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Special Edition

Reality online

The business impact of a virtual world

Outlook

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The Long View

Getting value from technology (now and in the future)

Joe W. Forehand
Chairman & CEO
Accenture

In my conversations with leaders around the globe, I hear much about the ever-widening gap between technology innovation and the application of technology to deliver business results. In broadband, it's the absence of the "killer app." In the corporate world, it's the daunting task of integrating current technology and enabling it to span multiple enterprises.

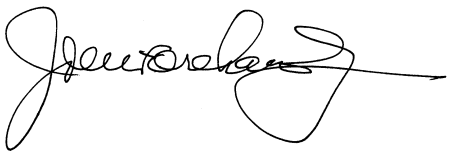
There's little evidence today of that big appetite we saw in the late 1990s to gain competitive advantage as an e-commerce pioneer. Instead, our clients are focused on shorter-term projects that will create measurable value for their companies. They are using proven technology to more easily and affordably deploy their existing assets in a secure and scalable way. This trend will likely continue for some time.

But let's look a few years out. The race to exploit cutting-edge technologies will resurface, no doubt, as the global economy improves. We will see bolder advances, such as innovation that gives inanimate objects the power to sense, reason, communicate and even act. We will move toward an environment where nearly everyone and everything is essentially "online" or interconnected through technology—a world that allows us to experience e-commerce beyond the confines of the traditional PC.

For example, embedded chips or sensors will provide a much broader view of the supply chain, enabling us to "see" the location of a particular good at any time. Auto insurance may be charged not only by the mile but also by who is driving the car and the car's location, allowing an insurance company to adjust the premium continuously to reflect the risks to which the driver and the car are being exposed. This *Outlook Special Edition* looks at the unlimited possibilities of what we call "reality online."

We believe the take-up of such technologies will create entirely new economic models and a new wave of innovation for businesses. We also believe companies must remain committed to creating value and understand the implications for their own businesses as they explore uncharted territory. In our work with clients, and within our own company, we have found that technology adds value when it addresses the fundamental economics of doing business, whether it uncovers a growth opportunity or improves a business process. We have also found that technology adds value when it does not get too far ahead of users and consumers—it needs to be accessible and actionable. In other words, companies must continue to work at closing the gap between the promise of technology and technology's ability to deliver positive business results.

The turbulent economic environment of these past couple of years underscores the importance of achieving results and creating sustainable value. This sharpened focus on value will serve executives well as we manage through the current challenges and lead our organizations into brighter times.



From the Editor's Desk

Practical visionaries

In business, it is often fashionable to speak of a "vision." And indeed, a very important component of good leadership is the ability to articulate a compelling view of the future to give a company focus and purpose.

But vision, like the future itself, is inherently elusive. If it is too broad or too grand, and not grounded in experience and knowledge, it is of little practical use. If it is too narrow and errs on the side of caution, it lacks the boldness and imagination to inspire growth and innovation. And in the realm of technology, with its potential for explosive change, developing a vision—and, by extension, asserting visionary leadership—can be as difficult as seizing quicksilver. After all, a vision of tomorrow's technology can become today's reality with dizzying speed.

The mission of Accenture Technology Labs is to help shape the future through research and development and to keep our technology vision relevant and timely. R&D at the Labs is a highly objective exercise. It is not dedicated to product development but instead is focused on studying new and emerging technologies to determine how they will affect business.

This issue of *Outlook Special Edition* represents the latest thinking of the Labs' leadership team, which is headed by Glover Ferguson, Accenture's chief scientist. To develop their vision, Ferguson and his colleagues—Anatole Gershman, Lucian Hughes and Stanton Taylor—have looked out roughly five years. Some of the building blocks, however—such as silent commerce and web services—involve maturing technologies that companies can exploit today for competitive advantage (and that regular readers of *Outlook* are already familiar with).

The team calls its vision "reality online"—the convergence of a number of technologies that, miniaturized and working together, will gather and intelligently deploy vast amounts of information, enabling reality itself to be captured online. This vision has evolved over the past few months, based largely on discussions at the Labs. And to ensure that it was also grounded in practical reality, the vision has been modified by feedback from business leaders with whom Ferguson discussed these ideas.

Perhaps most significant, this is a vision that extends well beyond business to explore changes that will affect the way we all work and live.

David Cudaback
Editor-in-Chief

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Glover T. Ferguson, chief scientist for Accenture, heads global technology research and innovation initiatives at Accenture Technology Labs, this company's research and development organization. Mr. Ferguson, who joined Accenture in 1974, has shared his perspectives in publications such as *Fortune, The Economist,* the *Financial Times,* the *Journal of Business Strategy, The Wall Street Journal, Information Week, Time, Harvard Business Review* and *CEO,* as well as on National Public Radio and MSNBC. He also writes regularly for *Outlook,* for which he is a senior contributing editor and author of the "On the Edge" column. Mr. Ferguson has participated in events and venues such as CNN's *Futurewatch,* IDC's annual IT European Forum, the Telecommunications Managers Association's annual conference, Sun's International Internet Associates Symposium, Internet World, Comdex Asia and Gartner's Europe Symposium/ITxpo. Mr. Ferguson is based in Chicago.

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Outlook Special Edition

Reality online: The business

By Glover T. Ferguson, Anatole V. Gershman, Lucian P. Hughes and Stanton J. Taylor

In the very near future, a number of technologies—powerful, miniaturized information, enabling physical reality to be captured online. And once every

impact of a virtual world

and cheap—will converge to gather and intelligently deploy vast amounts of aspect of business is online, the real promise of e-commerce will be fulfilled.

Have you ever wondered why you don't hear much about the "e-commerce revolution" anymore? After all, not that long ago it was *the* story in the business press.

E-commerce has faded from the headlines in part because it is largely taken for granted today. Indeed, who can imagine doing business without using the Internet or the World Wide Web in one way or another? Computer-based wireline commerce, which sparked the revolution in the late 1990s, is now usually referred to as "traditional e-commerce." Meanwhile, newer waves of innovation, involving wireless, television, voice and other technologies, have emerged. Many more are just over the horizon.

