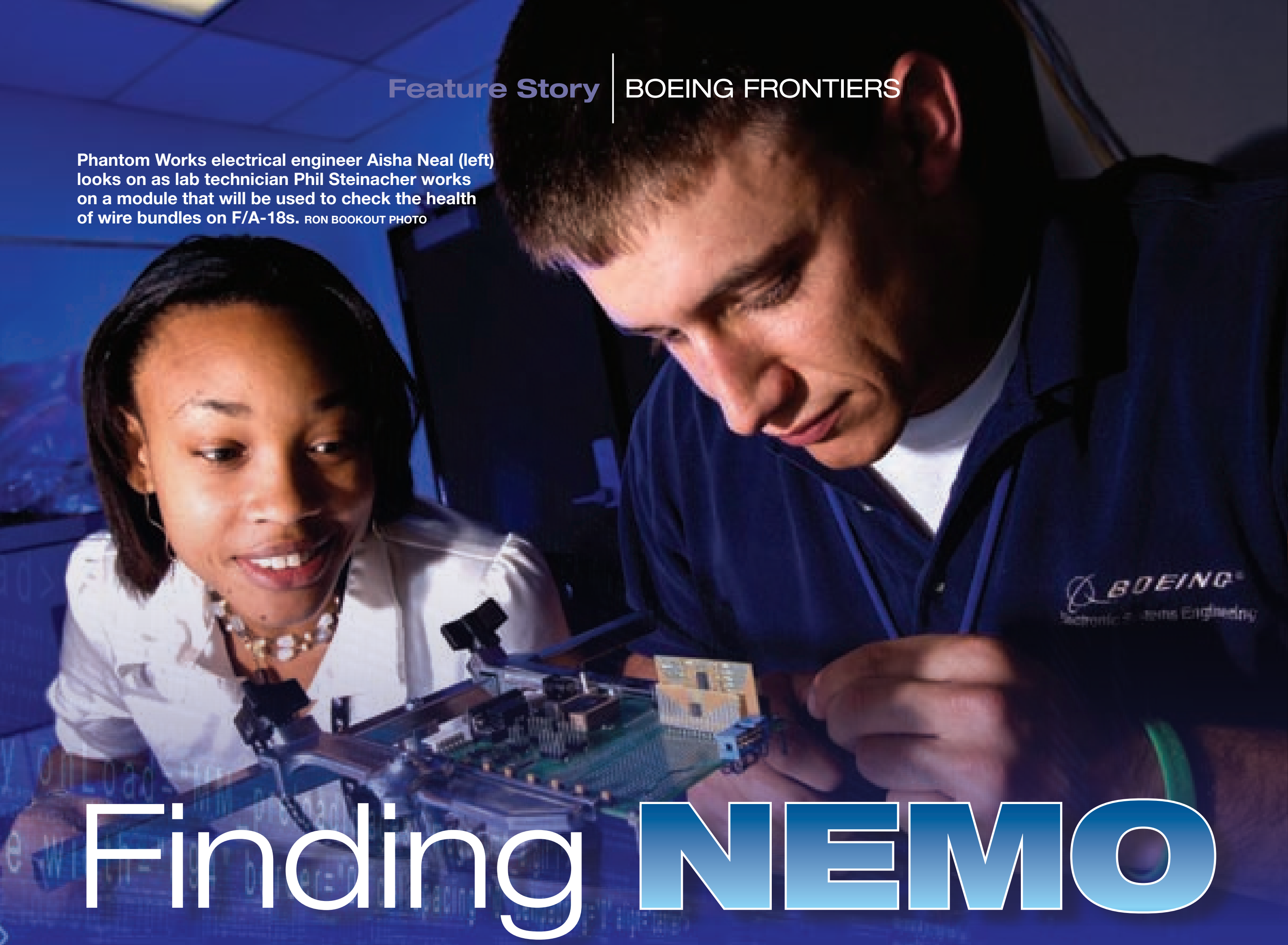


Phantom Works electrical engineer Aisha Neal (left) looks on as lab technician Phil Steinacher works on a module that will be used to check the health of wire bundles on F/A-18s. RON BOOKOUT PHOTO

Finding NEMO

'Situational awareness' and the power of the network aren't just battlefield concepts. Here's how these ideas will transform factories at Boeing

By William Cole

The year is 2018. A mechanic working on the upper wing of the 787 Dreamliner starts the day by pulling up work instructions that are projected right onto the wing.

