RICOCHET

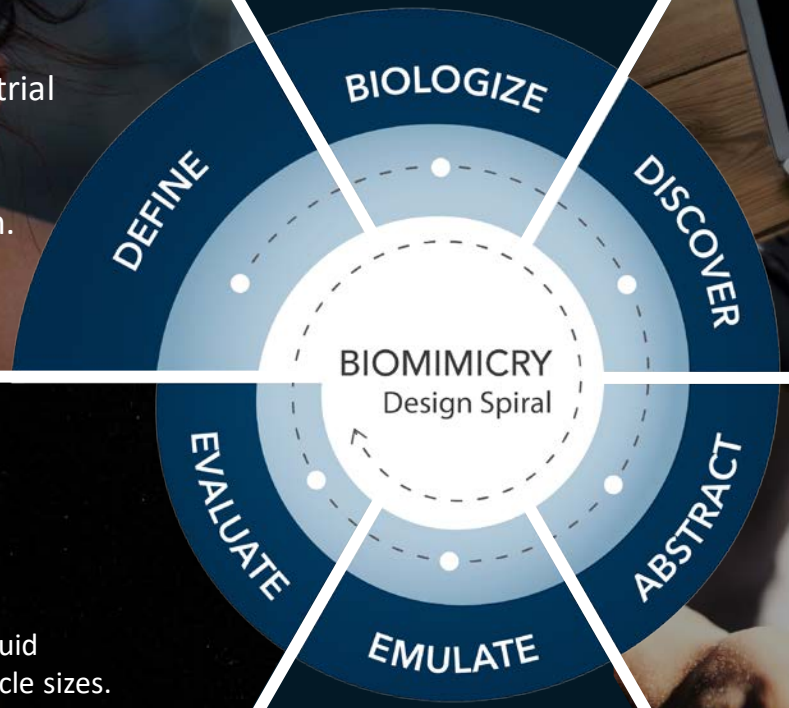
A SUSTAINABLE $PM_{2.5}$ FILTER

How might we reduce $PM_{2.5}$ in the air to avoid the harmful impacts of $PM_{2.5}$ on human health?

- Aim: block the $PM_{2.5}$ releasing process.
- Diseases: stroke, lung cancer, and ischemic heart disease.
- Sources: traffic, domestic fuel burning, and industrial activities.
- Existing Solutions: electrostatic dust collection, cyclone dust collection, and fabric filter collection.
- Remaining Defects: clogging, low efficiency, and consuming high energy.

How does nature filter small particles?

Could nature filter particles in a sustainable, effective, and efficient way?

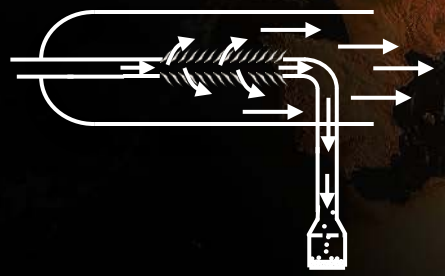


What are the biological strategies for filtering particles in nature?

Filtering-Feeding Mechanisms: sieve, hydrosol, and crossflow.

- Sieve: baleen whales, flamingoes, feather duster worms, and fiddler crabs.
- Hydrosol: salps and feather stars.
- Crossflow:
  1. Cross-Step Filtration: paddlefishes and basking sharks.
  2. Ricochet Separation: manta rays.

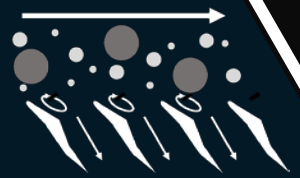
Approaching a viable solution



- Mimicking difficulties: fluid characteristics and particle sizes.
- Experiments: filtering efficiency of various particles in the air.
- Prototype: $PM_{2.5}$ processor in the diesel vehicles, named RICOCHET.

Bio-inspired design solution

Ricochet separation of the manta ray can best inform our design solution.