But in the wake of the dot-com crash in 2001, the idea of e-commerce also engenders a certain amount of rueful skepticism. Was e-commerce oversold? Did it really—could it ever—deliver on its promises?

For example, has e-commerce delivered value? In fact, it has. E-commerce has enabled new services that are up and running, and continuing to evolve. Online access to business and government has changed the way we seek out information and services. Online shopping has created a market for low-penetration goods; electronic auctions give individuals and companies a way to find buyers for pre-owned, used or otherwise unsold items; while retail financial services have almost completely switched to e-commerce. Meanwhile, CRM has been transformed by the delivery of customer service through the web, and online collaboration between businesses has been key to the growing use of outsourcing.

E-commerce has also delivered on the promise of greater efficiency across the value chain. Business-to-business e-markets have revolutionized the way large organizations do business. Through e-procurement, the cost of processing a purchase order has fallen dramatically. And as many elements of employee-benefit management were put online, self-service access has lowered company costs while increasing employee satisfaction.

A new definition

It's equally clear, however, that e-commerce hasn't yet achieved its full potential. That's because it has been limited, in large part, to human interaction via computers (and, to some extent, cell phones) with the Internet.

The focus of e-commerce, at least at the outset, was on automating tasks that could be done while the customer was sitting at a computer. Although all this has been important, even revolutionary, it involves only the relatively small transactional aspect of business. The reach and impact of e-commerce will continue to be limited until it includes the real world of tangible bodies and physical assets, where business gets done and costs are incurred.

Important changes are already in play to make this happen. What Accenture has dubbed "silent commerce" is broadening the definition of e-commerce. The use of ever more powerful, increasingly minuscule and incredibly cheap sensors will make it possible for essentially any object or venue to be "smart" and interactive, making commerce more ubiquitous than ever. Web services will expand the potential of computers by enabling them to communicate more readily using open-standard networks and protocols. (For related articles on silent commerce and web services, see *Outlook,* January 2002 and July 2002, respectively.)

Though advances in sensor technology are the driving force behind this dramatic expansion in the scope of e-commerce, other technologies are involved as well.

Miniature videocameras and microphones are becoming more sophisticated and prevalent, combining with sensors to be the eyes and ears of inanimate objects. (There are thousands of such cameras in Manhattan alone, and perhaps 2.5 million in the United Kingdom, which has the highest concentration of these cameras in the world.) The convergence of chemistry, biology and electronics is making it possible to digitize sensor data. The emergence of content standards will enable this rich new stream of data to be widely shared. (For a related article, see "Help Wanted: Chief Quantum Officer?" *Outlook Point of View,* November 2001.)

Soon, not only every*one* but every*thing* will be interconnected. People will no longer talk about "going online," because reality itself will be online; in the future, people may no longer talk about

"surfing the Net" but instead refer to "surfing reality."

What does this mean? What we're calling "reality online" goes beyond the idea of "virtual reality," which is basically a realistic but computer-generated world. It means that a number of technologies, working together, will replicate, reflect and enhance the physical world in which we live and move, a world in which businesses make, distribute, offer, and sell or provide their products and services—a world captured in context and in real time.

"In context" means that dispersed information will be organized around a specific individual, venue or object, making it possible to see and understand, so to speak, that person, place or thing. "Real time" means that the information will be updated almost continuously. Furthermore, it will be displayed, shared and used in ways that not only make it meaningful but also make it actionable, thus giving it the potential for real impact. (Reality online, of course, also raises serious privacy issues. For a related article, see "The business of privacy," *Outlook Point of View,* August 2002.)

Reality online will make it possible for a company to optimize the use of its physical assets, and hence its operations, and run the business not only differently but far more effectively. It will enable a company to define, understand and serve its customers in new ways; to operate on the basis of up-to-the-minute information; and, ultimately, to anticipate and respond to the future.

In short, reality online will bring every aspect of business into the realm of e-commerce—completing the revolution.

The technologies: The world on the head of a pin

Medieval theologians are said to have argued heatedly about how many angels could dance on the head of a pin. Today, nanotechnologists at the University of California at Berkeley have changed the terms of this ancient debate and taken it in a more practical direction. They are developing so-called Smart Dust, a major advance in sensor technology that will put incredible computing power into a device that could ultimately be as small as the period at the end of this sentence (see box, page 11).

Sensors aren't that small yet—not even Smart Dust. But they will be. And they will be so inexpensive that they will be able to be deployed by the millions. Most important, they will be far smarter than earlier forms of sensor technology, such as radio frequency identification devices (RFID tags). Not only will they be able to identify an object, they will also be able to give contextual information about its location, status, and past and present operating conditions.

Furthermore, these sensors will not operate in isolation; they will build upon and work in tandem with other developing technologies, including wireless capabilities and web services. These tiny devices soon will be able to identify, locate and power themselves; organize themselves into communications networks; and transmit a rich array of information.

More than anything else, the advances being made in sensor technology will enable reality online. This will have three important consequences.

The sensory web will be all-encompassing.
Once sensors are minuscule, powerful and cheap, they will be everywhere. Then, using wireless technology, all these sensors will interconnect, forming ad hoc networks. Potentially, all parts of these networks could sense, reason, communicate and act. These millions of interconnected sensors, working in conjunction with millions of tiny digital cameras, will provide an abundance of reliable data.

To what purpose?

- Sensors could be scattered over acres of ground, which could be useful, for example, for tracking wildlife roaming a vast wilderness or soldiers maneuvering over rugged terrain.

- They could be incorporated into the places where we live and work—even into something as basic and intimate as our clothing, making it possible, for instance, for an individual to enjoy the micromanagement of his or her surrounding temperature and humidity for optimal personal comfort.

- They could be attached to a person's fingertips, allowing an individual to interact with a computer by "typing" virtually instead of on a physical keyboard—or even to a quadriplegic's face, turning facial twitching and blinking into wheelchair and computer commands.

