SOMETHING TO PROVE

Robots are starting to replace human technicians in infrastructure inspection.

BY ALAN S. BROWN

MECHANICAL ENGINEERING THE MAGAZINE OF ASME Special Report

Robots have emerged as a force in infrastructure inspection.

That is especially true in the oil, gas, and petrochemical industries, which are not an obvious test bed for new technology. Because their assets range into the billions of dollars, their managers are very cautious about entrusting their facilities to any new technology. Yet even something as simple as inspecting storage tanks for corrosion and leaks shows why robots are increasingly popular.

Tanks are exposed to weather outside and aggressive chemicals inside. Users must periodically look for damage on their walls, roofs, and especially floors, where water under the tank can cause invisible corrosion.

To inspect a tank, operators must empty it, vent any toxic gases, and erect scaffolds to get to high structures. Depending on the intensity of the inspection, this takes weeks or even months. It also exposes workers to heights and confined spaces, two of the industry's most common causes of accidents and death.

Enter the robots. Magnetic robots crawl walls, traverse roofs, and search floors for flaws. Quadcopters do visual inspections inside. They are potentially faster and cheaper than humans, since they eliminate the need for scaffolds and confined space work.

On offshore oil platforms, drones check equipment and remote operated vehicles to search for problems in submerged pipelines. On land, they scan gases flaring from tall stacks for equipment leaks and overheating. Underground, their pan-and-tilt cameras illuminate the sides of pipes too small for humans to enter.

At Waukesha-Pearce Industries, a 100-year-old oilfield services company, Terry Nelson uses crawlers to check fire tubes, 20-foot-high chimneys that regenerate desiccants used to remove water and contaminants from natural gas.

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Cyberhawk began using drones to inspect offshore oil platforms 10 years ago. The company believes that autonomous drones cannot yet match drones piloted by trained pilots and inspectors.
Photo: Cyberhawk

"We used to shut the well, cool the tube, and pull it out and lay it on its side with a large crane," said Nelson, the company's production equipment services manager. "Now we leave it in place until it cools below 200 °F and send in a robot to map the erosion, corrosion, dents, and fissures. It takes six-to-eight hours."

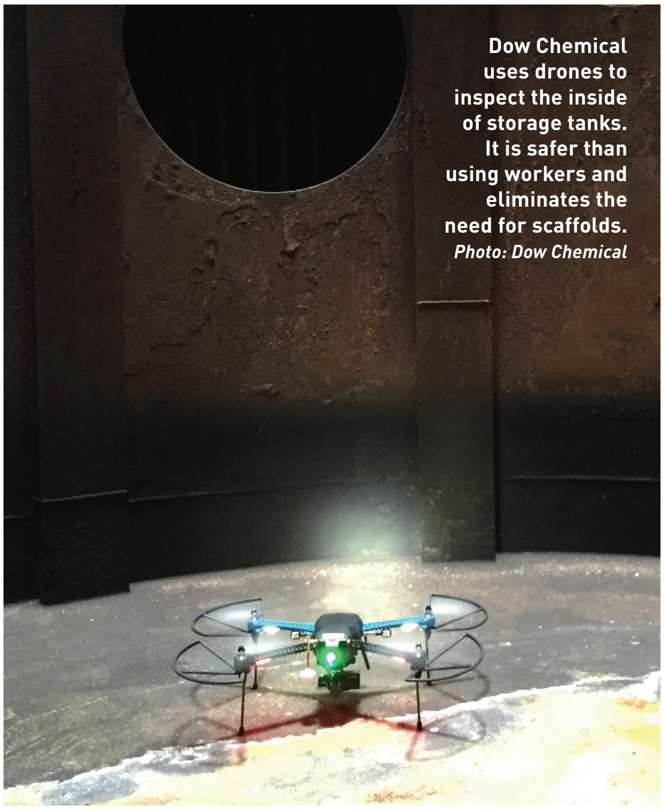
Robots cannot do everything yet, said Brad Tomer, vice president of operations at Avitas Systems, which applies Big Data techniques and robots for Waukesha-Pearce. Yet they do some things really well.