The images not only show step-by-step the job that has to be done but the specific tools required to do it. Through electronic sensors installed around the factory, the mechanic knows that the right tools and materials are available and exactly where to find them.

Moreover, a sophisticated electronic sensor embedded into the hand tool the mechanic is using can actually train the mechanic to do this specific job on the spot, using a tiny cell-phone-sized flat screen.

Laser images projected onto the airplane tell the mechanic exactly where to position the part. When the operator centers the fastening tool over a preformed hole, the tool draws information from a 3-D solid model and installs the fastener at the exact torque value.

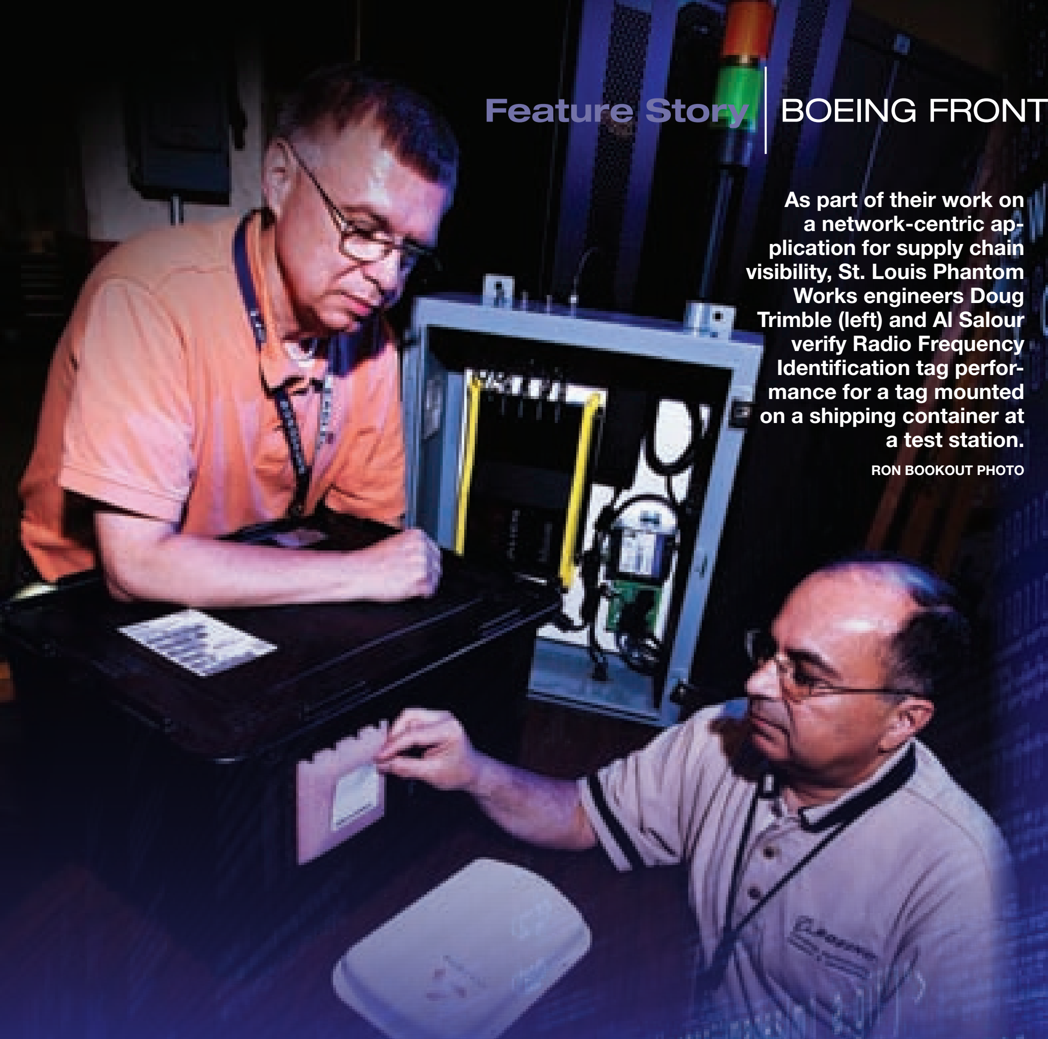
The tool then relays the installation information back to the system that provided the mechanic's work instructions, known as the manufacturing execution system. The system will verify the fastener was installed with the correct torque. Given the green light by the 3-D solid model, the operator continues through a work sequence of more fastener types of different sizes.

