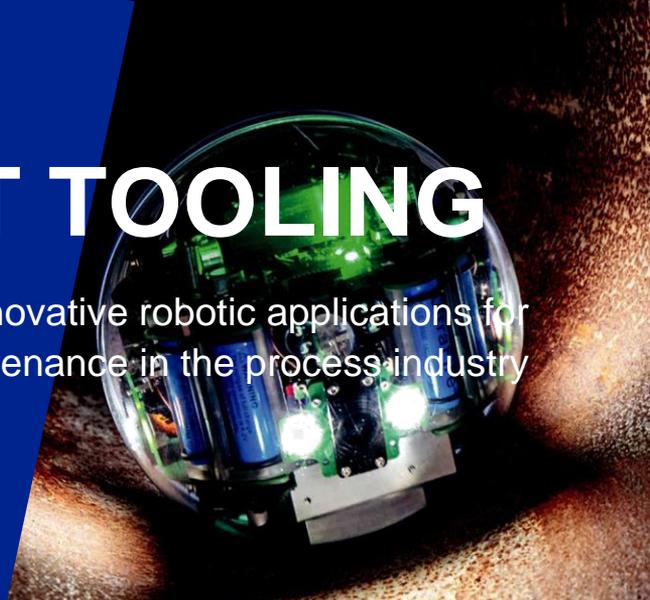


SMART TOOLING

Innovative robotic applications for maintenance in the process industry



Interreg



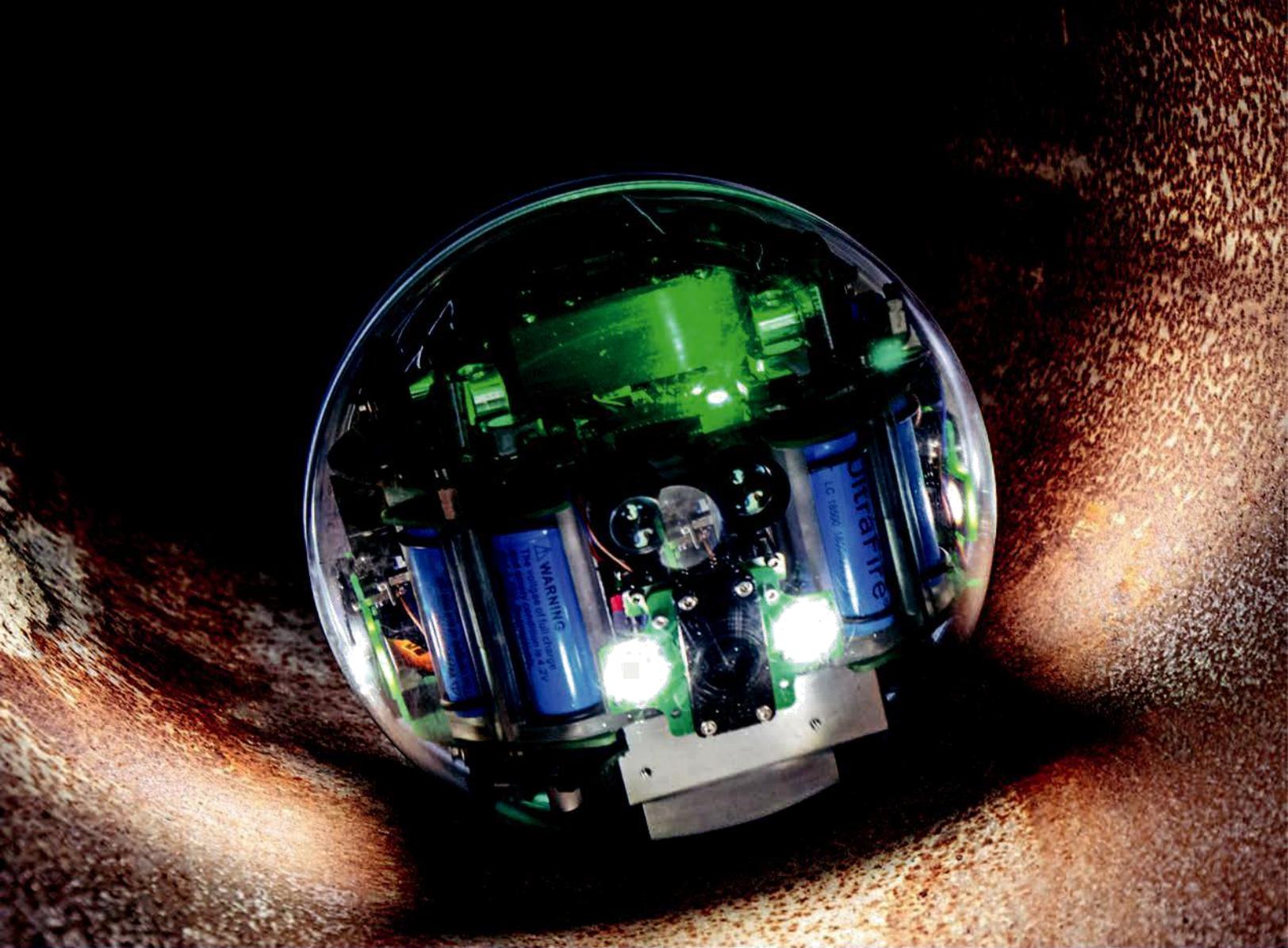
Vlaanderen-Nederland

Europees Fonds voor Regionale Ontwikkeling



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From 2016 to 2020, Smart Tooling has been one of the most important projects at KicMPi. This brochure has been compiled to give stakeholders and interested parties an insight into the project results.

The developed prototypes and innovative methods are brought to life with photos and text. The project partners and stakeholders give their ideas and opinions about the project and the results achieved.

<INTRODUCTION>

While installations in the processing industry are ageing, the rules on safety and the environment are becoming stricter. Asset owners are therefore looking for ways to make their installations as reliable as possible at the lowest possible price point.

Between 2016 and 2020 KicMPi worked with partners from Flanders and the South of the Netherlands on innovative technical solutions for the Interreg Smart Tooling project.

The aim was to develop new types of robotics by combining knowledge. The intended results of the project were prototypes for cleaning, inspection and workshop robotics. In addition, the inspection possibilities of drones were investigated. All eight work packages within Smart Tooling produced concrete results, from working prototypes to innovative working methods.

Smart Tooling is an Interreg Flanders-Netherlands project. The cooperation gave the partners an extensive cross-border network and led to surprising, innovative insights. The knowledge was disseminated by the companies in the

region and thus provides a breeding ground for future developments. A total of around thirty organisations from the Netherlands and Flanders were involved in the project.

Smart Tooling gave asset owners an insight into new technology that will enable service companies to maintain their installations more efficiently in the future. By realising the practical innovations, SMEs and knowledge institutions were able to increase their knowledge and improve their market position. By drawing up competence profiles for the new developments, which can be fitted into new or existing training programmes, all knowledge will remain available permanently.

Visit the YouTube channel Smart Tooling for videos >>>

< PROJECT ORGANISATION >

These project partners form the steering committee of the Smart Tooling project.

PROJECT MANAGER

KicMPi

Project management and communication

ASSET OWNERS

BASF, Dow Benelux

Input use cases and test facilities

DEVELOPMENT AGENCIES

Impulse Zeeland, REWIN, BOM

Selection of development companies and management subprojects

BRANCH ORGANISATION

BEMAS

Project support and realisation of work package competences

KNOWLEDGE INSTITUTIONS

Sirris, U Gent, U Twente, Avans University College

Management subprojects, project participation

Organisations involved in project implementation.

CLUSTER APPLICATION DRONES FOR INSPECTION

Drones confined spaces

Terra Inspection

Del Dynamics

Pozyx

Drones outside

Avular

Airobot

SPIE

Ghent University

Project coordination: REWIN

CLUSTER DEVELOPMENT OF INSPECTION ROBOTS

Inspection ball

ID-Tec

Ghent University

Serenity

VTEC

Snakebot

ExRobotics

University of Twente

Project coordination: Impulse Zeeland, KicMPi



CLUSTER DEVELOPMENT OF WORKPLACE ROBOTICS

Smart Glasses

Iristick
 Proceededix
 Sirris
 ENGIE

Cobot leak detection

ITIS
 Sirris

Cobot cleaning flanges

ENGIE
 Sirris

Project coordination: Sirris

CLUSTER DEVELOPMENT CLEANING ROBOT

Nobleo Technology
 Serenity
 Accerion
 VTEC
 Avans University of Applied Sciences
 DERC
 Buchen
 Group Victor Peeters
 Mourik

Project coordination: DowBenelux



The Smart Tooling project team: fltr Jan Mol, Debby Lambrechts, Pieter Raes, Veronique Naeye

<PROJECT TEAM>

Safer and smarter work in maintenance and inspections has been pursued for years in the processing industry. Due to recent developments in robotics, especially the availability of more computing capacity and improved sensors, the realisation of concrete solutions is getting closer and closer. After more and more robotics projects presented themselves, the KicMPi decided in 2016 to take the next step: the development of the Interreg Smart Tooling project.

KNOWLEDGE AND INNOVATION
CENTRE MAINTENANCE PROCESS
INDUSTRY (KICMPI) IS A
COOPERATIVE ASSOCIATION WITH
65 MEMBERS, CONSISTING OF ASSET
OWNERS, MAINTENANCE
COMPANIES AND KNOWLEDGE
INSTITUTIONS. KICMPI STIMULATES
COOPERATION BETWEEN
COMPANIES WITH THE AIM OF:
INNOVATING MAINTENANCE IN THE
PROCESSING INDUSTRY.

Project Manager Smart Tooling Jan Mol: "In 2015, KicMPi held several major meetings with asset owners, experts and users in the field of maintenance and inspection. The question was: where could robotics offer a solution for e.g. non-man entry situations and provide more security and efficiency? No less than 56 topics emerged from the meetings, all of which were points of attention that the industry was in need of.

INTERREG

Discussions with development companies showed that innovation could qualify for European subsidy through Interreg Vlaanderen-Nederland.

KicMPi General Manager Pieter Raes: "After an interview at Interreg Vlaanderen-Nederland it soon became clear that our activities were a seamless fit. Innovation is one of the four priority axes in their current programme. The organisation is located in a border. We also work on innovation with relatively



small enterprises: SMEs in the Netherlands and Flanders. That was also a condition of Interreg to stimulate the economy on both sides of the border".

PARTNERS

Jan Mol: "A good idea, which we continued with. We found partners in Dow, BASF, BEMAS, REWIN, BOM, Economic Impuls Zeeland, Avans Hogeschool, University of Twente, SIRRIS and Ghent University to submit a project proposal called 'Smart Tooling'. However, starting with 56 topics is impossible. Together with Dow and BASF, we have identified the most important areas of interest. What is industry really in need of? Which projects can offer results within the duration of this subsidy trajectory? We wanted to come up with concrete solutions. Concrete, result, structure: those were the key words when Smart Tooling was launched in September 2016".

WORK PACKAGES

Pieter Raes: "Interreg offers subsidies to stimulate economic growth. But you don't get that money just like that. They require accountability, accuracy and structure. You often hear people say: 'Interreg? That's complicated ...' The steps are clear, and if you just follow them, you'll be fine. The application and also the later project management itself went smoothly. In the end, eight work packages were described in the project proposal, complete with detailed budgets and forecasts".

"When the project proposal was approved by Interreg, we drew up the corresponding use cases together with Dow and BASF", explains Jan Mol. "These briefly and concisely describe a practical problem, the ideal solution and the minimum goals to be achieved. It's a planned way of setting up product development".

PROJECT PARTNER LIGHT (PPL)

The then concrete Smart Tooling project was communicated to small companies in the Netherlands and Flanders. BOM, REWIN, Impuls Zeeland and the Flemish company BEMAS took care of this. During briefing sessions on the use cases, developers and users of the future tools could show their interest in becoming, as Interreg terms suggest, Project Partner Light (PPL).

"At least 50 companies from Flanders and the Netherlands have applied," continues Pieter Raes. "In the end, after all kinds of pitches and discussions, 20 companies took part as PPL. These were existing single-person pitches, start-ups, but also larger organisations. All innovative, passionate technology companies".

Pieter: "That first phase was very interesting, especially when you look back on it. At the beginning you can see a dot on the horizon, but it is difficult to define a final destination. Innovation means that you create, develop and improve something existing. We wanted to deliver tangible solutions. Some PPLs

started off very well, but in the end it did not exactly gain a foothold. It also happened the other way around, with surprising results. Sometimes the technical solution was visible, but too expensive for practical use. In any case, in those three and a half years we have taken major steps in eight areas. We did that not only by bringing parties together, but also through successful events and webinars.

DESIGN

Within the Smart Tooling project, the asset owners offered the 20 PPLs the concrete questions and a test environment. BEMAS supported with a method to bring the necessary knowledge and skills around the new tools into words. This opened up the possibility of creating training programmes and qualifications. Last but not least, there was close cooperation with project partners University of Twente, Avans University of Applied Sciences, Sirris and Ghent University.

ECOSYSTEM

Jan Mol: "In addition to the practical development results, Smart Tooling has created a new cross-border ecosystem of motivated people who are open to innovation. A group that is characterized by a direct, practical, no nonsense approach. Report writers did not fit in - we really wanted to form a 'make it happen team'. The emphasis was on results.

"I think that as a project team we could keep the motivation and drive in it by coming up with clearly defined agreements. It is important to be clear about expectations and to remove barriers in good time. By keeping in close contact with the implementing project participants, we can look back on a successful cooperation and results".

"In the meantime, our two project assistants Debby and Veronique were keeping a close eye on everything" emphasises Jan. "They were like a spider in the web between all the partners and

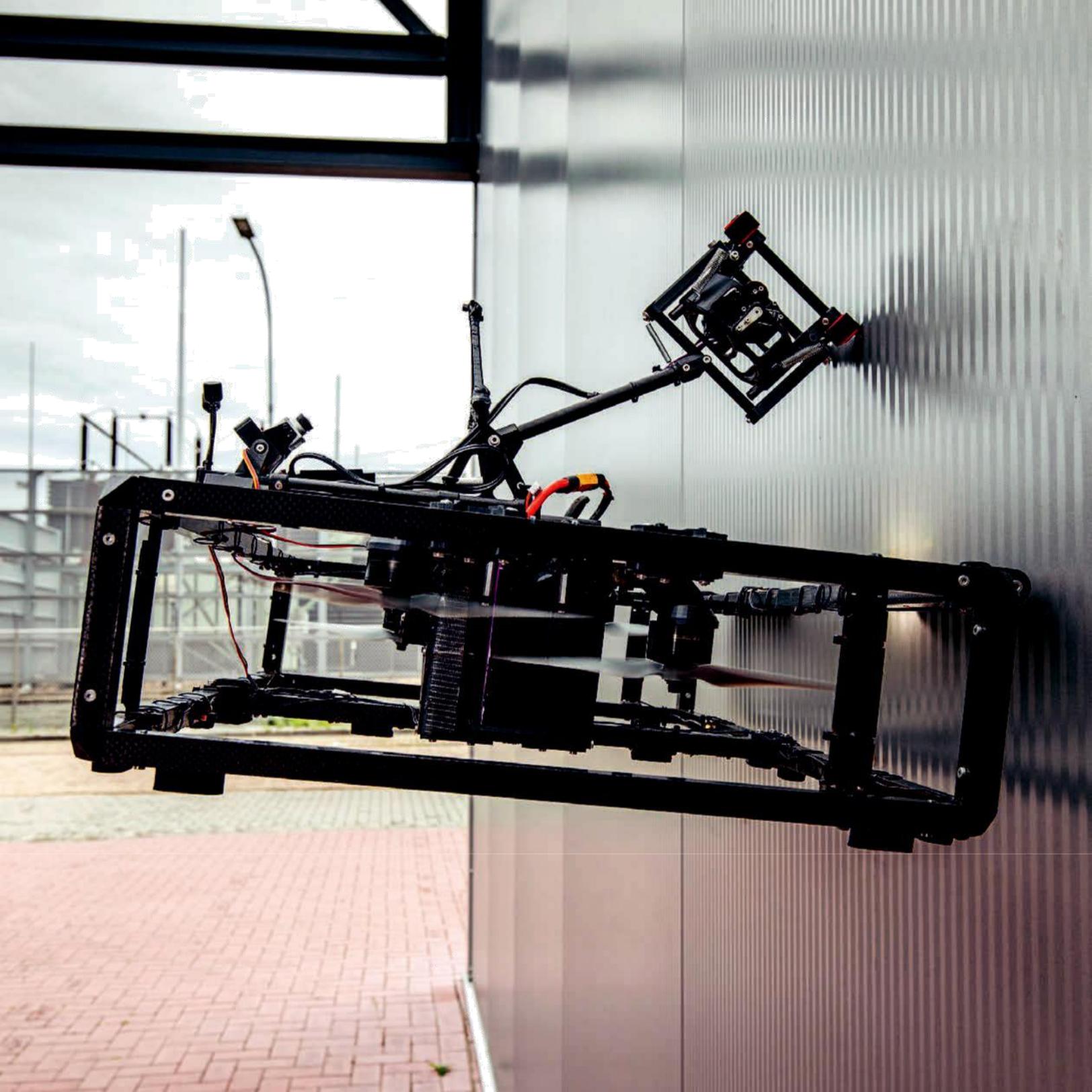
Interreg: the declarations, the progress report, the events throughout the process and much more. Two indispensable links in the chain of success of this project".