- Ultimately, they could be incorporated into the materials from which new products are manufac-


Ursa maj.
(Larger Bear)
Ursa min.
(Smaller Bear)
Leo min.
(Smaller Lion)
Lynx
Camelopard.
(Giraffe)
Leo
(Lion)
Regulus
Cancer
(Crab)
Canis min.
(Smaller Dog)
Procyon
Virgo
(Virgin)
Spica
Coma B.
(Berenice's Hair)
Canes ven.
(Hunting Dogs)
Arcturus
Bootes
(Herdsman)
Castor
Pollux
Auriga
(Charioteer)

Tiny devices soon will be able to identify, locate and power themselves; organize themselves into communications networks; and transmit a rich array of information.

tured. Imagine, for example, putting sensors into the paint used on a bridge, adding them to the oil flowing through a pipeline or fabricating them into the metal used to make aircraft parts. Each of those sensors could monitor its host's status millimeter by millimeter, detect and report changes in the host's condition, and even take corrective action on its own initiative.

The line between reality and the virtual world will all but disappear. Every real-world object, situation or individual could have a virtual double that replicates it in all-important ways. For the simplest example of a virtual double, think of the printer icon on your computer desktop: Click on it to get relevant information about the operating dimensions and status of the printer you use, wherever it is located.

Here's a more exciting example: a virtual sports center. A prototype for this center has been developed by Accenture Technology Labs, this company's technology R&D organization. The Labs, which are located in Chicago and Palo Alto in the United States and Sophia Antipolis in France, explore how to turn technological innovation into business results.

The Virtual Sports Center we have developed makes it possible to watch most any sporting event with a two- or three-dimensional realism and personal control you can't get on television. This is done by tracking and plotting the position of each participant—whether it's a yacht rounding the marks at sea, a car on the speedway or a football player on the field (or even the ball itself). The tracking is done by both passive technology, such as image processing, and active technology, such as global positioning system (GPS) transmissions or multi-camera triangulation, depending on the sport and conditions. This creates a virtual double of the event and all its participants, all in motion, updated in real time or near-real time.

Watching the event online, spectators aren't limited to the single view provided by conventional television but can be immersed into the event through wireless audio or video and chat, which can be accessible in a number of ways, including iTV, instant messaging and handheld devices. They can look where they want—focusing on a particular boat or player, for example, or backing up to take in a wider range of the action—just like in the real world. Think of its usefulness to coaches when plotting game strategies or improving a player's performance.

Now add into the mix Reality Instant Messaging, another Labs prototype, which emphasizes interactivity not simply with reality but with other people *about* that reality. Suddenly the spectator, who may be all alone anywhere on the globe, is part of a virtual group, chatting online with fellow fans about the game as they watch or even wager for fun, as if they were all there together. The spectator's view of the game is highly personalized, yet the viewing experience is highly social. Thanks to these various Reality Instant Messaging agents, the coupling of sociability and reality will be to the digital world what sociability and cooperation are to the real world.

Virtual sports should be lots of fun, but the concept of a virtual double is serious and practical. A virtual double can be "always on" and up to date, providing a logical focal point for organizing information in

Why (small) size matters

What's the big deal about tiny new sensors?

After all, sensing technology has been around since the 1840s, when cameras fastened to tethered balloons took pictures for topographical mapping. And radio frequency identification devices, although they have become more sophisticated, are still relatively simple. An RFID essentially consists of a tiny transceiver surrounded by fine antennae. These devices are generally passive (that is, without internal batteries), though some can be made active. RFID tags can be as small as a match head, although at this size, their capabilities are rather limited. Tags that contain more data and are capable of more functions are likely to be larger—credit-card size, even as large as a brick. The primary function of RFID tags is to track items (stationary or mobile), record their usage and make simple transactions. Think of a commuter transit pass.

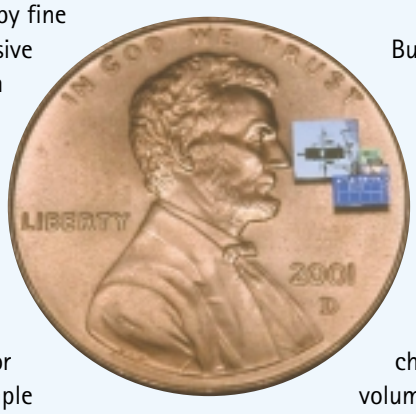

Figure A

What's new is the rapid development of increasingly sophisticated capabilities in sensors that come in increasingly smaller packages. Microelectromechanical systems, or MEMs, combine tiny sensors with actuators that are capable of assessing a situation and taking action. A MEM, when it senses a car's sudden deceleration, for example, triggers the deployment of an airbag. MEMs are constructed of silicon elements and can be currently produced on the micron scale—that is, one-millionth of a meter.

Several companies and research institutions are developing ever smaller and more powerful devices; in the future, devices will be possible on the nanometer scale—one-billionth of a meter.

But size alone isn't as impressive as the combination of small size and self-contained power. Smart Dust, being developed at the University of California at Berkeley, illustrates what is already possible—and what is coming soon.

In July 1999, Smart Dust was really more of a clump: It consisted of two silicon chips in a relatively clumsy package with a volume of 100 cubic millimeters. Today, the package measures about 12 cubic millimeters—it fits on a penny—and contains a clock, a digital controller, two sensors, an analog-to-digital converter, an optical receiver and transmitter, and five solar power supplies.

Cal Berkeley scientists are working to get each mote of Smart Dust down to a trim 1 to 2 cubic millimeters, with even more built-in capabilities, and hope to reach this "head-of-a-pin" size by 2003.