There's no guesswork, no manual calculation, no room for error and most important, no additional cost of rework as a result of operator error. The same approach applies to all tools that are connected to the control system: drill motors, sealant tools, dispensing equipment, paint guns, assembly jigs, and numerically controlled machines.

Other sensors and devices in the factory will constantly check the "health" of machinery, monitor safety materials and control even the use of energy. On the assembly line, electronic measurement and inspection systems will monitor and relay in-process information about every aspect of the assembly process.

That's just a glimpse into the factory of the future. Here, "situational awareness," a term often used in the military that refers to knowing exactly where everything is and what's going on, will be just as important in the assembly plant as it is on the battlefield.

But tools and sensors are the first layers of what will ultimately become a huge global system of systems—connecting facilities, customers, suppliers and external support and services—known as Network-Enabled Manufacturing & Operations, or NEMO.



As part of their work on a network-centric application for supply chain visibility, St. Louis Phantom Works engineers Doug Trimble (left) and Al Salour verify Radio Frequency Identification tag performance for a tag mounted on a shipping container at a test station.

RON BOOKOUT PHOTO

equipment and our shop floor operations into this bigger factory-controlled system-of-systems that would not only give us the information we needed but filter out the information we didn't need," he said. "Our vision now is to have this global manufacturing capability by connecting our suppliers and our internal operations into this massive controls system."

Part of NEMO's mission is to create what's known as the "cognitive" factory—an electronic factory that through a variety of sophisticated network-centric systems is able to think, reason, "be aware" and assist with making decisions based on real-time information. Those factories would be linked in Lean supplier networks to re-establish manufacturing as a competitive advantage for Boeing.

The cognitive factory will significantly reduce the effort of managing the factory floor. "Our employees do a lot of walking to get to the tools and parts they need or check inventory," Dods said. "The factory of the future will eliminate most of the time spent doing that. Shop floor workers and engineers will have fingertip visibility of all aspects of operations relayed to them by sensors and devices that are currently being tested in a majority of our pilot projects." (See story on Page 45.)

Sensors also will be used to take the work out of monitoring equipment and eliminate the clutter of batteries and power cords. They also will regularly check the health of machinery and systems, and recommend repair or replacement before they fail, said Doug Trimble, an engineer/scientist with Phantom Works and a member of the NEMO team. "We call that 'predictive maintenance,'" Trimble said.

Added Al Salour, an Associate Technical Fellow with Phantom Works, who is the principal investigator for an Network-Enabled Manufacturing task that is focused on factories inside Boeing: "With these pilots, we are going to build the model that can be replicated at all Boeing sites and offer value propositions that can result in a Lean and affordable manufacturing operation."

MODELED AFTER FCS

The NEMO concept is modeled on Future Combat Systems, the U.S. Army's modernization effort that will link soldiers to a wide range of weapons, sensors, and information systems. A Boeing-SAIC team is the FCS program's Lead Systems Integrator.

When FCS was first conceived, the concept struck a chord with manufacturing experts at Boeing. If FCS is designed to utilize network-centric capability on the battlefield and is demonstrating that the technology works today, why couldn't a similar capability be applied to the factory? Could a person on the shop floor or the engineer in a cubicle act as the "soldier" receiving all the right information for the most effective mission?

"We want to apply the same network-enabled concepts we are developing for our external customers to our own complex manufacturing operations," said Frank Doerner, vice president of AeroStructures, Manufacturing and Support Technologies at Phantom Works. He's been the sponsor of NEMO from its conception.

"The work that is going on will help create a seamlessly integrated operation, leveraging 21st-century information technology and network-centric architecture to create a manufacturing capability that provides Boeing with an enduring competitive advantage," Doerner added. "We have people all over the Boeing enterprise pooling their talents, creativity and resources to bring this vision to life and change the face of aerospace manufacturing."

NEMO advocates said this is a concept that will change the way products are created by reducing cycle time and overhead. It will standardize tools and minimize equipment costs. It will streamline factory-supplier-customer communications. Most of all, it will reduce paperwork and time spent looking for things and performing a variety of tasks manually.

SEEKING 'COGNITIVE' FACTORY

Bryan Dods recalls the time when the NEMO concept was hatched.