SECURE RESULTS

"Interreg offered us the necessary support in setting up and implementing Smart Tooling. Our project advisor Jorre van Damme in particular gave us excellent advice on submitting the project application. We also worked together with the Interreg organisation and had a pleasant working relationship.

"All in all, I found it one of the most enjoyable projects in my career. I am happy with the results and it is good to see that the parties involved continue to make use of the new contacts. Now it is important to secure the results for the future. As KicMPi, we will continue with OP Zuid Smart Maintenance Labs, Interreg Circular Maintenance and Interreg Practical Lab Corrosion under Insulation. The resulting cross-border Smart Tooling network will certainly be further exploited", concludes Jan Mol.





DRONES CONFINED SPACES

< NON – MAN ENTRY

WALL THICKNESS INSPECTIONS >

The metal walls of drums, towers and silos become thinner due to e.g. corrosion. Inspections on the inside show the residual wall thickness. Many of these places are only accessible with scaffolding. Furthermore, people are no longer allowed to enter these confined spaces within a few years. The Smart Tooling project looked for a way to measure non-man entry wall thickness using a drone.

SMART TOOLING OBJECTIVE

DRONE FOR INDOOR INSPECTION

- > EXTERNALLY CONTROLLED
DRONE IN CONFINED SPACE
- > CERTIFIED INSPECTION METHODS
- > CERTIFIED ULTRASONIC
WALL THICKNESS MEASUREMENTS
- > CERTIFIED DRONE PILOT

There were three main questions for inspection company Terra Inspectioneering (until 2019 RoNik Inspectioneering) and drone developer Del- Dynamics: How do you control a drone from the outside to a particular location in a dark, polluted room without a GPS? How do you get the drone to perform a correct wall thickness measurement? How do you communicate this data to the inspector?

All kinds of communication technologies were tested. Like a mini Ultra Wide Band system in cooperation with Pozyx. This resulted in malfunctions due to the shape and metal of the tank. Communication with radio waves was also investigated, but this method proved to be incapable of transmitting information in a robust manner.

SOLUTION WITH REEL

This meant the idea of wireless communication was dropped at this stage. Del Dynamics then developed a reel with an ultra-thin cable. "Like a spider, it leaves the wire behind," explains Arnout de Jong (CEO at Del Dynamics). "Within the project this was



tested up to 100 metres and that went well. So the drone pilot did not have to stand in the same space as the drone, using this method".

PRESSURE ON THE WALL

Terra Inspectioneering, specialised in drones and robotics in confined spaces, focused on wall thickness measurements in addition to positioning. Managing director Steven Verver: "For a wall thickness measurement, the drone has to 'hang' at exactly the right distance along the wall. Sensors that measure the distance and thus control the drone itself proved to be unreliable. The skills of the drone pilot are therefore essential. This quickly brought us to the question: what should a drone pilot be able to do? Because that is also part of the innovation".

"The probes were another technical challenge" continues Steven. "They have to apply sufficient, even pressure to the wall and pry a little for a correct measurement result.

One also has to take into account that a flying drone always moves, but we were able to solve that too. The gel needed for ultrasonic measurement was another issue. For this we found the solution in a gel pump, which is positioned on top of the drone".

LATER AMENDMENTS

In this way, great strides have been made towards the final goal. In the end, the reel system was not yet ready to be integrated into the working model, but it was ready for other applications of Del Dynamics. Meanwhile, Terra Inspectioneering developed a wireless method to fly in with the drone. This meant that the drone pilot and the inspector can stand outside the confined space as desired. The drone model was also later adapted to a robust square type. Terra Inspectioneering additionally developed special arms that can be used for e.g. roof and rafter measurements.



COMPETENTIONS

New technology require new skills. Because the project objective was so clear, and the drones could quickly be put into practice, Terra Inspectioneering developed competence packages together with BEMAS (see also page 42). It is now clear what knowledge and skills a drone operator must have on three levels. Terra Inspectioneering was able to set up its own international training programme, as a result of which the technology is available worldwide.

Steven Verver: "We have come a long way thanks to this project, it has put our company on the map worldwide. Four years ago, this inspection method did not exist. Now there is a unique, patented system that offers certified measurements according to approved inspection procedures. There is now a great deal of interest from the industry. It is safe, efficient and

it is a response to the upcoming non-man entry policy."

ALWAYS A RESULT

"We are now using the technology with the reel that we developed within this project for other applications" adds Arnout de Jong. "We came up with this after other methods were unsuccessful. But that also gives you more knowledge about those techniques. In this way you can use European subsidy money to tackle things that you wouldn't otherwise get a chance to do. After all, there is always a result, you always learn something".





< VISUAL INSPECTIONS VIA 3D PATHS >

Many installations are difficult to inspect due to their height. Drones can offer a solution. Smart Tooling worked on an industrial drone that flies safely outdoors while recording and communicating reliable inspection results.

SMART TOOLING OBJECTIVE

DRONE FOR OUTDOOR INSPECTION

- > ACCURATE GEO-REFERENCING OF IMAGES (LOCALISATION)
- > AUTOMATIC GENERATION OF 3D POINTCLOUDS
- > DATA SHARING
- > CAPACITY FOR CARRYING CAMERAS
- > 30 MIN AUTONOMOUS 3D PATH FLYING
- > REPEAT EXACT INSPECTION POSSIBLE

When the Smart Tooling project started in 2016, there was quite a hype around drones. Most of the time, it was just a hobby situation. There were hardly any drones that could be used on an industrial level and that could process data correctly.

The potential opportunities with drones were recognised. The needs within the industry had also been obvious for years: scaffolding is expensive, bulky and inflexible. Within Smart Tooling, Avular, Airobot and SPIE set to work to develop an industrial drone. This drone should fly safely, at a fixed distance from the installations. The drone had to use a thermal and visual camera to objectively and consistently visualise the corrosion, record the data and communicate with the inspectors.

3D PAD FLYING

Joop aan den Toorn (CTO at Avular) says: "To take photos that can serve as an inspection image, you have to get close to the installation. Of course, this also has to be done safely, without collisions. It is not always possible to fly manually or by sight. The solution was autonomous flying, according to a



captured 3D path. When the project started, drones were able to fly off a grid from above, but not with 3D. So we introduced height as a variable and calculated the dynamics of the drone in order to create an algorithm".

It was quite a challenge. Joop continues: "Because with drone technology is what it is: it works perfectly, or it doesn't work. But it has succeeded. Flying a 3D path, that wasn't possible at the beginning of the project. Over time, our drone was able to fly neatly along the installation according to a 3D flight plan, with descents and ascents, and take exactly the right photos at pre-programmed locations. The location of the images was accurately recorded. Because flying and photographing correctly is one thing. Collecting and processing the data is just as essential".

REPEATED INSPECTIONS

Because the route is programmed, the mission can be repeated for repetitive inspections. This meant, the time course of the corrosion can be made visible opening the door for trend analyses. In order to be able to make a

correct diagnosis, the analysis of suspicious points is usually carried out with contact inspections, which can be based on ultrasound, radioactivity or eddy currents.

DATA

Jan Leyskens (COO at Airobot): "Drones can therefore be a useful tool to identify these weaknesses with the right data. The intention was to end up with a fully assembled, industrially deployable drone including software for the inspectors. Our company offers data recording technology, including accurate GPS positioning. For this project, we used ultrasonic sensor technology for accurate distance measurement, and developed a software library in the Cloud for geo-tagging and labelling of images. This software can also automatically create a 3D image of the installation based on the photos. The software is very flexible, adaptable to the type of drone and the mission, for each asset owner".

COMPLEX

"We wanted to integrate all kinds of systems," continues Jan Leysens. "They have to communicate with each other, be supplied with power, have an autopilot function in the event of battery failure, and much more. We have been working on all these different aspects for a long time. The complexity of the joint technology, and the sub-areas within it, such as anti-collision, GPS and data processing, was too great to create a working prototype within the time and budget".

At the end of the Smart Tooling project an accurate geo-referencing of images, automatic generation of 3D pointclouds and data sharing were realised. Avular created a 'mapperdrone' with half an hour of autonomy and a video data link.

FIRST STEP INTEGRATION

Within Smart Tooling, Avular and Airobot were able to build, coordinate and partially implement their own sub-components. "We were able to realise the first step of the integration within the project and also discuss it with future end users such as SPIE and the asset owners. This has given us as a company more insight into their data usage: very instructive for further developments, because we are going to continue working with Avular on this drone", says Jan Leysens.

INTERREG HAS WORKED

"The basis we were able to lay is now a new integral tool for our company. We are using this as standard for automatic drone inspection of e.g. construction projects. So the Smart Tooling project has certainly worked for us! As a small company, you can take big steps with the Interreg subsidy".

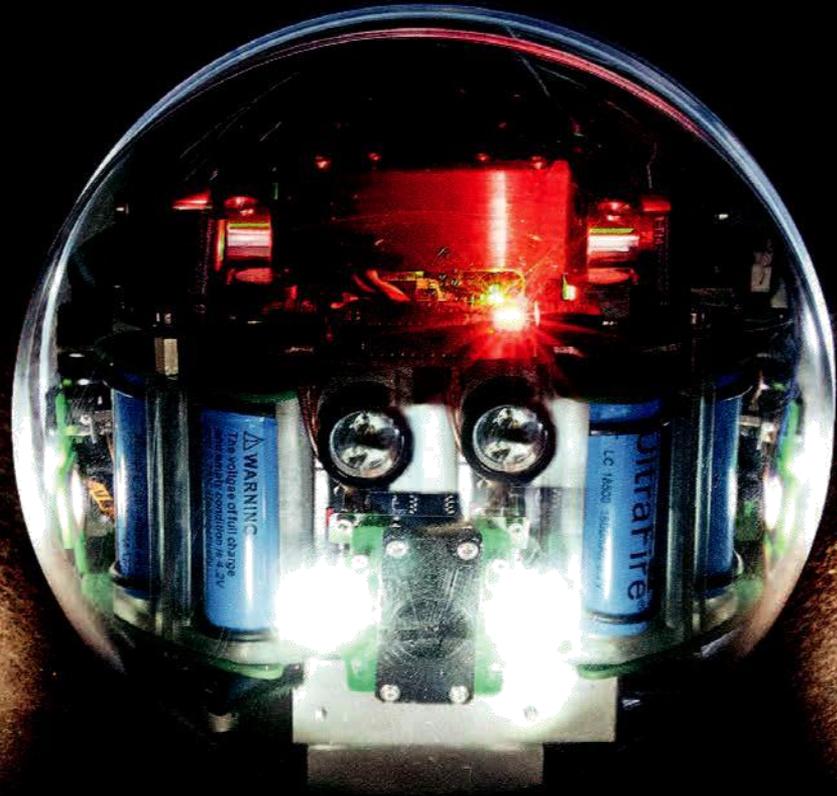
"We too have been given real opportunities through Smart Tooling," says Joop aan den Toorn. "We are a start-up and have worked with drones for all kinds of sectors, especially in agricultural and industrial applications. Through Smart Tooling we now have the right link with the world of industrial inspection.

We can supply the optimum drone for their unique image requirements. It is a good business case, so we will continue with this project. Within this network, where you have the right people at the table. And thanks to this project, we were really able to innovate in complete freedom. There was cooperation between all sectors. As a result, we can now not only fly 3D paths with our new drone for indoor inspections, but we can also use the technology for ground robots and other drones".

NEXT STEPS

Jan Leysens concludes: "The Smart Tooling project team felt that you had to be able to continue working as a start-up, but also knew exactly what the Interreg frameworks were like. They supported us very well with the project administration, it was not bureaucratic. We were free to use budgets as we saw fit. Now we are going to take the next steps. <<<





< INSPECTION OF PRESSURE VESSELS/PIPELINES >

Adequate inspections for corrosion - during operation, without downtime. That is a great wish of the processing industry. However, there is a lot involved. Measuring equipment in installations is exposed to high temperatures, pressures and aggressive substances. A method for fully automatic inspection in a fluid, in extreme heat or under high pressure was not yet available.

SMART TOOLING OBJECTIVE

INSPECTION BALL

- > WORKS UNDER EXTREME CONDITIONS
- > FLEXIBLY DEPLOYABLE
- > ROBUST, HOUSING SUITING DIFFERENT CONDITIONS
- > SEMI AUTONOMOUS
- > COMMUNICATION IN LIQUIDS
- > TIME-SAVING
ARTIFICIAL INTELLIGENCE + IMAGES

ID-Tec has been providing innovative solutions for the inspection, cleaning and renovation of pipes, tanks and other areas that are difficult for people to access since 2006. "In that context, we already worked together with Dow", says Ferry van der Valk (CEO of ID-tec). "We also had previous contact with KicMPi, which is why we were approached. Although our focus is on cleaning robots, within Smart Tooling we decided to focus on the tough challenge of inspection during operation. This was a new project for us. We have used the time available to take the first steps in an important, interesting development".

EXTREME CIRCUMSTANCES

In robotics projects, all kinds of disciplines always come together to form a whole. In this case, the challenge was in the extreme conditions under which all these disciplines have to function. Taking stock of the preconditions was therefore the first step.

"In this context, we talked to Dow and BASF so we knew more about the temperature and pressure requirements. We also got



clarity about the liquids in which the robot should operate and the shape of the pipes and vessels. On the basis of that information we, as builders of extremely robust robots, were able to assess the conditions we had to meet".

ROLLING ROBOT

"We ended up with a robot in a transparent, rolling ball. So not with wheels or magnetism, but a small inspection ball that offers a lot of flexibility. A ball of the right size always finds its way into pipe systems with all kinds of bends.

