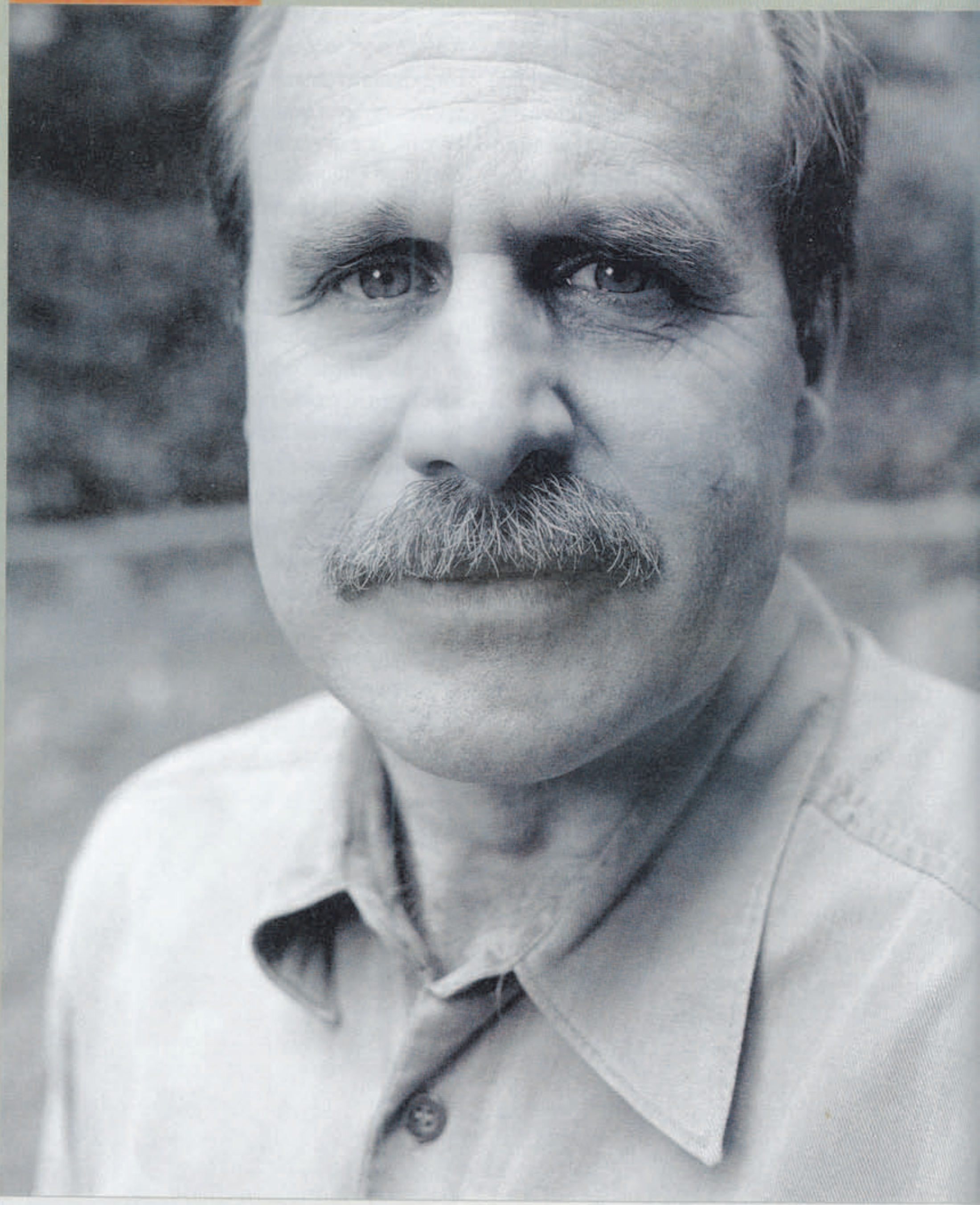
EXPERT VOICES PAUL SAFFO



Sensory Perceptions

Thanks to the new generation of smart sensors, machines talking to machines are creating the next leap in the evolution of automation—at work and at home.