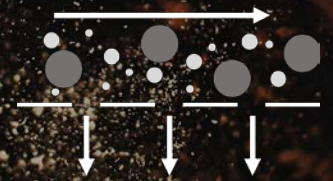


Bio-inspired design strategies for filtering

- Sieve

- Hydrosol

- Crossflow

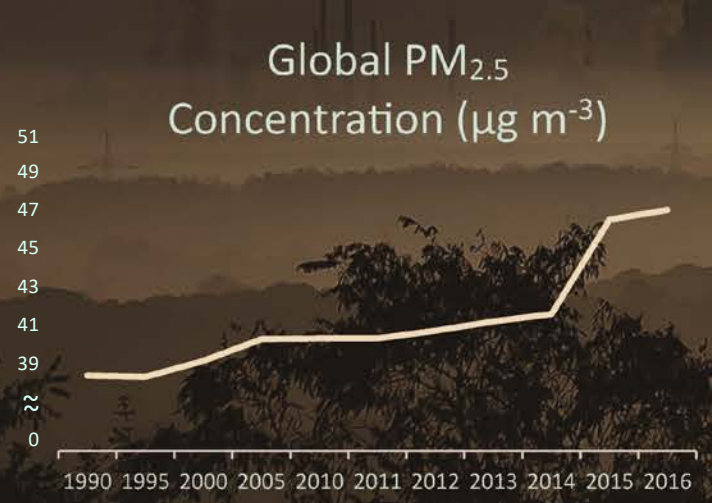


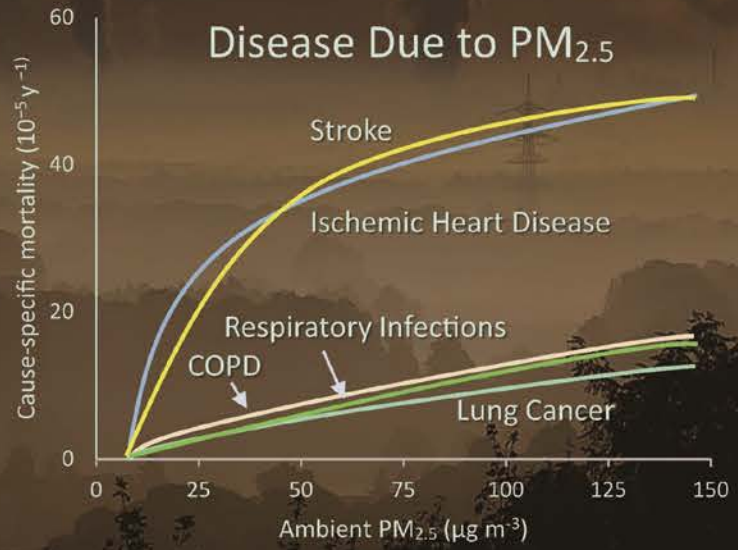
Motivation

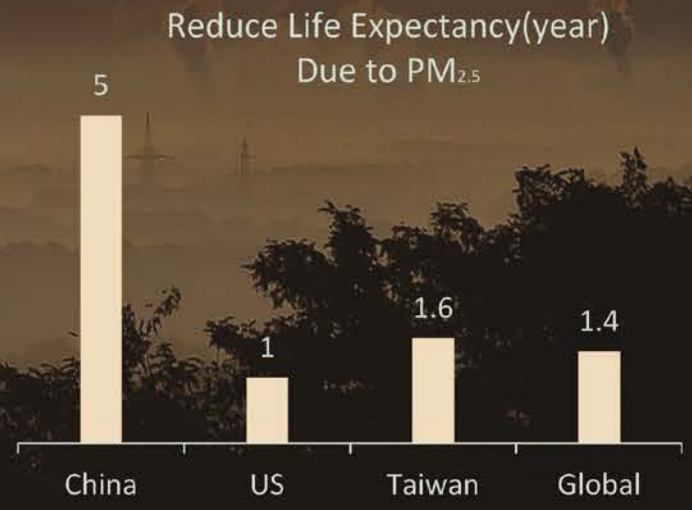
Why do we choose this topic ?

In recent years, air pollution is gradually regarded as a thorny problem. It leads to not only low visibility but also health problems.

