Mobility & Vehicle Design

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IDC

Nature and Forms

Emergency Evacuation Flight Suit

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Approval

This report entitled Nature and Forms: Emergency Evacuation Flight Suit by Harsh Vardhan Tripathi is approved for the degree of M.Des

Guide

Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been inclded, I have adequately cited and referenced the original sources.

I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Date : _____

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Contents

Abstract

Nature has various interesting forms that have developed through thousandsw of years of evolution. They are not just interesting to look at, but also have some core functionality baked into them. This project aims to study these forms, choose one of them and develop the form into something that not only celebrates the form being studied, but also uses its functional properties.

In this case, the form being considered is that of the winged seed of the maple tree. The structure of the seed, its reason of occurrence and properties were studied, and attempt was made to capture them into the design of a winged suit for emergency evacuation of skyscrapers.

Skyscrapers currently don't have efficient or fast modes of evacuation in case of emergency. This wing suit aims to solve that problem, through an affordable and easy to use solution, by leveraging the properties of the winged maple seed.

Introduction

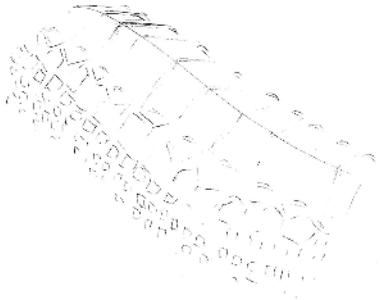
Natural forms are both fascinating and very efficient in general, having been honed and iterated upon by generations of evolution and natural selection. Their unique shapes are almost always linked with some physical property or functional reason. Or, they arise as a by-product of some life-sustaining process. From honeycombs to spiral nautiluses, they all have a reason to the form.

This project's scope was to survey some interesting natural forms, and select one of them for further study and eventual development into a product which not only celebrates the original form, but also utilises the functional aspect of the form. In this scenario, the maple tree's winged nut was studied to capture the essence of its whirly form, as well as understand the reason for its winged structure, and the properties of its winged structure and implement the same into a product.

Modern buildings have become exceedingly tall, housing more and more people further and further away from the ground. This makes evacuation in case of emergencies a nightmare. In absence of efficient means of evacuation, it was thought to implement the properties of the winged seed of the maple tree into a winged suit that helps people escape these mega-structures in a fast and simple manner.

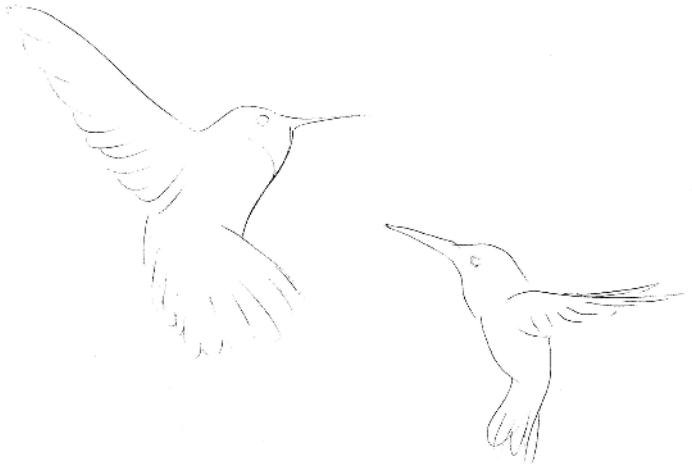
Part One

Natural Forms



Gharial (Gavialis gangeticus)

- Native to Indian subcontinent
- Fish-eater
- Thin & long jaw
- Males have growth on snout to resembles "ghara" or Earthen pot; hence, the name
- Jaw becomes shorter & wider with age



Bee Hummingbird

(family Trochilidae)

- smallest birds
- can fly backwards / hover
- flap wings 12 - 80 times / sec
- Can hibernate ~~to~~ conserve energy

Jellyfish

(Phylum : Cnidaria)

- Pulsating gelatinous umbrella / bell
- Long tentacles / stingers
- Transparent
- Flowing tentacles

Conifer Cone (Strobilus)

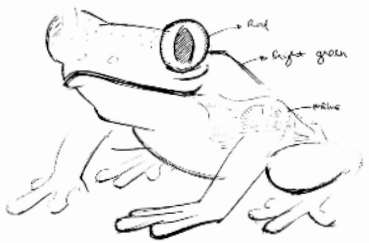
→ Female : woody
→ male : herbaceous & inconspicuous
→ scales contain spores
→ Fibbonacci series spiral

Monument Valley Rock formations
(Colorado Plateau)

→ Sandstone buttes
→ Formed due to differential erosion of layers of rock by wind / water

Red Eyed Tree Frog
(Agalychnis callidryas)

→ Non-poisonous
→ Camouflage (green)



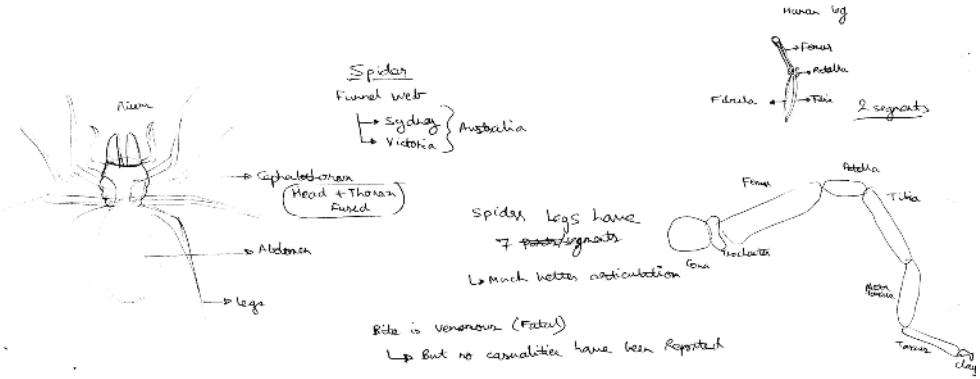
Bat
Order Chiroptera

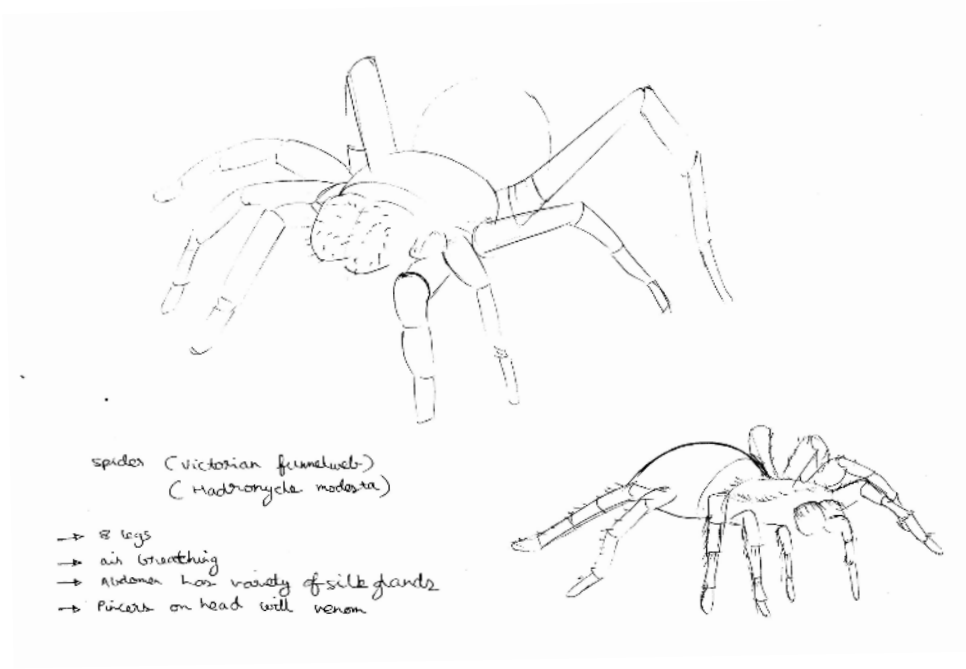
→ only mammal to actually fly
→ does not flap complete wing; only fingers
→ Fingers have "patagium" membrane

Maple winged seed

(Acer pseudoplatanus)

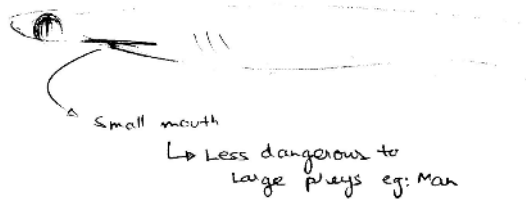
→ wind dispersal
→ Reticulate veins

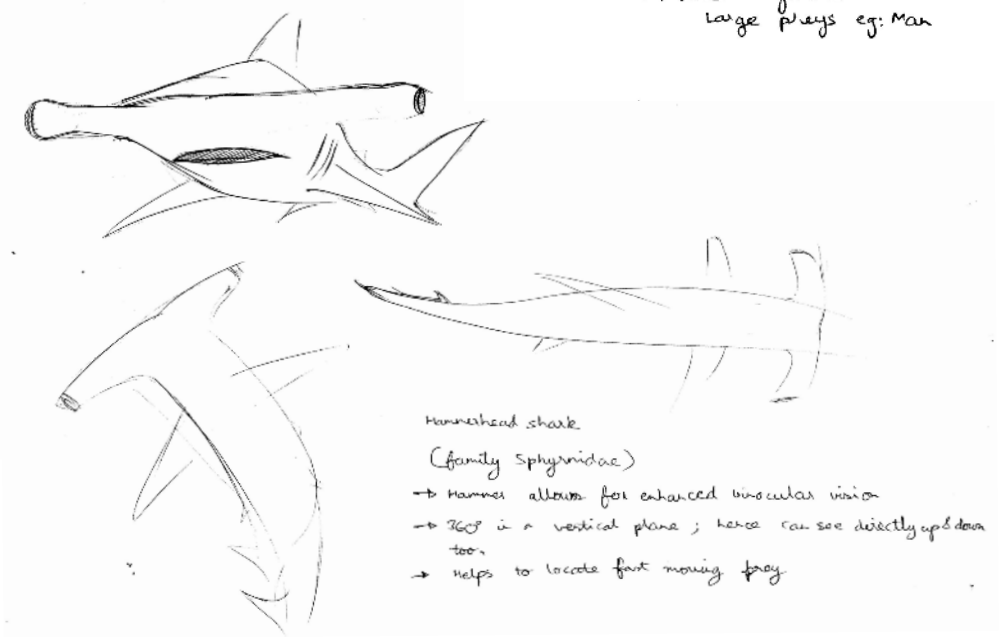




spider (Victorian funnelweb)
(Hadronyche modesta)

→ 8 legs
→ air breathing
→ Abdomen has variety of silk glands
→ Pincers on head with venom





Hammerhead shark

(family Sphyrnidae)

→ Hammer allows for enhanced binocular vision
→ 360 in a vertical plane ; hence can see directly up & down too.
→ Helps to locate fast moving prey

Funnel Web Spider

Hadronyche / Atrax species

Have a shiny black cephalothorax (a cephalothorax is a fused head and thorax)

Abdomen dark brown to black in colour

The male is similar to the female, but with shiny cephalothorax and legs [7]

Habits & Habitat

- Found along the Eastern coast of Australia
- Females remain in or around their spider silk-lined burrow
- Males are very aggressive & wander into human habitat. During late summer and autumn, males wander around in search of females and may enter buildings and homes.
- These are known to grip the prey tightly & bite repeatedly
- Venom is potentially fatal to humans, but fatal envenomation has not been observed yet
- Venom, however, has medicinal significance for killing breast cancer cells, since it targets very specific cells.[7][8]

Altrax Robustus in a warning posture

Webs

They build unique Funnel-shaped webs leading to lairs in underground holes. hence, the name.

