RESILIENCE: ENGINEERING a solution for the plastic PROBLEM

By Kira Coley

As soon as I opened the door to the Delft-based headquarters of The Ocean Cleanup, I could feel the energy in the room. The entire office was congregated around a table shaped like the array they have worked five years to perfect—enthusiastically sharing food and ideas.

"We encourage everyone to have lunch together here," said Lonneke Holierhoek, COO of The Ocean Cleanup.

The sight was similar to the concept itself: plastic debris concentrated in the center of a 600-meter long 'pipe' ready to be collected, shipped to land and recycled. A charmingly simple idea to begin addressing one of the most significant pollution problems facing our planet today.

While the idea behind the array seems straightforward, the problem of plastic pollution is extraordinarily complicated. Debris has continued to accumulate within the five ocean garbage patches around the world, the largest one being the infamous Great Pacific Garbage Patch (GPGP), located between Hawaii and California. A recent report led by The Ocean Cleanup estimates that the GPGP contains 1.8 trillion plastic items - equivalent to 250 pieces for every human on the planet. It is also now three times the size of France (or twice the size of Texas), with no sign of slowing its growth any time soon.

"Multiple sources are contributing to that pollution," explains Holierhoek. "Perhaps a lesser known source is the maritime and fishing industry which contributes substantially towards littering the oceans. We don't

The Ocean Cleanup research team processes ocean plastic samples in the laboratory.

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have the exact numbers yet but what we have found includes a significant fraction of marine rope, fishing gear and parts of aquaculture farms. We have also done research looking at how much plastic is entering the ocean from the coast, which is also a tremendous amount."

A lot of the material that ends up in the water does not make it to these garbage patches, but either sinks to the seabed or washes ashore, littering coastlines across the world. "The percentage of plastic reaching the patches is unknown and is a missing piece of the puzzle," said Holierhoek.

Researchers are trying to determine how much plastic reaches these garbage patches in further studies.

In the small laboratory located at the 'Hawaii' end of the office, a table piled high with various marine ropes, bits of broken buoys and crates displays a tiny portion of the type of debris the survey team finds in the GPGP. An assortment of plastic fibers and smaller items - some unidentifiable by sight alone, and others resembling all too familiar households items - have been sorted into dozens of Petri dishes by the research team.

"Fibers are another problem in the ocean, which isn't really spoken about as often as microplastics. Discarded ropes and nets start to break down, and once those fibers are in the environment, it's almost impossible to filter them out. It's also extremely dangerous to marine life it can twist inside them and puncture the tissue," explains Francesco F. Ferrari, resident Marine Biologist, and Environmental Monitoring Coordinator.

A lot still needs to happen to reduce the amount of land-based plastic reaching the oceans.

THE **GREAT PACIFIC GARBAGE PATCH (GPGP)** IN NUMBERS:

Measuring **1.6 MILLION** KM^2 or 3x the size of France

80,000 tons of plastic float in the GPGP equivalent to 500 jumbo jets

1.8 trillion pieces equivalent to 250 pieces of debris for every human in the world

46% of the total mass is made of discarded fishing gear

Total mass of plastic is **4x** to **16x higher** than previous studies have shown

Microplastic accounts for **8% mass** (in KG) but also **94%** of the counts

Mega Expedition mothership R/V Ocean Starr crew pulling a ghost net from the Pacific Ocean, 2015.

Reducing the amount of plastic that reaches the oceans is a challenging and complicated problem, as no one country is responsible for regulating or maintaining the high seas. For this reason, The Ocean Cleanup has stepped into this gap. "But to stop plastic entering the ocean from different rivers and beaches, is down to individual countries, governments and local communities." says Holierhoek.

"There is a lot of work still needed to improve waste infrastructure in those areas including reduction of plastic use in the first place. There are also technologies that can be applied to both clean it up and prevent it from entering the ocean, which is significantly easier than taking it out afterward. But even if from tomorrow onwards not a single gram of plastic enters the ocean, the plastic which is already in those patches will need cleaning. It is there to stay, harming the environment and all the marine life that mistakes it for food or gets entangled."

The office is usually a lot busier, explains Holierhoek as we make our way to the 'San Francisco' side of the office marked by a sign on the meeting room wall. Most of the communications team, along with founder, Boyan Slat, were attending an event in Alameda at the time, just outside San Francisco, where they are now assembling the array ahead of tests taking place this May.