In 2016, 4.1 million deaths were attributed to ambient air pollution from fine particulate matter ($PM_{2.5}$), which accounted for about 7% of deaths worldwide. Mortality rates in diseases such as ischemic heart disease (IHD), cerebrovascular disease (stroke), chronic obstructive pulmonary disease (COPD), and lung cancer(LC) increase as $PM_{2.5}$ increases. As estimated, exposure to $PM_{2.5}$ reduces average life expectancy 1.4 years globally, 0.5 to 1 years in the U.S., 1.6 years for a city at 25 μg m^{-3} which similar in mid-south part of Taiwan, and 3 to 5 years in polluted regions of China.



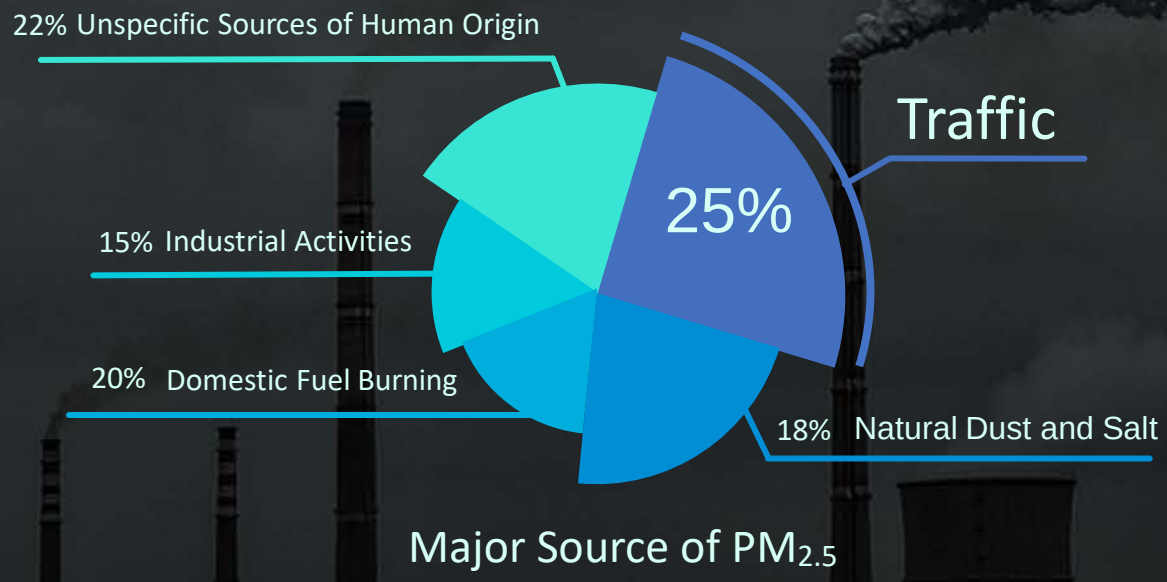




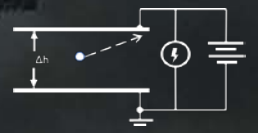
Problem Definition

Block $PM_{2.5}$ releasing process, as well as create a sustainable and highly efficient filter

Options for improving air quality include stopping the generation origin, blocking the releasing process, eliminating $PM_{2.5}$ in the air, and preventing $PM_{2.5}$ from getting into our body. The aim is to block the $PM_{2.5}$ releasing process and reduce $PM_{2.5}$ emissions. The major source of $PM_{2.5}$ is traffic. Modern filtration systems have many defects such as clogging, low efficiency, high energy consumption, and frequent maintenance requirement. Thus, we long for seeking better solutions from nature.



Major Source of $PM_{2.5}$

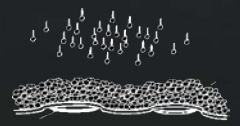


Electrostatic Dust Collection

Mostly equipped in factories.

Cyclone Dust Collection

Installed in front of other equipment in factories to collect bigger particles first.