Their lairs or burrows n the ground are-lined with spider silk

Unlike trapdoor spiders, these burrows do not have lids to trap prey. Instead, they have silk trip-lines radiating from the entrance. These spiders use these 'trip-wires' to catch their prey.

At night, the spiders would sit at the entrance of their lairs, with their hairy feet touching these silk trip lines. As soon as an insect passing by would stumble on one of these wires, it would vibrate, alerting the spider. The spider then immediately would pounce on the unsuspecting prey, and drag them down the silk funnel into the lair. [7]

Hammerhead Sharks

The “Hammer” is called “Cephalofoil”. It is a lateral protusion on the head of these sharks. This is soft in babies, to facilitate easy birth, since sharks are Viviparous.

Common types of Hammerhead sharks include[10]:

- Great hammerhead,
- Scalloped hammerhead,
- Smooth hammerhead
- Bonnethead

Great Hammerheads have been observed to be 18 feet/5 m long and weigh as much as 360 kg

The hammerhead’s disproportionately narrow mouth mean that they have to hunt at the bottom of the ocean.

Hence they have flat teeth at the back for grinding the shellfish that forms a major part of their diet.

Scalloped Hammerhead live in schools, which is unusual for sharks, which are mostly solitary hunters.

The schools have an astounding Male:Female ratio of 1:6

Cephalofoil Stucture

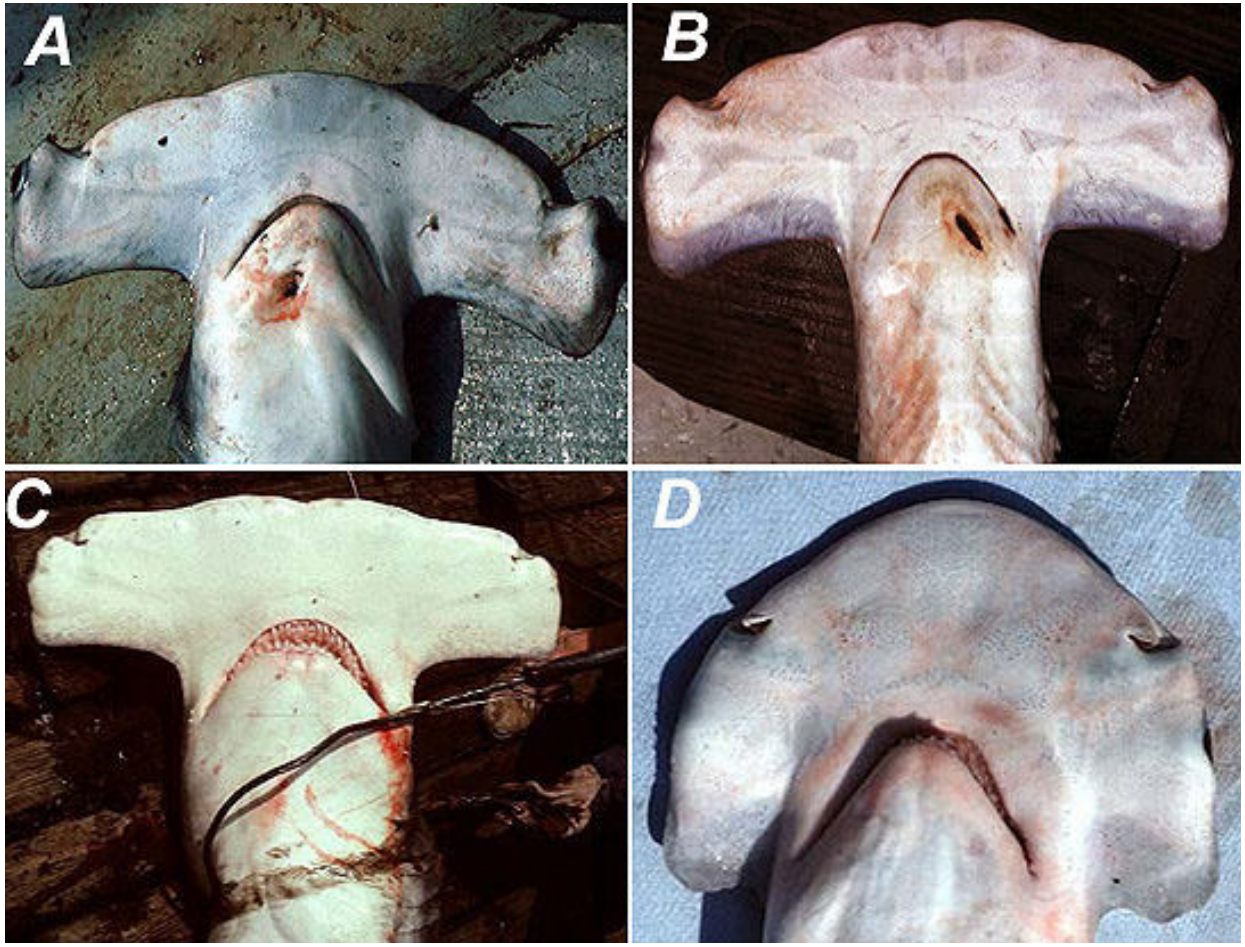
Classification based on shape of Cephalofoil[10]:

A. Smooth

B. Scalloped

C. Great

D. Bonnethead

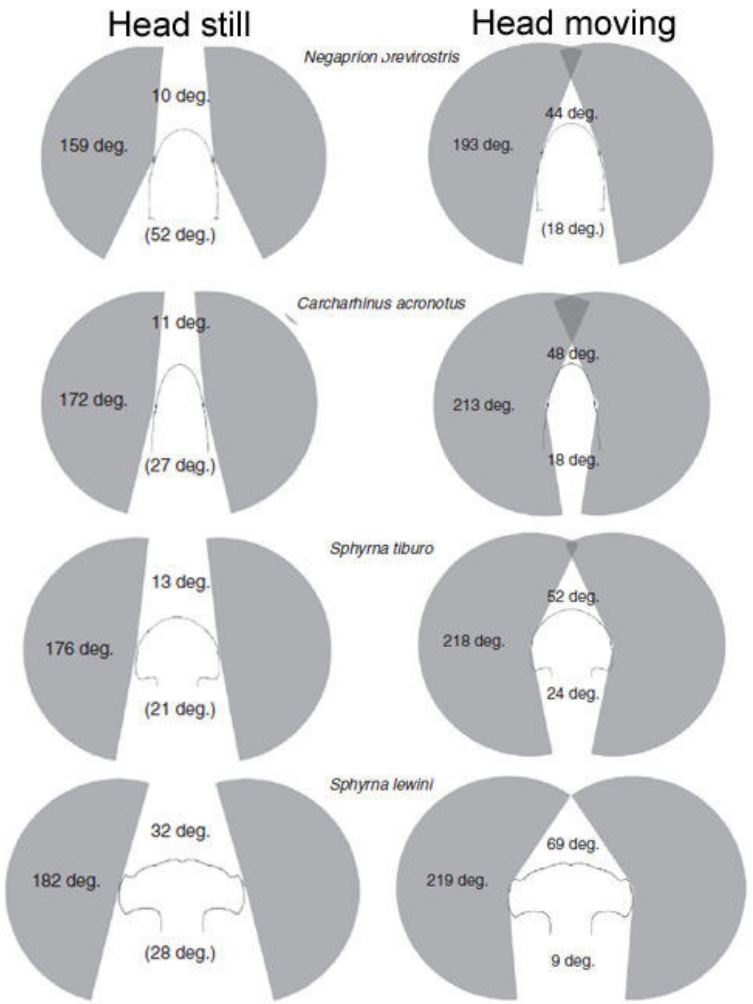


Enhanced Binocular Vision

It was previously thought that their hammers evolved to aid in swimming, hunting or sensory perception. however, recent findings have shown that the Cephalofoil gives hammerhead sharks a better field of vision.

“Binocular overlaps of the scalloped hammerhead and bonnethead increase to 69 and 52 degrees respectively, still outclassing the 44 and 48 degree arcs of the pointy-headed species”

The hammerhead species even have visual fields that overlap behind them, giving them a full 360 degree view of the world[12]