"In a given plant, they might do 40 percent of what was done manually before," he said.

And robotic inspectors are getting smarter and faster. Using advanced analytics and machine learning, Tomer slashed the time it took to survey 20 different wells to seven days, from 40.

Industry loves those numbers. It loves the improved safety and lower workers' compensation costs. The efficiency of robots reduces the need for people, and it likes the reduction in workforce.

Yet, given the size, cost, and complexity of their facilities, the industry remain cautious. So, why did refiners let in the robots? And how did they learn to trust them to conduct tests as well as human beings? The answer is complex, and it says a lot about how the next wave of robots might penetrate other industries.



Dow Chemical uses drones to inspect the inside of storage tanks. It is safer than using workers and eliminates the need for scaffolds. *Photo: Dow Chemical*

DRIVERS

Safety played an important role in bringing robots to Dow Chemical, said Twain Pigott, Dow's lead robot architecture specialist. His group wanted to use technology to reduce confined space, elevated fall, and equipment cleaning accidents.

"Those three account for largest number of injuries and fatalities in our industry," he explained.

Economics were also powerful. Because robots do not require scaffolds or ropes, they deploy faster and can reduce inspection costs by up to two-thirds, said Waukesha-Pearce's director of drilling and production services Fred Stow.

"In the old days, you would drive out to the middle of nowhere and spend all day running 100 different diagnostic tests," he said. "Now, I can fly there, map the assets, and take visual and infrared readings on the site. If we measure the assets more than once, we can see how they change and do predictive maintenance and root cause analysis of problems."

Oil and gas were ready for those arguments. Since the 1980s, many had used remotely operated vehicles—tethered underwater robots—to inspect offshore pipelines at depths where humans could not dive safely.

They were also converting cylindrical "pigs" used to clean oil, gas, and chemical pipelines into "smart" pigs outfitted with sensors to measure leakage and pipeline integrity.

Yet the industry "never took robots seriously until late 2010," said Adam Serblowski, who heads Shell's robotics program. "That's when drones opened people's eyes. They were fully commercial, and we didn't have to put in time to make sure the platform worked."

Serblowski first used drones to inspect the tall towers that flare off excess natural gas. Drones equipped with an infrared camera could inspect the flare while it was running and identify hot spots and uneven heating that were invisible to workers who mounted the tower only after it had cooled down.

Today, Serblowski describes his use of drones as "a list a mile long." For example, he now uses an Elios quadcopter encased in a pliant cage to inspect the interior storage tank walls and roofs. If it bumps into a protruding pipe or support, the cage absorbs the impact and the drone keeps flying rather than crashing to the ground.

"We still have to drain and vent the tank to make sure there is no explosive atmosphere present," Serblowski said. "Still, it's a gain because we don't have to put a person inside and we can inspect the roof without any scaffolding.

"The downside is that battery life is not great, since the drone has to carry the added weight of the cage and the sensors," he said.

As a result, a full inspection takes two days. Still, that is much faster than the time needed to build and remove an interior scaffold.

Inuktun's reconfigurable robotic crawler inspects the interior of a pipeline. By switching to magnetic tracks, it can crawl along the walls of a storage tank.
Photo: Inuktun

Drones awoke a new interest in crawlers. Dow uses miniature robots outfitted with pan-tilt-zoom high-definition cameras to crawl through smaller pipes that run between parts of its chemical plants. Shell uses crawlers with ultrasonic sensors to test its tank floors.

And the more industry invested in robots, the more companies launched new and better systems.

NEW MODELS

The result is a growing profusion of ever-more capable robots. One example is Inuktun InCommand Robotics' modular crawlers, which let users outfit one of several different chassis with an assortment of tracks, controllers, manipulators, cameras, and sensors.

"Instead of having one robot for a pipeline, one for the vertical walls of a tank, and one for railcar, users can buy our kit and configure it for whatever task you need," said Wes Kirkland, Inuktun's vice president of operations. "And the kit is not any more expensive than its competitors."