Futurist Paul Saffo isn't quite a household name in the way that Marshall McCluhan was in the 1960s, when he explained the meaning of rapid changes in communications technology to the general public. But Saffo is getting there. Since 1985, Saffo has been a technology forecaster studying long-term technology trends and their impact on business and society. As a director of the 34-year-old Institute for the Future in Menlo Park, Calif., Saffo has written essays about change in numerous publications, including The Harvard Business Review, Wired, The New York Times *and* Fortune. *The author of* Dreams in Silicon Valley *and* The Road From Trinity, *Saffo is also a member of the Stanford Law School Advisory Council on Law, Science & Technology. Among Saffo's abiding concerns is the coming revolution in sensors: tiny Micro-Electro-Mechanical Systems, or MEMS, which he believes we'll soon find in everything from cereal boxes to factory systems—and that can be applied to solving a wide variety of IT problems in data-switching and storage.*

In a recent conversation with Executive Editor Marcia Stepanek, Saffo says the sensor revolution has already arrived. Through radical improvements in getting computers to talk more and more with one another, machines have already begun to take over more of our repetitive, quotidian tasks, such as paying bills and running factory floors, says Saffo, "and we've just started to realize the marketing, IT and commercial potential." What follows is an edited transcript of his remarks.

We marvel at how computers have insinuated themselves into every corner of our lives, knowing all the while that in a few years, today's marvels will seem quaint compared with what follows. It turns out that about once a decade, a new technology comes along that completely reshapes the information landscape. In the late 1970s, that key enabling technology was the microprocessor, and its arrival set off a decade-long processing revolution symbolized by the personal computer.

Then another new enabling technology came along to displace the centrality of the microprocessor—cheap lasers. Much as the microprocessor slipped into people's lives hidden in PCs a decade earlier, lasers slipped into the lives of ordinary citizens hidden in everyday appliances—compact disc players, CD-ROMs and long-distance optical fiber phone lines. Lasers delivered bandwidth, huge volumes of storage on optical disk and high-quality communications bandwidth over optical fiber.

The consequence? A shift in emphasis from processing to access. In the 1980s, our devices were defined by what they processed. In the 1990s, our devices were defined by what they connected us to. And the poster child of the decade, of course, was the World Wide Web.

But we are beginning to see diminishing returns from merely adding more bandwidth to our access-oriented world. Now change is being driven by sensors—cheap, ubiquitous, high-performance sensors, or MEMS—and they will shape the coming decade.

In the 1980s, we created our processor-based computer "intelligences." In the 1990s, we networked those intelligences together with laser-enabled bandwidth. Now, in this decade, we are hanging eyes, ears and sensory organs on our computers and our networks. We're asking them to observe the physical world on our behalf and to manipulate it. This decade will be marked by a sensor revolution—a big leap in automation that will have a far-reaching influence on business and society.

Processing plus access plus sensors will set the stage for the next wave—interaction. By interaction, I don't mean Internet-

How do we seize on trends?

In New York City's Herald Square, a coffee shop lures patrons with the promise of home cooking. Photograph: Richard Pare, 2002

GALLERY12

variety interaction among people. I mean the interaction of electronic devices with the physical world on our behalf. The U.S. Air Force's new unmanned Predator spy plane, flying with two air-to-ground Hellfire missiles underneath its wings and now in testing by the Pentagon, is nothing more than a sensor-rich flying robot, controlled from a trailer miles away from the target by "pilots" at computer consoles.

But you don't have to go to Afghanistan to see this stuff. Get in your car. You've got sensors in automobiles running effectors that control their fuel consumption. A GPS on a chip is just a fancy sensor. The FCC has mandated that all mobile phones have built-in position-reporting systems in the very near future, so that when you call 911, law enforcement agents and emergency medics don't have to ask where you are. The way the government convinced mobile phone manufacturers (who hate spending an extra penny) to add these GPS sensors to their mobile phones was by saying, "OK, you do this, and in exchange you get a little benefit—you can use this to sell location-based marketing."

So there you are in San Francisco. It's one o'clock in the afternoon, you're walking down the street and your mobile phone chirps. You look at it and it's an electronic coupon from Colonel Lee's Mongolian Barbecue. They know you've eaten there before, and you haven't been there recently, and they know you are in the neighborhood, so they say, "If you get in here, we'll give you a lunch special." That's how sensors are going to take over the marketplace.

The fact that MEMS is not a new technology underscores an important point about how each successive decade unfolds. What defines each decade is not a technology's invention, but rather a dramatic, favorable shift in price and performance that triggers a sudden burst in diffusion from lab to marketplace. Like MEMS, both the microprocessor and communications laser were "old" technologies from a research perspective by the time their respective decades began. The novelty was that the devices suddenly were cheap enough to put into ordinary products in the marketplace.

Here's another example—piezo materials. They're typically ceramics that give off an electrical charge when deformed and, conversely, deform when in the presence of an electrical field. Piezos are particularly useful as surface-mount sensors for measuring physical movement and stress in materials. But more important, piezos are useful not just for sensing, but for manipulating the analog world. This is the real significance of the sensor decade. These devices won't merely sense and observe. They will also interact with the physical world on our behalf.

