THE ROAD TRAVELLED SO FAR TO

ground surveillance robots

Shell is always looking for ways to reduce safety exposure for facilities and personnel. However, in some cases, the highest risk for a person lies in the road travel to a site! Automation technology itself is not the challenge; it exists and Shell uses it a lot. It has unlocked new business areas such as deep-water seabed operations. No person ever goes out there to open a valve, read a gauge or paint structures. So why have onshore facilities not been fully automated? The answer is simple: cost. A walking person is often still cheaper than the sum of the available fixed automation technologies. Modern robotics, however, provides an alternative that mimics the benefits that the mobility of a person provides. One moving person or platform represents a thousand sensors. Robotics is about safety, efficiency and cost, and is an area Shell must embrace, especially when combined with digitalisation.

The digitalisation journey

Robots can be thought of as mobile automation, as they introduce mobility into traditionally automated activities by enabling a single tool or sensor to move around a facility as required. Such robots may one day address all the dull, dirty and high-risk tasks currently executed by humans. This creates a challenge though, as people are often fearful of new technology and change, so the challenge for Shell is how to incentivise the ecosystem. The fact is that there is more work to do with fewer people, so, for Shell to stay competitive, robotic technologies must be deployed to free human workers from simple repetitive tasks and enable them to focus on high-value-adding work. Communicating this fact must be done on a case-by-case basis, though, to ensure that all parties in the ecosystem benefit from these changing ways of working.

Robots are currently mainly used to mechanise existing activities; a painting robot is merely a mechanised brush. By introducing a digital workflow, the efficiency of robots can be increased. For example, in maintenance robotics, integrating multiple robots into one business work process promises many benefits: the painting robot will only paint when and where the inspection robot has found a bad spot (Figure 1). This is preventive maintenance in action, based on actual data, not modelled planning!

More obvious is the value of digitalisation to data-collection work processes. When integrated into an existing workflow, a robot acts as a consistent data-collection device to feed digital work processes and create actionable insights for the human operators.

The end-to-end process is the same for all robots, whether they fly, drive or swim. A robot is just a mobility platform; it is the data they collect that generate value. Like a person who gains experience over time, artificial intelligence keeps growing, yet that experience is instantly available to all robotic systems and will never retire. At Shell, this workflow is in place and is running for certain classes of robots.

The Sensabot programme

Ground surveillance robots are a foundational part of the Shell robotics programme: the.

FIGURE 1
Digitalisation for storage tank turnarounds.
Sensabot programme has run for more than a decade. Robotics technology had always seemed promising and it all came together in the Kashagan project: frontier technology for a frontier location. Frigid in winter, scorching in summer, remote artificial islands in the Caspian Sea and high hydrogen sulphide levels, all the industry extremes in a single location. Given the travel, health and safety challenges, responding to an alarm at a remote location was an expensive and time-consuming activity; it could take many hours or even many days to check out an issue because of the weather. This challenging environment provided the justification for solving the technical hurdles of robotics and proving that remote robotic operations were viable.

To address this challenge, the Sensabot (Figure 2) was developed. This is a big machine with many sensors and able to survive the extreme climate. Some of the lessons learned for Kashagan include that:

- designing equipment for hazardous areas where there is the risk of fire or explosion (Ex design) is difficult: it creeps in to all the details and adds to the weight;
- if you want low maintenance, get rid of the Ex-p (pressurised Ex enclosure) features and make robustness choices; and
- export compliance, shipment and local support require time and money.

For Nederlandse Aardolie Maatschappij (NAM), the Sensabot offered an interesting value proposition to reduce people on board offshore, yet the technology and commercial ecosystem needed to mature more. The NAM onshore gas production facilities offered an opportunity for this, as a robot would enable tasks lists to be reorganised and thus reduce site visits from twice a week to once a month. Calculating the benefits of travel and time savings enabled a commercial price target to be set for the robot.

With the original Sensabot, the team was looking to prove the technology, but with the next model, a commercial mindset was adopted that required a different approach. During the project scoping, the team learned the following valuable lessons:

- The total cost of ownership is crucial, therefore scale is needed through wide industrial adoption. Commercialise; do not build a customised Shell tool.
- Simplify: 30 Shell people will have 300 requirements. Stop aiming for perfection; start with a minimum viable product. What does a person do? See, hear, walk and communicate. So, a robot only needs a camera, a microphone, wheels and 4G-LTE wireless technology. Only do what is strictly necessary and then add additional capabilities once success is demonstrated.
- Shipping a robot is better than people travelling. Instead of putting more robot technicians on the road (while taking operators off the road), broken robots can be swapped to provide continuity and repaired at a central workshop.
- Changing work processes takes time and requires long-term learning and commitment in the whole organisation.