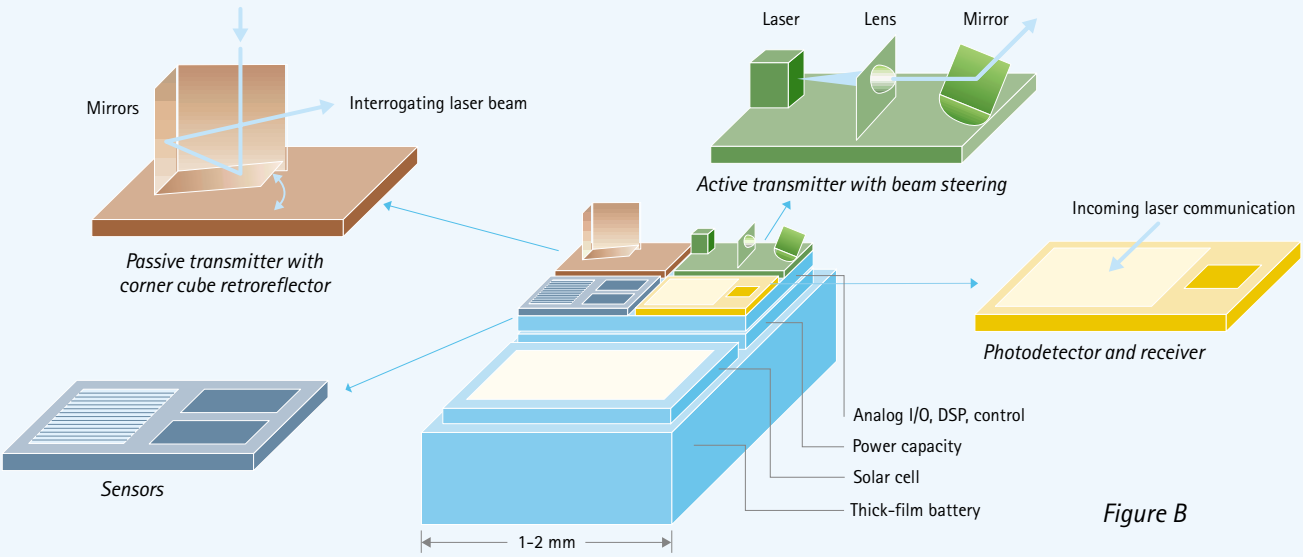

Figure B

Powerful, minuscule sensors, called Smart Dust, currently can fit on the face of a coin (Figure A). Nanotechnologists are working to make Smart Dust even smaller—approximately 2 cubic millimeters, or the size of a grain of sand (Figure B).

The sheer abundance of data will mean that what was once referred to as artificial intelligence will make a comeback.

context and sharing that information as needed. It is also capable of a degree of consistency and vigilance that human beings seldom, if ever, attain. And it can work in conjunction with the physical world, augmenting reality.

Practical applications? A virtual double of your body could continuously provide relevant biological data to your health-care team. Your car could have a virtual double, accessible to different degrees and for different purposes to the original manufacturer, your mechanic and your insurance broker. A pilot's cockpit view could be augmented by a real-world double of the ground below and the surrounding airspace, making air travel safer.

Information will be overwhelmingly abundant and instantaneous. Today, few businesses complain about a lack of data. But they should brace themselves: They are about to get much, much more. Consider some of the types of information that will be readily available once sensors are ubiquitous in the physical world.

- *Observational data* will be available for any object or location, telling where it is, what it is doing, how it is being used, whether it is performing up to expectations and more.

- *Personal data* on any individual (employee, customer or prospect, for example) could (with permission) include his or her contact preferences, background profile, clothing sizes, preferred leisure activities, reading or viewing habits, health status and so on.

- *Business-process data* can give companies the ability to see the big picture, showing where any item is in the product's lifecycle and what is happening to it at the moment—whether it is being manufactured, sold or (in the case of a service) provided, or in post-purchase use.

Now add in the business semantics data created by new languages, such as XML, that will allow businesses and business processes to communicate in a standardized way via web services. The sheer amount of information available will dwarf what businesses have today. What's more, this information will continuously change as it is revised and updated in real time.

The sheer abundance of data will mean that what was once referred to as artificial intelligence will make a comeback. All this data in and of itself will not be useful; indeed, its volume will be overwhelming.

That's why reality online must encompass intelligent filtering, sorting and aggregation of the data—much as our own minds filter, sort and aggregate the sensory overload we receive every minute of the day so that our personal reality is comprehensible and we can function successfully. A variety of different approaches—statistical analysis, modeling and logic patterns that simulate human reasoning—will need to be further developed and brought to bear for the data to be able to address the questions that astute business leaders will ask while making real-time decisions.

It's a compelling vision—and one that should have the attention of business leaders. Futuristic as reality online may seem, it is not that far away. And, most important, it will have real impact on practically every industry and every type of business.

The applications: Optimizing the use of physical assets

The Internet hasn't changed reality: We live in a physical world. Nearly every business is fundamentally about making, deploying or using physical assets.

That's most obvious in manufacturing, energy and retail, of course, where something is extracted or made, shipped, stored and sold. But it is also true in service businesses. The economics of health care, for example, depend on making the best use of expensive physical facilities, equipment, and the time and energy of highly qualified professionals. The travel industry makes use of trains, aircraft and automobiles, as well as hotel rooms and entertainment venues, to take people where they want to go and amuse them once they arrive. Everything consumers buy, use or touch is a physical asset.

Reality online provides new ways to move physical assets around and to manage them more creatively to reduce costs, increase yield and drive efficiency.

Even in an e-commerce world, businesses incur a large portion of their costs managing these physical assets. This is where reality online can have significant bottom-line impact. It provides new ways to get a digital handle on physical objects—to move them around and manage them more creatively to reduce costs, increase yield and drive efficiency.

Concrete reality

Consider, for example, how many companies operate fleets of trucks, buses, vans or automobiles. They represent a significant investment in assets that are almost always underutilized. For example, truck fleets run, on average, between 8 percent and 15 percent empty, because information about available cargo space is not quickly and readily available; that alone costs cargo companies almost $30 billion a year in lost revenue.

Those companies might take a lesson from a major North American cement company. It uses reality online to optimize its plant and fleet assets—and has transformed concrete delivery into a service business.

