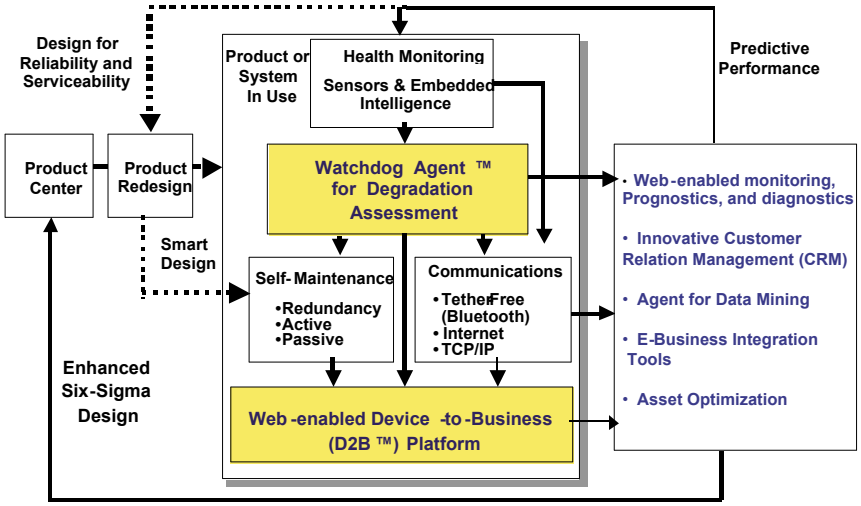
Harbor Research
PERVASIVE INTERNET REPORT
feature
APRIL 2003

Approaching Zero Downtime: The Center for Intelligent Maintenance Systems (IMS)

The IMS Vision



Watchdog Agent and Device -to-Business (D2B) are Trademarks of IMS Center

Source: IMS

OVERVIEW

The Goal: Near-zero-downtime for manufacturing, mining, farming, service, etc. equipment and processes.

The Means: Modeling optimum machine performance and monitoring real-world performance degradation, using sensor data already available (but underutilized) on most state-of-the-art equipment. Developing software systems to share this information over networks. Using the networked devices to schedule predictive maintenance before failure occurs. Ultimately, creating machines that learn, self-optimize, and even repair themselves.

The Players: A university-industry partnership consisting of The University of Wisconsin at Milwaukee and The University of Michigan, along with more than 40 corporate members (suppliers and adopters) and sponsors, including, GM, Rockwell Automation, Harley-Davidson, Hitachi (Japan), Intel, ITRI (Taiwan), Kone Elevators (Finland), Questra, Siebel, United Technologies, Xerox, and others.

Company Overview

Rockwell

Rockwell in brief

As one of the world's largest industrial automation companies, Rockwell's focus is on power control and information solutions. This focus follows a number of divestitures in which Rockwell spun off the semiconductor, aerospace & defense, large power transformer, aviation, and communications businesses.

Rockwell Automation, Inc.
777 East Wisconsin Avenue
Suite 1400
Milwaukee, WI 53202 US

Online
Web site

Telephone
Main: (414) 212.5200

Employees: Greater than 5000

Gross Annual Revenue: $1-10B

Rockwell Peers
Opto 22

- **The Gains**: An estimated $35B per year savings across the US economy, broken down as follows:[1]
  - Spare parts inventory reduction: $6B per year
  - Improved resources scheduling: $9B per year
  - Enhanced logistics and supply chain: $15B per year
  - Equipment uptime improvement: $5B per year

COMPUTING IN THE REAL WORLD

Marvin Minsky, one of the fathers of artificial intelligence, likes to say that we can make a computer capable of beating the reigning genius of chess, but we can't make a robot capable of walking across the street as well as any normal two-year-old child.

The real world is not a strictly regulated, closed system like a chess game. Sensing a player's moves on a wired chessboard and responding quickly and intelligently is one thing. Sensing—and physically responding to—reality (stones, curbs, potholes, pedestrians, oncoming cars) is quite another.

In fact, the entire AI industry collapsed (taking with it many worthy businesses founded by serious scientists, such as Danny Hillis's Thinking Machines) largely because it was unable to meet the unrealistic public and investor expectations generated by non-real-world computing triumphs like those of IBM's "Deep Blue" chess-playing machine.