Inside the ball is the robot, which moves the whole thing like a hamster in a wheel. The equipment itself is thus protected by the housing. The material of the ball depends on the type of pipe. We don't want any scratches that obscure the view of the cameras".

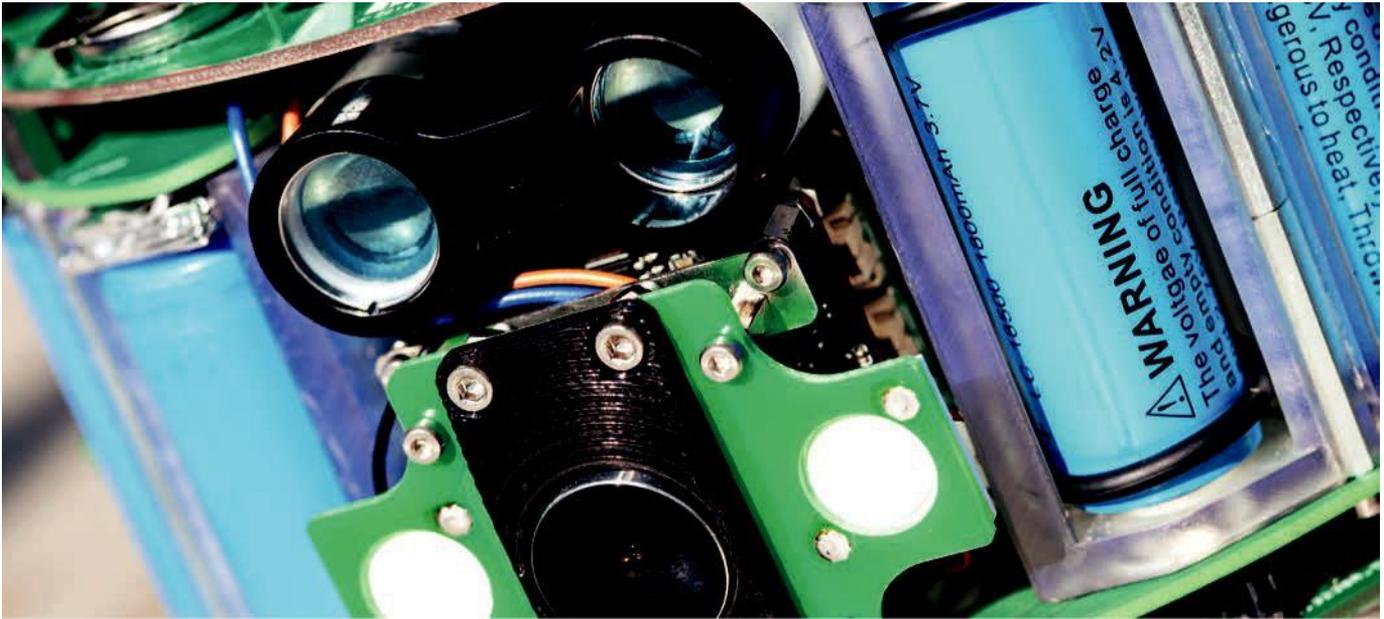
ULTRASONIC

Wires and cables attached to a rolling ball, that is impossible. But the circumstances and the requirements for wireless communication were tough.

A specialised research group at Ghent University was looking for a solution for three challenges: autonomy, inside of a liquid and in a metal tank or pipeline. Ferry: "They facilitated a test in a swimming pool, in which we discovered that the radio signal kept working up to a depth of half a metre. That depth was not enough, given the situation in the industry. After that, we continued the search ourselves, together with our own contacts, and found the solution. We combined the technology of submarines with robotics in sewers and went on to carry out tests with those. Eventually, we were able to send data via ultrasonic communication. This principle could also be used for the navigation and localisation of the ball.

DASHBOARD

Patrick de Boevere (Serenity): "I also worked on the software of the Cleaning robot. For the Inspection Ball, eighty percent of the requirements corresponded to those of the Cleaning robot when it came to



data processing, presentation and control. I have developed a generic solution where you can enter the inspection or cleaning in advance, with smart paths. The operator works with a dashboard. This could still be implemented for the Inspection Ball".

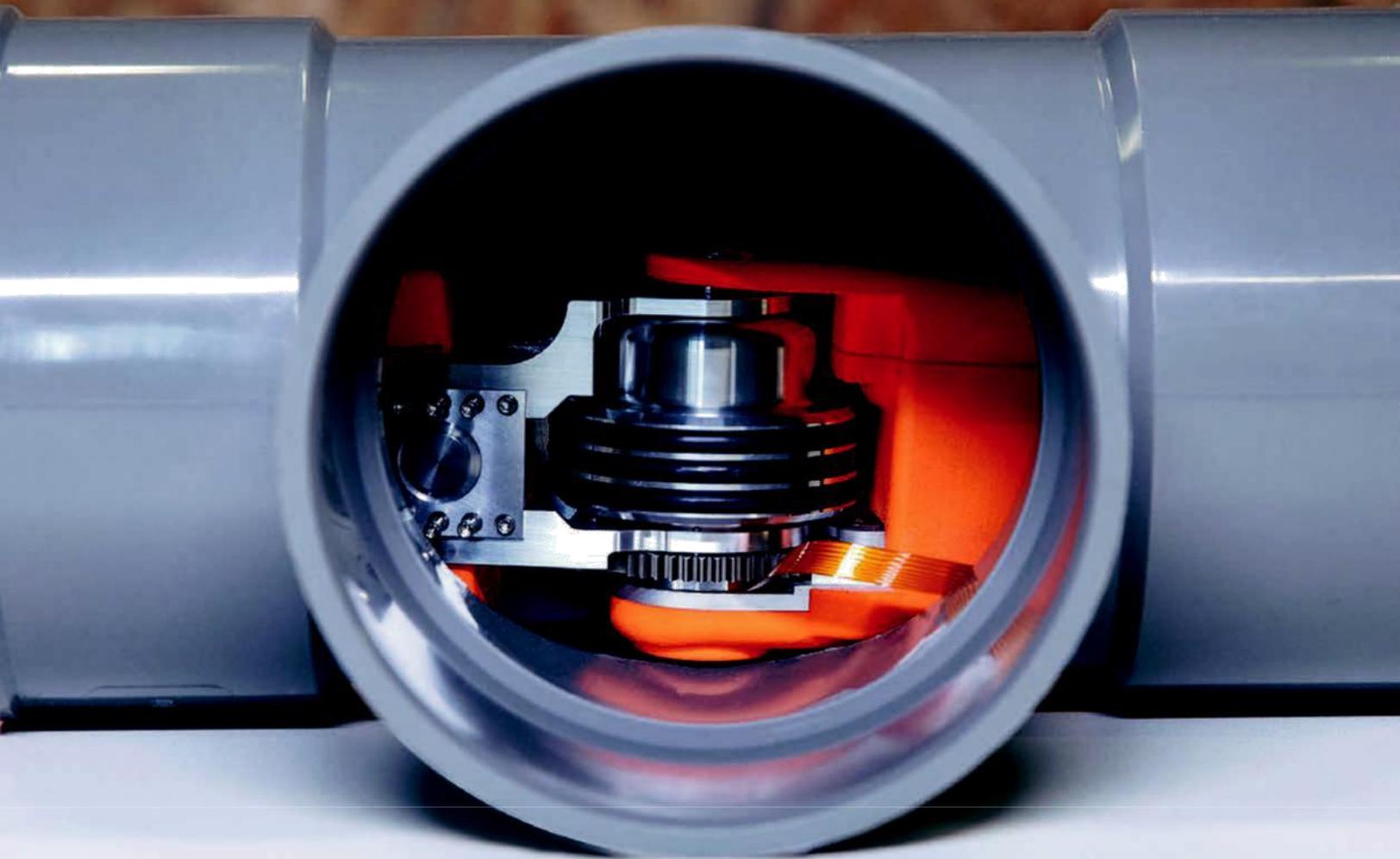
VISUAL

For ultrasonic contact measurements, e.g. for wall thickness measurements, an installation must be cleaned first. Ferry continues: "In the solution that the industry is looking for, i.e. inspecting during operation, this is of course not possible. So we work with visual inspection by cameras. You can also use AI, so the robot recognises what and where the corrosion. We continue to work on this intelligence, recognising all kinds of damage mechanisms in a tank. So the robot 'looks' outside. This is best done from a scratch-free housing, in a clear liquid. It is now possible to move around in it and measure well. And we know that the ball can withstand temperatures up to 80 degrees Celsius and pressures up to 4 bar. That's how far we have come in the Smart Tooling project.

SWARM

"A vision of the future, which will certainly come true, is to send a swarm of these inspection balls into a pipe, tank or pressure vessel. They move in the same direction, bundle all their information and can thus offer reliable measurement results. The best methods for mutual communication, localisation, data collection and analysis are issues that we need to address further. But it's possible, it's just a matter of time".

"There is now a prototype that cannot yet be used in industry, so further development is needed. We have done our best to make optimal use of Smart Tooling and will definitely continue with the Inspection Ball. So thanks to this project, the processing industry will be able to count on a robot in the future that provides information about corrosion under the toughest conditions, without having to take a factory out of operation. Together with the other parties, with Dow and BASF, we are also going to look at how something works in practice, for example in a steam pipe, with condensate and chemical oils. To be continued", says Ferry van der Valk. <<<



INSPECTION HORIZONTAL/VERTICAL PIPELINES

The processing industry uses countless kilometres of pipelines. The current inspection method uses "Pigs", which go through the large horizontal pipeline lines between sites and inspect for corrosion. But the on-site piping systems have a smaller diameter, all kinds of bends and run horizontally as well as vertically. They are also very tall, which makes manual inspection expensive. Fully automatic inspection on the inside is desirable.

SMART TOOLING OBJECTIVE

SNAKEBOT

- ALSO INSPECTION OF VERTICAL PIPES
- ANGLED BENDS POSSIBLE
- RECOVERY IN THE EVENT OF FAILURE
- 4 TO 8 INCH PIPES
- INSPECTION OF NON PIGABLE PIPES

Within Smart Tooling, ExRobotics collaborated with the University of Twente on a Snakebot. This robot is half a metre long and focuses on inspection of 4 to 8 inch pipelines, that are out of service.

Iwan de Waard (director ExRobotics): "We specialise in robots that have to do their work in Atex and IECEx zone 1 environments. Our remote inspector robot takes over the mandatory walking circle from the human operator, who uses their eyes and ears to check for gas leaks, for example. The robot does the same with sensors and cameras. But what is registered, on the outside, is already a defect. Within the Smart Tooling project, we focused on a tool to prevent problems by inspecting the pipeline.

VERTICAL

The existing solution with a "Pig" system can only be used in a horizontal pipeline. However, for the new Snakebot it is no problem to climb up steep vertically inclines and take right-angled bends.



It effortlessly overcomes the small 'ditches' at opened valves. How does that work?

Iwan de Waard: "The principle of the Snakebot is two triangles with three wheels at the corners. The corners of the triangle are adjustable, so the height of the robot varies. This allows the robot to clamp itself onto the pipe wall. In turn, the front and rear triangle are clamped and this way you get movement".

SLIPPING

The other project partner in the development of the Snakebot was the University of Twente. PhD student Nicolò Botteghi focused on managing project there. The most important requirement was the taking of bends and dealing with all kinds of unexpected situations.

Nicolò: "As a university we were involved in this project for the software, that controls the localisation and navigation of the Snakebot. We were able to do tests and simulations with our own little Snakebot, the 'Pirate'. This robot has a slightly different mechanics, but it did help us to detect bottlenecks.

An example: the Snakebot crawls through a pipe and encounters a residue of oil. This causes the wheels to slip and this is registered by the software as distance covered. This leads to erroneous localisation."

ADD INTELLIGENCE

"In that context, we must add intelligence, so that the robot knows: My wheels slipped but I am still in the same place. Localisation is everything in this type of inspection project. Calculating such unpredictable environmental factors is a challenge, and so is the limited space available for sensors. It all has to be very small, so you can collect limited information. Visual information with cameras is also not possible. Still, you have to manoeuvre accurately through that narrow pipe. So, doing a lot with little input."

RECOVERY

Iwan de Waard continues: "It is a complex whole, which we have really gotten our teeth into, because we have a good grasp of what is wanted in practice. That is why we scaled up the Snakebot in the Smart Tooling project.



We were also able to give it perfect mobility in right-angle bends by means of a design adaptation. This makes recovery possible, an important aspect in industrial use. For this situation, we let the Snakebot relax completely. It can then be retracted backwards, even through those right-angled bends".

TOO BIG

"Nicolò wanted more space for sensors, but a bigger robot in this case does not mean that you can take more luggage with you. More sensors mean more weight. And this robot has to climb with that extra weight. More weight means that more grip is needed. This extra friction against the walls can only be created with a stronger motor and this in turn means more weight. Everything scales up and before you know it, your robot snake is too big for the pipe. Space versus the demands you make, that's the big challenge".

FURTHER DEVELOPMENT

"It will mean that in the future we will be limited by the diameter of the pipeline and gravity when determining what

inspections can be carried out. We are now focusing on optimal mobility with sensors for autonomous movement. Then we continue with localisation and navigation. The next step is to determine which method of wall thickness measurement is desirable in the industry, and what we can offer via the Snakebot. And then we will look into the user interface for the inspector.

SWISS WATCH

"A robot 50 centimetres long, with 500 precision parts, that's a Swiss watch that crawls through a tube. We've built a new prototype step by step that incorporates all the new knowledge" Iwan concludes. <<<





< AUTONOMOUS CLEANING VESSEL WALLS >

Barrels, towers and silos must be cleaned in a timely fashion in order to enable high-quality inspection and thus ensure the integrity of installations. Cleaning has traditionally been carried out by people, using high-pressure cleaners. This is often no longer permitted by the processing industry. Within a few years, people are no longer allowed to enter enclosed spaces. That is why the Smart Tooling project looked for an autonomously operating cleaning robot.

