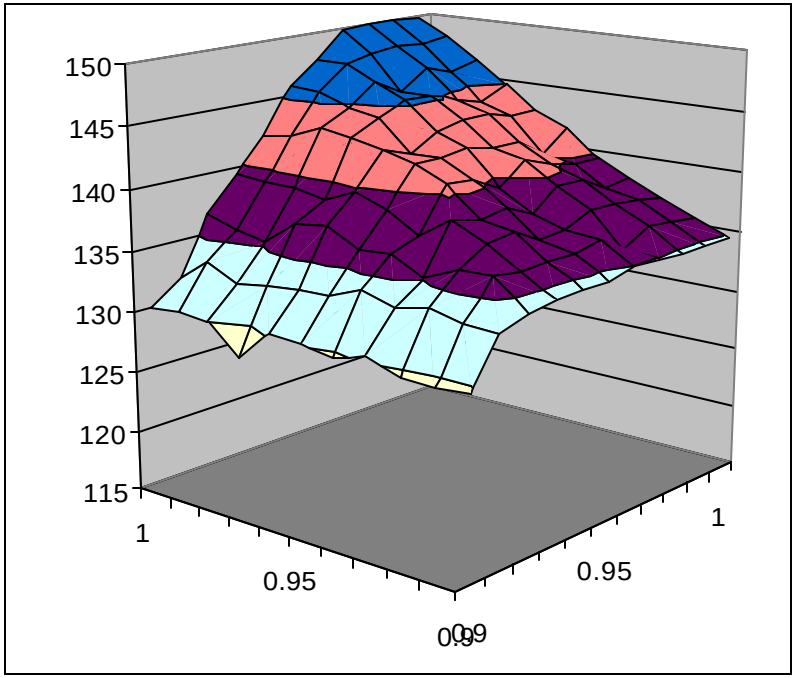
Sensitivity

Sensitivity





Degradation of (X1 & X2)

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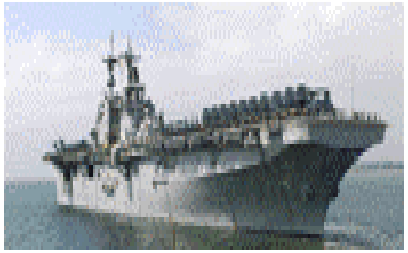
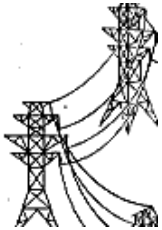
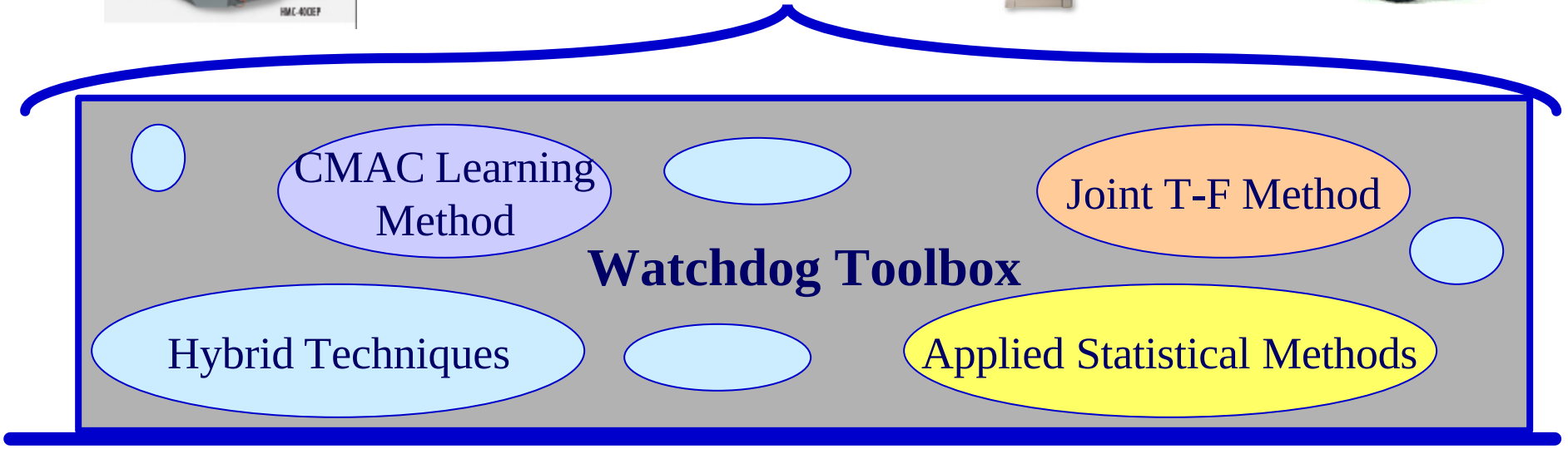
Watchdog Toolbox