Of course, digital computing has radically transformed human affairs. But so far, that transformation has taken place on the computer's terms. The marvels of computing have taken place in rigidly regulated, closed systems; so far, IT has floated blissfully above the profound messiness of reality. If you want the benefit of computing, you sit down at your computer. Once at the computer, you do things the way the computer expects them to be done. There's a big learning curve, and you're stuck in front of a screen. If your hardware and software are decently designed, the experience feels relatively "natural" after a while—but only because you, the amazingly adaptable human being, have adapted to it.

To this day, IT is like a baby in diapers—cared for by people, coddled by people, tolerated by people. And rather astonishingly, most people don't expect IT to get out of its diapers. They expect it to get cheaper, faster, easier to lift, and perhaps more entertaining, but they don't expect it to grow up.

Happily, IT is about to exceed most people's expectations: computing is finally on the verge of growing up and meeting the real world.

Company Overview
Intel

Intel in brief

Founded in 1968, Intel Corporation is a major player in the semiconductor manufacturing industry. The company sells many of the basics that make up a computer system. Offerings include microprocessors, chips, motherboards, software, and other products that serve as the backbone of computing systems and wired and wireless networks. Additionally the company sells embedded control chips that enable communication among devices.

Intel Corporation

2200 Mission College Blvd.
Santa Clara, CA 95052 US

Online

Web site

Telephone

Main: (408) 765-8080
Fax: (408) 765-9904

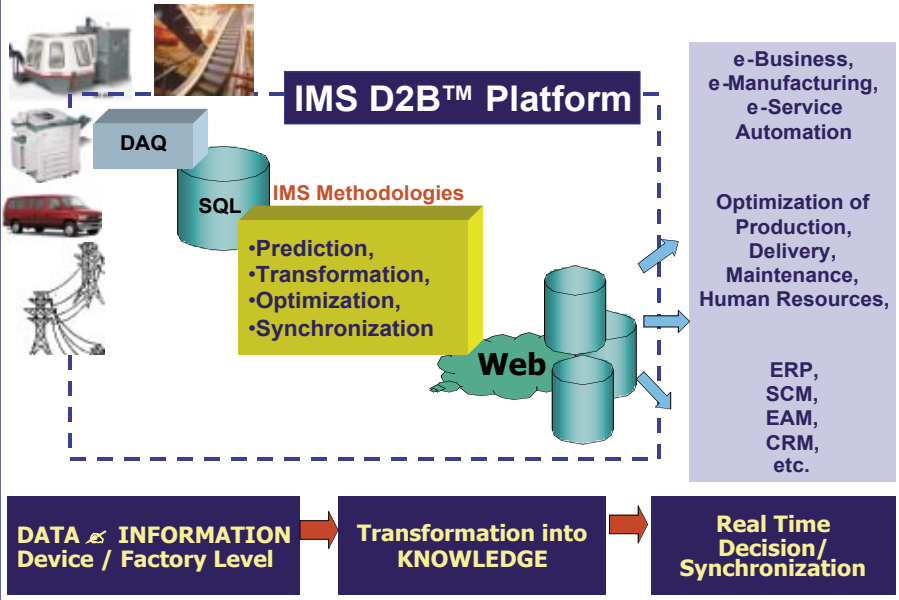
Employees: Greater than 5000
Gross Annual Revenue: Greater than $10B

Position in Harbor's SIGNALSmart™ Framework

- Services - Data Center
- Infrastructure - Servers/Storage
- LAN - Wireless
- Smart Devices - Microelectronics

Intel Peers

AMD



Source: IMS

ACADEMICS AND ENTREPRENEURS

As anyone in the AI community will tell you, bringing computing into the real world has proven to be much more difficult than even experts expected it to be. Most recently, the promise of the Pervasive Internet—i.e., billions of smart devices sharing their real-world data on a global network to enable what are now called "Web services"—has been greeted with cynicism similar to that encountered by its sexier and more dramatic sibling, AI. As an indication of how widespread the disappointment has become, the editor of a leading magazine for the "digerati" recently said, in a private conversation, "We've been hearing for years about the day when any electronic device will be able to talk to any other device. But when is it actually going to happen?"

