

From idea to world records: the lessons behind a robotic LEP repair breakthrough

Words: Lisa Emily Petersen

Years of failure, iteration and field testing turned an ambitious idea for robotic leading-edge protection (LEP) repair into a record-breaking commercial system.



The sun is setting across a field in southern Italy. Eighty metres in the air, on a wind turbine blade, sits Sparrow, a supposedly revolutionary repair robot. Above, a heavy-lift drone hovers with a hook dangling from a long rope. Its pilot is desperately trying to catch the robot's lifting mechanism and retrieve it from the blade. On the ground, a crowd of people in high-vis vests look on apprehensively.

The year is 2023, and Clobotics Wind Services has brought an entire seven-person robot team all the way from Denmark to Italy for Sparrow's first commercial job. Colleagues from China have even flown in for the occasion. The future of LEP repair is here. Only, it doesn't appear to be working.

The team has spent an entire week onsite and all they have to show for their efforts is 20 cm of sanded blade. The rest of the time has been spent trying to get the robot onto and back off the blade. Now, the drone batteries are drained, and Sparrow will have to spend the night on the wind turbine.

From idea to specification

Traditional LEP repair is labour-intensive, relying on teams of rope access technicians. As turbines get larger and fleets age, it has increasingly become an industry bottleneck. In 2021, the team at Clobotics set out to build an alternative for wider use: a repair robot that could be flown onto a wind turbine blade and carry out LEP repairs. At the time, no other company had attempted a drone-based solution, but Clobotics' customers and partners were supportive. 'No one doubted that we were going to build it,' Principal Engineer Lennart Kühlmeier recalls. Robots were to be the next exciting technological advance. But it would take five years to get there.

The Sparrow project started, as many engineering projects do, with a list and a crude drawing. Lennart sat down with a sheet of paper and sketched out the degrees of freedom needed for a robot capable of attaching itself, holding onto, moving back and forth and being retrieved from a blade. From there, the team assessed weight, cost, crew requirements and environmental conditions. To qualify as a disruptive technology, and to make the whole thing commercially viable, they set a target of two turbine repairs per day. The specification was ambitious, but it was a concrete goal to work towards.

Build it, break it, build it again

The problem of not being able to retrieve the robot with the drone in Italy wasn't an isolated incident. It illustrates the engineering philosophy that shaped Sparrow's development. 'To finish a product, you need to know where it breaks,' Lennart explains. 'So, to reach your goal quickly, you have to rush out and find where things fail.' For a small engineering team, this approach was partly practical. There wasn't the capacity to sit around calculating and modelling in the way a larger company might. Fortunately, Lennart and his colleague Mads Drachman, Senior Mechanical Engineer, are skilled at building things quickly and working with local suppliers. Their approach was to build things that almost worked, test them, understand why they failed and then build the next version.

After Italy, the Sparrow team got back to work. The failure had taught them that the robot was now capable of clamping onto the blade, but they needed to solve one of the most fundamental parts of the whole concept: how the drone could safely hook onto Sparrow to deliver and retrieve it. Back in the workshop, they designed five different lifting units, 3D printed scaled models of each of them and tested them repeatedly. 'Mads was literally standing in the backyard of the office testing every option using one of our DJI M300 drones,' Lennart says.

Test after test, week after week, they eliminated options until they found a mechanism that worked. The team used the same test-fail-rebuild approach throughout development, always keeping the original goal in sight. In this way, there was no scope creep. The design changed constantly, but the destination they were aiming for did not.