SMART TOOLING OBJECTIVE

CLEANING ROBOT: AUTONOMOUS FUNCTIONAL PROTOTYPE

> *PRECISE POSITIONING*

> *REPEATABLE ACTIONS*

INSPECTION ROBOT: PROOF OF CONCEPT

> *OBSERVES IMPURITIES*

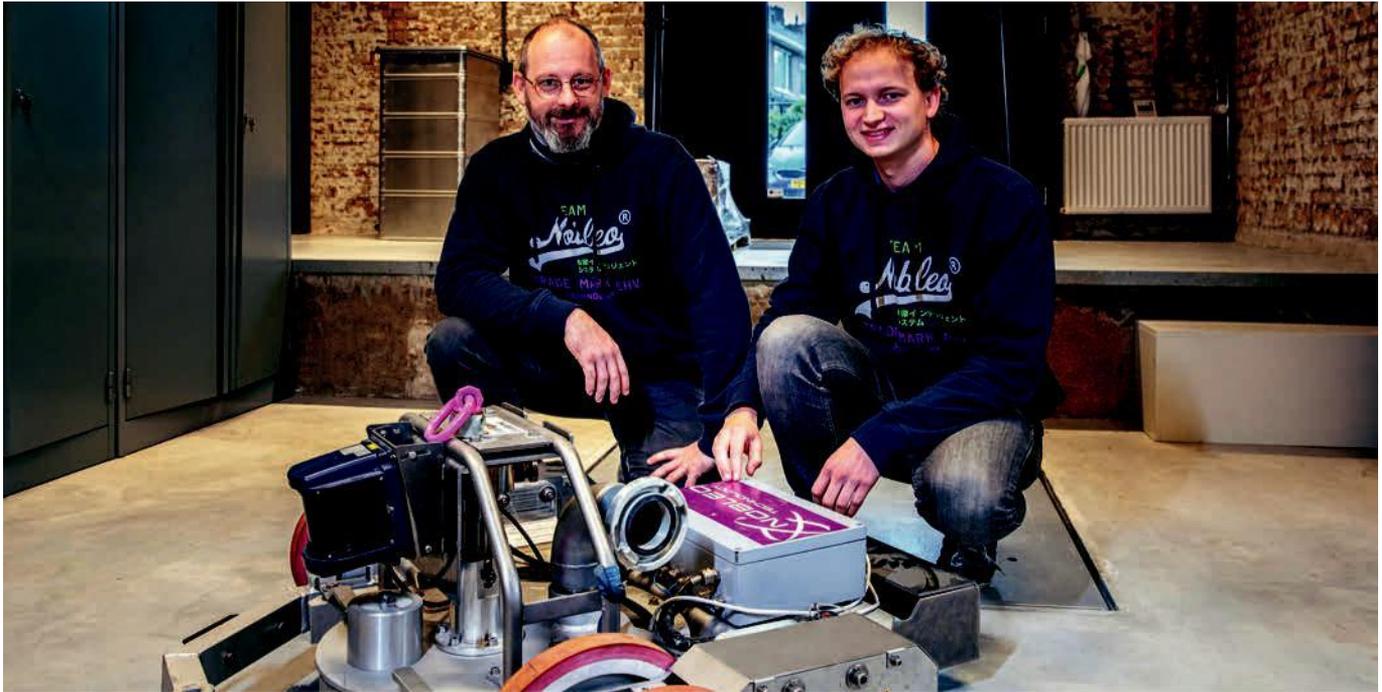
> *LINKS DATA BACK TO CLEANER*

>

Manual Industrial Cleaning is subject to strict legal requirements and safety risks. In addition cleaning must be perfect to prevent contamination and enable optimum inspection. A self-contained cleaning robot must, just like a human being, use many senses and take the right decisions to achieve the desired level of 'clean'. Within the Smart Tooling project, a large team has been working on this.

NON-MAN ENTRY

Industrial cleaning must therefore be done properly, efficiently and safely. Manual work gave a good result but was often not safe for the employee. That is why major asset owners such as Dow and BASF decided more than ten years ago not to allow this to happen again. And now it goes even further: 'Man-entry' in confined spaces will no longer be allowed in a number of years. Still, the cleaning has to be done, and so there is a great deal of work to be done



by the cleaning companies. Some cleaning robots have already been developed. These are controlled with a remote control. However, the operator still has to see what is happening, and thus stand in the confined space because the robot is blind.

In 2016, Smart Tooling started looking for solutions to achieve an autonomously functioning cleaning robot. Until then, there were tele-operated systems. A cleaning operator had to control the robot via a screen, so he had to be constantly present which was not efficient enough.

AUTONOMOUS

The Smart Tooling participants wanted to develop a compact, powerful robot, which you put in a barrel, tank or silo and take out again after a while. The result: A space that has been cleaned according to specifications and is ready for inspection.

Both technical and cleaning companies, worked together on an integrated system that was based on an existing type of cleaning robot. Autonomous location determination, navigation, inspection and reporting had to be combined.

Hans Borgt was leader of the cluster, being both a stakeholder from Dow and an a field expert. "In the end, an existing DERC Hammelmann crawler with remote control was chosen. This robot crawls with magnets against the tank wall and is a tried and tested cleaning robot. The system is connected to the outside world with hoses for cleaning and disposal," he says.

LOCATION AND ROUTING

Nobleo Technology, Accerion and Serenity then dealt with the issue of autonomy. Rob Hendriks of Nobleo Technology: "We gave the robot

answers to the questions: where am I? Where should I go? What is the best route? How should I compensate if, for example, my wheels slip? Our existing robotics platform for localisation and navigation has been configured for this type of crawler".

"Accerion's smart positioning sensors were added and we linked the whole thing to our 'global path planning' and dashboard" says Patrick de Boevere of Serenity. "This allowed Emma, as the robot was called, to do her job via an optimal route".

Various simulations were carried out with Emma and in 2019 she crawled up against a tank wall at Dow on her own. Hans Borgt: "In addition to locating and navigating, Emma can also register and report whether there are any anomalies. For example, a little less water pressure, or a bump. When something like this happens, the exact location of the incident in the tank is recorded, and she can return to carry out an extra cleaning there".

IS IT CLEAN?

A discussion that sometimes runs high in a household also applies to a tank in industry: When is it really clean? Where the eyes of the cleaning employee used to be able to see whether the contamination was gone, it now had to be done by the robot. That is VTEC's specialisation. They replace the human eyes with sensors, which detect contamination by measuring surface roughness. This can also be done with black light, as organic pollution gives a certain type of reflection. There are other techniques that teach the robot whether a surface is dirty or not. AI has also recently entered the cleaning sector.

EMMA & PARTNER

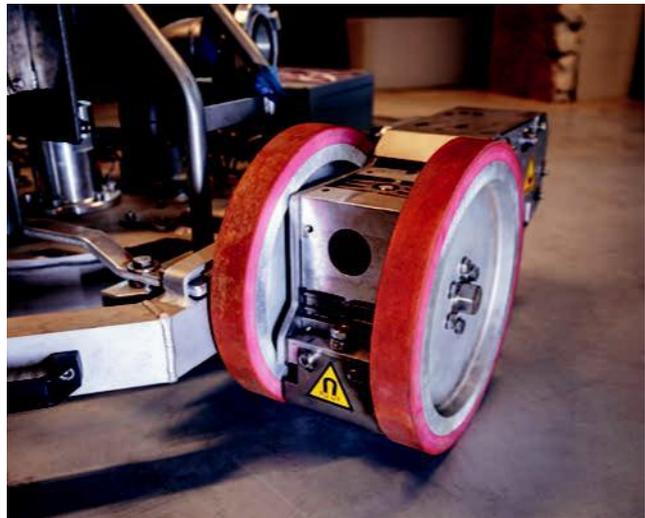
The combination of cleaning and inspection in one robot turned out not to be possible. The vibrations and humidity caused by high-pressure cleaning resulted in deviations on VTEC sensors for the 'cleanliness measurements'. The students of Avans University of Applied Sciences in

Breda developed a separate inspection robot with all the special sensors, which can 'drive' behind Emma. At the end of the project, it turned out that this robot was easy to control and that integration of the inspection results in the Serenity software, i.e. Emma's 'brain', was possible. This means that Emma can return to 'dirty' places.

Cleaning robot Emma is still 'one of a kind'. She is a working prototype that cleans well via a planned route and reports deviations with location. Before Emma can become a commercial product, she needs to be made even more robust and ATEX certified.

There is proof of concept with regard to the associated inspection robot. So it has been demonstrated that it works, but EMMA and its inspection partner could no longer be tested in practice together within the project - partly due to the Corona crisis.

Hans Borgt is happy with the results. "We will certainly continue. And the techniques that were developed during the creation of Emma can probably also be used for other types of mechanical inspections". <<<





< SUPPORT AT A DISTANCE >

The approach of the Smart Tooling project was to tackle an existing problem in the field of maintenance and inspection with a new innovative tool. With the Smart Glasses it was the other way around: the smart glasses already existed, but had to find its way to applications in the process industry and learn from practice.

SMART TOOLING OBJECTIVE

SMART GLASSES

- > REMOTE ASSISTANCE
- > DIGITAL WORKING PROCEDURES IN ONE OUTWARD LAG
- > REAL-TIME REPORTING
- > LIVE STREAMING OF CAMERA IMAGES
- > KNOWLEDGE TRANSFER

This project is a good example of the favourable flow within Smart Tooling. At first, ENGIE was only involved in Smart Tooling via the workshop Cobot - the robot that works with people. Peter Paulissen, Cobot expert at the Belgian knowledge institute Sirris, visited ENGIE at the Maintenance Valuepark in Terneuzen to look at the wishes and possibilities (see page 34). He also discussed the need for digital work instructions. A paperless workshop, and having your hands free while at work.

In the initial phase of Smart Tooling, KicMPi and Sirris organised an event in Antwerp about Cobots and digital work instructions. There was a lot of interest and the companies Proceedix and Iristick came on board immediately. Proceedix offers a software platform that offers procedures, work instructions and inspections paperless. A few years ago, Iristick developed smart glasses for remote assistance. Within Smart Tooling, the combination was made: with the addition of Proceedix's digital workflow, the



Smart Glasses became even 'smarter'. With glasses like these on their noses, technicians can use both their hands anywhere, while reading the work procedures in the glasses and receiving support from an expert who watches from a distance. On the side of the glasses there are buttons to browse through the instruction, but they can also be voice-activated. The glasses can take photos and provide real-time reporting.

NEW TECHNOLOGY

"We want to continuously improve and optimise our services", says Mark de Kok (ENGIE consultant). "After getting acquainted with Smart Glasses, we wanted to investigate to what extent we could use this technology for 'remote assistance'. That was completely new to us, but looked promising. That's why we embraced it and carried out all kinds of tests and pilots over the course of a year. With a positive result, which we are now fine-tuning even further".

"At ENGIE we now have around twenty spectacles in use nationwide for work in the non-residential construction sector. Within certain zones in a chemical plant it is not yet

possible, because of ATEX regulations and because the glasses still have to be certified as highest class safety glasses. This autumn we will start with some pilots for our customers. You will then find out when it is ready for use. In part, it is therefore still a test, because we also want to overcome all possible obstructions e.g. in the area of privacy legislation. But so far the principle really works very well. There is also a lot of interest from ENGIE nationwide".

USER

Mark de Kok: "There are more providers of smart glasses, but we find the Iristick spectacles very comfortable for the user. The intelligence and the battery are not on the glasses, but in a paired smartphone. That's why it's not so heavy. The battery also lasts a long time.

"In order for all this to go well, you do need to make agreements with your employees. Together with BEMAS, we paid attention to the competencies that technicians need to have in order to go into the field with such an expensive tool. Furthermore, Smart Glasses are not the same as a licence. The technician must



still have the same basic knowledge. However, it is true that people learn much more quickly in this way. In terms of training we really benefit from it. In this way you can support less experienced people in a very practical and pleasant way and give them more knowledge. Technicians are still hard to find and this makes knowledge transfer a lot easier".

SPECIALIST TEAM

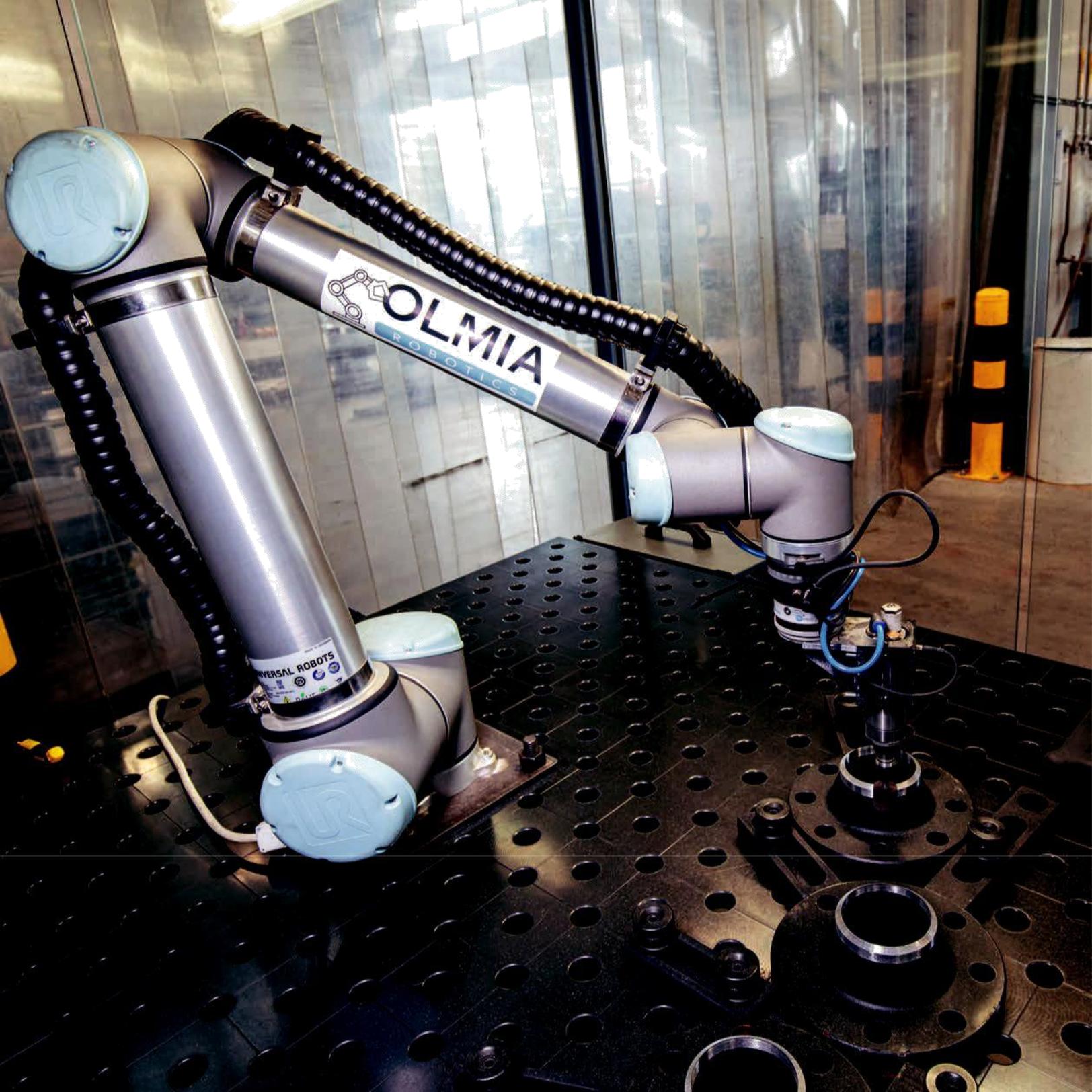
"And what we at ENGIE also think is an important aspect: people who, for whatever reason, are no longer at work, remain perfectly employable. Someone with a disability can assist remotely, or a retired person who would like to continue doing something can join a team of specialists. That's great for people and for the company.

COMPLETION

Johan De Geyter (CEO at Iristick): "We started as a company in 2016. These glasses, including Proceedix software, have been in production since mid-2018. It is a completely in-house development

and the only smart glasses made in Europe. We already offer this for medical and logistical applications. Through Smart Tooling we worked with a party in the industrial sector for the first time. We received a lot of information from the field and that helped us a lot. You could say that our knowledge of the market accelerated, that we were able to develop faster. That we had made further progress was particularly apparent when Covid-19 got a grip on the world and we were ready to play a role in finding solutions. Particularly now that everything has to continue, 'remote assistance' can be essential. Smart Glasses can bridge distances so that people don't have to move. It now turns out that this technology is hugely relevant.

"Smart tooling was very decisive and concrete for us. It was much more than just being facilitated, there were good, productive contacts. Through this project we came into contact with the Dutch industrial sector, which is very important to us", concludes Johan De Geyter. <<<



< CLEANING FLANGES >

Workshops play an essential role in maintenance. Here, parts are cleaned and repaired. Some of these jobs are repetitive, monotonous and sometimes dangerous. An example of this is grinding flange connections. A collaborative robot, or Cobot for short, can potentially take over these kinds of activities from humans.