Actually, the Pervasive Internet—which will soon introduce an unprecedented level of system intelligence and automation into business operations worldwide—has faced an even greater challenge than making a robot walk safely across a city street. At least in the case of the perambulating robot, we presume that no one is actively trying to run the creature over. But pervasive technologies face overt hostilities from various quarters (labor unions, misguided privacy protectors, misinformed members of the public and their elected representatives), as well as the standards battles being waged by private-sector companies who want the next era of computing to be based upon their proprietary technologies.

And that's on top of the engineering magic-trick of connecting and monitoring a manufactured world that was never designed to be connected in the first place.

Ironically, the dot-com crash has been a good thing for the Pervasive Internet (at least in the long run) because it has sent leadership back

Company Overview

Questra

Questra in brief

Questra is an enterprise software and services company that helps businesses reduce service and support costs by connecting geographically disparate assets to the Internet.

Questra Corporation, Inc.

350 Linden Oaks
Rochester, NY 14625 US

Online

Web site

Employees: 10-50

Gross Annual Revenue: $5-20M

Position in Harbor's SIGNALSmart™ Framework

- Services - Systems Integration
- Infrastructure - Applications/ Enablers

Questra Products

Questra Smart Service Solution

Questra Peers

Axeda
Lantronix
emWare

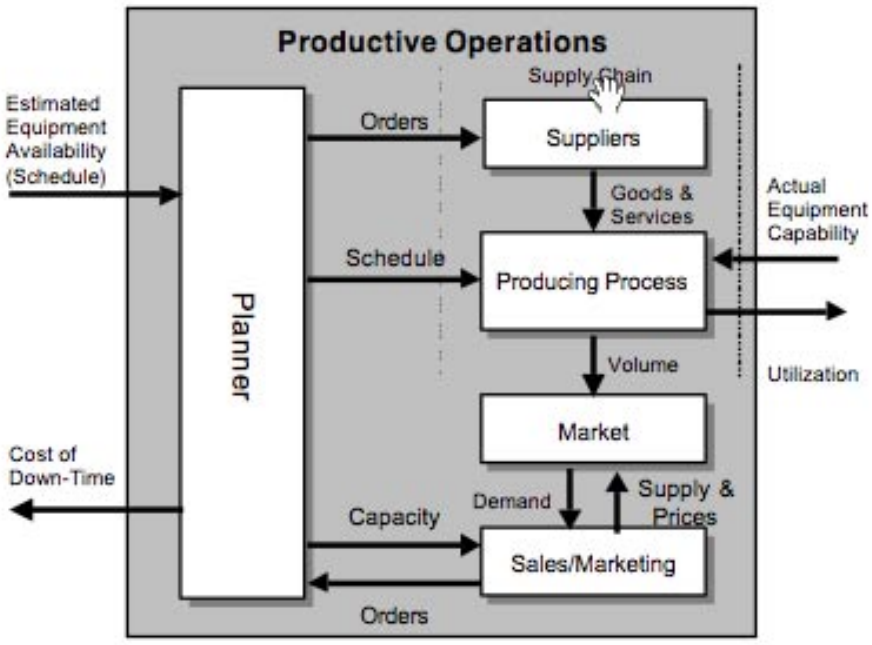
into the sector responsible for creating the Internet itself—academia. The Internet was funded by the military, and the military is certainly interested in pervasive technologies. But most significantly, the academy is now partnering with the sector that creates the real manufactured world—industry. Many important and foresighted companies have seen that the benefits of deep business automation are too important to be left to serendipity.

THE CENTER FOR INTELLIGENT MAINTENANCE SYSTEMS

Like the **Auto-ID Center** at MIT (the subject of our March, 2003 Feature), which is working to create "an Internet of things," the Center for Intelligent Machine Maintenance (IMS) is a university-industry consortium dedicated to joining theory and practice. Specifically, IMS is a National Science Foundation Industry/University Cooperative Research Center. IMS's industry members contribute cash or in-kind donations of technology, equipment, and expertise, enabling IMS to create the research environment, industrial testbeds, and standardized software tools that will make automated "machine health" a reality.