From a working robot to a commercial product

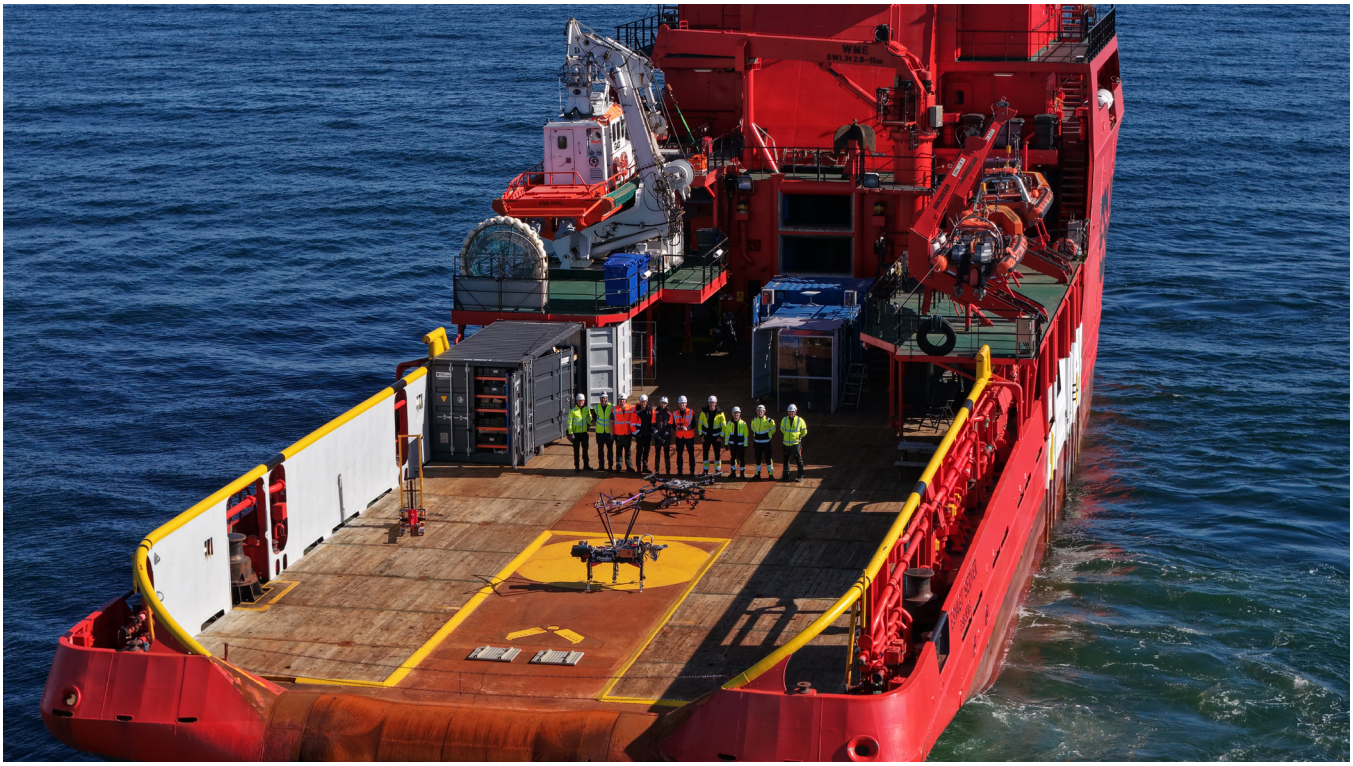
By 2025, the many failures and iterations began to pay off and the team was ready to move offshore. Initially, the team was nervous because the cost of downtime is much higher offshore, and there is less room for a failed operation. Yet offshore operations brought an unexpected advantage. 'You're standing on something that moves, yet the offshore environment is more consistent; you're positioned the same way relative to the turbine every time,' Lennart explains. In this sense, it's easier to establish procedures that hold up.

With the reliability of the deployment and retrieval process improved, and more modern LEP materials, the team quickly reached new milestones on offshore projects. On their best day, they managed to complete LEP repairs on a full rotor, halfway to their original goal of two turbines in a day. But of course, the engineering doesn't stop once a product is proven to work. 'They say a minimum viable product should be something you feel a bit embarrassed about a year later, and that's true for Sparrow,' reflects Lennart.

To push Sparrow to the next stage, in 2026, Clobotics CEO George Yan asked the Sparrow development team to execute the season's first offshore campaign themselves. The decision brought the development team directly into commercial operations, exposing them to the small practical issues that can prevent a technology from being used more widely. 'In hindsight, it was a huge win and a massive boost to the product's maturity,' Lennart reflects. Being there in the field allowed the team to identify and resolve issues as soon as they cropped up. As George correctly pointed out, a successful commercial service can't depend on a handful of engineers knowing how to make a robot work. It needs procedures that can be repeated by a wider team, in real operating conditions.