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D2B™ Platform

Embedded Monitoring

Prediction & Performance Assessment

Data/Information Transformation

XML

Web

Optimization

Synchronization

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

Optimization of Production, Delivery, Maintenance, Human Resources,

Logistics Systems etc.

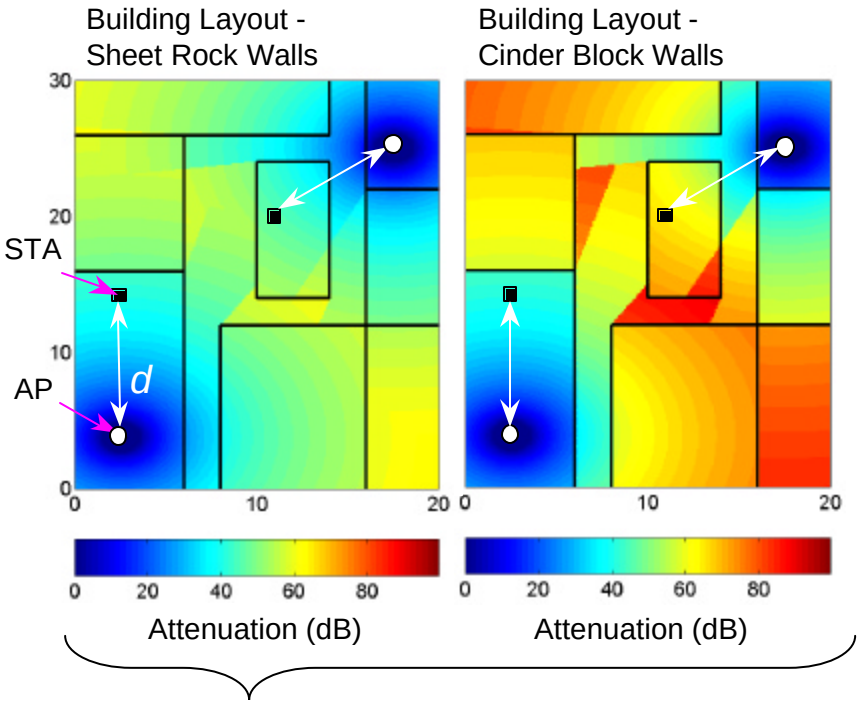
DATA / INFORMATION
Device / Factory Level