"We have tested components in the North Sea and in laboratory conditions," says Holierhoike. "We've also done a lot of calculational modeling, and now we really want to test the final concept in the environment where it needs to perform. In a few weeks, we will launch a smaller 120-meter version of the array which in its entirety will be 600 meters. And we will start testing it to see how the system behaves while on tow as well as in the Great Pacific Patch."

The system will need to be towed a long distance to reach the GPGP which is around 1000 nautical miles away and always on the move. The engineering team wants to see how the array will behave during the long journey and while it is active on site, so that they can make any necessary modifications before the larger full-scale system is assembled and tested in a location closer to shore in July-August this year.

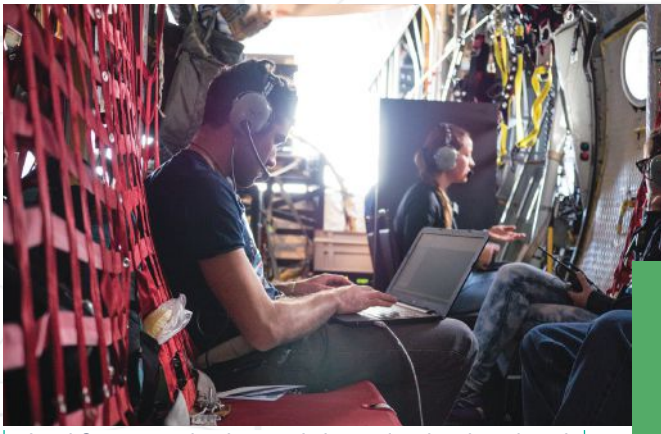
AN EVOLVING CONCEPT

Founded by Boyan Slat in 2013 at the age of 18, the non-profit organization now consists of more than 70 engineers, researchers, scientists and computational modelers working daily to rid the world's oceans of plastic. Along the way, they have faced an incredible amount of engineering challenges. While its concept is simple, translating it into hardware that can survive harsh conditions in the ocean makes the design process remarkably complicated.

"If you walk into a park in fall, there are leaves everywhere. You can come in with the truck and pick them up leaf by leaf, but that is very labor-intensive. It's much less labor-intensive if you use a leaf blower to make piles before removing the leaves. That is the basic idea behind the ocean array - to collect and concentrate the plastic into a pile, so it's a lot easier to take out. And all of the hard work is done by the environment. There are no propelled systems: it is all autonomous and works with nature, moving with the currents. This way, you always follow the plastic because you're behaving like plastic."

The first idea was to use a 100 km-barrier fixed to the seabed and let the currents move the plastic into the system. But the financial investment required for the initial installation and construction, and the engineering challenges for the mooring system alone, made it a less viable concept. The new design is already a significant im-

Ocean Force One's arrival at Moffett Airfield in Mountain View, California, 2016



Lead Oceanographer Laurent Lebreton logging data aboard Ocean Force One during the Aerial Expedition, 2016.

Assembly of the first cleanup system in progress, Alameda (CA), April 2018.

The Ocean Cleanup computer rendering, close up. Credits: Erwin Zwart / The Ocean Cleanup

The new design is also far more efficient regarding collection rates...

The Ocean Cleanup computer rendering, system with support vessel. Credits: Erwin Zwart / The Ocean Cleanup

The Ocean Cleanup computer rendering, support vessel. Credits: Erwin Zwart / The Ocean Cleanup

provement because not only can it be built on a smaller budget, it is easier to test, modify and replicate. Once the clean-up has begun, Holierhoek hopes they can create several more arrays, perhaps even of larger size, and have them operate constantly and autonomously within the GPGP. The new design is also far more efficient regarding collection rates than the old model and has greatly accelerated the schedule - a fact greatly appreciated by the team as they move closer to starting the anticipated clean-up process.