SMART TOOLING OBJECTIVE

COBOT FOR FLANGE CLEANING

- > TAKING OVER REPETITIVE WORK
- > CONSISTENT QUALITY
- > LESS PHYSICAL STRAIN
- > EASY (RE)PROGRAMMING
- > FLEXIBLY DEPLOYABLE
- > INVESTIGATE OTHER STAKES

One of the first partners within the Smart Tooling project was Sirris. This Belgian non-profit organisation supports companies in introducing technological innovations.

Peter Paulissen was closely involved on behalf of Sirris in the implementation of Cobots in workshops.

"In the initial phase, KicMPi and Sirris organised an event in Antwerp where we gave information about Cobots and digital work instructions," says Peter. "It turned out that many entrepreneurs had the image of an impressive industrial robot in mind. One that is big and unstoppable. But Cobots are quite small and handy. They are made to stand safely next to a human, have a safety stop and adjustable safety limits. You can push the robot arm away in no time.

ENGIE AND ITIS

Peter Paulissen: "During the event we were able to explain a lot. A number of companies wanted to know more and I have



visited those in the following months. They showed me all kinds of cases, but a Cobot could add nothing to many of them. There was too much variation in it. It must really be repetitive, monotonous work that does not change every hour. A Cobot is very easy to program if you want to give it another task: you make the desired movement yourself with the Cobot arm, and the program memorises this. Eventually, two concrete use cases came out: at ENGIE in Terneuzen and at ITIS in Goes".

TIME-CONSUMING TASK

Mark de Kok (ENGIE consultant): "We were curious about this innovation and wanted to know whether the Cobot could help in creating a better quality of execution and above all a safer working environment for our employees. In our workshop in Terneuzen all kinds of mechanical operations are carried out, such as deburring, drilling holes and milling. The cleaning of flanges is also a time-consuming job that comes back every day".

LAB SET UP

"Via Smart Tooling, in close consultation with Sirris, we were able to see whether a Cobot could assist us in grinding down all those flanges. After a visit to our company, Sirris first made a test setup in their own lab, where everything was tested. That went very well, so we started with a Universal Cobot, which we deployed in daily practice with the support of Sirris".

"This introduction to a Cobot, and the concrete pilot with the flanges, went very well. The new employees who are going to work via our company school Coflex have become acquainted with it. It's good if young people can use innovative techniques. Now we are also looking for other possibilities. For example, we are thinking about the combination of cleaning and welding.

Within Smart Tooling we were given the opportunity to get to know this new technology in practice", says Mark de Kok.

Peter Paulissen: "Deployment of Cobots is a process within a company, people have to get used to it. Due to the often specific nature of the work, the use of robotic solutions in workshops is rather limited. But we are convinced that the current technological developments provide sufficient opportunities to develop applications that allow the work to be carried out more accurately and safely".

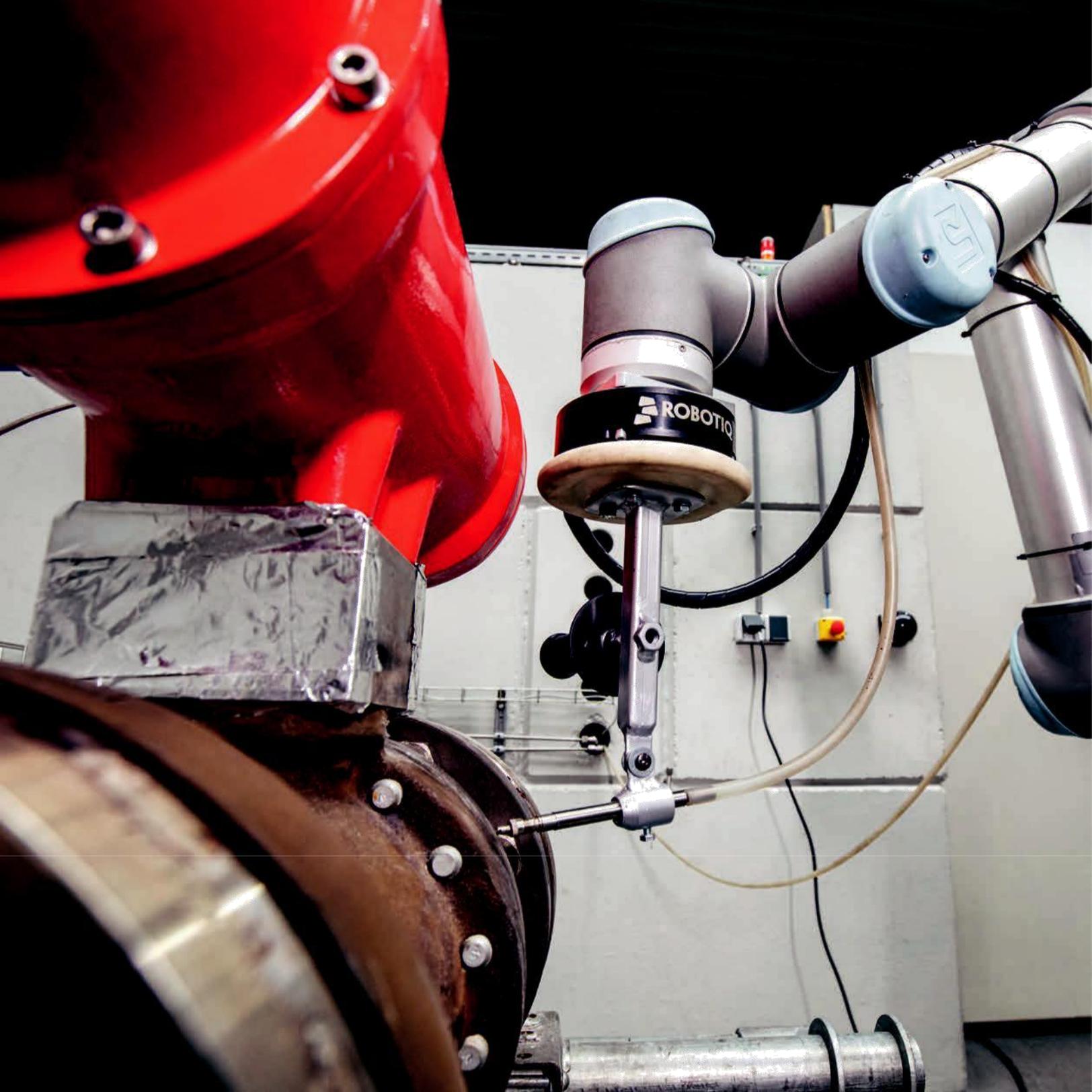


WHAT IS A COBOT?

Cobot is a shortened version of the word cobotics, which in turn is a contraction of collaborative robotics. A Cobot is a clever tool that makes the technician's work easier. It ingeniously combines the perceptual and cognitive abilities of humans with the repeatability, precision and (physical) abilities of the robot. This combination creates much more flexible processes, not only because of the reprogrammable nature of robots, but also because it cancels out the now obsolete segregation of man and robot, i.e. the separation of man and robot for safety reasons.

ADVANTAGES COBOT

- > *SUITABLE FOR SMALL WORKPLACES*
- > *FAST PAYBACK TIME WITH GOOD DEPLOYMENT*
- > *EASY (RE)PROGRAMMABLE*
- > *LOW IN WEIGHT, EASY TO MOVE*
- > *QUICKLY ADAPTABLE WITH OTHER GRIPPER*
- > *PHYSICAL RELIEVE TECHNICIAN*
- > *REPETITIVE ACTIONS OF 10-20 KG*
- > *AVOIDS HUMAN ERROR*
- > *SMART ASSISTANT*



< SAFE LEAK DETECTION >

New types of valves are tested for leakage before they can be installed in plants. This is done in a bunker, under simulated process conditions such as high pressures, temperatures and other extreme factors. A certain test protocol also simulates years of use. Being physically present at this leak detection can be risky for a human being. A collaborative robot, or Cobot for short, could be the solution.

SMART TOOLING OBJECTIVE

COBOT FOR LEAK DETECTION

- > *TECHNICIAN IN A SAFE PLACE*
- > *GAS DETECTION WITH PROBE*
- > *LOCATION IN 3D*
- > *CUSTOMER CAN WATCH ONLINE*

Colin Zegers (Director ITIS): "Our company is an independent organisation. We test all kinds of critical equipment such as valves, flanges and heat exchangers. We do this on behalf of large chemical and petrochemical companies. They buy these parts from a manufacturer, often with the aim of using large numbers. The manufacturer does test his end product, but in order to be sure that certain equipment will function properly under operating conditions for years on end, we expose it to sometimes extreme conditions in a safe environment. In doing so, we look, smell and measure. If the leakage is less than or equal to the maximum allowable leakage value, we can then issue a Type Approval".

SAFETY AND EMISSIONS

"In this way you bring potential problems to light in a controlled environment. Asset owners can better guaranteed the safety of the installations with this tested equipment. They can also prevent emissions," says Colin.



"Here in Goes, in one of our six bunkers, we install the valve and then test according to a fixed protocol or standard. For safety reasons we do this first with a liquid, then with a tracer gas such as helium or hydrogen. The major bottleneck in these leak tests is that we have to get close, while a pressure of 1000 bar or more can be on the valve. We have been looking for a solution to these risky situations for quite some time now.

THEIR OWN COBOT

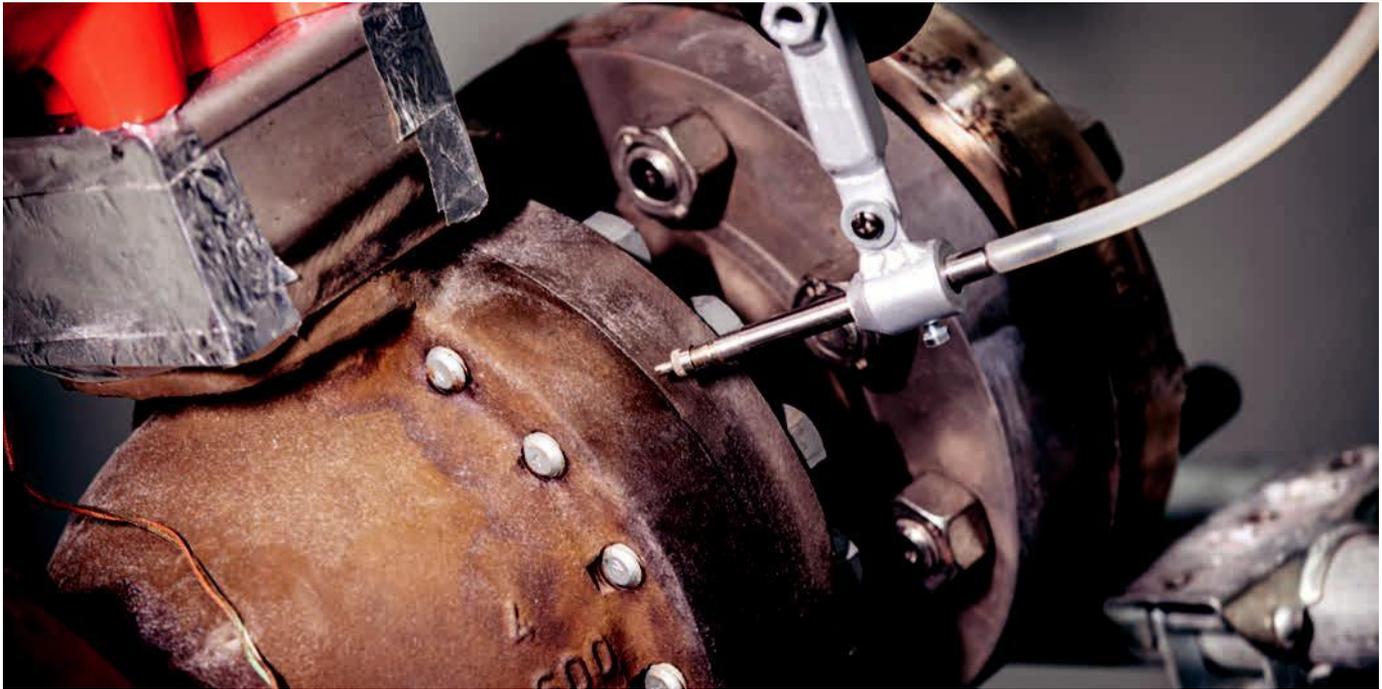
ITIS came into contact with the Belgian knowledge institute Sirris via the Smart Tooling project (see also page 62). Sirris has a lot of experience with collaborative robots in industry, in short Cobots. A Cobot works side-by-side with humans and takes over repetitive, and in this case dangerous, activities.

Colin: "Peter Paulissen from Sirris made a set-up in their lab that was workable for us. At first we were a bit

Sceptical but in the end, after a thorough research and testing phase, we were able to obtain a Cobot ourselves. With the support of Sirris we can now easily reprogram it for other products. That is an important point: we are not so true programmers. But with a Cobot, programming for another application is really easy. You get more out of it by using it in a wide range of applications".

SNIFF OUT

"Now we put the shut-off valve in the bunker on pressure just like usual. Only humans don't get close anymore. The Cobot sniffs out the equipment with a special probe. When it detects the tracer gas, a message appears on the screen of our technician, who is watching from a safe room. The coordinates of leaks are recorded and you can see the location of the leak in a 3D model. By the way, even customers on the other side of the world can watch live with



to see with their own eyes whether the valves they might want to use in dozens of factories have passed the test".