Transformation into KNOWLEDGE

Real Time DECISION / Synchronization

Applied Wireless Issues

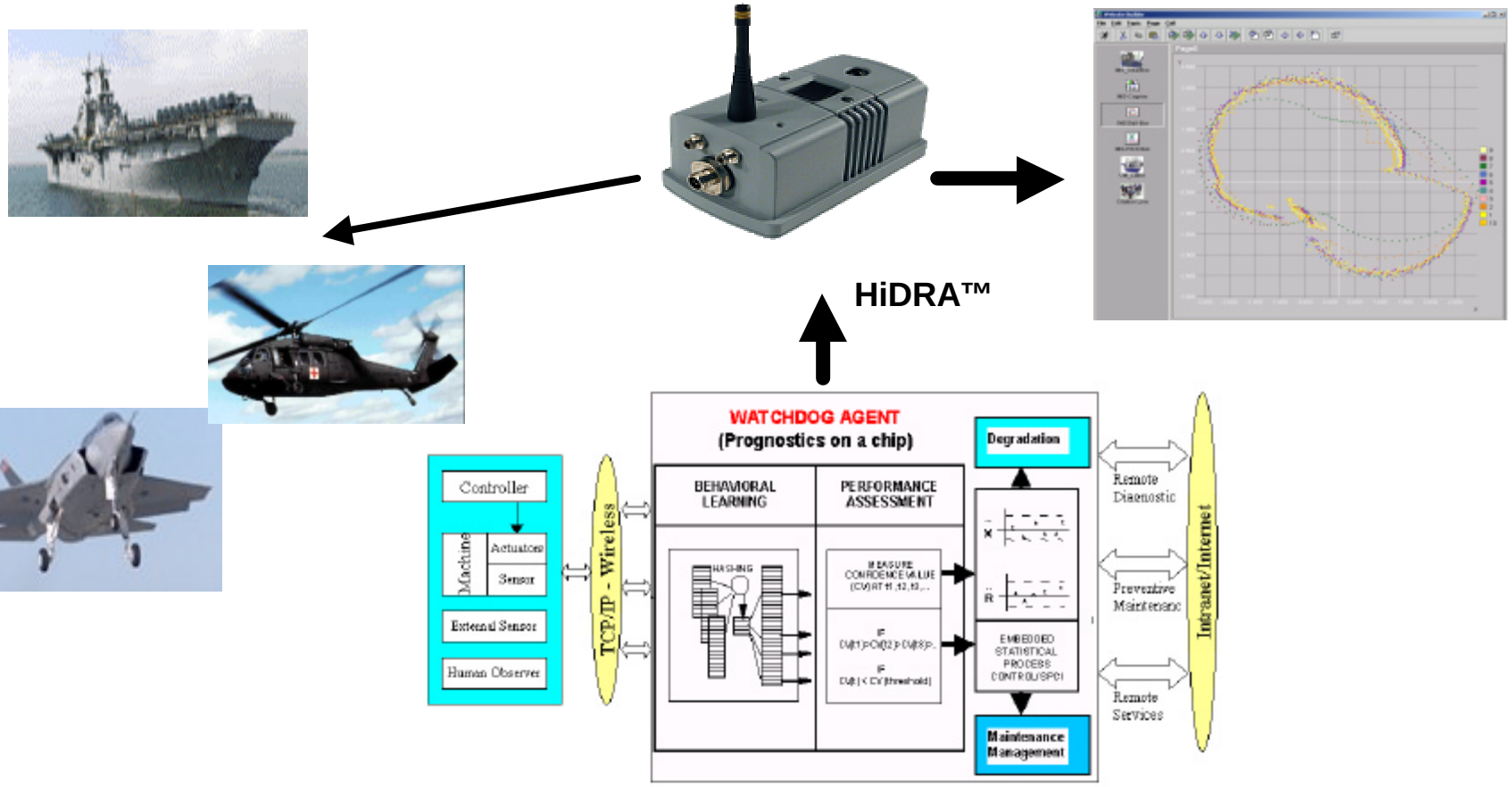
- **Communication Network**
  - **Wireline vs. Wireless**
  - **Performance - Throughput vs. Latency**
  - **Reliability - Control vs. Monitoring**
  - **Cost - ISM Band**
- **Wireless Technologies**
  - **IEEE 802.11**
  - **Bluetooth (IEEE 802.15)**
  - **Proprietary**