Fabric Filter Collection

Commonly used by domestic application

Federico Karagulian et al., *Atmospheric Environment* (2015)
Man-Ting Zheng, Research on Estimation and Reduction Technology of Fine Suspended Particulate Emissions from Diesel Vehicles (2009)

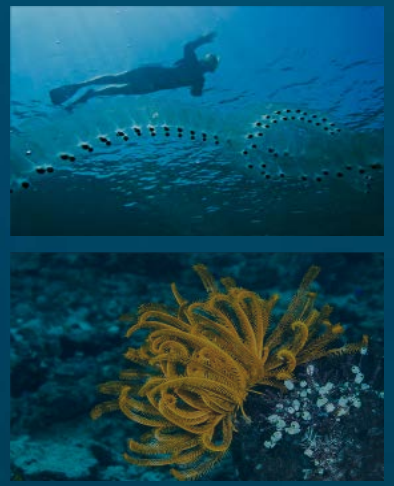
Biological Strategies

Food-filtering mechanisms in nature

There are four categories of filtering strategies, organisms gather their food by sieve, hydrosol, and crossflow. Except for crossflow, most mechanisms are easily clogged. In crossflow, cross-step and ricochet are extraordinary mechanisms that can filter particles smaller than the pore sizes and nearly resist clogging. Ricochet separation in manta rays provides great filtering efficiency and a simple structure for emulation. Therefore, we choose the manta ray as our model.

Sieve

Baleen Whales: baleen
Flamingoes: lamella
Feather Duster Worms: radioles
Fiddler Crabs: setae