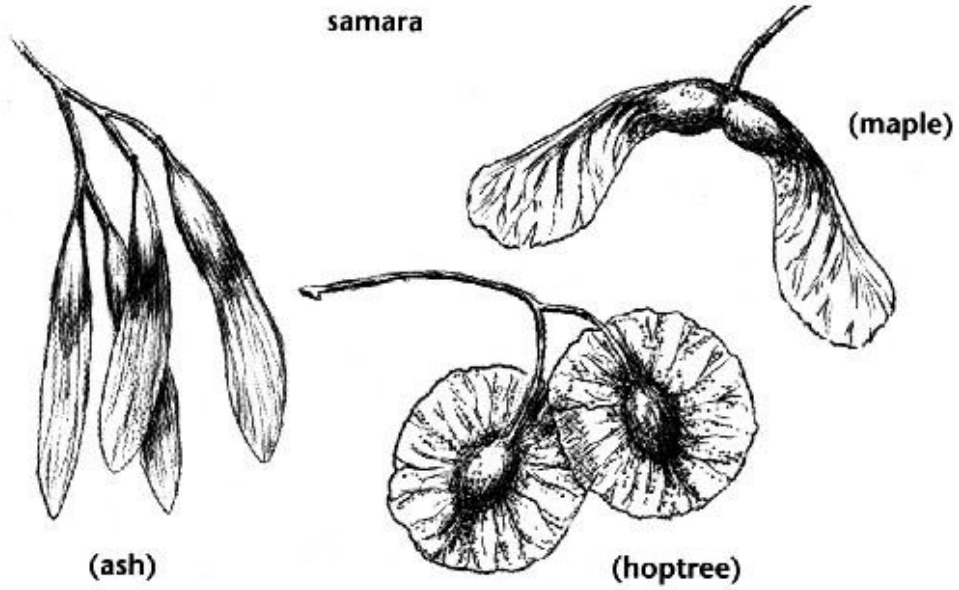
Maple Seed

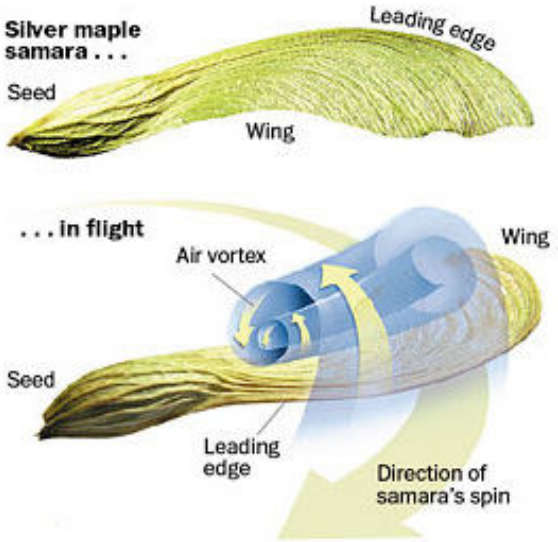
Winged dry fruit of the Maple tree is called a “Samara”

It is not a seed, but actually a complete dried fruit (called Achene) with its peri-carp modified into a wing

Other trees like Ash and Hoptree also possess Winged Achenes, although their shapes are different.

Combretum zeyheri





Structure and shape of the Samara wing in detail

Part Two

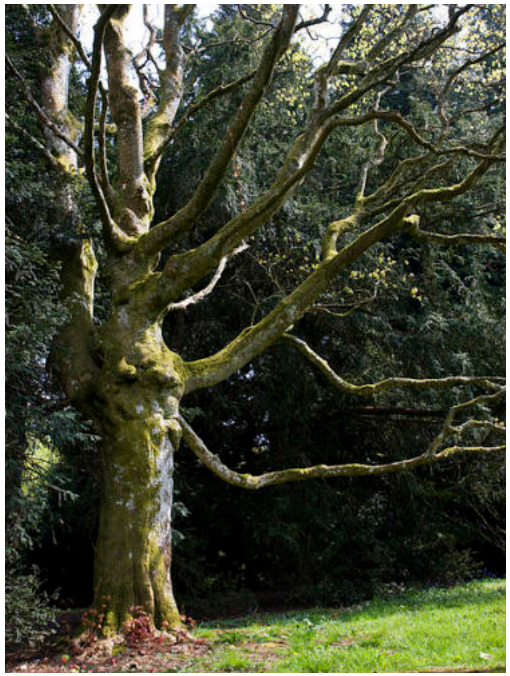
The Maple Tree

Maple Leaf

The Maple Tree has Palmate Leaves, which are so called because they resemble the palm of a human hand. Their distinct shape makes them easily identifiable.

The leaves are made up of distinct sections, or Lobes. In between these lobes, there are gaps called Sinuses.

Maple trees have Deciduous foliage. The leaves turn bright red/orange in autumn and are shed off.[11]



Maple Flowers

Maple Roots

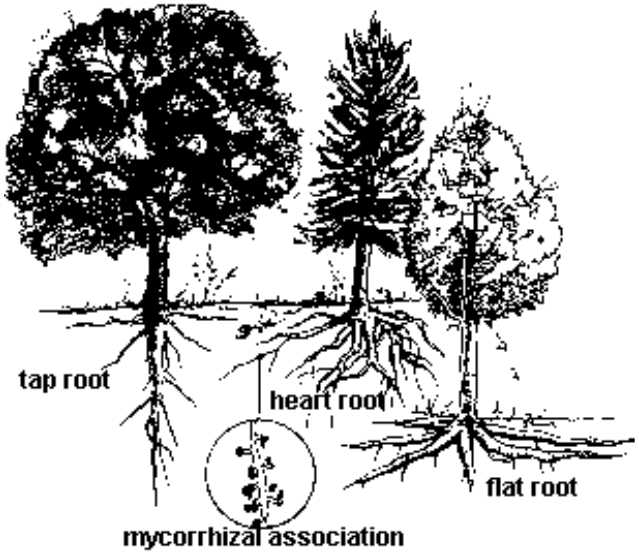
Normally, tree roots can be classified into:

- Tap Roots
- Heart Roots
- Flat Roots

Maple roots are of the flat type.

The roots can spread 1.5-3 times the size of the foliage canopy, and stay close to the surface (within the top 6-12 in of the soil) [13]

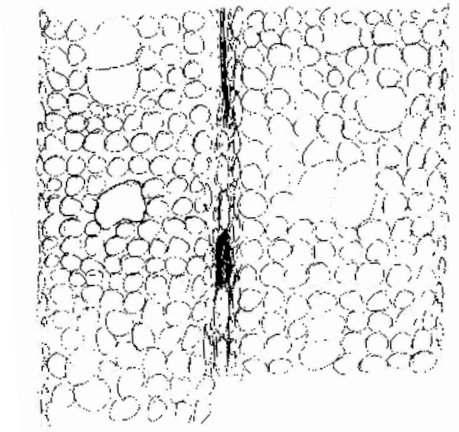
The roots of a tree extend far from the trunk and are found mostly in the upper 6 to 12 inches of soil.

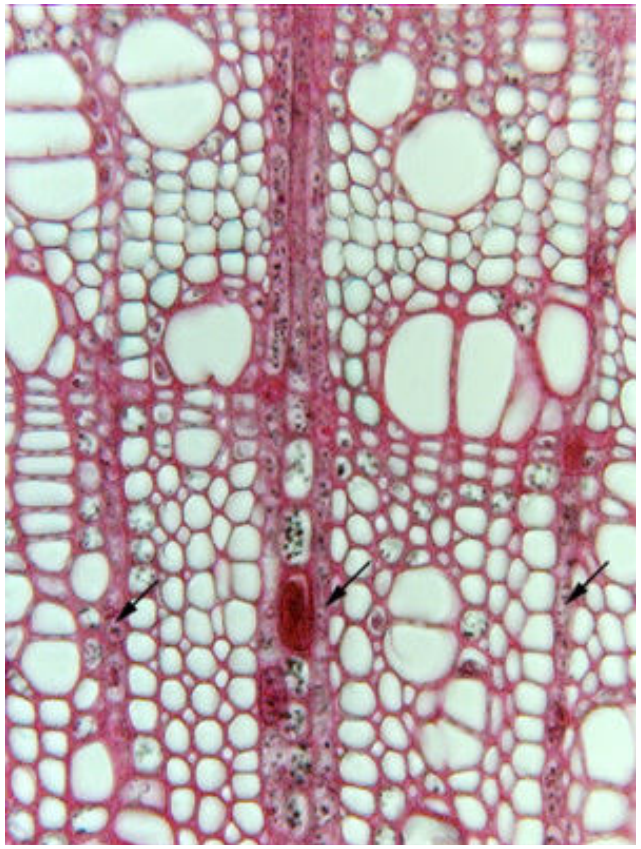


Maple Wood

The outer part of the trunk is rich in sap containing cells.

Sap is high in sweetness, and is tapped to make syrup famous for use in North American cuisine.





Maple wood is prized for making acoustic music instruments, for its sonorous sound and beautiful patterns. Type of Pattern depends purely on chance and part of the tree from where the wood was extracted.

Modern high-end instruments made of composites and other lightweight materials still incorporate a thin layer (laminated) of maple wood to ensure great sound quality.

Birds Eye Type

Flame Type

Quilted Type

Burl Type

Maple Fruit (Samara)

Fruit is dry (achene)

Pericarp (fleshy part of common fruits) is dried and modified into a wing

Types of Maple Trees

Red Maple

Leaves are a bright Red colour, and have 3-5 Lobes, with V-shaped Sinuses. Between the lobes, hair like strucures are present. The e`dges of the leaves are covered with several teeth.[11]

Sugar Maple

This tree is mostly used to extract Maple syrup.

Its leaves are smooth and have 5 lobes, with 3 teeth present on the edged of each lobe. The Sinuses are U-Shaped.

The bark of the tree is Grey-Brown on colour

Norway Maple

It is European in origin, and grows mostly in Northern Europe.

Its leaves have 5 lobes, and the fruit (Samaras) are red in colour.

Silver Maple

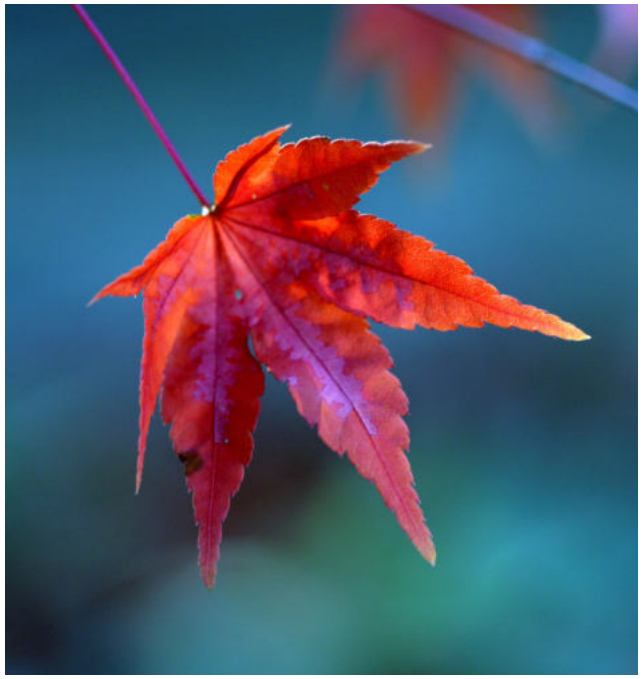
The leaves have 5 lobes, with deep sinuses. The leaves are lighter in colour, with downy silver undersides.

The bark of the tree is Grey and rough

Japanese Red Maple

The leaves of this tree are smooth and petal-like. they have several lobes, which are distinct from each other.

The fruit (smaras) are bright red and smaller in size.



Why do Maples produce Samaras?