Radio Propagation Issue

Prof. Ivan Howitt, EE UWM

Tether-Free Embedded Infotronics Agent



HiDRA™ from Rockwell Scientifics

Remote Monitoring and Prognostics of Defenses Equipment

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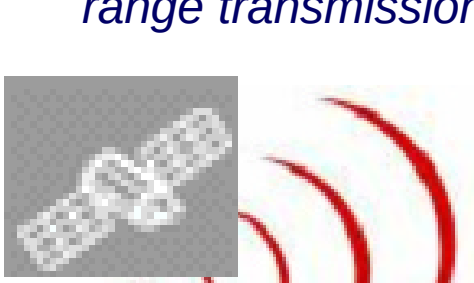
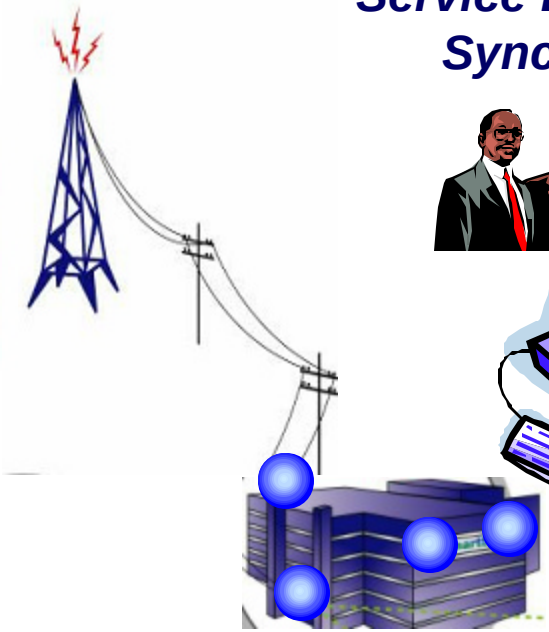
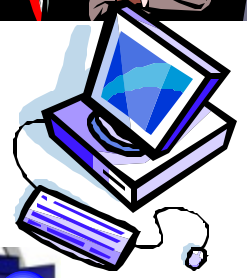
Alarms
Prognostics
Remote diagnostics
Service Dispatching
Synchronization

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

Cellular phones or GPS for long range transmission







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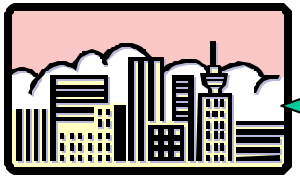
Logistics Infotronics Agent (LIA)

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

Usage, Service & Maintenance



Product delivery

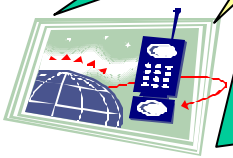
5. Design Innovation through life cycle intelligence

Logistics Infotronics Agent (LIA)

Tether- Free Transmission

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

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



Producer's Product Life Cycle Intelligence (LCI) System

4. Update product usage information in the Life Cycle Monitoring System

Logistics Infotronics Agent

(LIA)

Today's Acquisition and Logistics Systems

Customer Needs

Product, Process, and Enterprise Design (PPED)

e-Procurement

Supplier Evaluation & Selection

Decision

Sourcing

Enterprise Database Mgt System (EDMS) (design, manufacturing, suppliers, testing, etc)

Life Cycle Service & Maintenance (LCSM)

Manufacturing Enterprise Execution System (MEES)