Hydrosol

Salps: mucus net
Feather Stars: feeding arms

Cross-Step

Paddlefishes: gill rakers
Basking Sharks: gill rakers

Ricochet

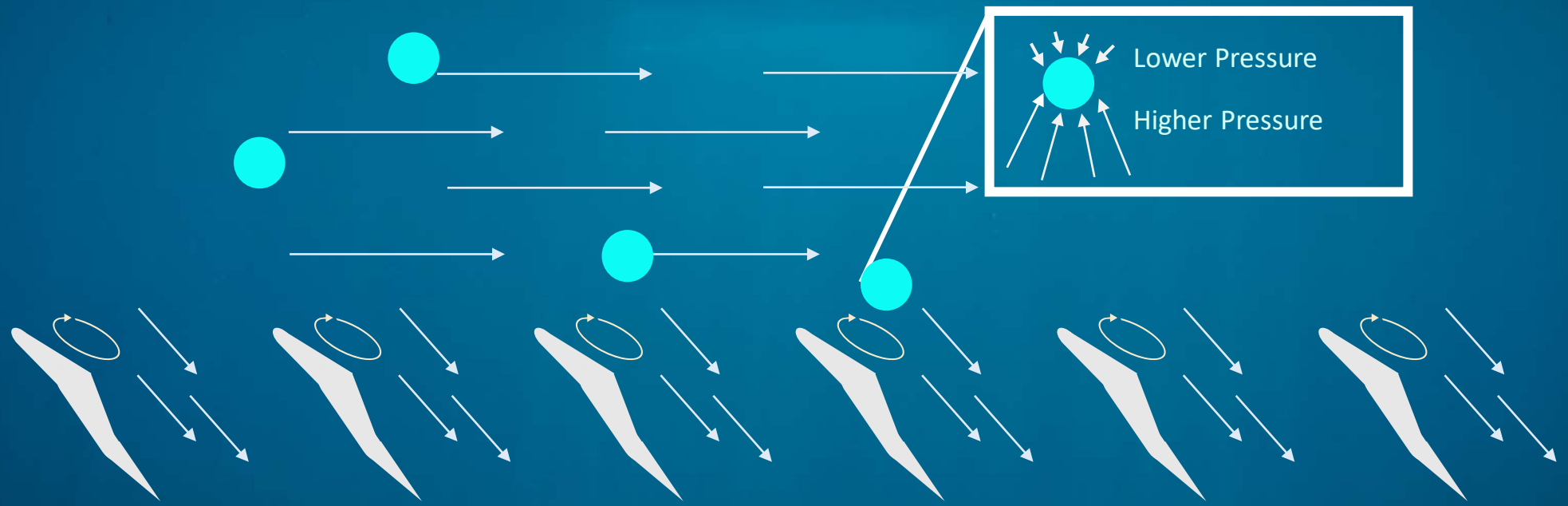
Manta Ray: gill rakers

Manta Ray

A filter-feeding fish equipped with highly specialized filter lobes. When manta ray swims, its mouth is filled with seawater. As seawater passes through the pharyngeal, plankton is concentrated in front of the esophagus while water leaks out through the gills. Manta rays close their mouth and swallow gathered plankton every few minutes. Different from other filter-feeding fish, manta ray can filter particles smaller than the pore size, allow high flow rates, and resist clogging. Its structure causes particles to ricochet away from the filter pores physically, which is called ricochet separation.

Raj V. Divi, James A. Strother, E. W. Misty Paig-Tran, SCIENCE ADVANCES (2018)

Ricochet Separation



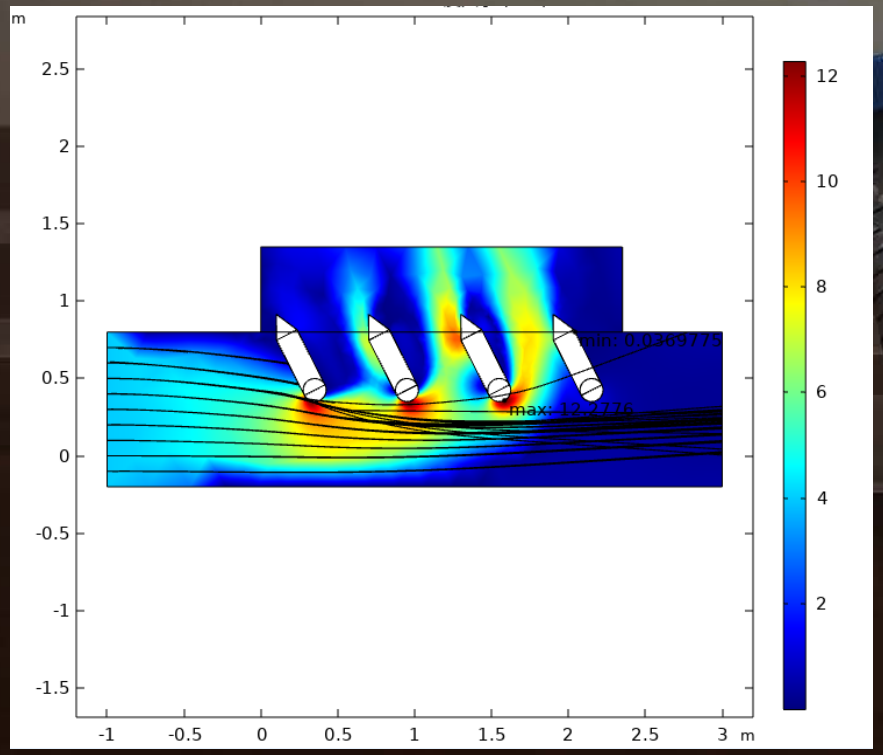
With the highly specialized structure in its mouth, plankton will be concentrated while seawater leaks away, which is called ricochet separation.

To achieve blocking $PM_{2.5}$ from the pollution source, we would prove in stages that the manta-mimicking structure can work in the air as well and it could perform efficiently in smaller particles.

Raj V. Divi, James A. Strother, E. W. Misty Paig-Tran, SCIENCE ADVANCES (2018)