By taking this commercial approach, the Sensabot Mark 3, now known as the ExR-1 (Figure 3),
was an order of magnitude cheaper than previous versions, a fraction of the weight and easier to deploy. NAM ordered the first 10 of a total scope potential for 100+ but had to step out of this programme in 2020 because of business pressure during the COVID-19 pandemic.

In the meantime, the robots were getting attention at larger sites to help automate some repetitive tasks, primarily emission detection. The robots were given gas detectors but needed autonomous navigation. Line following using the robot’s downfacing camera was selected as the cheapest and fastest option for autonomous navigation. Within a few months, the systems were demonstrated successfully (Figure 4). However, line following outdoors offered some good and bad revelations. A good one was that on-site staff get used to these robots and keep routes clear of objects and sometimes even make scaffolding tunnels for them. The bad surprises were that weather, light changes and surfaces affect navigation, for example, a 40-year-old concrete floor turned orange, like the lines, when wet.

Today, the reliability level is such that these robots can run unattended. Yet, a robot still operates on the permit-to-work principle, that is, a person needs to verify that it is safe to start a mission, as for on-site operators. When a remote person is about to start a robotic mission, they make a call to the permit desk for permission, then press the button and the robot runs its mission to the end.

In the case of a high gas level, the robot’s control screen starts flashing and sounding an alert to trigger a direct response. However, robots notice the low-level leaks too; they are finding very small parts-per-million leaks with greater reliability than traditional systems and manual processes. Many hydrocarbons are heavier than air, so, because the robot is close to the ground and runs around the equipment, it will come into contact with any gas leak. Leak detection is now moving towards emission detection with the goal of catching the tiny leaks that cause greenhouse gas effects. To address Shell’s <0.2% methane-leak commitment for liquefied natural gas facilities, a test is being performed on an ExR-1 with a FLIR G300a optical gas imaging camera on its back in an Ex housing.

Running emission-detection rounds is now proven; it happens daily at Pernis refinery in the Netherlands. The next challenge is to move further into operator rounds: spotting evolving issues before they cause a leak. So, not just reading gauges, but general site integrity monitoring. This is a good example of tasks that can be automated to enable the operators to focus on more valuable activities such as line-ups and first-line-maintenance.

In this scenario, the robot is merely the roaming camera. The real magic happens in the cloud, where machine vision algorithms analyse the pictures (Figure 5) and convert the data to actionable insights. The end-to-end data flow (Figure 6) is fully automated and data are written to the data historian ready for analytics. Shell has a growing suite of applications and is continuously adding new categories and improving the running ones.

Giving project teams a leg (or four) up in construction

Quadrupedal ground robots can rightly claim more intriguing and inspiring marketing than their tracked counterparts. Legged robots, with advanced control capabilities, offer agile, highly mobile platforms that enable an increasing variety of payloads to go to worksites and remote locations.

The commercial availability of Boston Dynamics’ Spot (Figure 7) robot was a groundbreaking...
moment for industrial robotics, specifically quadrupedal systems, and generated significant interest across many industry sectors, including construction. Key players in the architecture, engineering and construction domain, including Brasfield and Gorrie and Foster + Partners, have been quick to configure and deploy Spot robots, with a focus on automating the collection of visual data on construction sites. By automating site surveying, construction teams are no longer reliant on specialist contractors or personnel, which reduces costs and offers digital capabilities fed by these data, for example, 4D progress monitoring and safety threat detection. Using robotic platforms for site surveys improves capture consistency, thereby enabling time-related comparison against prior captures and building information models.

Construction sites can be dynamic environments where weather and activity can significantly change the context in which a person or robot needs to navigate and manoeuvre. This is where quadrupedal type robots offer a point of difference. Both Boston Dynamics’ Spot and Anybotsics’ ANYmal D robots feature the same lidar and cameras that drones and crawlers use to understand their environment, identify obstacles and plan routes. It is, however, the legs that offer greater efficiency of movement than unmanned aerial systems (UAS) and make them better suited to handling common construction site features (such as scaffolding) compared with a crawler robot. Table 1 compares quadrupedal, crawler and aerial robots.