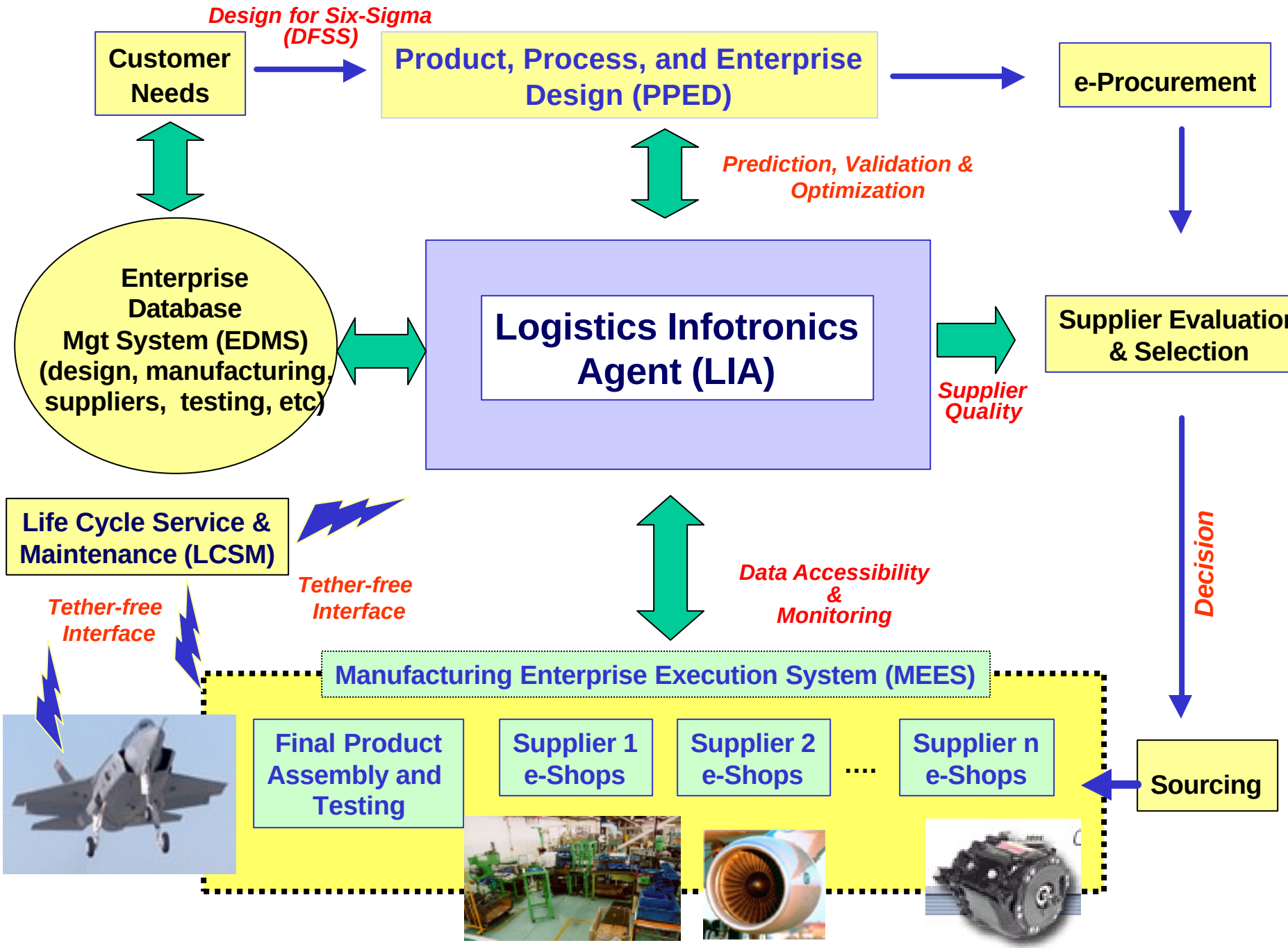
Final Product Assembly and Testing

Supplier 1 e-Shops

Supplier 2 e-Shops

....

Supplier N e-Shops


Design for Six-Sigma (DFSS)
Customer Needs
Product, Process, and Enterprise Design (PPED)
e-Procurement
Prediction, Validation & Optimization
Enterprise Database Mgt System (EDMS) (design, manufacturing, suppliers, testing, etc)
Logistics Infotronics Agent (LIA)
Supplier Quality
Supplier Evaluation & Selection
Life Cycle Service & Maintenance (LCSM)
Tether-free Interface
Tether-free Interface
Data Accessibility & Monitoring
Decision
Manufacturing Enterprise Execution System (MEES)
Final Product Assembly and Testing
Supplier 1 e-Shops
Supplier 2 e-Shops
....
Supplier n e-Shops
Sourcing

