Markforged

Case study

Markforged Parts Prepare for Landing

Comparing the Numbers

	Cost	Time
Markforged Part	$34.79 (material)	19 hours
Machine Shop - Aluminum	$661.08	3-5 days + shipping time

A Shattering Blow

The Snotbot hurtled down toward the Ocean Alliance research boat, its operator hoping that he could get it back in as few pieces as possible. With the boat moving, the wind blowing, and the drone running low on batteries from carrying so much weight, all landings need to be quick. It's pilot would be satisfied with any touchdown that at least saved the electronics housing , but that was not a guarantee. Ocean Alliance, a research organization that has studied whale behavior for nearly 50 years, has partnered with Olin College of Engineering, a unique engineering school in Needham, MA, to develop a novel method for collecting biological information from whales. Their solution, the Snotbot, flies over surfaced whales and collects the liquid expelled from their spout. The robot

Ocean Bound

Design a drone that collects whale tissue for Ocean Alliance

Shipwrecked

Past multicopters broke upon landing presenting the need for quickly prototyped solutions

Land Ahoy

Markforged printed, lightweight landing gear, absorb the impacts of crash landings

Happy Landings

Since using high strength, nimble parts from the Markforged printer, the landing system has never broken

is much less invasive than the traditional tissue collection method, which involves shooting a biopsy arrow at the whale. While using the Snotbot is a much more effective method, landing the drone on a moving boat with rough wind conditions nearly always results in a crash. One of the problems the drone's designers have to solve is that no landing gear thus far has handled impact reliably.

Devynn Diggins, a mechanical engineer in her junior year at Olin, has accepted the challenge and has worked on the Snotbot for over a year. As part of Olin's Intelligent Vehicles Lab, Diggins works under Drew Bennett, a professor of robotics and systems, to discover new ways to improve the drone with each prototype. From making the Snotbot resistant to saltwater, to designing landing gear that can handle rough landings, to protecting the blades from rough waves, the pair have faced their fair share of challenges with this drone. Efficient design of the drone is a critical balancing act: a heavier drone will waste more battery life, but a light drone may be too fragile to succeed.

Toughening Up

"The original landing gear we had were traditional carbon-composite layups, and they all shattered on landing...," Bennett explained. "We needed something that had more give, more flexibility, more compliance. But it also had to be really strong." Traditional carbon fiber layups just weren't strong enough. The landing gear was just too brittle to handle the impact, even when testing on land, so the team needed a different solution, and they needed it fast. The window of good conditions for whale research was shrinking, and Diggins and Bennett didn't have the time to wait for another order of spare parts. "Because we were having these problems during testing, we were even more worried about if we were to go over a whale with our vehicle and something went wrong, then the landing gear could snap, preventing us from retrieving the vehicle and possibly

> "With the Markforged, we're able to change what kind of a fiber we put in the polymer, which let us change the characteristics of the part ... that led us to a part that was unique to the vehicle and to the problem ..."
>
> -Drew Bennett
> Professor of Robotics and Systems
> Intelligent Vehicles Lab
> Olin College of Engineering

harming the whale in the process." Diggins described. "When we heard about Markforged, we realized that there was a way for us to 3D print new copies of our landing gear based on our existing design, that was just as light but even stronger than what we were currently working with." The fiber options on the printer provided room to experiment with different designs and materials with a quick turnaround time, as Bennett recounts: "We didn't know what the right landing gear was, and with the Markforged, we could try different materials, we could try different geometries on the landing gear, we could run out and test them out back...we could make changes to the design, and that allowed us to create the necessary landing gear fast enough to meet Ocean Alliance's needs for their operations." They soon created a lightweight solution with the Markforged printer's nylon and embedded Kevlar. "The Kevlar gave us the strength we needed for the shape, but at the same time it gave us the flexibility we needed to absorb the force of the impact," Bennett described.

The Markforged, while initially only used as a quick landing gear fix, provided many more opportunities to shine as a prototyping and learning tool over the course of the project. "Moving into another phase of designing for our vehicles, we realized that when we're flying our vehicles just above the surface of the water, we run the risk of accidentally submerging the motors and possibly damaging our systems," Diggins explained. "Keeping this in mind, we decided to redesign the arm assemblies of our hexacopters with Markforged parts so they'd be able to safely navigate our vehicles close to the surface." The arms were redesigned to protrude out from the body of the drone at an angle, raising the motors higher above the water. Just like everything else on the Snotbot, the arms need to be light, but strong enough to support the body of the multicopter. The standard carbon fiber arms provide a great balance of the two

> "Knowing that the Markforged landing gear wasn't going to snap under the pressure ... we felt much safer giving it to Ocean Alliance to send out to real animals."
>
> -Devynn Diggins
> Mechanical Engineer Student
> Olin College of Engineering

requirements, but bent carbon fiber tube is expensive to come by. Diggins used the Markforged printer to reduce manufacturing time and part weight while still conserving strength: "The parts we wanted to make...would require machining in order to create the precision and strength that we needed. However, the weight of the machined parts would be far too great for us to be able to accurately fly our vehicles above whales. The 3D printed strength of the Markforged came in handy." Once again, the printer served as a great prototyping tool to produce the parts necessary to succeed.

Taking Flight

The pair of engineers couldn't be happier with their upgrades. "We never had to worry about our vehicle coming back in more than one piece," Diggins described. The Snotbot hasn't had a single landing gear failure since the modification. While the new arm adaptors have not yet been tested on the Snotbot, the success of the landing gear has given the team high hopes for the other components. Bennett, proud of his student's accomplishments, was very satisfied with her work: "without the Markforged, she never could have built the right assembly." With the help of the Markforged printer, the Olin Intelligent Vehicles Lab can prototype faster, stronger, and cheaper not only for just the lab's fleet of drones, but for the entire school. The printer has opened up as another manufacturing resource for students in need of high strength parts, and Bennett is amazed at how the students have used the printer in creative ways. "We're really happy to have the Markforged and we'd like to keep working with it, pretty much forever, at this point. Every time I think we've figured out how to use it, some student will come in with a brand new idea to use the device in a way we never thought." The printer's reputation has spread far and wide in the semester it's been running, and now the Snotbot is just one of a wide collection of projects the Markforged printer has helped succeed.

Check out what the Snotbot has been up to here:
http://www.whale.org/tag/snotbot/

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Markforged's mission is to bring high strength 3D printing to everyday engineering. Offering the world's only 3D printing systems capable of automatically reinforcing engineering plastics to aluminum levels of performance and beyond, Markforged enables every business to easily manufacture parts with structural strength right on the desktop. The Mark Two Industrial Strength 3D Printer empowers professional users to affordably create workhorse 3D parts that solve real problems, as well as realize reinforced structures never before possible. Markforged technologies are delivered with thoughtful, powerful software designed for collaboration, sharing, and scaling.

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