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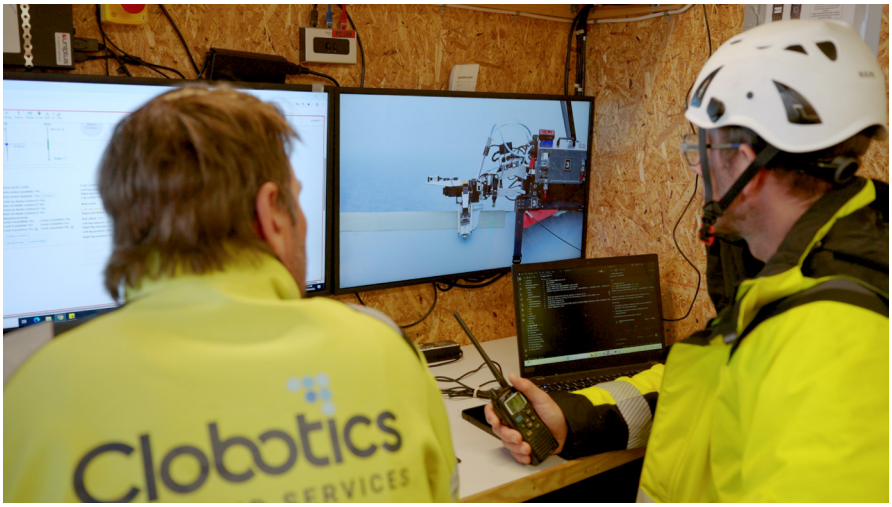


After yet more adaptations, Sparrow can now deliver results without the development team present. And the world records kept building: eight blades in a day and the fastest LEP repair ever at under 30 minutes for a single blade. Kim Lorentzen, Managing Director of Clobotics EMEA, credits Ørsted, the team's commercial partner, with helping make this progression possible. 'Without Ørsted, we wouldn't be here.' Ørsted became a partner at an early stage when the product was still immature. The team was given the opportunity to work on low-risk projects where they were allowed to fail because the consequences of failure were minor, even though the risk of failure was high.

Lennart adds, 'There was an openness acknowledging that perfection didn't matter for the first few projects; the priority was simply that the robot worked, though the quality had to be high for the next phase.' That combination of room to fail, alongside healthy pressure, helped Clobotics push Sparrow from an engineering project towards a commercial service.

The development isn't finished

Today, Sparrow is a mature product capable of an average LEP repair cycle time of 45 minutes per blade. Across 800 flights completed this year, the team has not recorded a single operation where they were unable to land or retrieve the robot. They have come a long way from that field in Italy. More operators are adopting the technology. At the time of writing, Sparrow has just completed campaigns in the UK and Denmark, and is heading to Sweden and Spain next. But commercial deployment has not ended the development process. Back in the workshop, the work continues. The next iteration of Sparrow is already in development, with new capabilities that will soon be tested, probably fail and then be improved.



Today, when the team at Clobotics think back to that first campaign in Italy, they can't help but laugh. The day after Sparrow spent the night on the blade, it was still proving almost impossible to get it back on the ground. After hours of failing, they decided to go for a last-ditch effort and if they didn't successfully hook onto the blade, they would have had to turn the wind turbine's rotor until the robot fell off. The drone flew back up, the engineers held their breath and of course, on that final attempt, they managed to retrieve Sparrow. It's a funny story, but it's also a reminder of what it takes to push the boundaries.

For Lennart, there is something familiar about the journey from a sketch on a sheet of paper to a robot capable of breaking records offshore. He compares it to the early pioneers who launched the first megawatt wind turbines in Denmark: small groups of people creating everything from blades and foundations to towers and control systems. Teams casting blades in tents next to the turbines, working for a year and a half before finally pushing the button and watching the turbine generate its first kilowatt-hours.

'That's why I entered the industry,' he says. 'Because it was full of people who cared and wanted to make a difference.' Sparrow has brought back some of that pioneering spirit: a small team trying something that had not been done before. A lot of things that didn't work, and, eventually, a technology that does.

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