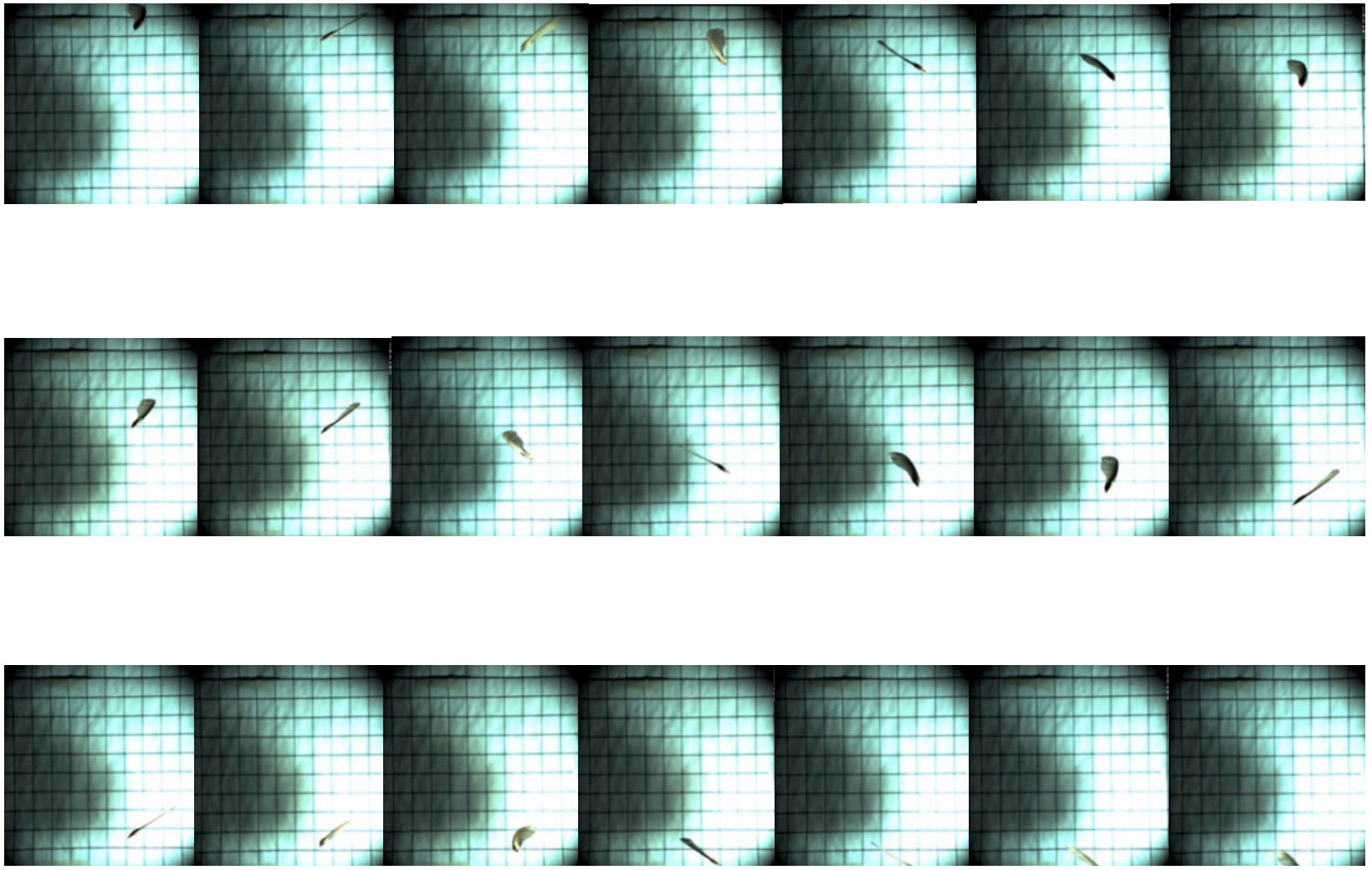
Flat Root structure of the Maple trees means seeds falling close by will mean increased competition to the parent for survival

Maple is a pioneer species (weedy) and and hence, the trees produce large quantities of seeds, which must be spread as far as possible to ensure maximum viability

Common methods of transfer of seeds prove to be unsuitable in case of Maple as:

- Gravity: Wont work because larger distance is needed
- Water: Maple is a temperate deciduous plant. Water bodies not readily available
- Animals: Fruit is not fleshy, so it's not as attractive to animals

Descent of a Samara



Part Three

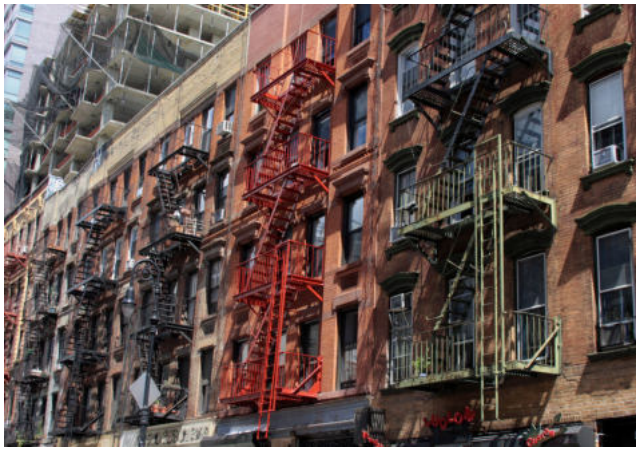
Wing Suit

Problem Areas

Emergency Evacuation

Multi storeyed buildings have been required since long ago to have external fire escape routes to evacuate personnel in case of fire and other emergencies. These are generally found in the form of external metal staircases attached to the sides of the buildings. But, as mentioned earlier, modern sky scrapers have been growing very rapidly. They have become mega-structures, housing more and more people further and further away from the ground. This creates serious headaches for the firemen and other emergency personnel while evacuating the building. As a result these external staircases are no longer feasible nor safe means of evacuation.

As a result, modern skyscrapers all have internal staircases, usually in the areas surrounding the elevator shafts. These



Book Tower, Detroit: One of the tallest buildings with external metal fire escape

staircases are designed so that they can take the entire population of a floor can be accommodated in the stairwell without an issue. This pegs the permissible population of a floor at 28 and the minimum permissible width of the stairs at 44in. "In arriving at this decision the idea has been that all of the persons on all floors shall be able to remain in the stair tower without any movement, a person requiring about 22 inches in width, and one person to stand on every other stair" [1][2]. In case of larger buildings with floor population greater than 28 persons, it is required to have multiple stairwells.

However, this is still an inefficient method of evacuation, as it is slow (for a 100-storey building, evacuation time would exceed 4 hours) as the people have to walk down the stairs. Also, it completely disregards the physically challenged, the elderly, pregnant women, and others who are unable to climb down a hundred storey building.

Current Alternatives

Emergency Parachutes

Inventor Morris Shahbazi has invented what he calls an “SOS-Parachute”. Its construction allows it to be deployed within 100feet, which is far less than regular parachutes. This enables it to be used as an effective means of evacuating a tall building by just jumping off a balcony while wearing it.[4]

While this system enables rapid and mass evacuation of the building, it doesn’t take into account the physically challenged, heart patients, pregnant women and other such users who might not be able to use such a physically-intensive system. Also, there is a certain amount of skill involved in the operation of a parachute, and manoeuvring it once deployed to prevent crashing into other hazardous spaces.

Reel-based Descent Systems

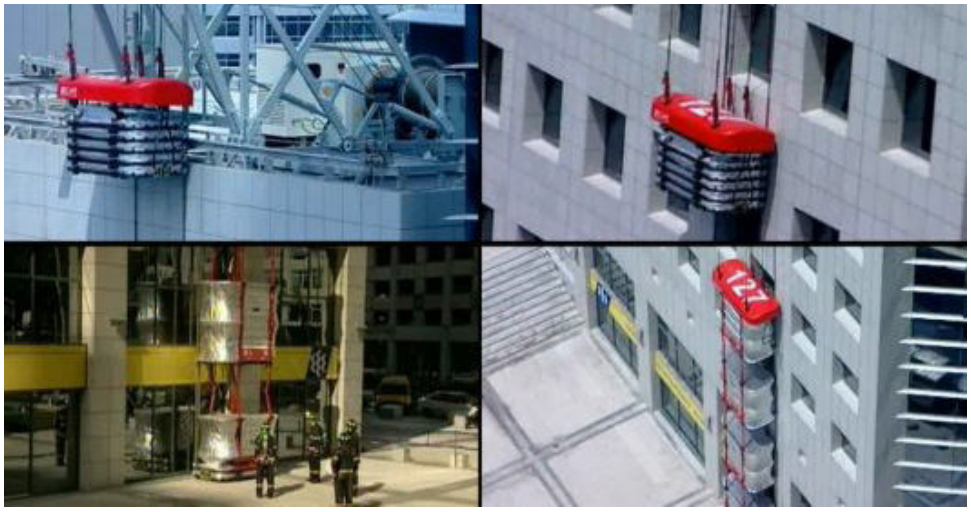
These systems are basically modified abseiling systems, which enable use by a wider demographic with relative ease, and little or no training required. These include systems which strap the evacuees into a safety harness and descend them along the side of the building at a controlled rate on a reel, using machinery to arrest their descent.

Although these systems are relatively fast, and safe to use by a wide variety of population, the complex machinery required for their operation make them an expensive alternative. [3][6]

External Emergency Elevators

This system developed by Escape Rescue Systems, consists of a rooftop mounted arm, which deploys in case of emergencies, and drops down lines along the outside of the building. These lines have a collapsible elevator attached to them. This elevator cabin expands ad starts to ferry passengers out from the building. At the same time, this elevator provides easy and fast access to the building's interior to the firemen, and other emergency personnel to fight the fire from within, and provide assistance to those in need. To increase capacity, the elevator can also have multiple cabins. And accessibility ramps inside the building provide access to the elevator to the physically challenged.

Although the system is quite effective, its complexity of construction means that it is quite an expensive system to install and maintain.[5]



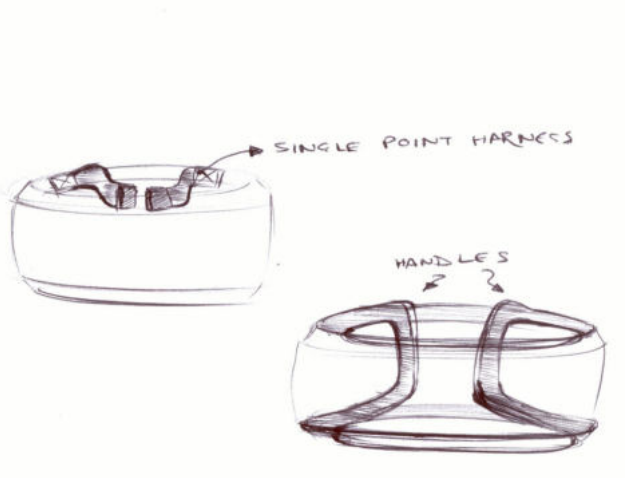
Wing Suit

In such a scenario, therefore, to make sense, any evacuation system must avoid the shortcomings of the existing systems, build on their best features, while bringing something completely new to the table. Hence, such a wing suit should essentially:

- Be easy to wear: strapping on should not take too much time, to ensure speedy evacuation. While at the same time, it should be secure enough so that it does not come undone during use
- Have Minimal machinery: minimal machinery would mean lower cost, both initial and maintenance, as well as lesser chances of failure
- Allow a controlled rate of descent: this is essential to ensure safety and comfort of the evacuees
- Need no special skills needed to control: the evacuees should not be required to possess any prior training to use the equipment.
- Be suitable for a wide type of users: All types of users should be able to use it irrespective of physical disability, old age, and other handicaps.