When smart machines are networked and remotely monitored, and when their data is modeled and continually analyzed with sophisticated systems, it is possible to go beyond mere "predictive maintenance" to machine "prognostics"—the process of pinpointing exactly which components of a machine are likely to fail, and when.

Planning Production Operations based upon knowledge of monitored machines.



Source: IMS

Company Overview

Auto-ID Center

Auto-ID Center in brief

The Auto-ID Center is a joint venture among 90 companies and three major universities: MIT, University of Cambridge, and University of Adelaide. The center was founded to create "an Internet of things" in which everyday objects are automatically and wirelessly visible to the network via "tags"—most commonly RFID tags that use radio frequency signals to transmit position information as well as other data.

Auto-ID eliminates the need for manual inventory counts and greatly reduces supply chain problems. The ultimate goal of the Auto-ID Center is to make virtually any object instantly identifiable on a global network, enabling the objects themselves to provide reliable real-time information to businesses.

Auto-ID Center

Massachusetts Institute of Technology
400 Technology Square
Sixth Floor
Cambridge, MA US

Online

Web site

Email

Main: info@autoidcenter.org

Telephone

Main: 617.452.2521
Fax: 617.253.1643

Employees: Less than 10

Gross Annual Revenue: Less than $5M

Auto-ID Center Products

Savant

IMS's mission is to create infrastructure and software tools that will make it possible to achieve near-zero-downtime of industrial machinery. When the "health" of machinery is almost perfectly visible, a business can plan intelligently rather than being blindsided by failure. If a machine is about to fail, a sibling machine's output might be accelerated (even automatically) to compensate for it, or another machine's output might be slowed down, or the delivery of raw goods to the failing machine might be postponed. Whatever the case, knowledge becomes the power to optimize processes, save significant amounts of money, and achieve across-the-board "business automation.

Evolution of product, manufacturing and quality goals as automation has matured.

	1980s	1990s	2000-2010
Product Focus	Intelligent Mechatonics (data & control intelligence)	Products that Think and Link (information & computer intelligence)	Products that Learn, Grow, Reconfigure and Sustain (knowledge & e-intelligence)
Manufacturing Focus	Factory Automation (flexibility)	Enterprise Automation (agility)	Business Automation (velocity)
Quality Focus	SPC & TQM for Mfg process (factory)	Six-Sigma for Business Process (enterprise)	E-service for Customer Solutions and Asset Optimization (customers)

Source: IMS

SEEING FAILURE BEFORE IT OCCURS

Most machine maintenance today is either purely reactive (fixing or replacing equipment after it fails) or blindly proactive (assuming a certain level of performance degradation, with no input from the machinery itself, and servicing equipment on a routine schedule whether service is actually needed or not). Both scenarios are extremely wasteful.

To human beings, it often seems that machines fail suddenly, but in fact machines usually go through a measurable process of degradation before they fail. Today, that degradation is largely invisible to human users, even though a great deal of technology has been developed that could make such information visible.

It may come as a surprise to many people that most state-of-the-art manufacturing, mining, farming, and service machines (e.g., elevators) are actually quite "smart" in themselves. Like the gas and