Simulation

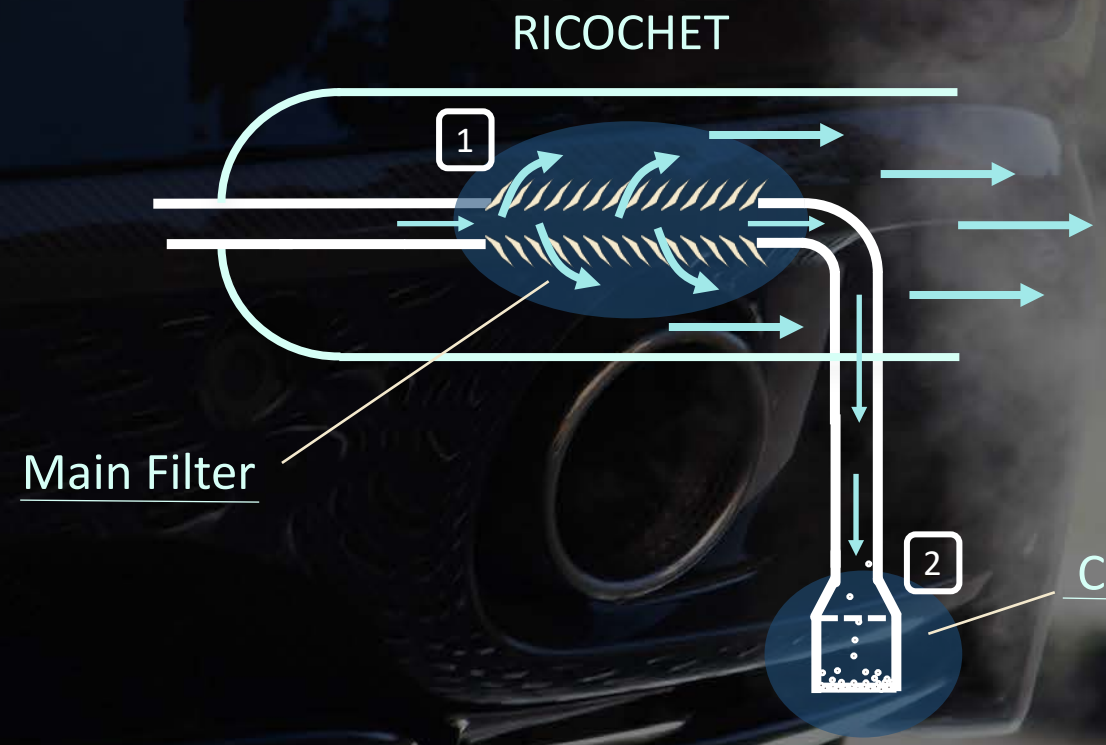
Examine the filtering feasibility of the structure in the air



We use COMSOL Multiphysics, a CFD (Computational Fluid Dynamics) simulation software, to analysis that whether the manta-mimicking structure can work well in air.

Beside is our result. The result shows that the manta-mimicking structure can work in air as well. Though it makes an important step of our design, there's still things we could look more detail into.

Prototype


RICOCHET
1
Main Filter
2
Collector


Engine
De-NOx catalyst
Oxidation catalyst
DPF
RICOCHET

Value

Sustainable development

- Our value proposition:

  Our sustainable filter system can resist clogging, reduce damage to the environment, and consume lower energy. Our prototype conforms to "Be resource-efficient (material and energy)" in the life principle.

- The unique value we can offer to our potential customer:

  Reducing automobile manufacturers the additional cost from environmental regulations like fines, taxes, or extra cost.

  Compared to the current particulate matter filter, our filter maintains a certain efficiency, has a longer lifespan, and reduces maintenance costs. During the transition period between our environmental protection regulations being gradually strict and the automotive market is still the dominant market. We provide a new option for automotive manufacturers to reduce the cost due to obeying environmental regulations.

- Our device potential:

  We have designed this anti-blocking, efficient, low-maintenance-cost, and sustainable filter system. In the future, we will further optimize our design so that it can be used in a multitude of different applications such as chimney, truck, and can even actively filter $PM_{2.5}$ from the air.

Entrepreneurial Journey

2020.02
- Problem Definition
- Searching Biomimicry Strategies

2020.04
- Design prototype
- Register BGDC

2020.09
- Biomimicry Launchpad
- Stakeholder interviews
- Proof our prototype

2020.12
- The Ray of Hope Prize
- Optimize our prototype
- Customer Validation
- Apply for patent

2021.05 & Vision
- Cooperate with manufacture
- Attract investors
- Marketing & Build branding
- Product development

Biomimicry Design

Prototyping and Testing

Product Design

Manufacturing

Business and Customer Validation

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RICOCHET

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