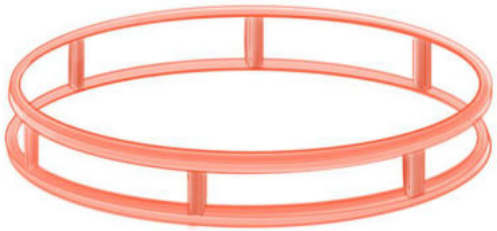
Iteration 1

The first iteration is a simple ring with a large wing attached to the outside. The ring is itself made of two concentric parts. The user straps him or her into the inner ring, while the wing rotates with the outer ring. The inner ring also has handles for the evacuee to grab onto.

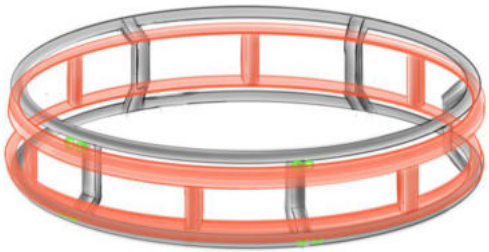


Construction

Core stator ring



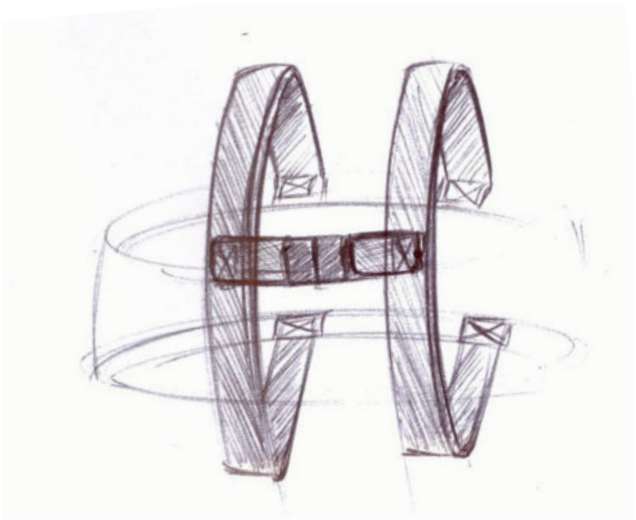
Rotor ring (to which wing is attached)

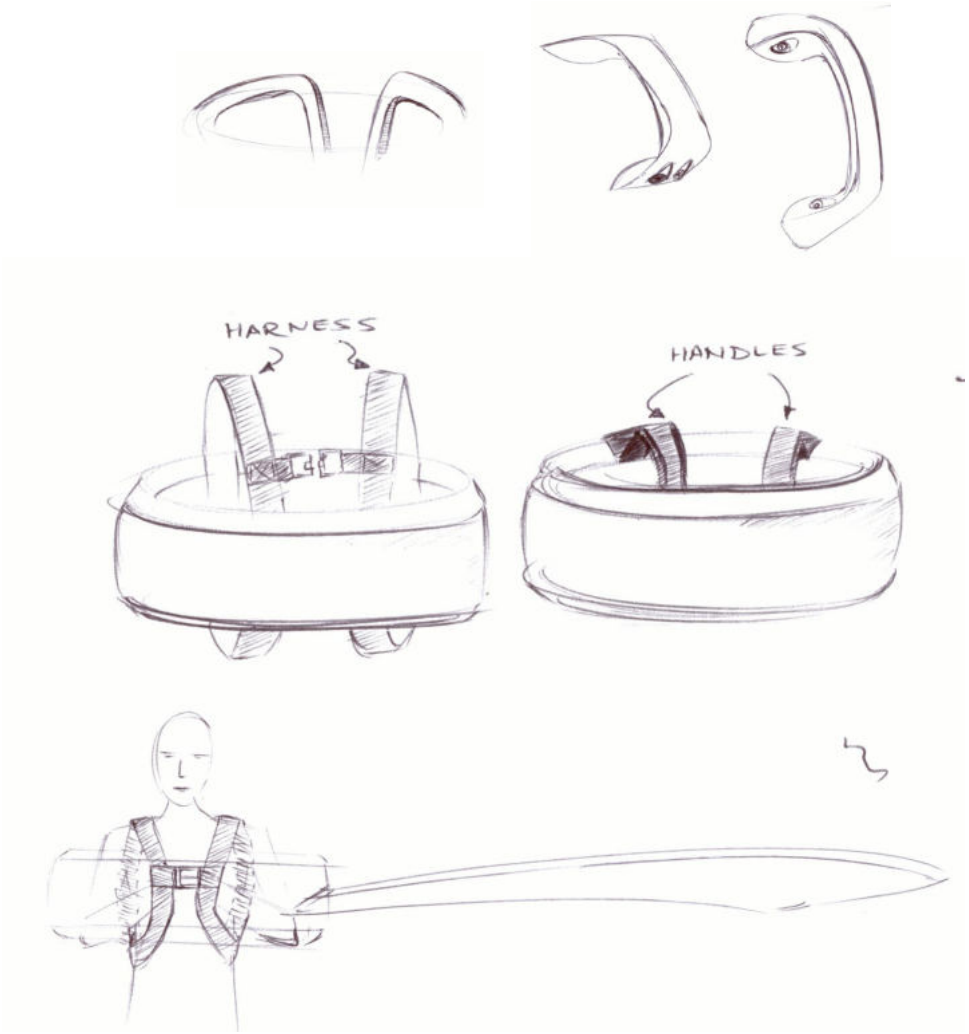


Assembly

Iteration 2

The second iteration is basically an iteration on the harness configuration, switching to a design that provides better safety and anti-slippage in case the evacuee goes unconscious. While at the same time allowing freedom of movement, fast usage, and compatibility with Indian female clothing.

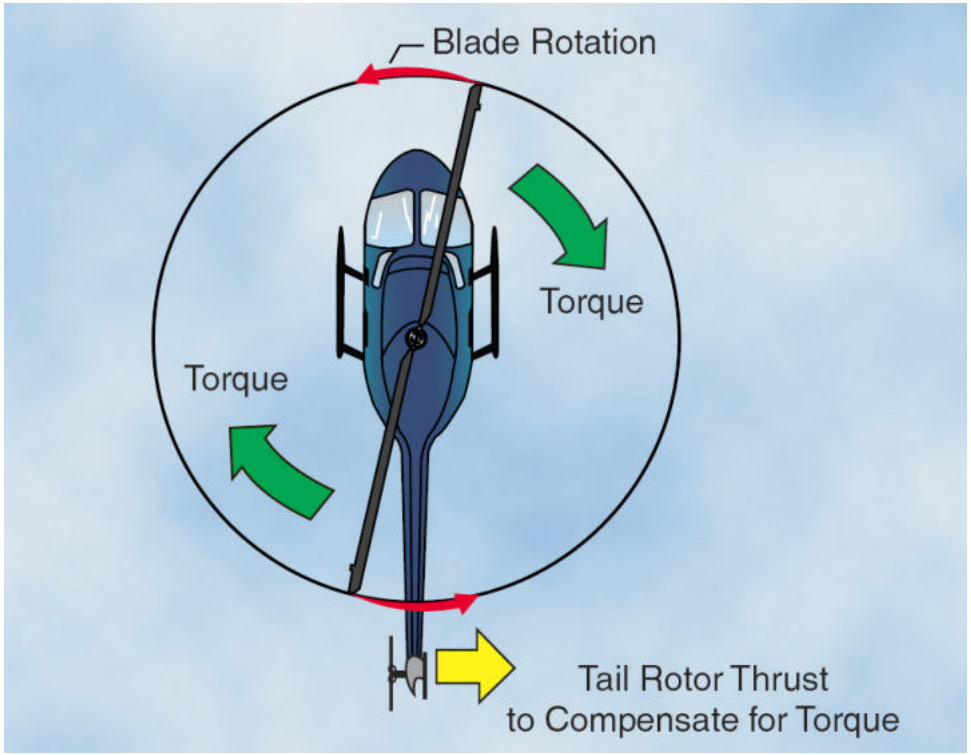




Secondary Rotor

Since the evacuee's body is not fixed, and the friction between the two rings can never be zero, unless an external stabilizing forced is applied, their body will rotate with the wing. This phenomenon would cause nausea to the users, and also make the suit's flight path difficult to control.

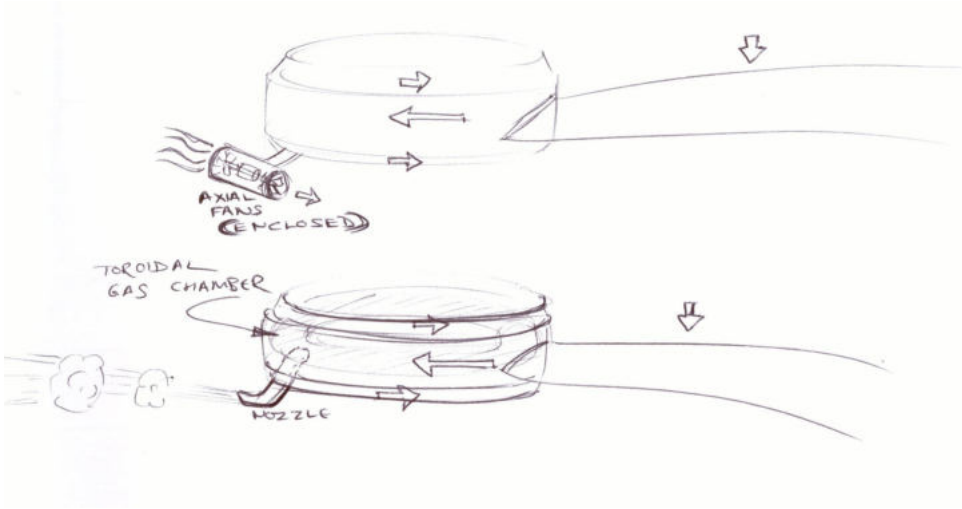
This would be quite similar to the way early helicopter prototypes used to behave without the secondary rotors: spiralling out of control.