A few years ago, K2 came out with a ski that had a piezo layer in it, creating a primitive "smart ski" that sensed ski chatter and then dampened it out by running electricity out of a sensor in the ski. Years ago, researchers at the Georgia Institute of Technology were engaged in a whimsical application of this—they created a piezo-augmented "smart guitar" that mimics the sound of a high-end traditional guitar at a much lower cost. All of this is bringing us to the point of creating new classes of "smart materials"—materials that actively sense and respond to the surrounding analog environment.

At our level, reality is analog. Computers are digital. And in a very important respect, digital is dead. The fast growth is in analog. Sensors suck up data in an analog environment, and then you've got to do a conversion so a computer can work on the data. We already know that there are certain classes of problems that are harder to solve in the digital space that are relatively more straightforward in the analog space. Therefore, we may see the rebirth of analog electronics big time—silicon-based analog electronics.

The impact of sensors will be as surprising in the decade ahead as microprocessors were in the 1980s and lasers in the 1990s. And the surprises will be additive because of new interaction among existing generations of technology, with some of the most interesting applications of sensing technology applied to dealing with current problems. It's still early, but in the future, society and business will be saturating the world with communications and information. The future is not going to be people talking to people; it's not going to be people accessing information. It's going to be about using machines to talk to other machines on behalf of people. That's where the growth is going to be. It's also why all of our assumptions about available bandwidth and how much bandwidth we need is wrong by orders of magnitude, once all of these machines start talking to each other.

We're not talking machines like, say, computers. We're talking about washing machines, cars, bank machines, appliances of all kinds, oatmeal in boxes tagged with sensors that tell the factory it's just been bought from the Costco in Novato, for example.

High Fidelity

Consider RFID—Radio Frequency Identification Devices. MIT has a lab called the Auto ID-Center developing this technology. What is RFID? It's an ID chip, a computer on a chip that you can embed in, say, a box of detergent, and the detergent now can tell you what it is, where it's from and where it went once it left the store. Sure, its obvious application is factory inventory control, but you can use it for all sorts of things. Believe me, the market for RFID is vast. Today, when you're thinking of machines talking to machines, people think about the personal computer or the mobile phone. But that's not even the start of it. Machines talking to machines are all about little devices inside everyday things that we won't even see and won't even know exist. Imagine a home burglary system that's wireless. Each little burglar alarm, each little burglar sensor has its own processor with its own Web page.

Imagine that your washing machine has crapped out, so you go buy a new one. And you're looking around, and the high-end ones have this big sticker on the side that says "Internet-ready," and you think to yourself, "Who do they think I am, Bill Gates? I don't need a washing machine that talks to the Internet." But as it happens, you end up

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buying the high-end one because it has some other features you want. And so the company comes and installs it and you plug it in and get it all going, and as the installers are leaving your house with the packing materials, you go back into the house and your washing machine suddenly wakes up. It turns out that it's got Internet connectivity, but it also has a little wireless transponder in it. And it wakes up and it listens for a radio signal, and it picks up this little signal from the 802.11 box on the side of your house that you already use for wireless Ethernet distribution for your computer. And it says to the box, "Hi. I'm a washing machine. Would you mind if I use some of your band-

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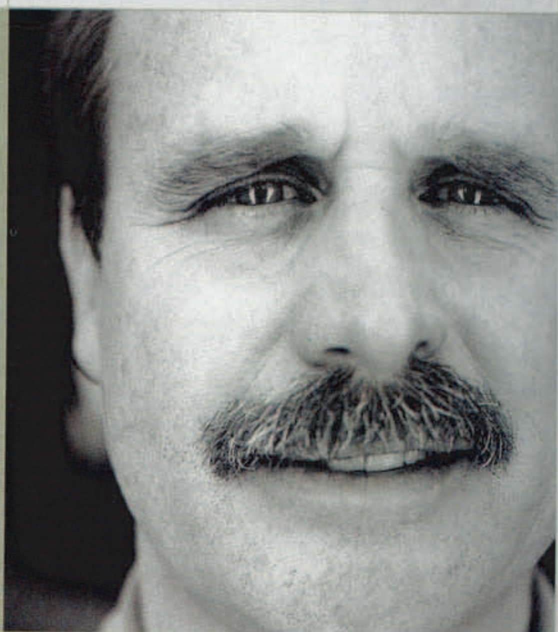

width sometime?" And the box says, "Fine." And completely unbeknownst to you, your washing machine starts a conversation with your computer and your Ethernet box.