The value of a remote site presence
The COVID-19 pandemic has forced everyone to consider ways in which to access construction sites, facilities and colleagues remotely. Shell’s construction sites are no exception. In addition to creating a viable way to execute routine site surveys, quadrupedal systems also offer construction teams a chance to collaborate with remote engineering and project teams.
Site visits offer remotely located personnel an opportunity to build relationships with site teams and to understand the context in which work is being conducted, which can be key to fully evaluating the risks and opportunities relating to delivery. With Spot, ANYmal and their crawler counterparts, this is a capability that can be delivered: site personnel can “walk the dog” to key work areas while having a live dialogue with remote personnel.

Through the Shell Robotics, Digital Project Delivery and Future of Construction programmes, work is now ongoing to test the value of these solutions through the delivery of a user experience that modernises work. Shell’s digital infrastructure and services are ready to plug in a Spot robot at any time using the same cloud portal as for an ExR-1. (Watch this short video comparing a Spot robot and an ExR-1 in action.) As per the journey of the ExR-1 and Sensabot systems, this is a learning exercise with opportunities to exploit synergies with digital initiatives across Shell.

**The future is now**

Ground robotics are, today, where UASs were a decade ago. The hardware is available and a growing number of deployments across industry are proving the viability of these tools. However, the tools are still early stage enough that end-users have questions about how to engage with them and get them deployed. As with UASs, commercially available tools breed a commercial ecosystem of suppliers and service companies that will help to move ground robotics from the innovation space to sustainable tools. Across the existing programmes, the focus is on hammering down costs. The price determines the size of the deployment volume and the success. Keeping it simple is keeping it inexpensive without any illusion or ambition of solving all the challenges at once.

This focus on sustainability and cost is leading to replication opportunities. The ExR-1 robot, for example, is qualified as an emission detector. It is better than conventional leak detection systems and can run autonomous unattended missions with minimal effort for operating shifts. At Pernis refinery, there will soon be four robots running multiple missions daily. An additional 10+ deployments within a year are being worked on in Asia, the Middle East and North America. There is also growth in the use of non-Ex robots; for example, the Scotford complex in Canada has acquired two Spot robots to experiment with all kinds of non-Ex and manipulation tasks. The results are promising and give the teams confidence in using Spot robots for construction monitoring activities.

**In closing**

Robots offer an exciting opportunity for Shell to reduce health, safety, security and environmental exposure and increase production reliability and project progress insights and, ultimately, to do so at a lower cost. Consequently, the Shell robotics team is striving to keep the solutions built around these tools as cost-efficient as possible to maximise replication and value generation potential. There are always alternatives to robots (people, sensors, etc.), so it is critical that robots are benchmarked against these solutions to ensure that they are the

<table>
<thead>
<tr>
<th>Robot type</th>
<th>Spot</th>
<th>ExR-1 and ExR-2</th>
<th>DJI and Emesent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload</td>
<td>Manipulators, lidar, cameras, microphones, speakers, etc.</td>
<td>Lidar, cameras, microphones, speakers, etc.</td>
<td>Cameras and lidar</td>
</tr>
<tr>
<td>Endurance (min)</td>
<td>90</td>
<td>120–360</td>
<td>30 (max.)</td>
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<tr>
<td>Stair climbing</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Complex structures (scaffolding, pipes, etc.)</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Operator required</td>
<td>No*</td>
<td>No*</td>
<td>Yes</td>
</tr>
<tr>
<td>Weather sensitivity</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Site commissioning and installation required</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Operation in explosive atmospheres</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

*Specific missions only

**TABLE 1**

Operational comparison.
best option for a given problem. Shell is not doing this by itself though; an ecosystem of robot suppliers, integrators and service companies is emerging. This ecosystem is helping to increase access to the robots while driving down costs and increasing functionality. This will be critical to the normalisation of these robotic tools, as end-users will be able to focus on the solutions and not worry about robot supply.

The future is bright for ground robotics, but changing processes and people’s mindsets takes time. It is important that Shell continues to deploy these robots so that solution confidence, value achievement and learning progress. Robotics is a great example of technology innovation that will propel Shell’s competitiveness and ability to meet its Powering Progress goals.

**Further reading**

See how Shell has been applying robotics in the air; Ayo Adediran and Adam Serblowski explain how unmanned aerial systems are not only useful at remote locations ([Shell TechXplorer Digest](#)).

**AUTHORS**

**Berry Mulder** is the leader of the Shell Robotics Centre of Expertise and is committed to developing Shell to use robotics, not to developing robots for Shell, and thereby positioning Shell as an industry leader in emission detection and safer work execution. He is also active in cross-industry organisations for standardisation and innovation. Berry has a degree in chemical engineering.

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