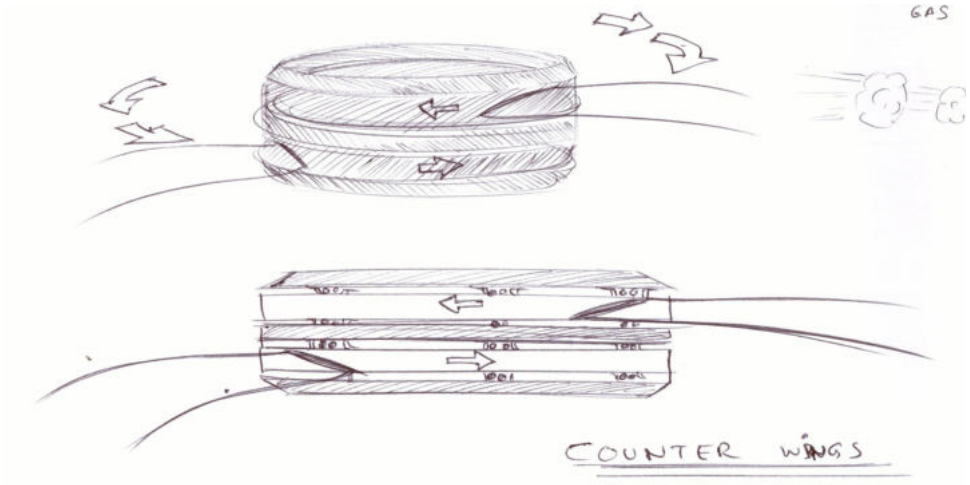


Iteration 3

This problem can be solved by using external forces. This can be implemented by using nacelle-enclosed axial fans or jets of compressed air. However, these solutions require a power source or a tank of compressed air.

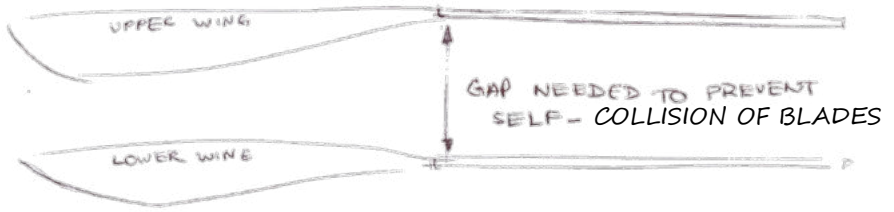
Alternatively, taking a cue from one alternative helicopter designs, a second co-axial wing with profile opposite to the first wing can be used to generate double thrust, and counteract the torque at the same time.

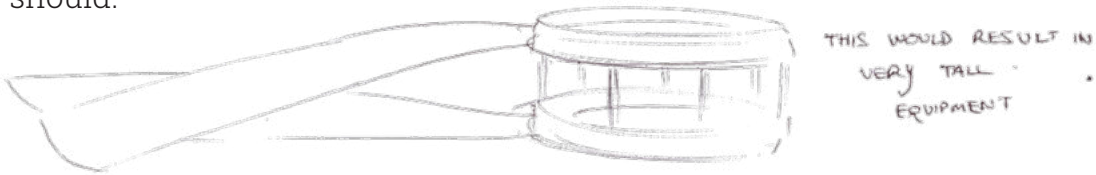


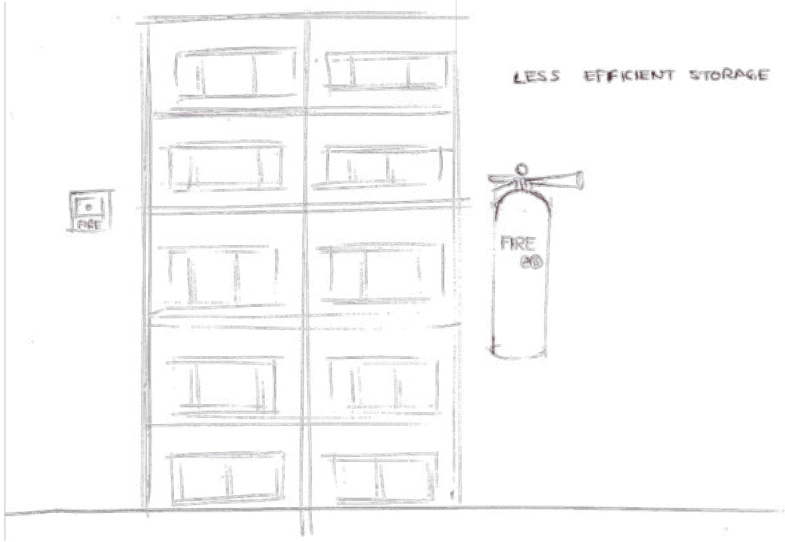


Stacking

However, coaxial rotors are prone to self-collision of the blades. To prevent this occurrence, it is necessary to provide a considerable distance between the two blades in the axial direction. However, this distance would increase the size of the product, making stacking inefficient, and taking up more space than they should.