Rather than rigidly scheduling its fleet to meet incoming orders, the company manages deliveries dynamically. Each truck is equipped with a computer and a satellite GPS transmitter, which give a central dispatcher a continuously updated picture of the truck's location, speed, direction and load status—in effect, creating a virtual double of that vehicle. When an order comes in, the dispatcher can send the nearest truck to the nearest plant—all the while continuing to monitor weather, traffic and inventory levels near the order site so that changes can be made to get that truck (or, if necessary, another one) to the site on time. Meanwhile, the company's production plants are linked through a satellite communications system so that they can dynamically adjust their production schedules to shifts in supply and demand.

Customers pay a premium to order, but they aren't balking. In return, they gain the flexibility to change their order up to the minute of delivery, at no extra charge. And if the delivery is late, they get a 5 percent discount. The cement company rarely needs to pay, however: It has reduced its delivery window from 3 hours to 20 minutes, with an on-time performance of better than 98 percent.

Bottom line: The company is growing its business yet using 35 percent fewer trucks than before, and it expects to save $100 million in 2003 on fuel, maintenance and payroll. At that rate, it won't take long for the company to pay off the $200 million investment in technology upgrades it has made over the past decade.

Going with the flow

Reality online also makes it possible to anticipate and prevent the failure of physical assets, which could be costly or even catastrophic. This is possible because millions of tiny sensors can be distributed throughout complex facilities or extensive operations and monitored continuously, if necessary, even from miles away.

How the streams of data from these sensors can be aggregated and managed is illustrated by our Labs' Sensor Aggregation Models, an application that receives data wirelessly; transforms these millions of discrete sensor "snapshots" into a cohesive, integrated

People performance

Are people also, in a sense, physical assets? If employees are business assets—and expensive ones, at that—then improving the processes by which they work together in the physical world can also bring bottom-line benefits.

Reality online can do just that, as is being demonstrated through prototypes recently developed at Accenture Technology Labs.

Take, for example, the Accenture Personal Awareness Assistant (see photo), which is essentially a wearable computer with camera and microphone capabilities. It has many uses, one of which is to bring collective intelligence to bear, in real time, on a difficult problem. Ever been stumped by an unexpected question in a high-stakes meeting? Imagine the value of having online peers, experts and other advisors, located throughout the world, to whisper guidance in your ear. Who wouldn't want this sort of team in their corner when they're in a tough spot? The Personal Awareness Assistant could be an invaluable asset to lawyers, negotiators, teachers, social workers and police officers.

The Accenture Virtual Collaborative Design prototype also supports people working productively together, even when they are miles apart. When scientists, engineers, designers or artists collaborate, they have to do more than talk to one another. They need to see, even manipulate, the same models, samples or other objects.

Although videoconferencing has improved in recent years, it is still essentially television in the boardroom. Visualization software lets people "share" objects, but with minimal personal interaction. Virtual collaboration, however, allows people to work together in a very real way. Team members can see each other as if through a window; take turns touching, holding or moving objects; and call up documents or other reference materials on-screen. The interaction seems natural, so it's more productive. Companies can save on travel costs. Much more important, they can get the best out of their brightest people. (For more on virtual collaboration, see "The subtle power of virtual collaboration," *Outlook,* July 2002.)

Going one step further, today's workforces are likely to be scattered throughout the world. As telecommuting and office "hotelling" become increasingly common, those employees may not even have a fixed worksite. How can executives manage productivity and morale when they can't walk the halls? How can employees collaborate opportunistically when they can't run into one another in the coffee room? And how can a person with an idea find a colleague willing and able to take a few minutes to kick it around?

The Accenture Global Awareness Wall prototype is designed to address these concerns by making people virtually real to one another. It consists of flat-panel touch-screen monitors embedded in a large wall map of the world. Each monitor represents a regional worksite and provides information on the people who are there as well as the context in which they are working (local news, weather, economic information and so on). Information is available at different levels of granularity on request.

Standing in front of the wall, an employee can "see" who is in another office, access a local webcam stream and send directed audio messages. In the future, the wall may even respond proactively to the person standing before it, identifying that person and calling up information or finding individuals that he or she is most likely to find of interest.

Simply put, the Global Awareness Wall aims to restore to widely dispersed worksites the immediacy and spontaneity of the traditional single-office location.

Embedding sensors in equipment, components or materials can prevent catastrophic failure and change the way day-to-day maintenance is done.

view of the environment; and then builds visual models of the data that reflect the current real-world situation in an easily understandable way.

Where would that be useful? Anywhere there is an oil pipeline is one answer. Many of the world's major pipelines run hundreds of miles across varied and often inaccessible terrain; they are vulnerable to different threats at any point along the way. Monitoring them around the clock is expensive, but so are accidents. Not long ago, a hunter shot a hole in one pipeline, causing a nearly 300,000-gallon spill that has cost more than $7 million so far to clean up.

Suppose, though, that the pipeline was studded with sensors and that the oil itself carried sensors along in its flow. These sensors could continuously monitor the rate of flow, the oil's viscosity and temperature, and many aspects of the surrounding environment. A change in pressure somewhere along the pipeline, for example, might be detected by sensors either in the pipeline walls or in the oil itself, providing an early indication of a leak. Engineers spotting a deviation from the normal performance could pinpoint the location of the problem using GPS capabilities, zoom in to check other factors and take action as needed. A leak or puncture could be fixed before it became a rupture—and a disaster.

Or suppose that sensors were embedded in the metals used to make critical components of an airplane engine. By monitoring the engine for early signs of imminent failure—fractures, for example, or metal fatigue—these sensor systems could prevent a crash.

The combination of tiny advanced sensors and Sensor Aggregation Models could be highly useful for any physical asset—equipment, plant or far-flung facility—that is difficult to monitor continuously but cannot be allowed to fail. For example, Accenture scientists have developed a prototype for a portion of a nuclear power plant that demonstrates how the idea could be applied to large-scale industrial facilities. Imagine a plant in which all intricate, critical equipment is richly embedded with sensors that could, as the situation requires, detect any change in performance levels, call for maintenance, assist the maintenance crews, signal regulators or trigger a shutdown.