Of course, you don't know this at all until one morning, you're late for work, you are rushing out the front door, and you almost knock over the Maytag repairman who's about to push your doorbell. You say, "What are you doing here?" He says, "Oh, didn't your washing machine tell you? It's got a flat bearing and it sent me an e-mail last night screaming for help." Well, you and I both know that this example is a mighty oversimplification, and the world won't exactly turn out that way—but that's the automation trajectory we're talking about here.

This isn't pure blue sky. Electrolux is already doing it. They wanted to do this because there's this huge unserved market of young people who would love to have a washing machine in their house or in their apartment and hate going to the laundromat, but they don't want to be held down by having to carry a washing machine through their multiple changes of residences. Well, Electrolux had this solution. They said we're not going to sell people a washing machine. We're going to give them a washing machine, and we will charge them by the load. The machine will be in their house, but the title will remain with us. It was basically having the convenience of a machine at home, and yet you as the consumer just paid a monthly bill. They tested this on the island of Gotland in Sweden, and are thinking of expanding it to a wider market.

Or take the Coca-Cola example. With MEMS, you can do something that's simple with a vending machine. Just given a sense of what time of year it is and what the temperature might be like outside, if you walk up to a Coke machine in February and there's snow on the ground, they might sell you a Coke below cost. But if you walk up to the same Coke machine, say it's on a golf course and it's the middle of summer and it's 100 degrees out, they're going to charge you a premium.

Other applications? Take quality control. Put moisture temperature sensors in a fast-food store's fryers so that you can find out if the humans changed the oil frequently enough, what the temperature of the fries were when they went in, if they were kept in the fryer for the right amount of time. If they're in there too long, the fryers can alert you. And so forth. You could create a fry robot that does it all better than humans now do, and every day that data is sent up to the headquarters of McDonald's Corp. for quality control.

All sorts of pieces of remote machinery

toil away unnoticed beneath our streets or out in the middle of nowhere. Load them up with sensors with a two-way telecommunication system and you can ask, "It's 11 p.m., do you know what your transformer's doing?" That's a huge problem for the utilities industry. And there are public safety implications, like railroad crossings. Think how nice it would be if you could know the status of a railroad crossing at all times and know if the gate really did go down. People already have put some sensors in these gates, but nobody's doing it right yet—putting smart sensors in there so that you really have proof that that gate went down and the track is clear. Now it's an awfully expensive thing to do with electromechanical technology, but boy, you combine wireless with the existing communications link along that railroad, add in a couple of chips, and *voilà*. It can be done, and much cheaper now than ever before.

Data Overload

But before all of this can take off, there are big problems today that must be solved. The problem at the moment is that basically everything in your life will start to have a processor and some communications ability, and we're going to have huge problems about moving data—huge issues—and not just issues about the volume of bandwidth, but architecture and client/server issues. On one hand, client/server is a big help because what you want to do is drive client/server architectures deep into houses. I don't want just a client/server box in my house. I want my alarm system to have its own server and my entertainment system to have its own server. Who knows? Maybe a whole new service industry will have to be created to support it all. But in the end, it's probably going to mean that peer-to-peer is vastly more important. If one light switch needs to talk to a light bulb, it would be better if the two could just talk directly instead of having a server box match with it.

So the reigning issue here is the sheer volume of information. It's getting huge, and it will get much bigger. The irony of the information revolution so far is that there's not really that much information involved compared with what's ahead. The volume of bandwidth is one issue, but also it's an issue of the architecture of the bandwidth. That's a problem already. That's why AT&T is in such deep trouble, because they have a whole bunch of circuit-switched bandwidth. It's also why getting away from circuit-switched networks toward routed and more exotic bandwidth is the way to go: It drives down costs and increases speed.

And here's another point. I think "information revolution" is going to go down as one of the most inept terms ever. It worked fine for information theory pioneer Claude Shannon and his mathematical theory of communications and all that, but when they really touch and change our lives, information systems cease to be information systems. They're media. This is a media revolution. We're in the middle of a transition from an age of mass media that started with the introduction of the television to an age of personal media that got off to a halting start with the personal computer. And there are some big differences between the two. Mass media, largely passive, delivered the world to our living rooms—but all we could do was press our noses against the screen and watch. It was one-way, it was largely passive. We did, though, have slumbering interactive desires—in the form of channel surfing with remote controls. Personal media is much more active, and that's the Internet and the Web, and it's getting more and more active. So far, the activity has been human-to-human. Now increasingly, it will be human-to-machine and machine-to-machine. We're going to expect that we can interact with everything around us.

Sure, the sensor revolution is going to take a little while. But before we're through, we're going to see some things that kind of look like the Jetsons. It comes one device at a time. But it's already begun.

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