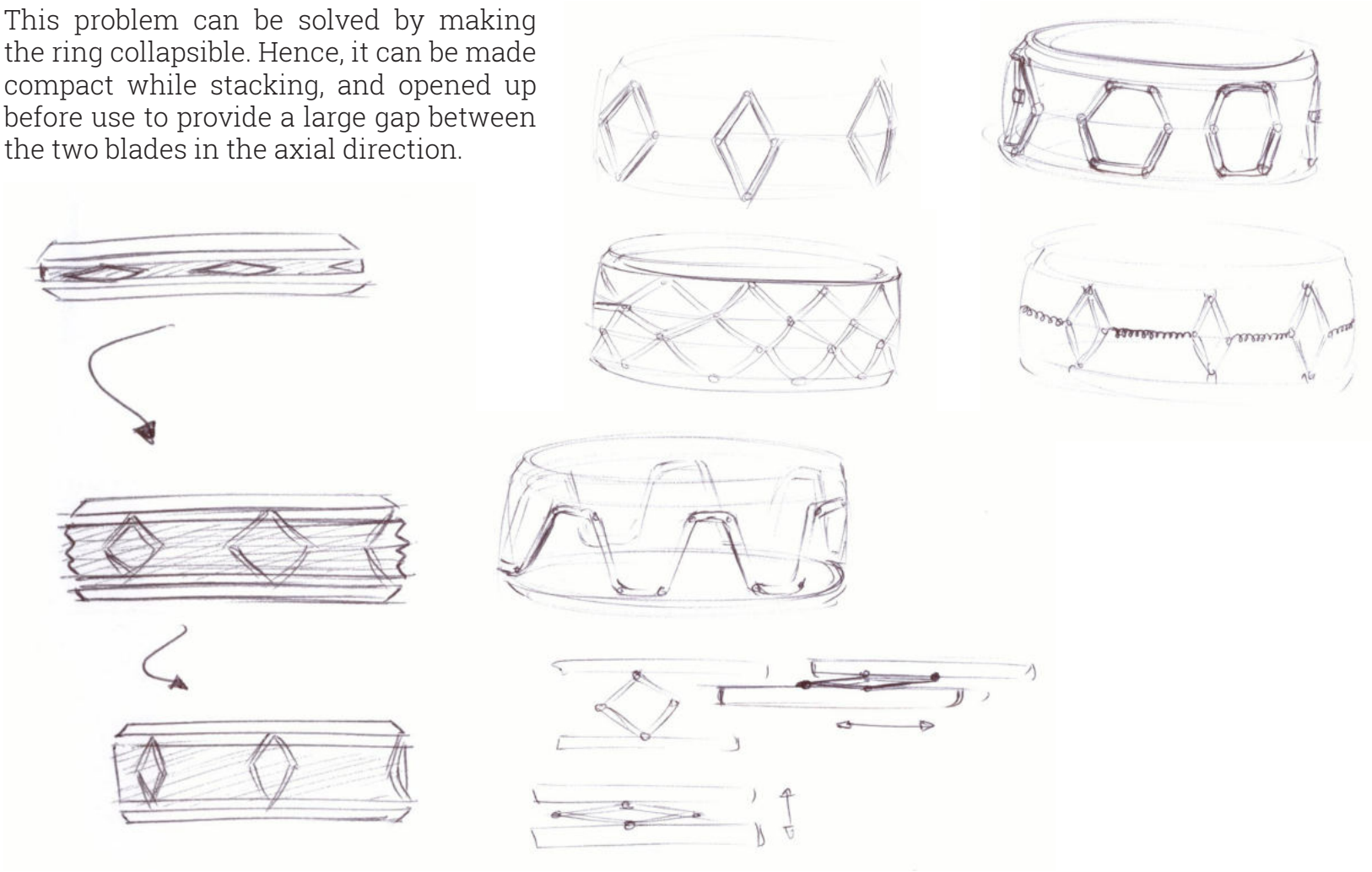


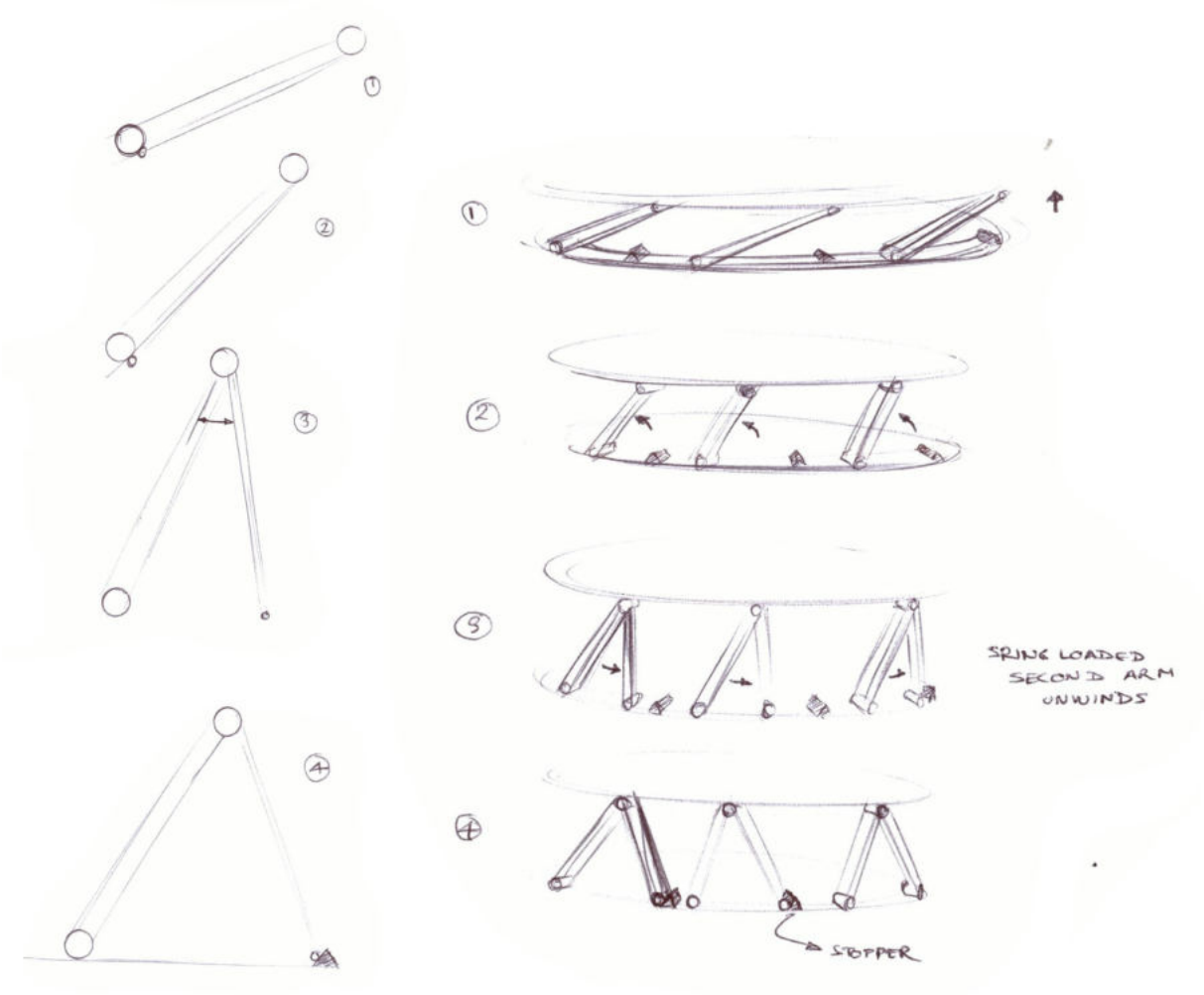




Collapsible Ring

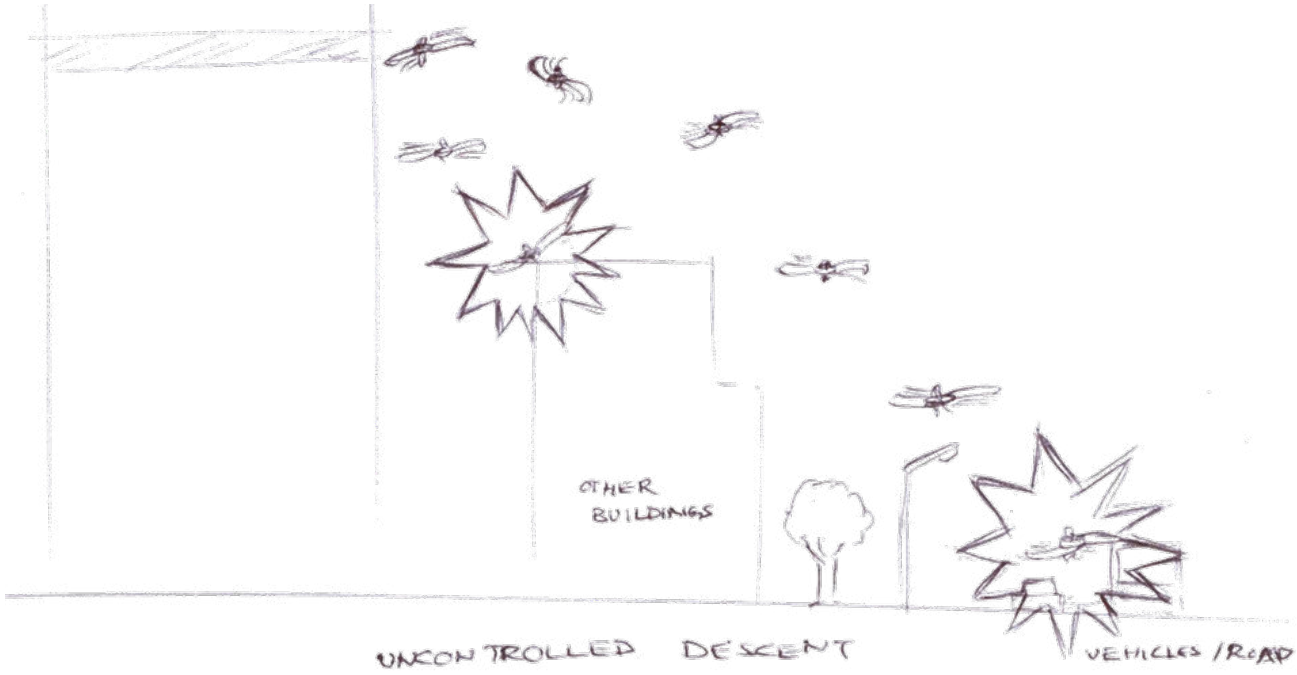
This problem can be solved by making the ring collapsible. Hence, it can be made compact while stacking, and opened up before use to provide a large gap between the two blades in the axial direction.




1
2
3
4
SPRING LOADED
SECOND ARM
UNWINDS
STOPPER

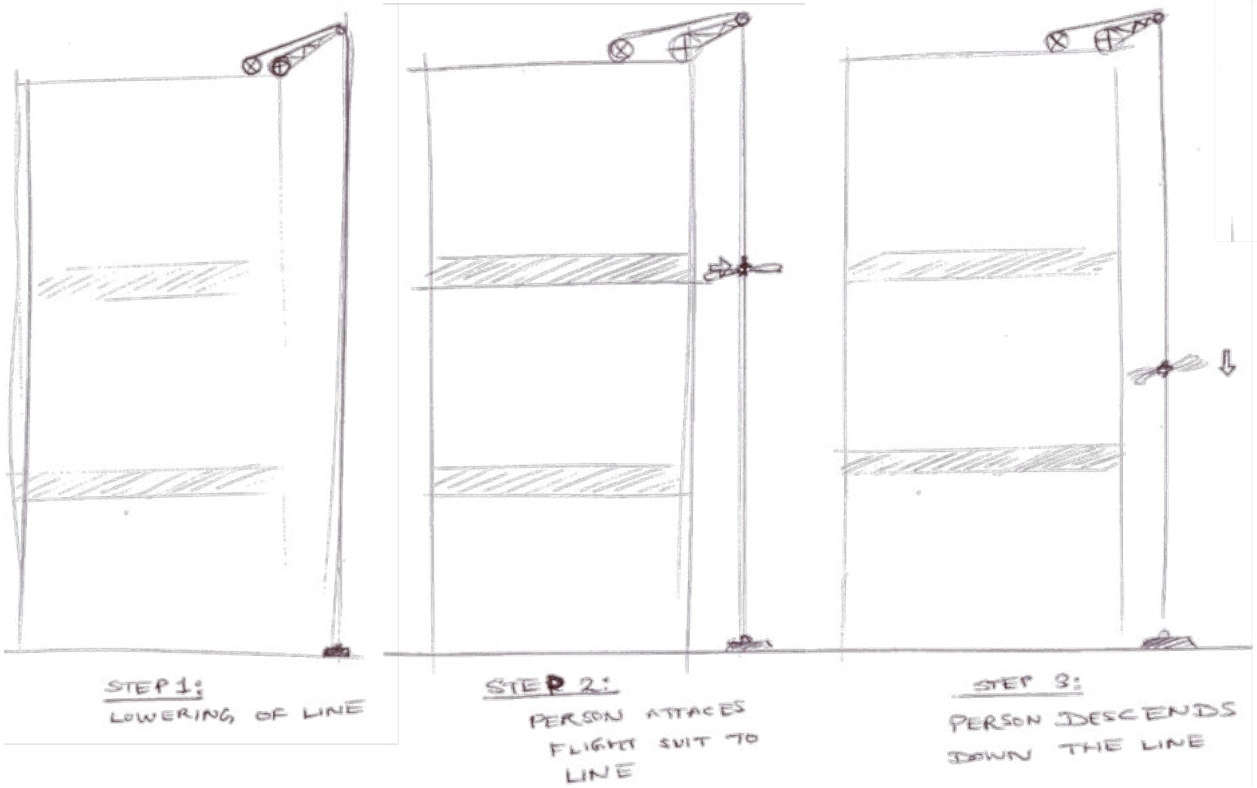
Flight Hazards

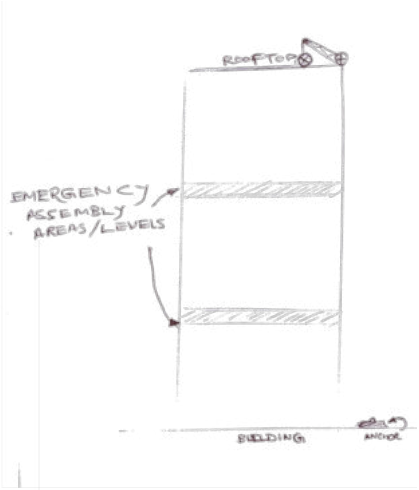
Letting the evacuees descend in the suits might be easy, but the evacuees need to be trained to control and manoeuvre the suit in order to reach the ground safely. Otherwise, they might crash into buildings, trees, oncoming traffic, and other objects. Also, high speed winds at great heights these skyscrapers reach can possibly blow away the evacuees far away into hazardous areas.