Preempting failure

Embedding sensors in equipment, components or materials can do more than prevent catastrophic failure. It can also change the way day-to-day maintenance is done. Traditionally, equipment is serviced after being in use for a set number of hours—and that number often reflects the expected point of failure for a weak machine. As a result, many pieces of equipment are taken offline for maintenance long before they actually need it. Sensor technology makes it possible to monitor the true condition of individual pieces of equipment, anticipating their failure and scheduling maintenance on an as-needed basis.

AMSKAN Ltd., an Australian engineering services company, uses currently available sensor technology to monitor railcar axle boxes for heat buildup, an indicator of imminent bearing failure. Sensing stations positioned along the tracks detect when there is excess heat, match the reading with a specific railcar and notify central maintenance of that railcar's need of service.

As sensor technology advances, even more sophisticated methods of detection will be possible. Field maintenance will also become quicker and easier. A maintenance worker looking at a virtual double of the equipment or assembly will know instantly and with certainty the condition of all components, their performance specifications and their maintenance histories. The end result will be equipment that stays online and performs more reliably than before.

Reality online has other important applications. For example, it can give new insight into how to design, sell and maintain products. Most companies lose track of their products as soon as those products leave the shipping dock. Manufacturers have very little idea how the items they produce are actually evaluated by consumers, how they are used after being purchased or how well they hold up in customers' hands. In other words, they cannot be sure that they're producing and delivering the best products possible.

New insight

That lack of real-world information can be overcome by embedding sensors in the products, then giving consumers incentives to share data about post-purchase use. Manufacturers as well as retailers will be able to track which products are taken off the shelf for inspection, for how long and whether they are ultimately purchased—all of which could provide insight about whether a customer was intrigued (or perhaps confused) by the product design.

In the automobile industry, telematics—services and applications provided by the two-way, typically wireless exchange of data between objects—already are in use, though they are currently limited to in-car services to the driver, such as navigational support using GPS. But in the future, they will be employed to enable manufacturers as well as various OEM suppliers to get real insights into when, where and how various customers drive; what features they use; and how different parts of the vehicle perform over time.

Similarly, electronic-game manufacturers could insert sensors into game consoles, resulting in a stream of information about playing patterns, gaming sites and equipment performance. Product designers might learn how to design better keyboards, for example, while software suppliers could learn what aspects of a game are most fun.

Post-production information can also be valuable for those who make or service industrial equipment or durable consumer goods. They could, for example, access a virtual double of those objects after purchase and track how the objects are used—even track when those items break down, get fixed or are re-sold.

With this information, they could design products better suited to how customers actually use them, and spot opportunities for upgrades, additional sales or service. If, for instance, the manufacturer sees via a virtual double that a customer is running an industrial pump at 98 percent utilization, and that it is heating up to within 5 percent of design tolerance, it might be helpful to suggest that the customer acquire a more heavy-duty model. Customers willing to share their data will find themselves in mutually beneficial partnerships.

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The customer: Getting to one

Reality online will transform the Web into a virtual mesh, encompassing everyone and everything, gathering information, organizing it in context, and enabling either humans or smart objects to take action. That will take us well beyond the original promise of computer-based e-commerce, which was to identify and better serve individual customers. Reality online will make it possible to monitor, understand and act at the level of the individual unit, whether that unit is a person or a discrete physical entity. In other words, we will be able to manage the physical world at a highly granular level, getting maximum performance from each individual unit.

Think of the implications for agribusiness. Right now, farmers manage whole fields—fertilizing, irrigating, controlling pests and harvesting according to information generalized over acres. But once millions of tiny sensors are dusted over the fields, a farmer will have specific localized data, making it possible to manage different plots according to their specific needs, even down to individual plants. The result could be lower costs, higher yields and fewer chemicals introduced into the environment for pest control.

The idea is equally applicable to the management of forests or vineyards. On ranches, sensor data could be organized around an individual steer or sheep so that the rancher could track its food, water, reproductive cycles and more, making changes to optimize each animal's growth and health.

By using sensor technology to monitor individual units, it becomes possible to spot and hold off problems that might go undetected too long when relying solely on data about the aggregate. Ranchers, for example, might notice small changes in the behavior of individual animals that could indicate a health problem. Imagine the value of identifying and isolating those animals before a disease spreads through the herd or across the countryside.

Cooling off

Monitoring individual units can preempt problems in the mechanical world too. Hewlett-Packard Co., for example, is trying a new approach to cooling semiconductors. The problem is that as chips become more powerful, they generate more heat. What's more, the development of chips with compound functionalities means that some areas of those chips will be much hotter than others. Spraying the whole chip isn't the answer, because excess coolant that doesn't evaporate will pool and cause malfunction. HP's solution? The company is using its inkjet technology to deliver precisely controlled streams of coolant to individual areas of each chip.

That same principle can be applied in any number of industrial scenarios. Detecting and acting on highly localized needs for heating, cooling, lubricating and so forth can keep large or complex pieces of equipment running at peak performance.

Reality online can also change the way that products, especially complex industrial equipment, are bought and used—in effect, changing the business model for equipment makers.

Of course, technology is not always intuitive—if you've ever had trouble setting the timer on your VCR to record a television show, you know

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what we mean. So how can consumers cope with increasingly sophisticated computer systems? The answer can be a virtual double of that computer, with a unique URL and with different subsets of the full information available to relevant parties.

Technical support people, for example, could get an overview of the whole system, revealing what hardware and software was installed and running. Peripherals suppliers could be given access to advise and confirm that their add-ons would work before a customer completes a purchase. Customers could get real help, without struggling to answer a list of questions asked by a service technician.

Now take the idea to a greater level of complexity: Imagine how valuable a virtual double would be for the owners of industrial equipment, vehicles or aircraft. These expensive assets have long lives during which they are individually altered and maintained until each becomes nonstandard, and therefore harder to describe or understand—and hence service.