Product Overview

Java

Producing Companies

Sun Microsystems

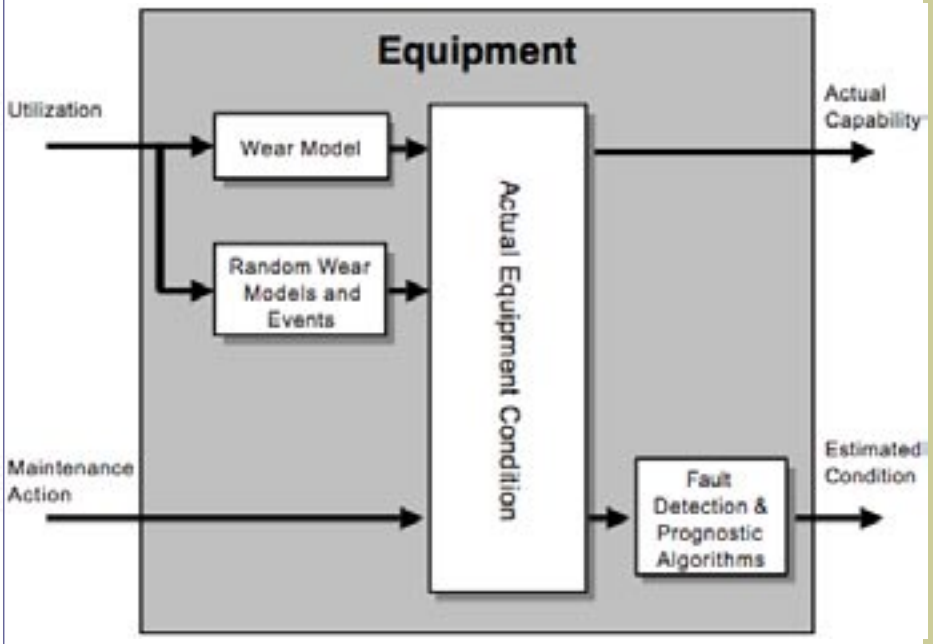
Java in brief

Java is a programming language designed for network-based applications. It was created by Sun Microsystems and released to the public as an open, free specification. In theory, it is completely platform-independent, enabling programmers to "write once and run anywhere," freeing them from the need to tailor their code to the differences in various operating systems.

Widespread adoption of Java would be a good thing for Sun in terms of reputation, credibility, etc., but it would not automatically mean that the company would make money from the invention, or even recoup its investment. Like all Open Source tools, the playing field is quite level—even when it comes to the tool's developer. Competitive advantage stems entirely from the creative use, extension, and support of the tool in the marketplace.

Some observors view developments like this with cynicism, as if the company's "gift" to the world were in fact a Trojan Horse. But Harbor Research sees Java as one of the first examples of a large corporation "getting it" about global, platform-independent computing, and about the need for open standards and tools. With Java, we see Sun attempting to establish an important worldwide standard by giving away a significant piece of intellectual property, without deriving automatic advantage for itself.

electric meters on your house (the latest ones are full of silicon and have digital readouts), modern industrial equipment contains many sophisticated sensors and computerized components capable of delivering data about the machine's status and performance.



IMS model for monitioring equipment condition.

Source: IMS

The problem is that little or no practical use is made of most of this data. With the exception of some pilot programs carried out by Schlumberger and others, most electric meters (household and otherwise) are still "read" by a human being making a physical visit to the site.

It seems so obvious that the meter should be networked and monitored continually, and that the resulting information should be used as the source of a new business model and a new customer relationship. So why isn't it happening?

The problem is essentially identical to the industrial-sector problem that IMS is working on. We have the devices, but we do not have a continuous and seamless flow of information throughout entire processes. Sometimes this is because the available data are not rendered in useable form. More often, no infrastructure exists for delivering the data over a network, or for managing and analyzing the data even if the devices were networked.

SMART DEVICES, NOT-SO-SMART WORLD

Despite the amazing amount of silicon "intelligence" in manufactured objects all around us, we still live in a strikingly dumb world. For the most part, our real-world devices don't talk to each other, and thus most of the value of their information is lost.

Company Overview
Schlumberger

Schlumberger in brief

Founded in 1927, Schlumberger provides a full assortment of oil and gas services. The company offers seismic surveys, drilling, wireline logging, well construction and completion, and project management.

Schlumberger (pronounced "Schlum-ber-ZHAY") has conducted pioneering pilot projects in the networking and remote monitoring of electric and gas meters.

Schlumberger Ltd.
153 E. 53rd St.
57th Floor
New York, NY 10022 US

Online
Web site

Telephone
Main: 212-350-9400
Fax: 212-350-9457

Employees: Greater than 5000

Gross Annual Revenue: Greater than $10B

It's easy to say that "devices should talk to each other" without bothering to break it down and think about it. So let's put it in the simplest possible terms. For devices to "talk to each other" in a meaningful way, they need to have:

Something to say
Sensed information about status, performance, environment.

A language to say it in
The sensed information must be in a useable form, or converted to a form that works in the agreed-upon protocols.