The kit includes magnetic tracks that let the robot crawl up a wall, through a pipe, or under a roof. Because the system is waterproof—Inuktun's first robots inspected water pipes—magnetic robots can inspect offshore production risers as they come out of the water and ship hulls below the water line in lieu of bringing the vessel into a dry dock.

Another robot developer, Diakont, is building a crawler that will inspect gasoline and petrochemical storage tank floors—without draining the tank first. Diakont has proven its Stingray robot in 12 fire water tanks, and plans to inspect its first petrochemical tank this fall.

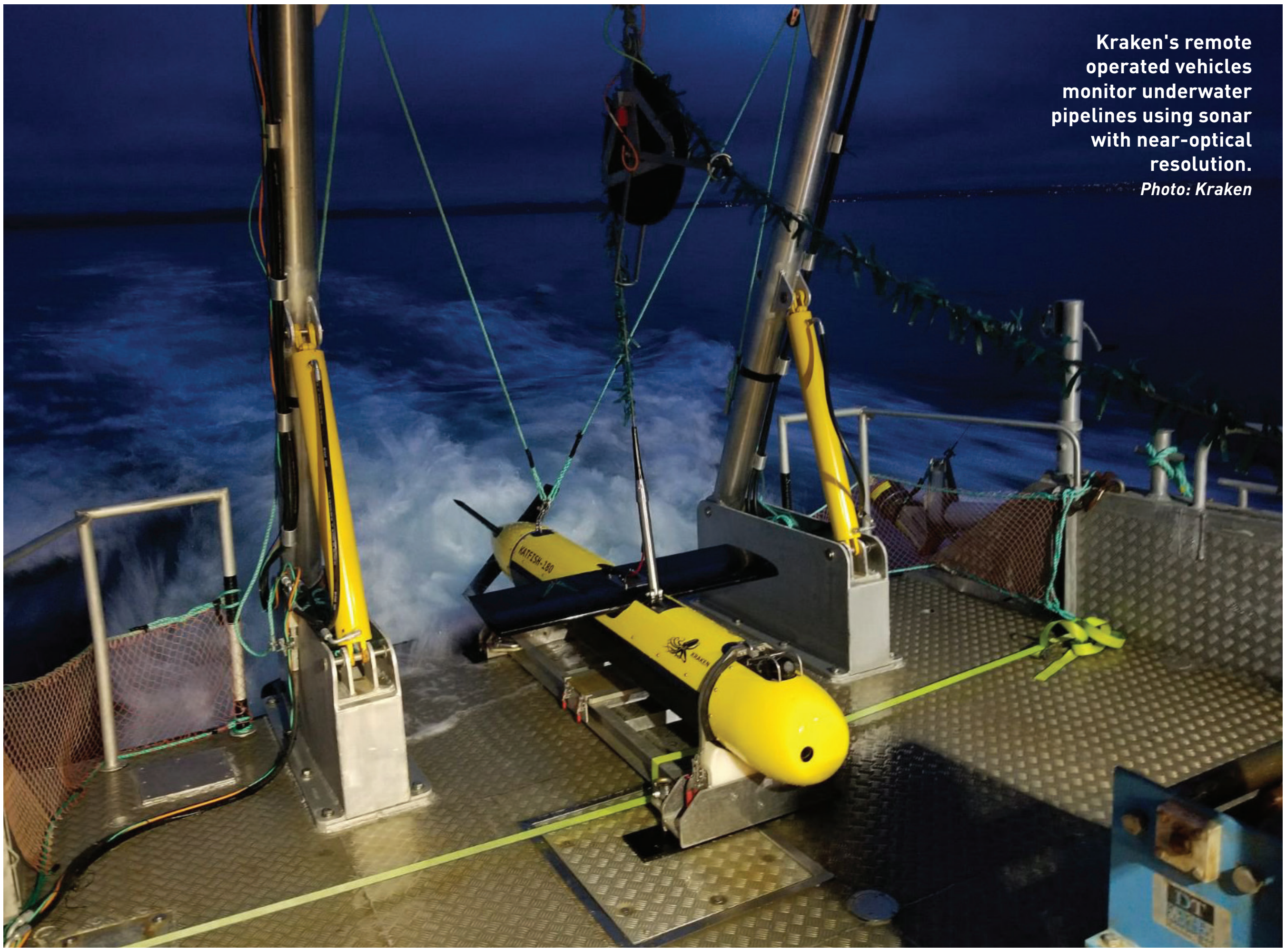
Naturally, the robot is rated for an explosive environment. Its umbilical conduit, which also acts as a winch, delivers electricity and pressurizes the robot with nitrogen to 50 bar.