"We first started thinking about this in 2001 when network-centric operations was a new hot topic," said Dods, senior manager of Assembly, Integration and Test at Phantom Works in St. Louis, who is leading the NEMO effort. As he remembered, team members began to discuss this concept in meetings, and the team tried some simple equipment integrations on the factory floor.

"We realized we could replicate the Future Combat Systems approach and network our

PILOT PROGRAMS ALL AROUND

Several NEMO implementations are focused on the 737, 777 and 787 assembly processes at Boeing Commercial Airplanes, Salour said. But the NEMO philosophy is being applied to research and development projects companywide. Fastening projects for the F/A-18, for example, involve several team members.

"The plan is to build an architecture that applies to the whole enterprise," Salour said. "At the same time, we are working closely with our program customers and support functions to make sure that R&D investment dollars are applicable to the needs of these programs."

Sidney Ly, an Associate Technical Fellow and lead engineer responsible for Factory Information and Automation Technology R&D in the BCA Material & Process Technology organization, is working with his team to make sure the NEMO technology-development mission is aligned with the technology needs of the factory. He also is participating in the development and hands-on testing of NEMO architecture.

"It's great to be part of a team taking on the challenge of making all that possible—initially through the success of the pilot projects and technology breakthroughs, then through technology transitions and replications," Ly added. "Ultimately we're hoping to see resulting cost savings—and happy customers."

NEW LOOK WITHIN 5 YEARS

Full implementation of the NEMO concept is five to 10 years away, Dods said. But he added: "I believe within five years you'll see a different look on our shop floor as far as how we manage manufacturing."

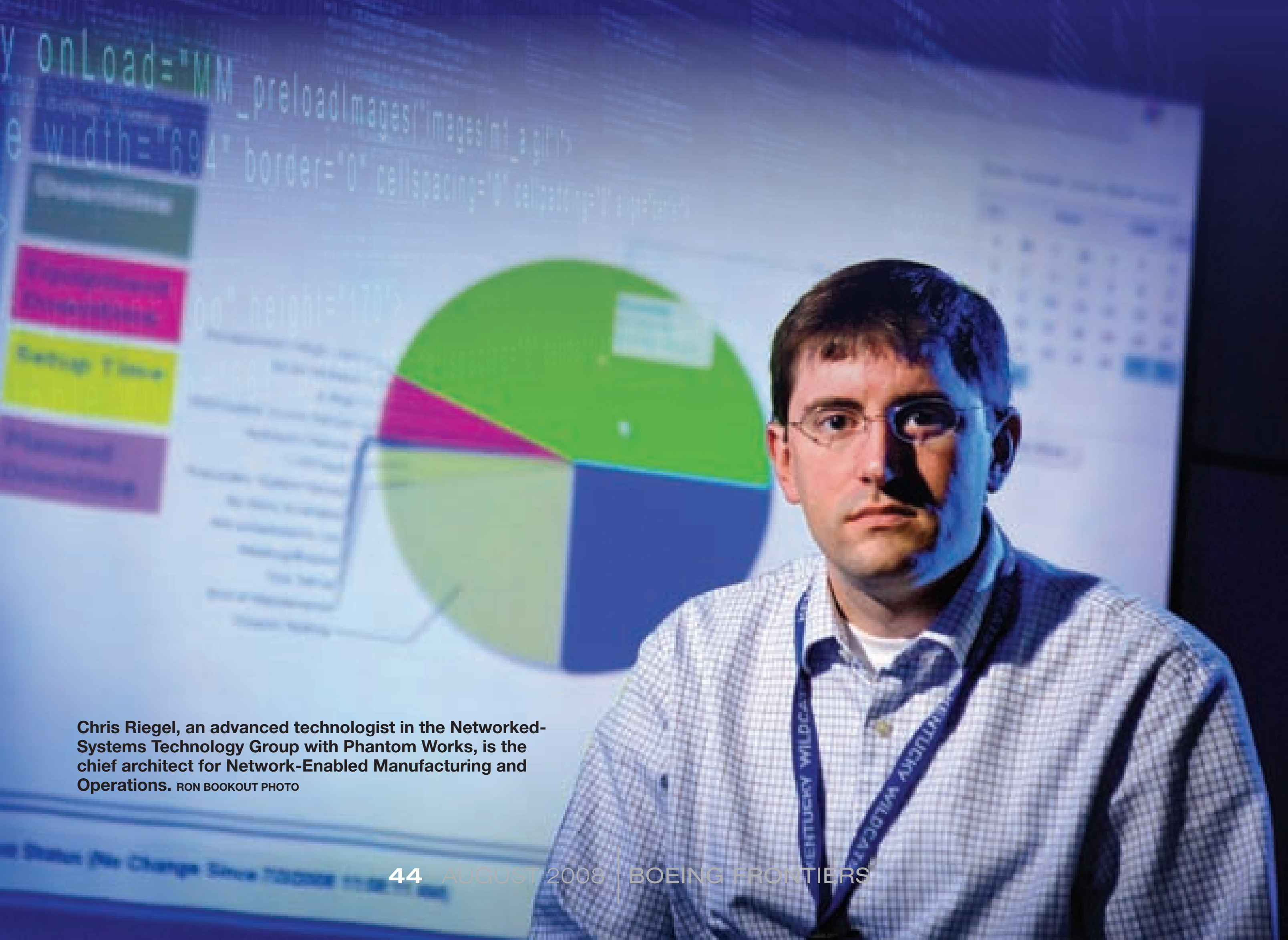
In the meantime, there's no shortage of ideas, and many of them are derived from the growing use of electronic communications tools in the commercial marketplace and other industries.