ACCREDITATION

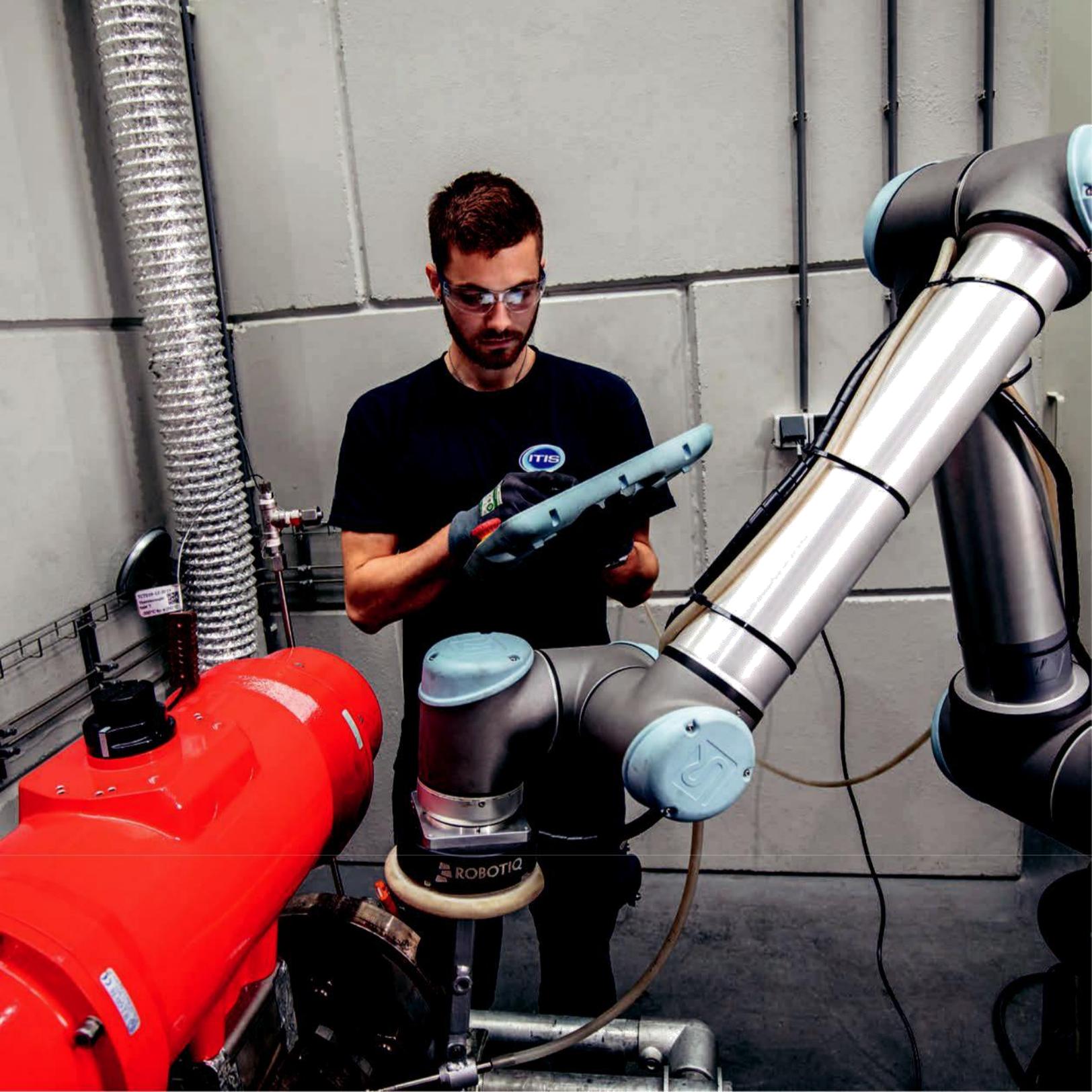
Colin: "Together with BEMAS, we have now mapped out all the competencies needed to carry out a leak test with the Cobot. What can you expect from a person working with the Cobot? To this end, we have defined three levels.

"We liked the principle of establishing competences very much. That is why we have described and structured all our work according to this system. In this way, you immediately generate a documented training plan. This is good for your company, but also crucial for our accreditation according to ISO 17025. And for an independent testing institute or conformity assessment body, this accreditation is very

important for success. We have come a long way. In the near future, ITIS will be one of the few companies where equipment can be tested within set quality standards. For some tests it will even be the first and, for the time being, only company in the world".

KICKSTART

"Smart tooling has really boosted our company," says Colin. "We think we can provide even better support to asset owners with the help of the Cobot. Especially now that we have a safe, accredited and advanced technology, which is already in full use and with which we can test more and more things. We have worked hard on the Cobot, but the kickstart came from Smart Tooling. The project team has done a really good job. It is often difficult for smaller companies to come into contact with this kind of new technology. Now we are leaders in our branch. <<<



WIM VAN CAUWENBERGHE

The Belgian Maintenance Association (BEMAS) was a Flemish partner in the Smart Tooling project. Developing innovative robotics for maintenance is one thing, but the human being happy remains the central focus. Professionals must be able to work well with new technology. With its expertise, BEMAS brought structural clarity to the necessary competences.

"In Belgium, BEMAS brings together all parties involved in maintenance and asset management", says Wim Vancauwenberghe (Director). "Our goal is to achieve optimal, or as we often say 'world class' asset management together.

KNOWLEDGE AND SKILLS

"In addition to our own activities, we at BEMAS find it very important to contribute to external innovative projects. This always results in new insights and useful solutions, with the ultimate goal of broad deployment in the industry. The Smart Tooling project enables us to contribute to innovative robot applications. It is very important that people are able to work correctly with these robots. If you think about it for a moment, you can see that, for example, an operator of an inspection

drone must have a high level of knowledge and skills in order to be able to carry out proper inspections in a chemical storage tank".

GOOD ROBOT OPERATORS

Good robot operators ensure that the robots deliver quality work, in a safe and efficient way. This is to the advantage of both the asset owner and the service provider.

"Together with the robot specialists, we have mapped out the necessary competences in detail within Smart Tooling. Many elements were in the minds of the developers and experts, but in order to pass on that knowledge and experience, it has to be written down. That is why this was an integral part of the Smart Tooling project".

LEARNING OUTCOMES

"The competences have been defined using a European methodology based on Learning Outcomes.

We are striving for an unambiguous definition: a kind of uniform language to describe the necessary knowledge, skills and attitude for a certain task. Knowledge can be: knowing all the buttons on the control panel. A skill means dealing with the control switch. The third component, which really belongs here, is the attitude and maturity. How experienced are you? Can you perform this task without supervision?

UNIFIED APPROACH

"The great advantage of such a uniform approach is that it provides concrete and verifiable insights and actions. Training providers can use this to develop a tailor-made training programme. And a company can use it to perfectly check to what extent its robot operators have the right competencies".

DISCIPLINE

"To correctly describe a competency, requires discipline. You have to formulate everything as concretely as possible. If you say: you have to be able to drive a drone for this work: Do you mean flying a circle? Or fly stably along a wall at a distance of five centimetres? Record it, that way you avoid discussions and you are unambiguous, anywhere in the world".

THREE PROJECTS

"Within Smart Tooling we have detailed the competences for three projects: Drones in closed

spaces, Smart Glasses and Cobot leak detection. The methodology we use only works if the tool is already being used in practice. We have come furthest with the drone inspections for wall thicknesses inside tanks. After all, Terra Inspection is already working on it. We are now able to structure all the competences needed to carry out drone inspections. The company has also already defined three 'levels' for drone operators. That's very interesting for them, because they are a worldwide centre of expertise where all kinds of people follow a training course".

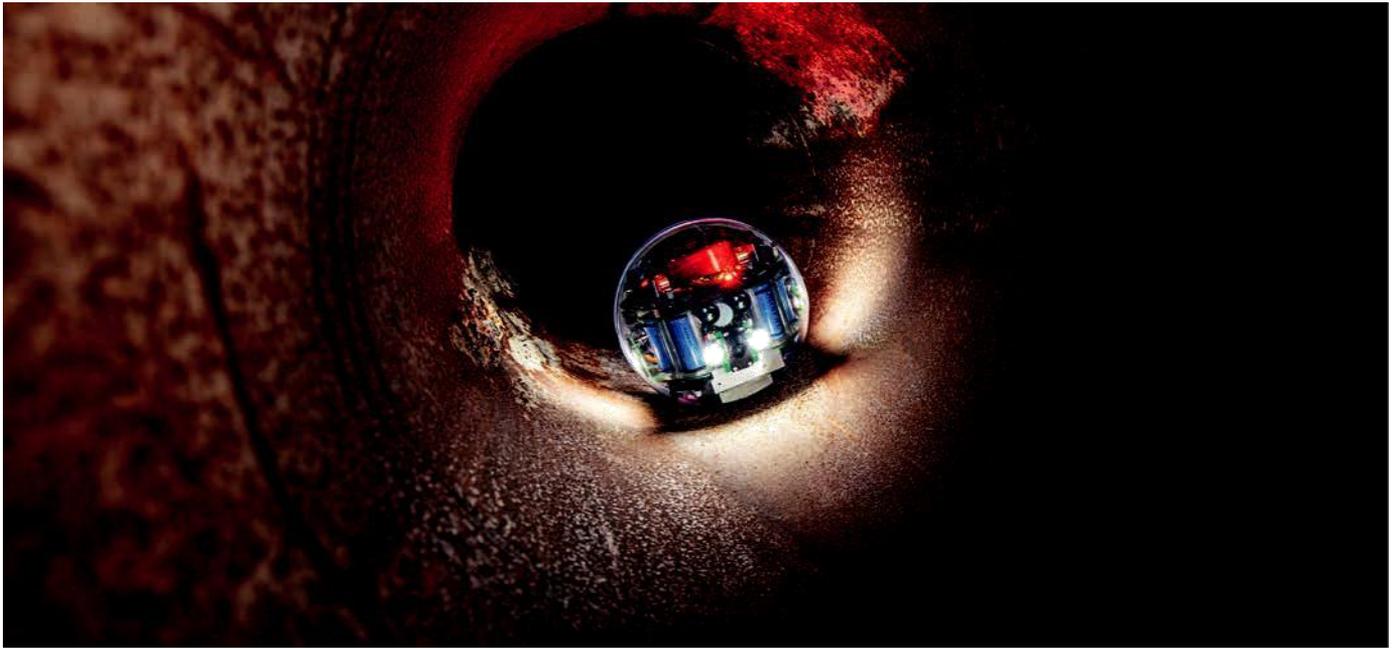


"Smart Glasses for remote assistance is another example. We have come a long way there too. It all seems easy to walk around with these glasses, but there are certain skills that you have to master before you go on the road with this rather expensive tool. For users such as ENGIE it is useful to be able to tick the box: you can send this person safely and efficiently into the field with smart glasses. Finally, we have worked on the competency package for an inspection Cobot, with which Itis can carry out leak detections under safe conditions.

We have provided the methodology for the other projects. In this way, the companies that are still working can set to work themselves.

PEOPLE REMAIN CENTRAL

Wim continues: "Smart Tooling fits into the new world of Industry 4.0. Unprecedented possibilities are opening up, for example by 'predicting' future malfunctions and estimating the remaining useful life. But without skilled professionals, we will get nowhere.



"There will not suddenly be a robot operator training course. Perhaps it will become a basic competence for all technicians: briefly deploying the robot for a pipeline inspection".

If an algorithm predicts that a flange has to be replaced at some point, a human will still have to do that work correctly".

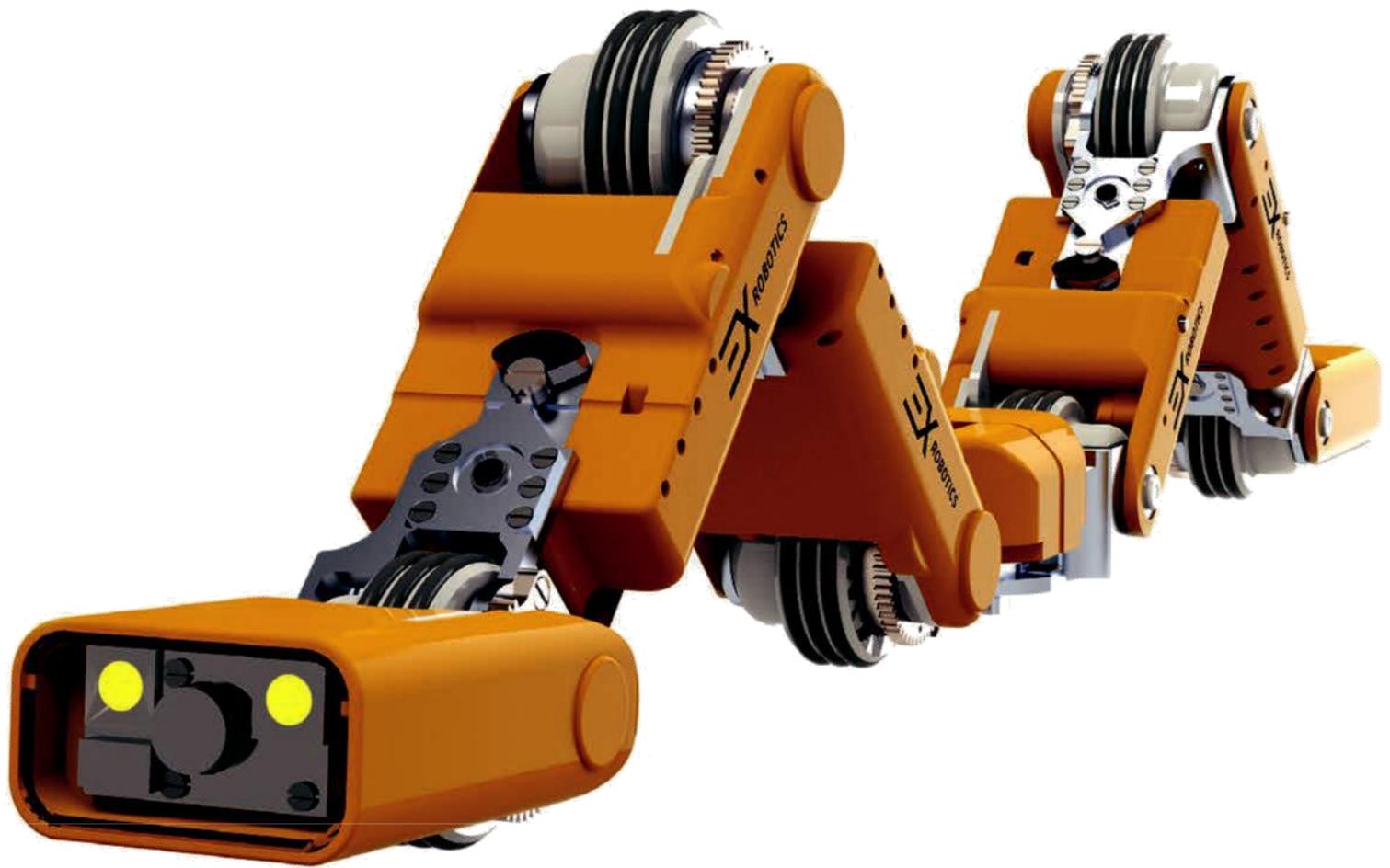
DANGER

"Thanks to robotics, new, interesting jobs are being created. New opportunities ... but at the same time there is also a danger. Because of all the innovations and predictive possibilities, less invasive maintenance is required. And that in turn means that young people see the insides of machines and installations less often. In the future, process installations will be replaced by robots that are

perhaps no longer open to inspection at all. We have to take this into account when we want to send technicians into the field".

SEIZE THE OPPORTUNITIES!

"Anyway, we live in exciting times. Thanks to the current wave of innovation and Industry 4.0, the boardrooms are once again talking about maintenance. To everyone who works in maintenance, I say: seize this opportunity and do something about it. Embrace the possibilities and the changes that taking place now" concludes Wim Vancauwenberghe.



STEFANO STRAMIGIOLI

Prof. Dr. Stefano Stramigioli is Professor of Advanced Robotics at the University of Twente and knowledge partner in the Smart Tooling project. Aside from being a scientist, Stefano is a talented speaker on robotic applications and Artificial Intelligence.

"A few years ago I gave a lecture at an event on maintenance inspections. That's where I met Jan Mol from KicMPi", says Stefano. "It turned out that we had quite a few common ambitions. My department fit perfectly within the framework of the Smart Tooling project so we stepped aboard. For scientists it's really fantastic if a professional group like KicMPi ensures that a subsidy comes in. And that we, as the University of Twente, will then be one of the parties that can work with it".

"Robotics have been used successfully in many different areas for some time now, for example in the medical world. In maintenance and inspections in the industry it is

relatively new. The challenges we face to obtain a well-functioning, robust and autonomous robot have not yet been overcome, but we are well on our way".

KEY GROUP

Stefano: "For example, from 2013 to 2016 I was an advisor to the European Petrobot project, where significant steps have already been made. All kinds of large companies were involved. In fact, it was the beginning of the focus on robotics in the industry. It was also the start of Sprint Robotics. KicMPi then came into the picture as an important group for the processing industry".