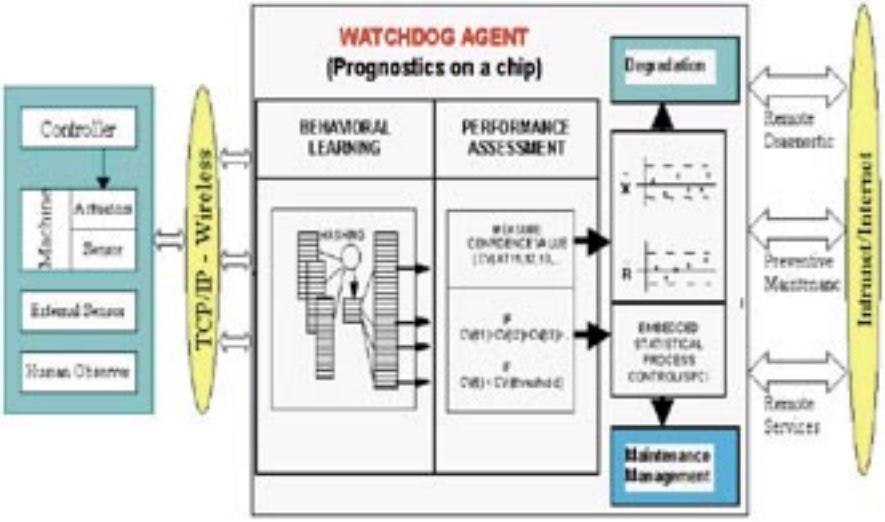
The "vocal cords" to make the statement
A physical or software-based interface for getting information out of the device and then "amplified" and sent.

An "atmosphere" to transmit or conduct the statement
Connection to an "always-on" global network using agreed-upon protocols, e.g., Internet access.

Someone to hear what has been said
Another device or a language-parser in network or on a server.

Intelligence to understand the statement
Layers of server-side middleware, database managers, data-mining procedures, reasoning agents, network applications for data analysis, etc.

Actions to take based upon what has been heard and understood
"Web services": control-signals sent to other devices, dynamic web pages or physical reports generated for human eyes, production or shipments or maintenance scheduled automatically, self-maintenance performed if possible, etc.



The core enabling component of the Intelligent Maintenance System is the smart Watchdog™ agent.

Source: IMS

Product Overview
Watchdog Agent

Producing Companies
IMS

Watchdog Agent in brief
A neural network-based "digital doctor" inspired by biological perceptual systems and machine psychology theory, Watchdog™ Agent consists of embedded computational prognostic algorithms and a software toolbox for predicting degradation of devices and systems. It is being built to be extensible and adaptable to most real-world machine situations.

COMPONENTS OF IMS RESEARCH

IMS research and its industry testbeds are focused on fulfilling precisely the requirements we just outlined. The following are the primary thrusts of IMS research:

Sensor Fusion

In most production equipment or systems, different sensors measure different aspects of the same physical phenomena.[2] In much the way that human "stereo" vision gives us depth perception, or multiple 2D perspectives can be combined into a 3D view, IMS is working on software to "fuse" available data into a more useable, holistic image of the actual state of a machine component.

Watchdog™ Agent

A neural network-based "digital doctor" inspired by biological perceptual systems and machine psychology theory, Watchdog Agent™ consists of embedded computational prognostic algorithms and a software toolbox for predicting degradation of devices and systems. It is being built to be extensible and adaptable to most real-world machine situations.

Device-to-Business (D2B™) platform

D2B™ consists of system methodologies that transform machine/product data into useable formats and allow for the integration and synchronization of this data with other business systems, suppliers, and customers.

Java tools for application development and network data-sharing

IMS is creating network software for the manipulation and transmission of machine/product data, and for application development.

Applied wireless systems and development of embedded peer-to-peer networking technology

IMS is assessing/validating various enabling technologies and protocols for remote monitoring and wireless communication in production and service environments.