Reality online will make it possible to truly know individual customers, which is key to fulfilling the original promise of e-commerce. For example, consider the dilemma of a retailer who wants to offer discount coupons (physical or electronic). A store might sell 50,000 items, but any given customer might buy only 300, and the truly price-sensitive one only a dozen.

The traditional approach is to offer all customers the same fixed discount on certain popular products. But by combining demographic data with newly abundant purchasing data (available from checkout systems and loyalty card programs or by tracking online purchases), it is possible to create a virtual double of each customer's purchasing patterns. Then a retailer could individually tailor coupons—the items offered and the amount of the discount—simultaneously optimizing customer satisfaction and store profits and sales.

Skin deep

Going even further, reality online captures and simulates an individual's physical characteristics or sensory preferences. A virtual body double, for example, could replicate a person's measurements head to toe, even capturing coloring and skin tone. With that body double it would become possible to custom-tailor any item of clothing—suits from Hong Kong, shoes from Italy or a real Panama hat.

The ability to digitally represent a real person could solve one of e-retailing's current shortcomings. Customers have been more willing to shop online for products that can be sampled electronically (think of a book excerpted on an online bookstore) or described through agreed-upon specifications (say, a particular digital zoom camera). Highly personal products involving fit and taste have been harder to sell. Now that, too, could change.

With a virtual body double, a customer could order personal items online, confident that they would fit and look good. That would be a real benefit for customers, who now often order the same item online in three sizes or colors to find the "right" one, and to online retailers, who grapple with return rates of 40 percent. A customer could share that body double with friends or family who might be shopping for a gift, or make it available to retailers who could then suggest new items for purchase.

Human skin is the body's largest organ, and one of the most difficult to capture digitally. Yet that's the idea behind Skin Station, developed jointly by technology company

MEMSCAP and the French cosmetics maker La Licorne Laboratories SA. The device combines sensors, electronics and software containing clinical and medical data on skin: Users touch the sensors with their wrists to get personalized profiles. Skin Station, which is expected to debut at European cosmetics counters in late 2002, also has potential applications in dermatology offices.

Or imagine the power of a virtual nose, able to consistently detect and digitize the highly sensory experience of smelling. Accenture Technology Labs have developed a prototype called Scent Insight, which is built around an electronic nose that can smell and analyze fragrances. With this information, it is possible to tell a customer who likes one fragrance what others he or she might enjoy, or to guide a company in creating successful new fragrances. A man could splurge on expensive perfume for his wife, certain that she would love and wear it. The technology could be extended to other sensory experiences such as taste (which is based, in large part, on smell). A coffee lover could confidently order an exotic flavor online, knowing that its "crisp, clean taste" will truly be to his or her liking.

Since the e-commerce revolution began, businesses have been talking about granularity and personalization—but the reality has often been just lots of data about sales transactions. It takes reality online to create the rich picture of the real world that makes it possible to observe and act on the smallest of units.

Service with a smile—and a sensor

Reality online does more than just enable companies to manage at the most granular level. It also opens up new ways to define and deliver service to customers as individuals, offering them a level of personal convenience never before possible.

For an everyday example, think of package delivery—and the frustration of either waiting around for a package or getting one of those "failed delivery" notices. There is an alternative: The package could find you.

That's the idea behind Accenture Technology Labs' Dynamic Delivery prototype. In essence, the data required for delivery is organized around the customer, and the service draws on a range of technologies that enable reality online. Intelligent agents and global positioning system capabilities track the customer's whereabouts. Wireless services notify the customer of an imminent delivery, give the driver access (with permission) to the customer's personal calendar, and e-enable signature payment and signature release as needed. A wearable computer with a heads-up display feeds the driver the latest information. All this, in combination, brings the customer and the package together in real time.

Another opportunity lies in providing any number of services to individuals, on demand, wherever they are. Again, this is possible through a marriage of technologies that find individuals, show their situations in context and connect them to others who can share information and offer help.

Think of the busy executive with no time to exercise until late at night. Can he get a personal trainer at 10 P.M.? Yes—virtually. A trainer available online could watch the executive work out, monitor his technique, answer questions and provide motivation. Similarly, imagine an executive landing late at night in a foreign city she doesn't know. An online guide could help her overcome language and other barriers to enable her to successfully navigate the city.

Service breakthroughs like these will happen as it becomes possible not only to reach anyone, anywhere, at any time, but to see and understand the context of their reality at that moment—where they are, what they are doing, how they are moving and responding . . . and, therefore, what they need. This is the ultimate in personalization.

The decision maker: Functioning in current time

As information flows faster and communication becomes instantaneous, business should operate in real time. But it doesn't. Decision making—the ability to act on all this information—isn't keeping up.

It's no secret that we now get information more quickly than ever before. Until the mid 1800s, news couldn't travel faster than a ship could sail or a man could ride. Then came the telegraph—then the telephone, the fax, e-mail and now instant messaging.

Reality online picks up the pace even more dramatically. It's "reality" in part because it is continuously updated, creating an ever-changing picture. Furthermore, the information available from innumerable sensors, cameras, microphones and so on doesn't come as a single message, like e-mail, but as a wealth of data that must be aggregated and made meaningful, again at speed.

A useful model for thinking about the problem is the OODA loop. The US Department of Defense acronym stands for Observe the situation, Orient yourself to it, Decide what to do, and Act. OODA is a loop, because action changes the situation, so the process begins again with observation of the new reality. Success goes to those who move through the loop fastest, because they are most likely to exert control over the situation.

Now apply the OODA loop to business. Typically, too much time is spent in the Observe stage of the cycle, and too much of the data is either historical (sales figures, product performance) or about what is happening today (where is the product in the supply chain?). The challenge isn't to eliminate that data, which is valid and useful. It is to get more current information, meaningfully displayed so that business leaders can more quickly orient themselves, decide and act. Rather than gathering data about the past (year, quarter, even day) to manage better today, the goal is to have up-to-the-minute data, in context and at our fingertips, to anticipate and take charge of tomorrow.