"We first built on existing mechatronics technology: a small crawling robot to inspect the low-pressure network of gas pipelines. With this Snakebot, called Pirate, we started working in Smart Tooling, together with ExRobotics and our PhD student Nicolò Botteghi. Thanks to Smart Tooling we were able to finance it. Nicolò was especially committed to the intelligence of the robot. The morphology was in order, so we as a department did not pursue this further. However, it was the intention that the robot would work autonomously, not with a remote. This means, you have to work on artificial intelligence."

THE REAL WORLD

"In practice, AI has to deal with ever-changing, unpredictable circumstances. In a virtual environment, or a physical environment that is fairly stable, for example a room, AI is quite simple. This also applies to a perfectly clean pipe. But the situation in the processing industry is different. Sometimes there is oil in the pipeline, or other pollution. You don't know where or when. This means the robot has to learn how to turn his 'body' with slipping wheels".

"So the expertise has originally grown from the mechatronics side, the design of the robot itself. Good engineering produces a robust robot that crawls through a small pipe. Thanks to Smart Tooling, we were able to pay a lot of attention to the fundamental problem of autonomy, i.e. intelligence. How can you create intelligence in a robot? How should it learn? We performed many

tests in a simulation environment. We were not able to test on a real robot, in practice. But we were able to generate knowledge for the next steps in automating crawling robots in pipelines".

"The basic concept for 'learning' based on unknown factors is now there. So the next step is to work with a company with a real robot again. Hopefully in a next project."



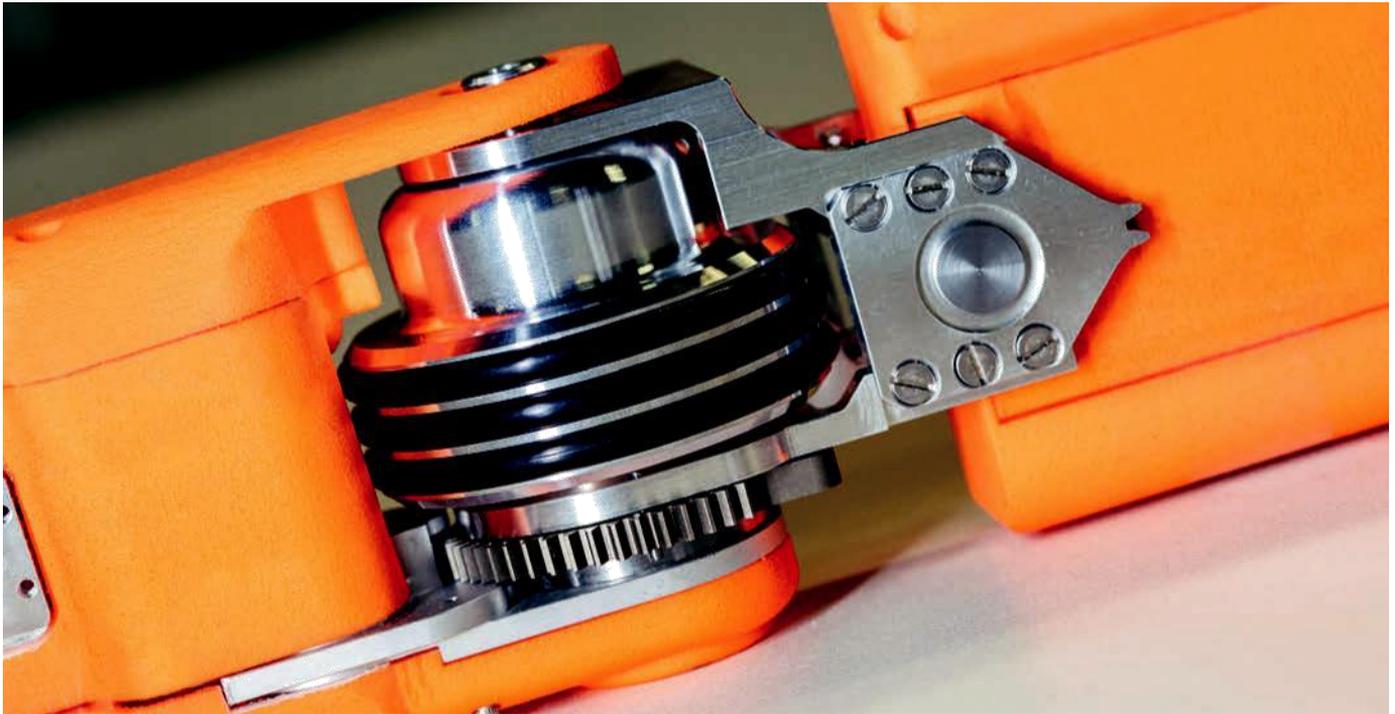
COMPLEX

"In the meantime, AI is also being further developed. Reinforced and deep learning, for example, are growing in the medical world and this also broadens our horizon. But beware ... 99% of people say: AI is the solution to all problems. That is not just the case. With a few lines of software you get nowhere. What we want is much more complicated than playing chess or GO with a computer. Getting a small robot to come up with something on its own is much more complex. In a virtual world you know everything, so there are algorithms. That is a model, not reality.

Moving and reacting in and to a physical world is much more complex. What is going to happen is not clear, so you have to measure and decide in the moment, learn from your own mistakes and the environment you don't know. That is where the challenge lies for us.

FUTURE

"This interaction between body and mind is becoming more and more interesting because more and more computational power is becoming available for intelligence in robotics. That is an important element.



"Smart Tooling is one of those projects that are the start of an investment in this line of research and engineering, and very relevant to the industry."

But robotics is the engineering science of integration, it is not one thing! It is electronics, mechanics, materials, computer science ... everything together produces results.

COOPERATION

"I greatly appreciate KicMPI's project team. From 'Genesis' to the implementation of the project, we worked together in a smooth way. We had very positive and constructive interactions! I think the result of Smart

Tooling is more important for the long term than the project results themselves. There is now a robotics ecosystem for inspection and maintenance in the Netherlands and Belgium. Smart Tooling is one of those projects that is just the beginning of an investment in this line of research and engineering, and very relevant for the industry. I really hope that there will be more projects after this" concludes Stefano Stramigioli.



PETER VOORHANS

Peter Voorhans (Global Improvement Leader): "Dow is a permanent partner of KicMPi. Every year we indicate what we are interested in. Robotics is high on our agenda, because as of 2025 we will no longer be able to have people work in enclosed spaces.

So Smart Tooling was a project in which we were happy to participate".

"You prefer to interrupt a continuous production process as little as possible. Nevertheless, our factories must be in optimum condition to guarantee safety for people and the environment, and to supply the desired products. Cleaning is usually a necessity for inspection. And many installations are difficult to access".

"Our ultimate dream is to inspect during operation: you put in a measuring instrument that works well in a barrel of chemicals. Within this Interreg project, something like that has started to take shape. Literally. We are looking forward to the moment when the Inspection Ball is ready for use.



This is a groundbreaking development. We also like to help with further 'teaching' the software, so that the ball gets to know the damage mechanisms in a tank. It must be done step by step, and together we will succeed.

"Dow has , like BASF, contributed to Smart Tooling from a common interest. We were always in sync with them and had an excellent contact. The cooperation with knowledge institutions such as Avans, and the universities in Ghent and Twente, was also extremely important. In the future, however, we will have to think about secondary vocational education. After all, they will be the ones working with the new tools.

"It all went very well. Especially the flying in with drones and the cleaning project has been very successful. And hopefully soon we'll get a working inspection ball".



SEÇMEN AKBAS

Seçmen Akbas (Project Lead Innovation in Maintenance) represented BASF within the Smart Tooling project. "At BASF, the Antwerp 4.0 project is ongoing. Innovation and Maintenance is one of the workstreams. We are looking into the possibilities of using robotics and drones for inspection and maintenance. The Smart Tooling project was a perfect match for this".

"Dow and BASF are consumers, so they will feel the benefits of robotic solutions. Within this project, we have outlined the problems, indicated the direction and offered testing possibilities together with Dow. But we also learned a lot during the project, thanks to the feedback we always received from the developers. So it was already a win-win situation at that time".

"All Smart Tooling subprojects were relevant to us. Quite a lot has been tested with the inspection drones in confined spaces, which carry out wall thickness measurements there. These tests are important in order to

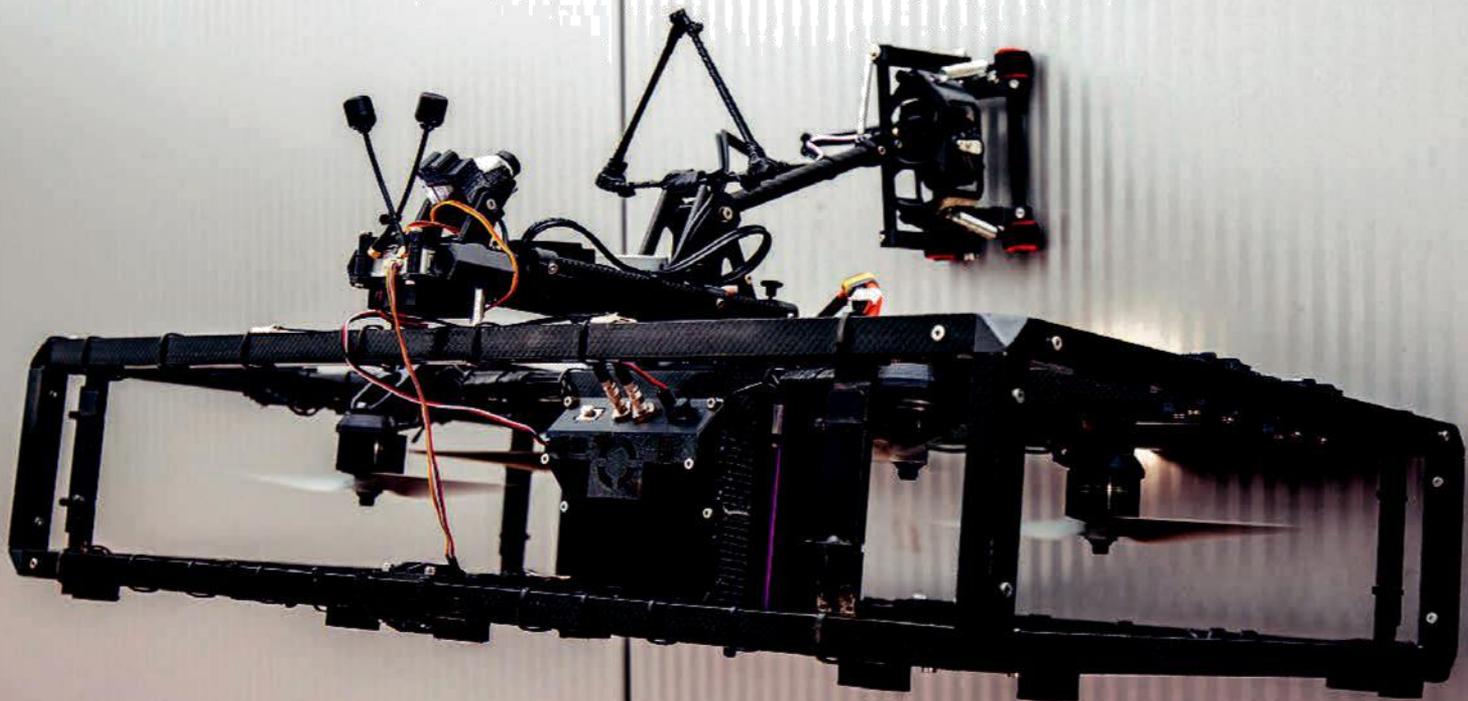
to test the new steps in practice. We found working with drones for indoor and outdoor inspections very interesting. The that were found for cleaning are also promising. The goal was not to deliver commercially finished products but prototypes, which can be further commercialised. In order to be able to achieve this, we are still running a number of tests.



"We have met a lot of people who are all working on innovation in the processing industry. We will certainly continue to use that network after the project. So that has been a real enrichment".

"The relationship with Dow was also very good. As consumers we have the same problems and wishes. We communicated openly and constructively, for the benefit of the

developers, and thus also for ourselves. In addition, we enjoyed working with KicMPi. In short, BASF is very satisfied!



BRAM DE KORT

Bram de Kort is director of Interreg Flanders-Netherlands. This European fund for regional development subsidises cross-border projects for smart, green and inclusive growth. Over the last seven years, the emphasis has been on innovation, sustainable energy, the environment and resources, and labour mobility. Smart tooling fitted in perfectly within this picture.

"There is one Europe, but borders still exist. They cause difficult problems, but also interesting opportunities and insights" says Bram de Kort. "Interreg is an initiative that wants to stimulate cross-border cooperation firmly and concretely. The idea behind it is: if the borders are completely open, with few obstacles, then economic and social gains can be made on both sides".

INNOVATION

Every seven years, an Interreg partnership in a European border area may propose a programme. Bram: "For Flanders-Netherlands in 2013 the emphasis will be on four

spearheads: innovation, sustainable energy, environment and resources, labour mobility. Projects that want to be eligible for subsidy must therefore be cross-border and offer added value within those four themes, specifically also to small businesses. The Smart Tooling project of KicMPi and partners was a perfect match.

"After all, the idea that KicMPi came to us with is about bringing together innovative knowledge from both sides of the border. Learning from each other, offering each other opportunities for new customers or for new long-term partnerships, that is important to us. And also a broader horizon

for smaller companies that often operate in their own niche market".

"After all, innovation always starts on a small scale, as an idea that slowly takes shape. Take an innovative technology entrepreneur from Goes. He logically knows his own sector in his own direct environment. He also has a reasonable picture of the other Dutch players in his niche".

"By reading all kinds of publications the entrepreneurs also has a good view of global developments. However, he doesn't know whether someone in Ghent or Antwerp has any sort of interest in his ideas or his work. Through a project like Smart Tooling, it is precisely these opportunities that come into the picture".

"Much has been achieved in concrete terms. But at a time when it could just as easily have been individual in Flanders as it was in the Netherlands, we as Interreg missed our target. In that respect, I think Smart Tooling is a very good project. Many developments have brought together practical knowledge on both sides of the border by companies and educational

institutions. For example, a prototype was developed by a company in Flanders, the extra module and tests were carried out at a knowledge institute in the Netherlands. Everyone did what they were good at. All those people, from companies and other organisations, who discover each other and also each other's markets, that's pure profit for the region".

"The cross-border aspect is therefore perfectly covered. But, of course, it all has to be economically advantageous. After all, this is about deploying European

taxpayers' money with a tangible benefit for all the people in the region. There, too, I see that the story of Smart Tooling makes sense.

EMPLOYMENT

"Smart tooling is not only about technology but also about employment. In Zeeland, Flanders and part of the south of the Netherlands, thousands of people earn their living in relatively old processing industries. Older installations, in a region where requirements in the field of safety and the environment are

high, certainly in comparison with other parts of the world. Of course, the most important thing is that people should be able to work safely and that there should be no environmental incidents. With the robotics applications from a project such as Smart Tooling, you literally give the asset owners the tools to keep their installations efficient, safe and well maintained, at an acceptable cost. Also in the future.

"People often think that robotics automates something and thus threatens a person's job. That is by no means always the case. The

projects within Smart Tooling do jobs in the industry, which are unsafe,

impossible or too expensive for a human being. It is precisely this that creates work for the companies that develop, build and perhaps even export the tools. But also with the users. Work that used to have to be done manually is now done with the aid of a robot, or with other new innovative tools. For a maintenance worker, this means learning new skills. It also creates jobs. Moreover, working in Maintenance is also much more interesting for young people.