Product Overview

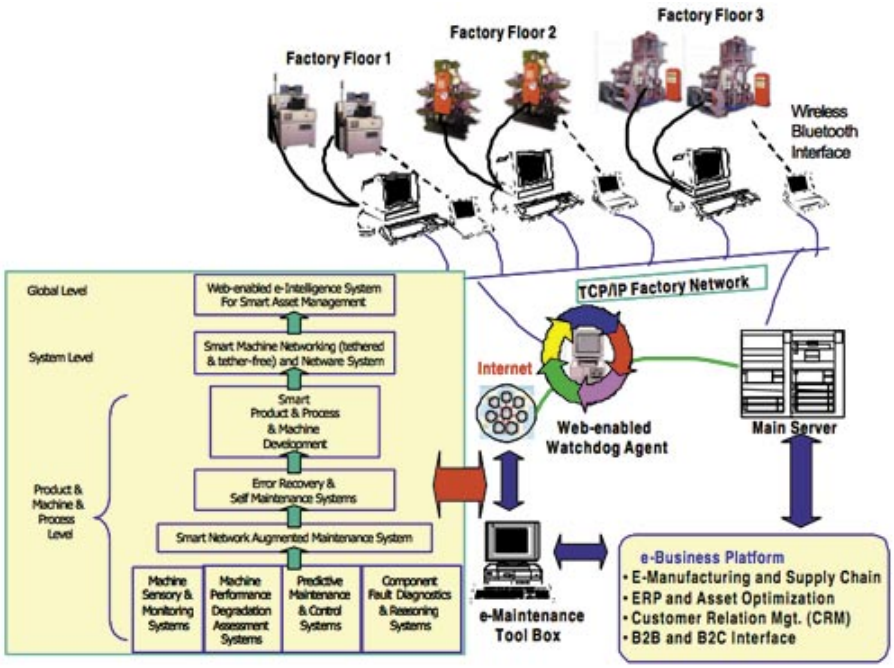
D2B Platform

Producing Companies

IMS

D2B Platform in brief

Device-to-Business (D2B™) platform consists of system methodologies that transform machine/product data into useable formats and allow for the integration and synchronization of this data with other business systems, suppliers, and customers.



Integration of e-Manufacturing and e-Maintenance.

Source: IMS

IMS MEMBER CONTRIBUTIONS

IMS's function might be thought of as supplying the "last mile" of machine health to companies that have themselves developed important pieces of a full solution, and that stand to benefit greatly by sharing technology and information rather than simply providing research funding. Some IMS members and sponsors and their technological and business interests include:

- **GM** (pilot e-manufacturing testbed in a real automotive assembly plant to enable near-zero-downtime performance).
- **Harley-Davidson** (predictive maintenance systems for machine tools)
- **Hitachi** (intelligent condition-based monitoring and maintenance of gas turbine)
- **Intel** (semiconductor fab equipment and processes)
- **KONE Corporation** (smart remote elevator monitoring and autonomous service calls)
- **Micro Mobio** (next-generation Bluetooth wireless systems)
- **Rockwell Automation** (energy and power systems, asset optimization & management, wireless machine sensors, factory open systems)
- **Siebel** (CRM and e-business solutions)

Company Overview

Xerox

Xerox in brief

Xerox is a major provider of copy machines, printers, scanners, and other office equipment for both home and corporate use.

Xerox is a sponsor of The Center for Intelligent Machine Maintenance (IMS), and is working on next-generation office equipment that will be remotely monitorable and capable of initiating automatic service and replenishment calls.

Xerox Corporation
800 Long Ridge Road
Stamford, CT 06904 US

Online
Web site

Telephone
Main: 203-968-3000
Sales: 1-800-275-9376
Support: 1-800-821-2797

Employees: Greater than 5000

Gross Annual Revenue: Greater than $10B

- **U.S. Postal Services** (remote mail processing equipment monitoring)
- **Velicon** (high-speed spindle monitoring)
- **We Energies** (power generation monitoring and predictive maintenance)
- **Xerox** (smart copiers that prevent jams and autonomously initiate service calls)

TURNING MANUFACTURERS INTO SERVICE PROVIDERS

When a manufacturer is able to monitor its equipment remotely, and offer intelligent service plans based upon the real-world status of machines, the manufacturer is in a position to sell not merely equipment but a full business solution based upon that equipment—a solution that amounts to true, across-the-board "business automation."

This will be of particular interest to OEMs that find themselves increasingly "disintermediated" from their ultimate customers—many of whom are often not even aware of who the OEM is. An OEM that stays connected to a customer for the life of a product can provide solutions-packages that might include not only smart maintenance scheduling but also vastly more intelligent, targeted marketing, as well as offers (from the company itself, or from partners) of data-warehousing and management services, upgrades, third-party merchandise, business expertise, and so on.