"If any rubber seals or gaskets fail, instead of fuel going inside the robot you have nitrogen going out," said Steve Trevino, Diakont's business development and strategy manager. "It has 3-D sonar to avoid floating pipes, columns, or cathodic protection supports inside the tank. It uses magnetic flux leakage sensors and eddy current sensors to find and characterize any tank floor anomalies."

"New tanks are usually not inspected until they are 10 or 15 years old," Trevino explained. "A lot can happen in that interval. Because operators don't have to drain their tanks, our robot makes it affordable to do more frequent inspections. That lets them plan in advance when they need to drain the tank to replace some plate on the floor."

New sensors have added to robot capabilities.

In fact, Kraken Robotics started out making synthetic aperture sonar, which builds images from multiple sonar transducers. By using video game chips, which excel at



Kraken's remote operated vehicles monitor underwater pipelines using sonar with near-optical resolution.
Photo: Kraken

building images, to process the information, it slashed system costs dramatically.

Kraken's sensors provide enough range and resolution to image 3 cm gas bubbles leaking from a pipeline hundreds of meters away.

"Resolution is important for trusting data," David Shea, Kraken's vice president of engineering, said. "Our system produces almost optical quality images. There's no doubt about what's out there."

Kraken decided to get into the robot business when users had trouble integrating the new sensor into existing ROVs. The business jumped when oil prices started to decline.

Offshore oil and gas companies, which inspect thousands of miles of underwater pipelines, were already using ROVs tethered to large ships. Switching to Kraken's ROVs increased their scanning range significantly, helping operators complete inspections faster and reducing the cost of operating expensive survey ships.

A methane sensor developed by Lance Christensen, a scientist at NASA's Jet Propulsion Lab, could have a similar impact on drones. His laser spectrometer, developed to search for signs of life on the Mars *Curiosity* rover, samples methane down to the parts per billion level. That is three orders of magnitude more sensitive than existing devices.

Chevron and the Pipeline Research Council helped repurpose the sensor to let drones search for gas leaks while flying along a pipeline. Drones can also measure methane and wind velocity downwind from a petrochemical plant and use the data to pinpoint any gas leaks.

NASA licensed the technology for commercialization.

TRUST

As noted, managers running billion-dollar-plus refineries and petrochemical plants are cautious about new technology. So how did they learn to trust robots? The answer depends on whom you ask.

For many, the answer is simple: "You're not necessarily trusting the robot," Inuktun's Kirkland said. "You're trusting the sensor. If it works in your hand, then it should work on your robot. All the robot does is put it there."

Besides, humans are always in the loop. This usually includes one person guiding the robot and another carrying out the inspection. At Dow, for example, certified inspectors deploy robots only after putting together a detailed inspection plan. Even when a robot autonomously executes a plan, the inspector is responsible for the quality of the data.

"It's no different than having the inspector in the process," Pigott said.

Yet operators remain cautious. If they follow a standard, it is, "Trust, but verify."

Before Waukesha-Pearce began inspecting fire tubes, for example, Nelson attacked a perfectly good unit with drills and grinders to simulate different defects.

"When we ran the robot through the pipe and it found every anomaly, then we knew we had something," he said.

Verification can take time, added Avitas' Tomer. This is especially true for Avitas, which analyzes data from multiple sensors to predict maintenance problems.

"One client gave us 30 years of maintenance data but held back the last five years to see how well we could predict what would happen," he recalled. "We were very accurate, but even then, they spent one year doing normal inspections and running our system together to see how they compared."