"Through the Smart Tooling project, we are developing as an internationally oriented region in the field of robotics within maintenance in the processing industry"

Flying with a drone in a tank, or operating a Snakebot, that is of course very exciting".

EXPORT

"Smart Tooling has brought added value to the region in many ways. The project contributes to the preservation of our processing industry and thus to employment. In addition, new business activity is also being created because the new robot tools are being developed mainly in smaller companies. They are exploring their horizons with the new applications and are able to deploy technology globally".

COOPERATION

"KicMPi has facilitated and stimulated cooperation between all parties. There were many workshops, many meeting moments with the project group. In the last four years a cross-border cluster has emerged from which much more will emerge in the future. Through a project such as Smart Tooling, we are developing as an internationally oriented region in the field of robotics within maintenance in the processing industry".



JO - ANNES DE BAT

KicMPi has been able to count on the support and enthusiasm of the Province of Zeeland since its foundation. The Smart Tooling project shows again that the Cooperation between the Province and KicMPi leads to beautiful and important innovations in the processing industry.

Commissioner Jo-Annes de Bat: "We think it is important that the processing industry, which provides many jobs in our province, is technically and financially in good health. KicMPi is committed to this. Within the Smart Tooling project, a number of concrete steps have been taken to help achieve this. The cross-border network, both national and international, is also of great importance to Zeeland.

"The KicMPi connects education, business, asset owners and innovators/start-ups. In addition to the concrete technological results, the effect on the economic development, safety for staff and the environment are also important".



"The relationship between the Province and KicMPi is very pleasant and business like. I myself see them as a very independent, well-functioning organisation, with the right priorities. Their strength is the coordinating and stimulating role. I sometimes hear them say: 'We have grown up by not doing things! That's true, but they do make it happen for others. In fact, they themselves are the lubricant for innovation in our region'.

"The openness to share knowledge across borders can only benefit us as a region. The cooperation with, for example, the University of Twente and Ghent University is important to us. Innovation is high on the agenda of the Province of Zeeland, so we are looking forward to further cooperation with KicMPi".

SMART TOOLING

< DEVELOPMENT COMPANIES >

Regional development companies are involved in the initial design of the Smart Tooling project. They were also responsible for the steering committee as project partners.

REWIN

As a development company, REWIN has a lot of experience in initiating and stimulating innovation trajectories. These competencies were used for the Smart Tooling project. Due to its neutral role, REWIN connects companies in the chain and with educational and knowledge institutions.

For the Smart Tooling project Stefan van Seters of REWIN used company contacts and knowledge of robot technology. Especially in the field of drones, REWIN has developed and implemented several (Dutch and European) projects since 2010. It was therefore a logical decision for Stefan to supervise the innovation projects 'Drones enclosed spaces' and 'Drones outside'. Together with the Aerospace Engineering & Maintenance training of Avans, a successful presentation and demonstration day was organised in 2020.

At the Dutch Drone Center Aviolanda Woensdrecht more than 150 attendees could admire the innovations. After more than three years, these projects were successfully completed with working prototypes and a clearly proven usefulness. In the meantime, REWIN has started a follow-up with KicMPi, in the Smart Maintenance Labs project.

IMPULS

Development organisation NV Economic Impuls Zeeland (Impuls) has deployed its extensive network in the regional business community in the Smart Tooling project. From the Logistics & Maintenance cluster, Impuls supplied project management for the innovation projects in the field of inspection, especially for the Snakebot and the Inspection Ball. By using Impuls, clear and specific use cases could be developed. The further follow-up in the project was done successfully in close cooperation with KicMPi.



The Snakebot and the Inspection Ball have been developed into a prototype. The users have shown great interest in these applications.

BOM

Together with entrepreneurs, the Brabantse Ontwikkelings Maatschappij (BOM) is building a strong, sustainable, future-best Brabant economy. It does this by sharing knowledge, forming (international) networks and providing capital for innovative Brabant companies and sustainable energy projects. In addition, the BOM stimulates innovative, foreign companies to establish themselves in Brabant. Research carried out by the BOM showed that many activities in maintenance & services are eligible for (further) robotisation. Companies with competencies in the field of sensing,

mechatronics and vision technology, the process industry such as Dow Chemical and BASF, and knowledge institutions such as the University of Twente and Avans have difficulty finding each other.

The aim of the Smart Tooling project was to bring these parties together and to contribute to the development costs of applications with financial resources from the Interreg V programme. This allows clusters of companies to develop a proposition that can be marketed worldwide.

The BOM has made its knowledge and expertise in the field of business development available to guide clusters towards a good business model. <<<

< COBOTS & DIGITAL WORKFLOW >

Sirris is a Belgian non-profit organisation that supports companies in introducing technological innovations. The organisation has offices in eight locations in Belgium. There is also a test laboratory at each location.

Peter Paulissen, who works at Sirris within the Smart & Digital Factory, was involved in Smart Tooling from the start. In the end, he managed two projects related to the use of Cobots in the workshop, plus the Smart Glasses project. "Sirris immediately said yes to KicMPi's request to participate. We have a lot of expertise in the field of cobotics and digital work instructions and are convinced that these elements have an added value for maintenance and inspection in the process industry. Nevertheless, the use of Cobots in workshops is still rather limited. There really is still a lot to be gained there. These machines quietly work side by side with people. They are very flexible to use, simple to program and can offer quality and safety in repetitive work. Also a digital workflow instead of paper can bring many benefits to a maintenance or inspection company".

"I have found Smart Tooling to be a very positive experience, especially the synergy between companies on both sides of the border. I saw two young Flemish companies, Proceedix and Iristick, working together with a large Dutch company like ENGIE. Everyone learned from this. We from Sirris as well. Through Smart Tooling, we have realised new innovations that we can already introduce to other companies. That's what we do it for. I can certainly see Sirris and KicMPi working together in the future as well".



< WIRELESS COMMUNICATION >

Within the IDLab research group of Ghent University and imec, 60 researchers focus specifically on wireless technologies and flexible soft and hardware. This expertise came in handy in the Smart Tooling project.

During a Smart Tooling event, the research group gave a presentation on all kinds of wireless technologies. This brought new insights, because there are several possibilities to achieve a goal. The choice of technology involves aspects such as desired distance, speed and accuracy.

In addition, there is the reality of practical situations: which forms of wireless communication function under which conditions, for example at high pressures and temperatures, or even in a liquid, are desired? Lab tests and simulations then provide a definitive answer. But sometimes researchers have to be confronted with reality, for example for the 'Inspection Ball'. Jeroen van Hoebeke, professor at the University of Gent/IDLab:

"We have very good testing facilities, but decided now just use a swimming pool. The radio signal remained active up to a depth of half a metre. If that isn't possible in practice, it means that you adapt the robot, or choose another wireless technique. In the 'Drones outside' project we also looked for optimisation, for communication and localisation. There, we were able to add intelligence to the system. In this way, we tried to provide pieces of the development puzzle".

"With this Interreg project, we as a research group have regained some of the reality ourselves. Through contact with the developers and the industry, we can see better what the needs are through interesting use cases. We apply that knowledge again. <<<

< INSPECTION ROBOT AFTER CLEANING >

Avans University of Applied Sciences has been involved in Smart Tooling since the beginning. For Avans robotics is an important subject. One of the goals within the project was to develop an autonomous robot for cleaning and inspection of confined spaces.

A number of fourth-year students from the Academy of Engineering & ICT were involved in Smart Tooling, as a final project before graduation.

The students calculated that the cleanliness measurements during cleaning could not be accurate enough to draw any conclusions. The high-pressure cleaning disturbed the sensors. It was therefore impossible to make one robot for cleaning and inspection. As a result, they successfully developed a separate, well-functioning inspection robot. This can now inspect a tank autonomously and manually, and is relatively cheap.

Lecturer Jos van Kreijl*: "As a university of applied sciences, we were very happy with this Interreg project. It gave us time that we could immediately convert into new knowledge for the school. Thanks to this project we have learned a lot about robotics and software in particular.

Moreover, this robotics project gave our students the opportunity to learn to work with different disciplines. They usually only deal with their own discipline, but in this design several aspects came together. I am satisfied with the result: the students have done a good job, because there is now a prototype robot that works, from which the business community can benefit".

**IN MEMORY OF*

During the creation of this brochure we received the news that Jos van Kreijl died at the beginning of September 2020. We fondly remember Jos' contribution to the project and his collegial and pleasant way of working. <<<

EVENTS & HIGHLIGHTS

Several events were organised within the Smart Tooling project. The project partners also actively participated in trade fairs and other meetings to showcase new developments and share knowledge. Below are a few highlights.

Maintenance Antwerp

21/22 March 2018 and 27/28 March 2019

KicMPi works together closely with BEMAS, the Belgian maintenance branch organisation that organises the annual Maintenance Fair in Antwerp. In 2018, visitors to the Robot Demo Zone were able to become acquainted with the innovative robots of Smart Tooling. During Maintenance 2019, the project partners demonstrated several prototypes: wall thickness measurement with drones in confined spaces, inspection of pressure vessels and pipes with snakebot and the inspection ball, the first autonomous cleaning crawler, drone technology for safe flying in open spaces and live streaming technology for hands-free remote assistance. The demonstrations were provided by Serenity, RoNik Inspectioneering (later Terra Inspectioneering), ID-tec, Nobleo Technology, DERC, Avular, ExRobotics and Proceedix.

Maintenance Gorinchem

On **17, 18 and 19 April 2018**, the Smart Tooling project was present during Maintenance 2018 in Gorinchem. Here too, visitors could get acquainted with the innovative robots.

KicMPi and iTanks demonstrated new technologies and services, in collaboration with various startups and innovators.

Smart Tooling promo event I

On **29 June 2017**, the Smart Tooling promo event I took place. On that day, the progress of the Smart Tooling robotic applications was presented and demonstrated. There were presentations of them: Age Balt (Dow Benelux), Jeroen Hoebeke (University of Ghent), Johan Engelen (University of Twente) and Willem Endhoven (High Tech NL).

Ronik Inspectioneering, Delft Dynamics and Pozyx explained the use of drones in confined spaces. SPIE, Avular and Airobot presented about flying outside with drones.

In the field of workplace innovation, ITIS, Sirris, Proceedix and Iristick gave a presentation. VTEC, ID-tec, and Serenity told the visitors about the inspection of barrels. Cleaning by means of a robot was discussed extensively during the presentation by Buchen, Mourik, Group Peeters, VTEC and Serenity.

Smart Tooling promo event II

The Smart Tooling promo event II took place on **27 September 2018**. That day, too, the innovations in the field of inspection and Industrial Cleaning were presented to the public. Prof. Dr. Stefano Stramigioli, Professor of Advanced Robotics at the University of Twente and knowledge partner in the Smart Tooling project, gave an introduction about the future of robotics. In addition to the robotics demos from the Smart Tooling project, robotics applications from the European Roadshow of Sprint Robotics were also shown.

Interactive workshop robotic applications

On **7 November 2018** KicMPi, in collaboration with the University of Twente, organised a Smart Tooling workshop on robotic applications for maintenance in the process industry. Further participation in this workshop took place: BASF, Dow Benelux, Serenity, ExRobotics, Sirris, Terra Inspectioneering, Mourik Services, ENGIE, ID-tec, Avans University of Applied Sciences and BEMAS. The results of the workshop resulted in a preliminary list of new robot applications to be developed.

Open Day Province of Zeeland

During the Open Day of the Province of Zeeland on **23 February 2019**, KicMPi represented the Smart Tooling project together with Terra Inspectioneering and Dow Benelux. It was a busy day. Approximately three thousand visitors from all over Zeeland were able to enjoy an extensive programme. The Smart Tooling project partners presented various robot innovations.

Funding: The Future

On **19 September 2019** Interreg Vlaanderen-Nederland organised the event Funding: The Future. On this day, the future of Interreg Vlaanderen-Nederland was discussed.

Participants could experience how Interreg Vlaanderen-Nederland is bringing the future closer. Of course, the Smart Tooling project was also represented here. Terra Inspectioneering was present with their drone for wall thickness measurement in confined spaces. Nobleo Technology showed their autonome cleaning

crawler en Iristick/Proceedix demonstreer-den hun Smart Glasses.

Workshop workshop workshop innovation

KicMPi, in collaboration with BEMAS and Sirris, organised a Smart Tooling workshop in Ghent on **3 December 2019**, with the theme of workplace innovation. Participants gained insight into the practical application of Cobotica and remote assistance.

Cluster event Smart Tooling

Closure Minor Aerospace Engineering & Maintenance

On **24 January 2020**, a well-attended Smart Tooling cluster event took place in the Drone Lab of the Dutch Drone Centre at Businesspark Aviolanda. The event was a collaboration with the Dutch Drone Centre, REWIN, Avans University of Applied Sciences and KicMPi. This time a combination was chosen with the final presentations of the minor Aerospace Engineering Maintenance (AE&M) of Avans University of Applied Sciences. Avular, Airobot, Terra Inspectioneering, Del\$ Dynamics and SPIE presented innovative flying robot solutions: drones for indoor and outdoor inspections. Flight demonstrations were also given. KicMPi also provided an interactive workshop on the innovative application of drones in the maintenance world.

Smart Tooling End Event

The Smart Tooling End Event is scheduled for **19 November**. The innovations developed within Smart Tooling will be demonstrated with videos this afternoon. As a result of the corona crisis, the event will be organised as a webinar and streamed live, so that many people can become acquainted with the innovations.





< SMART TOOLING YOUTUBE CHANNEL >

On the Smart Tooling YouTube channel you can watch interesting videos about the subprojects and events.

EVENTS

Smart Tooling Promo Event 2017
Smart Tooling Promo Event 2018
Maintenance Easyfairs 2018

DRONES CONFINED SPACES

UT Drone demo	RoNik*
UT Wall drone operations	RoNik
UT Beam drone operations	RoNik
Innovation UT-measuring with drones	RoNik
Wall thickness measurement with drone	

* Now Terra Inspection

CLEANING ROBOT

Indoor positioning	Avans
Cleaning simulation	Avans
Autonomous cleaning system	Nobleo Technology
Software test at Group Peeters	Nobleo Technology
Update Cluster Cleaning	

SMART GLASSES

Applying Smart Glasses in installation technology (Leakage detection and) Augmented	INNO BREAK ENGIE
Reality update/Smart Glasses	(ITIS and) Proceedix

COBOT FLANGE CLEANING

Testing Cobot workshop	ENGIE
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COBOT LEAK DETECTION

Leakage detection (and Augmented Reality) update/Smart Glasses	ITIS (and Proceedix)
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Interreg 
EUROPESE UNIE
Vlaanderen-Nederland
Europees Fonds voor Regionale Ontwikkeling

KiK | MPI
Kennis- en innovatiecentrum
Maintenance Procesindustrie



< COLOFON >

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Status

CHARGED	OFFFLOW PUMP	HEALTH PUMP	BOT HEALTH	COM HEALTH	SHUTTLE HEALTH	MOTION HEALTH	NOISE SENSOR	OBSTACLE	SYSTEM
LOW	OFF	NOOP	NOOP	NOOP	NOOP	NOOP	NOOP	OFF	NOOP

Bot

ID Ferno V1.00

Bot Process

WORK	JOB	MOTION	clear	NOOP	NOOP
NOOP	NOOP	NOOP	clear	2	41 (N)

Network

fracc: 41 (N)

Sequence Progress

start seq	00:01:36	41 (N)	end seq	00:02:18
stop seq	11:25:24	NOOP	start seq	11:29:19

Plane Position

0.430	0.405
-0.148	0.444

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