But even makers of commercial equipment (typically not disintermediated from customers) stand to benefit greatly from the Pervasive Internet work being done at IMS. For example, KONE Corporation, one of IMS's member companies, is the world's fourth-largest manufacturer of elevators, escalators, and autowalks. Yet 60% of KONE's revenue comes from maintenance and modernization of its machines, as well as maintenance of automatic building doors from other manufacturers. Despite its manufacturing, the company calls itself a service business.[3] Since KONE has had the foresight to position itself as a leading service provider in its market, the machine prognostics of IMS will gracefully blend with KONE's existing business model and serve to improve that model and enhance the company's profitability.

CONCLUSION

Jay Lee and Jun Ni, the Co-Directors of IMS, recently estimated that the application of the "business automation" techniques and procedures being developed by their organization could result in a $35B annual savings across the US economy, as follows:

- Spare parts inventory reduction: $6B annually

Company Overview

KONE

KONE in brief

KONE Corporation was founded in Finland in 1910, and is now the world's fourth-largest manufacturer of elevators, escalators, and autowalks. Yet KONE considers itself a service company: maintenance and modernization accounts for nearly 60% of net sales, and the company also seeks growth from servicing other manufacturers' automatic building doors.

KONE is a member of the Center for Intelligent Machine Systems (IMS), and intends to incorporate global device networking and machine prognostics into its maintenance and modernization strategies.

KONE, Inc.

KONE Corporate Headquarters
One KONE Court
Moline, IL 61265 US

Online

Web site

Email

Main: us.communications@kone.com

Telephone

Main: 309-764-6771
Fax: 309-743-5469

Employees: Greater than 5000

Gross Annual Revenue: $500M - $1B

- Improved resources scheduling: $9B annually
- Enhanced logistics and supply chain: $15B annually
- Equipment uptime improvement: $5B annually

But to participate in such savings and efficiencies, companies need to understand and act upon the opportunities now. Beyond the technology itself, the Pervasive Internet is all about partnerships and alliances. Driven by new consortiums like IMS and MIT's Auto-ID Center, and with the additional impetus of new social drivers like homeland security, the technical "plumbing" issues of global device networking, and the applications for true enterprise automation, will see remarkable advances in the next calendar year.

Members of research partnerships will have earliest access to full solutions, and this will provide an important advantage. Even so, the tools of device networking and Web-based business services will be commonly available very soon. While there are certainly first-mover advantages, the crucial differentiator will be the imagination, creativity, and efficiency with which companies use the capabilities engendered by global device networking: automated asset management, supply-chain management, customer-relationship management, and so on. Intelligent use of these new capabilities will take time to plan. Often, it will involve significant re-structuring of business processes, business models, and business alliances.

The Pervasive Internet is nothing short of the next great era of digital technology. Its opportunities will literally dwarf those of the PC and dot-com eras, and it marks a distinct divide between 20th century business and 21st century business. Right now, many foresighted companies are hammering out the last details of Pervasive Internet supply and adoption. If your company is not one of them, your competitors are stepping into the future without you, and you will likely lose your chance for 21st century global market leadership.

NOTES

[1] Telephone interview with Jay Lee of the Center for Intelligent Machine Maintenance (IMS), April 9, 2003..

[2] IMS web site.

[3] KONE web site.

A Note on the Online Version

The interactive online version of *Pervasive Internet Report* includes more content than this PDF version. In particular, you will find online:

- **Events Channel**. A rich, databased listing of Pervasive events broken out by event category and venue.
- **Venues Channel**. A full query of our Pervasive Knowledge Base for each of the ten major Pervasive venues we have identified, listing all related Companies, Products, and Events.
- **Numerous sidebars**. All channels of *PIR* are studded with clickable links that query our database for micro-profiles of Companies, Products, and Events.
- **Real-time content**. The PDF version is static, reflecting databased content at time of issue. The online version queries the Knowledge Base in real-time, always showing the latest updates by Harbor analysts.

If you're a subscriber, log in to *PIR* here:

http://harborresearch.com/pir/

Not a subscriber? Examine a full, free demonstration of *PIR* here:

http://harborresearch.com/pir_demo/