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But at what point does all this information become too much? That's a legitimate concern for businesses, many of which are already building ever-bigger warehouses for the raw data they already have. When sensors become as small and omnipresent as dust, don't they threaten us with a data dust storm? Will reality online help us—or bury us?

Accenture believes that this is a problem created by advances in technology—but also one that technology can solve. Here's how.

First, not all of this data requires our attention. Smart objects can be programmed to do some of the work themselves. Automobile airbags, for example, don't wait for you to see a crash coming and flip a switch; they rely on a microelectromechanical device that detects the car's rapid deceleration and deploys the bag in a microsecond.

As sensors become more sophisticated, they are also becoming capable of forming ad hoc networks and of communicating, via web services, with computer applications. More and more, we'll be living in a smart world where the objects around us will take care of themselves.

For example, shipments of temperature-sensitive food, such as fresh fish, already can be marked with simple RFID tags that record temperatures during shipping, indicating whether the fish ever got too warm, and when and where that happened. That's useful information, but it doesn't do anything to prevent spoilage. Soon, though, that shipment of fish will have a sensor attached that would not only detect a rise in temperature but also turn on the air conditioner, solving the problem.

In much the same way, microsensors scattered over a farmer's field may not only note when individual plants need water but also turn on localized irrigation units to meet those needs. Sensors embedded in industrial equipment could anticipate a coming breakdown and gen-

Intelligent software can help by sorting through the blizzard of available information, finding what is credible and relevant, keeping it current and presenting it in a way that is meaningful to the decision maker.

Making decisions at e-speed

In today's extraordinarily fast-paced business world, opportunities can appear and disappear in an instant. Business leaders need to be able to execute just as quickly. But having the latest information instantly available and continuously updated is only half the challenge. These days, people also expect an instant response. Two prototypes from Accenture Technology Labs address this challenge.

Live Information Models integrate streams of data from multiple sources, internal and external, via the Internet. These live data streams are embedded into desktop applications that allow users to build simple and flexible analytical models to be shared with one another.

Currently, this prototype is being applied primarily to augment enterprise integration solutions by aggregating enterprise data—such as sales figures, customer information or supply chain data—and then presenting that data in a practical spreadsheet format. The information can then be shared among internal users or with trusted external partners and suppliers. A retailer, for example, might combine real-time inventory data with frequently updated market research as an aid to strategic decision making.

The emergence of web services, which provide a communication standard for applications over the Internet, opens up the possibility of incorporating different types of data, including those coming across corporate or enterprise boundaries. Live Information Models could integrate streams of information on the physical world coming in from sensors, and the prototype's modeling capabilities could be adapted to create new types of displays that would best capture continuous changes in this data.

The Mobile Decision Support prototype (shown above) takes information availability one step further. It monitors crucial functions within an organization, recognizes an event or juncture that calls for action, and conveys the vital information instantly to all key decision makers via a Java-enabled, "always on" mobile phone or digital organizer.

Alerted to an incoming message, the decision maker can use the menu options and communication capabilities of the mobile device to act on the spot or to bring others into the decision-making process, all within a matter of seconds. A user also can program the system to recognize significant variations in key indicators and to take prompt action on its own.

Here, too, the prototype is currently designed to monitor conventional business functions, such as inventory, ordering and payment processing. But web services make it equally feasible to monitor data from sensors, making Mobile Decision Support a key component of functioning in real time.

erate a maintenance call—or shut the equipment down to prevent a crisis.

Credible and relevant

When humans do need to see the data and make a decision, intelligent software can help by sorting through the blizzard of available information, finding what is credible and relevant, keeping it current and presenting it in a way that is meaningful to the decision maker.

Think, for example, of the Internet, which can be both a rich source of information and a frustrating thicket of meaningless (and annoying) clutter and dead ends. Each year, businesses spend more than $13 billion on market research about their products and services, with a growing portion of that budget being spent on researching the Web. But the Internet has more than 550 billion documents, most of which are unstructured—and that's not counting the information available in chat rooms, on message boards, on intranets and in newsgroups. This information comes in a plethora of languages and formats, from multiple electronic sources and locations. How can a company learn anything meaningful without spending a fortune?

Part of the answer will lie in specialized search programs designed to home in on specific types of relevant information and bring only that information to a manager's attention, in an organized way.

An example can be found in another Accenture Technology Labs prototype, Sentiment Monitoring Services, which helps companies use Internet sources to gauge public perceptions of various features, products, brands or organizations. Combining a search agent and a perception engine, this prototype searches preferred websites or newsgroups for opinions, reads electronic content in multiple languages, interprets the sentiment of the text toward the product or service, and analyzes the results. And it does all this quickly and continuously, giving companies up-to-the-minute information and rapid feedback on any timely development, such as a new product launch.

Even more creatively, technology can help individuals find what they may not even have known they were looking for. The Accenture Knowledge Discovery Tool, for example, has been dubbed a "search engine on steroids"—but its essence is its intelligent software. This Labs prototype can explore all relevant data repositories, probing for those that are most current, pertinent and actionable, and then display that knowledge as though it were part of a single integrated database.

When a user queries the Tool, the screen fills with color-coded clusters of associated information, each of which can be tapped for additional layers of information related to that cluster. Rather than make a direct search based on clumsy attempts to find the right keyword, users can browse in an enriched environment, finding materials and making connections that they might not have discovered on their own.

Users can also find useful human contacts, as the Tool identifies individuals with similar research or knowledge interests, and then puts them in touch with one another through a chat room. With this prototype, technology takes a proactive role in organizing and offering information in a way that is related to patterns of human thought—and so of highest value to the individual.

Reality online offers immense quantities of new data about the real world, coming at us minute to minute. But the challenge for business leaders is not simply to manage an even more intense data overload; technology can help solve that problem as software becomes increasingly intelligent. The human challenge is knowing what is of value or recognizing a useful insight when it appears. Reality online harbors a million useful answers—if we pose the right questions. ■

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