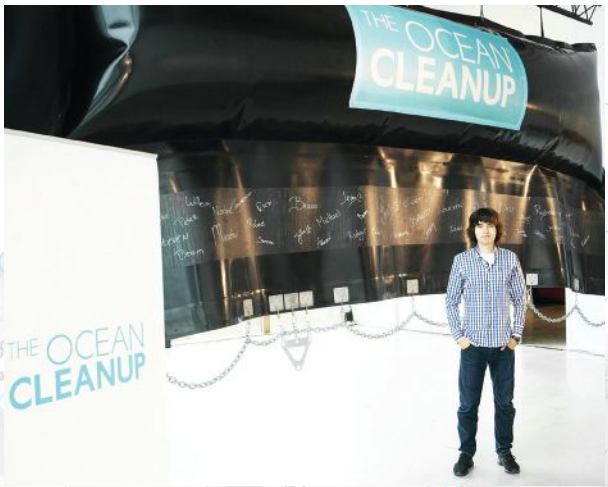
"The materials that we are using, however, have never been used for this sort of application. The material needs to be flexible enough to move on tops of waves, but it also stiff enough to maintain a certain shape. For the main part of the array, we are using what you could describe as plastic pipes. And while pipes have been towed over the ocean before, it was always with the intention to sink it to the seabed and pump stuff through it. But we are not doing that. There has been and will be, a lot of 'unscheduled learning' experiences regarding the design and the materials we use. We are delighted that a lot of the suppliers are really excited about what we're doing, and everybody is willing to help us to come up with solutions to problems as they arise."

The Ocean Cleanup is also working closely with the International Maritime Organization (IMO) under the guardianship of the Dutch government. The system will be equipped with radar detection, an AIS system, and lights so any ships within the vicinity will know where the array is operating. There will also be a Maritime Notification sent to different shipping organizations and Notices to Mariners which will broadcast the array's location.

"But in perspective, for this area three times bigger than France we have found that on average, looking over 15 months' worth of data, only three ships pass through in that region each month. There is not a lot of shipping activity there."

FACING THE CRITICS

Not long after The Ocean Cleanup revealed the first concept, some members of the scientific community came forth with criticisms of the system's design, concerns of the impacts it may have on the environment, and skeptical of the overall success. While the new design of the array has since improved, criticism facing the project still remains.



Boyan Slat in front of demo model of prototype barrier during prototype release event in Scheveningen harbor, The Netherlands on June 22, 2016.

The Ocean Cleanup Announces Pacific Cleanup to Start in 2018

In their design process, the team is currently working to minimize any impact on the environment and prevent entanglement risk.

“The plastic out there, however, is causing a great entanglement risk in itself,” said Holierhoek. “By taking it away at frequent intervals, there will be an improvement. We are also taking great care to monitor any changes in bird and fish activity during trials, that may be owing to the presence of our system or the higher concentration of plastic. And we will be working with several universities to assess the effect of both our system and accumulated plastics, tackling any effects responsibly. Once we begin to scale up, we can take all of those lessons learned from trials, minimize our systems impact and really maximize the positive outcomes.”

The Ocean Cleanup is having an Environmental Impact Assessment completed by an external firm based on the new design, and an environmental management plan will be in place to monitor and mitigate any ecological risks.

The other form of criticism is that the resources and efforts The Ocean Cleanup are applying to the patches, can instead be used for developing source reduction solutions.

“That is another debate: what should we be doing first?” Holierhoek continues, “Nobody feels responsible for the high seas. But there are a lot of organizations already working on source reduction solutions with governments and local communities, trying out different ideas and improving waste infrastructure. In our opinion, it shouldn't be 'either-or,' it should be 'and-and.' As a global community, we have to do both. We can't do it by ourselves. There will need to be policy changes as well as waste management improvements and cleanup operations happening in parallel.

“And we are a technology company looking at solutions from a technology perspective. We try to invent stuff that solves the problem. We are not policymakers. That really is not our expertise or the sort of contribution we can make. What we can do is help to generate a lot of attention to the problem.

“This summer is going to be very exciting for everyone, because not only are we learning more about the system's capabilities in the field, but we are actually starting to clean up the ocean. To almost be at this point is both stressful and exhilarating. It's not often that you can live through a phase in any sort of organization that has an idea and actually sees it come alive, so it's pretty unique. Boyan really brought this issue to life in an inspiring way: pollution is a problem and man created it. But rather than blaming, we work together to create technology that solves these real-life human-made environmental problems. Not many people were saving the world at that age. And it is thanks to Boyan, and the amazing team and collaborators supporting us, that we have got to where we are today.”

The coming months will signal a major milestone for The Ocean Cleanup. And there are many who are now watching the upcoming activities in anticipation to discover if humans have successfully engineered one viable solution to removing the growing plastic mass residing in the high seas. After five years of a hectic ‘trial and error’ development process, the resilient team is now working to complete tests, begin scaling up the system and addressing any further engineering or environmental challenges as they arise, before the array can finally debut on the GPGP ocean-stage this summer.