If today's robots already reduce human risk and cut inspection costs and time, the next generation of increasingly autonomous robots promises even more benefits. Once a human has selected where to inspect a facility, the robot will fly to those spots, take measurements, and leave. Large facilities and offshore oil platforms may even have resident robots that do those tasks daily.

"In order to do analytics well, we need to detect changes in the condition of equipment, and that is facilitated by taking the same measurements over and over again," Tomer said.

Repeated observations under different conditions also improves the ability—and speed—of machine learning tools to recognize and analyze the data they receive. When assigned to create 3-D models of 20 wells, Avitas took four hours to survey the first one and 48 hours to process the data. After learning to integrate data from several sensors and account for changing light and shadows, the last well took less than 15 minutes to survey and six hours to crunch the numbers.

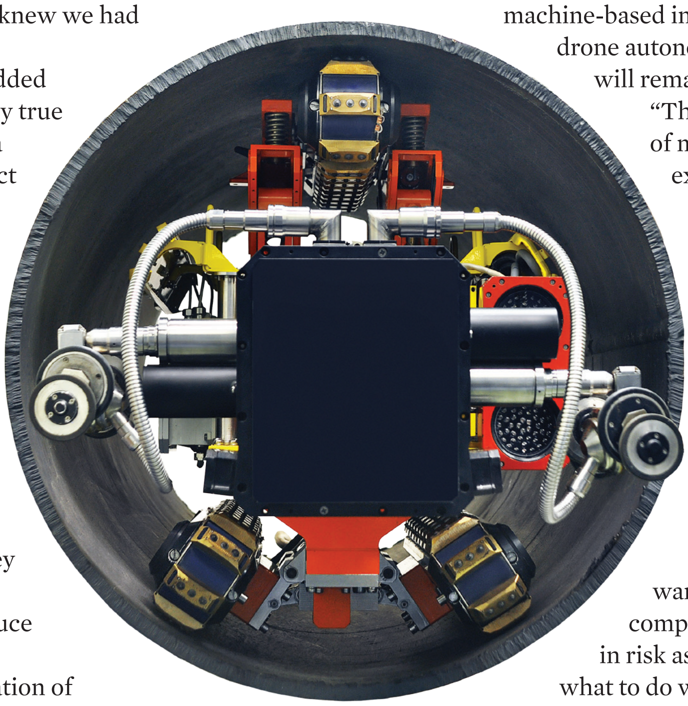
"The more you use machine learning, the more accurate it gets," Tomer said. "It becomes more economical and causes fewer problems."

Tomer's goal is to combine autonomous flights and sensor data with digital plant models and operational plant data to do more sophisticated types of predictive maintenance. "When you combine data, that's really where you get insights," he said.

Others are more cautious. That includes Patrick Saracco, vice president of technology solutions at Cyberhawk Innovations, a company that began inspecting North Sea oil platforms 10 years ago. While Cyberhawk is investigating machine-based image analysis and embraces drone autonomy, Saracco believes humans will remain in the loop for a long time.

"There is always the risk of missing 1 or 2 percent of existing defects," he said. "And the oil and gas industry is so diverse, it's hard to automate. Each offshore platform is different, and their materials differ in color, refractivity, and temperature. Furthermore, the risk factors are so high, you want to have a pilot there to take over should something happens.

"Also, platform owners want pilots to have training and competence—not just in flying, but in risk assessment. They have to know what to do when there is electromagnetic interference or strong wind gusts when flying under the deck," Saracco said. "Autonomous flights will get there, but certainly the technology and competence of those systems is not there yet."



Diakont's RODIS can measure metal loss, corrosion, and various anomalies in pipelines up to 55 inches in diameter.
Image: Diakont

Serblowski agrees: "Today, the human is absolutely doing the inspection. Someone is processing and signing off on the data."

Yet he, too, is drawn by promise of data analytics to improve robotic inspection efficiency. Companies like Shell already use digital control systems with remote sensors and actuators to run their plants.

It is not much of a stretch to envision digital robotic systems inspecting their plants as well. ME

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