Current Members and Sponsors

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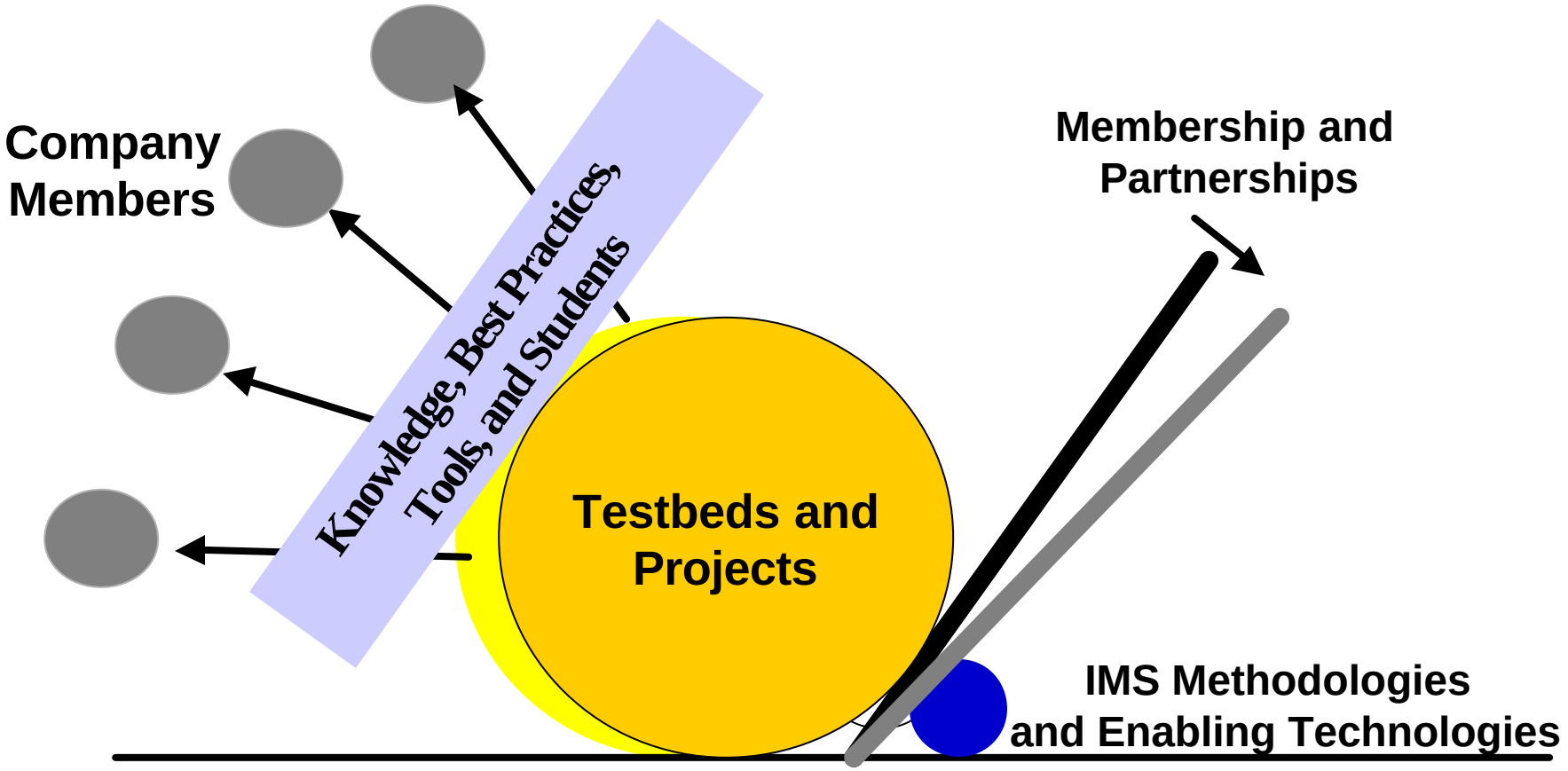
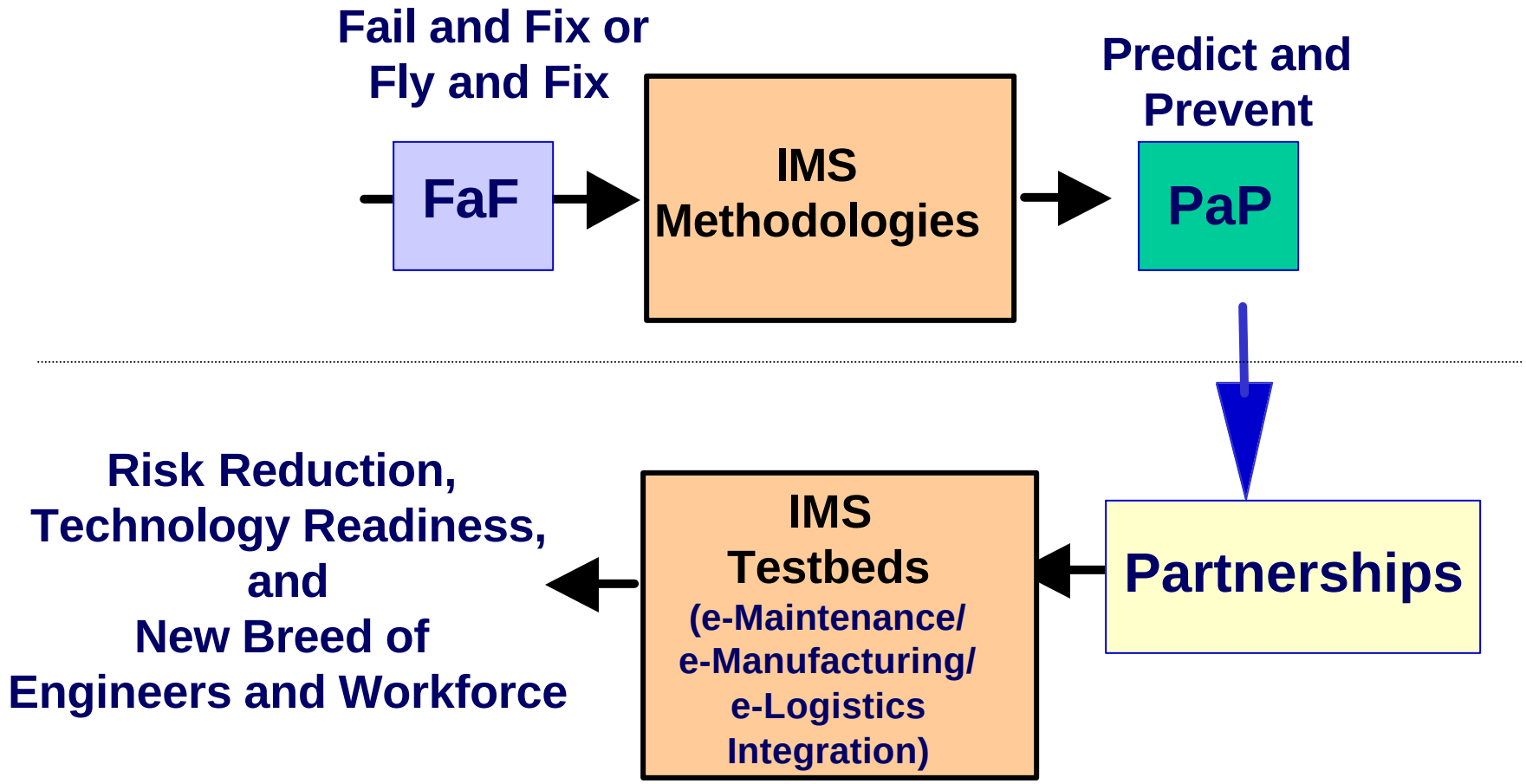
- Rockwell Automation
- Ford Motor
- GM
- Johnson Controls
- Eaton
- Harley-Davidson
- Xerox
- Wisconsin Electric Power
- United Technologies
- Siebel Systems
- GE Medical Systems
- Toshiba (Japan)
- A.O. Smith
- Intel
- U.S. Postal Services
- National Instruments
- ITRI
- PMC
- Kone Elevator
- API
- 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
Partnerships
IMS
Testbeds
(e-Maintenance/
e-Manufacturing/
e-Logistics
Integration)
Risk Reduction,
Technology Readiness,
and
New Breed of
Engineers and Workforce

Thank You

For More Information

www.imscenter.net