"All the technologies that teenagers are playing with today in terms of social networking are being fed into the enterprise," said Chris Riegel, an advanced technologist in the Networked-Systems Technology Group with Phantom Works and the chief architect for NEMO. "This makes for better collaboration, problem solving and replication across the enterprise."

Certainly, the team is drawing on every resource. Aisha Neal, a Phantom Works electrical engineer, is using experimental sensors to test F/A-18 wire bundles on the shop floor. Boeing just hired two doctoral graduates from Missouri University of Science and Technology as advanced technologists: James Fonda, who is working on wireless technologies, and Jonathan Vance, who is working network controls and "how to bring the network to the shop floor."

"We have people in Southern California and the Puget Sound region working on various projects associated with NEMO. But this is more than just a project or program. It is becoming a culture, a philosophy among our employees," Dods said. "This is an exciting time. NEMO promises to be a revolution in manufacturing, and I'm proud to say it started right here at Boeing." ■

william.cole@boeing.com



Chris Riegel, an advanced technologist in the Networked-Systems Technology Group with Phantom Works, is the chief architect for Network-Enabled Manufacturing and Operations. RON BOOKOUT PHOTO

In Renton, Wash., Sidney Ly (from left) and Joe Fletcher, Associate Technical Fellows; Russ Tice, contracting engineer; and Sujith Mally, assembly technology engineer, discuss the 777 Gemcor Real-time Machine Monitoring Dashboard application—one of the Network-Enabled Manufacturing team's pilot projects.

MARIAN LOCKHART PHOTO

Pilots for the future

Network-Enabled Manufacturing & Operations pilot projects and devices are currently being demonstrated at Boeing facilities. They include

Point-of-Use Kit Tracking: Sensors mounted on factory walls detect movement of valuable assets in real time. Other sensors are attached to materials received from suppliers and automatically report to inventory tracking systems as they pass through dock doors or when they leave storage cribs in the factory.

Wire integrity testing "motes": Devices that continuously monitor the health of airplane wire bundles through shipping, receiving and during factory installation. Currently the devices are being used to check F/A-18 wire bundles in St. Louis.

777 and 737 Gemcor machine monitoring: Machine monitors that report machine downtime and reasons for the downtime, which will result in better scheduling.

737 sealant cure-time monitoring: Temperature and humidity sensors to keep track of sealant cure times.

737 wheel-well B-nut installation: Location sensors integrated into torque tools to help ensure 100 percent installation of tubing prior to functional tests.

Smart tools: Drilling and installation tools adapted with sensor electronics for user authentication, setup information, calibration status, and interactive go/no-go functions.

Facilities condition–based monitoring: Sensors attached to electric motors for monitoring the operation and health of plant and facilities equipment such as heating and cooling systems, air compressors, paint booths, ovens, and exhaust fans. These sensors help ensure functionality and provide prognostic capabilities.

Nondestructive evaluation and defect collection: Integrated plans to collect nondestructive test and defect data from the ultrasonic scanners, report as-built conditions, and maintain records.

Time- and temperature-sensitive materials control: Sensors added to sealant freezers to accurately track inventory and usage, and the supporting infrastructure to streamline receiving process transactions and reduce material waste.

—William Cole