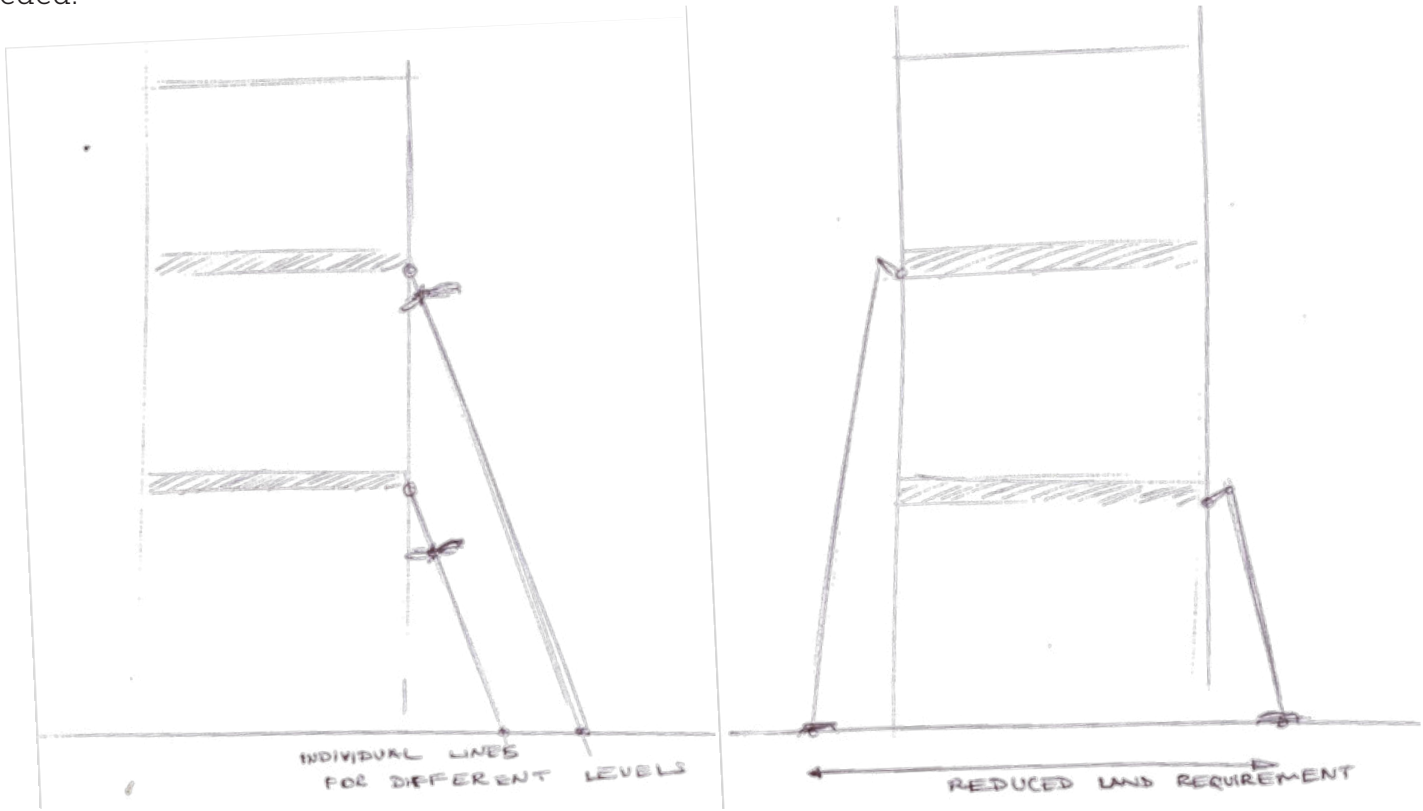
Controlled Descent

The evacuees can be ensured a controlled and guided descent without the need of any prior training by providing a guiding line from the roof along the side of the building. The ring can be attached to this line, and the evacuee can descend safely.



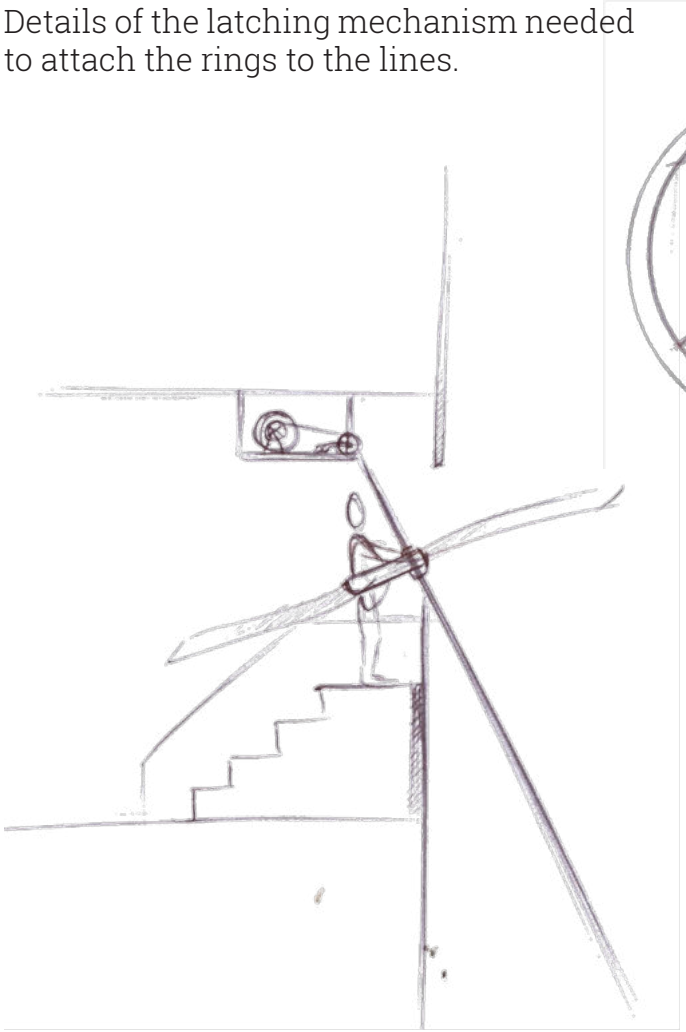


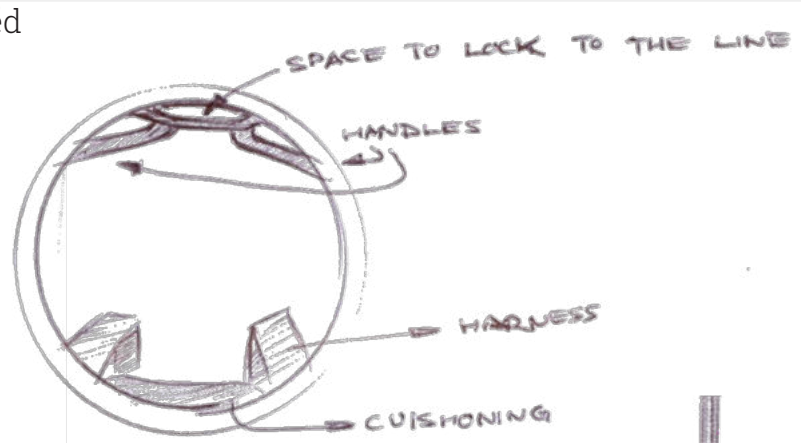
Alternatively, the lines can be dropped from the individual designated evacuation floors. This would make attaching the rings to the lines easier. Also, the lines can be arranged around the building to save real estate needed.

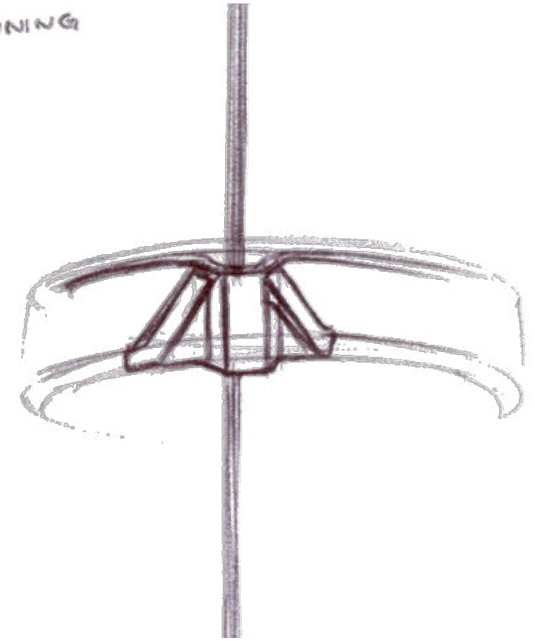


Latching Mechanism

Details of the latching mechanism needed to attach the rings to the lines.



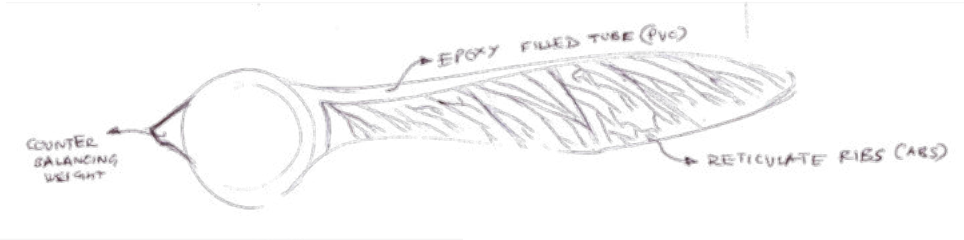


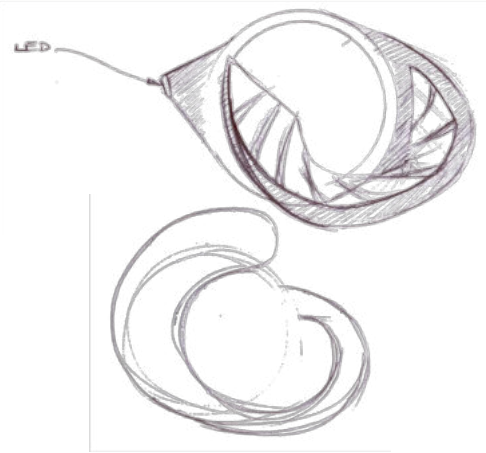


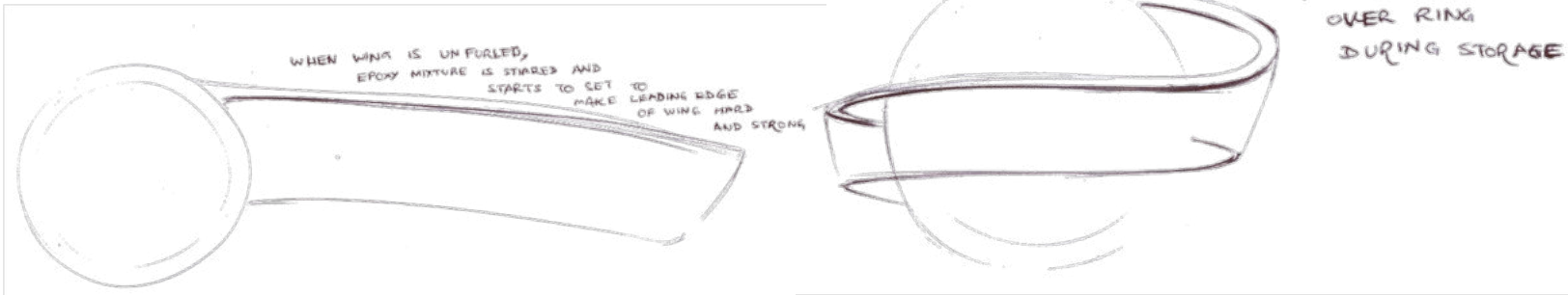
The Wing

Similar to the rings, the wings of the suit would also need to be folded during storing them to save space. This would necessitate a flexible wing. However, such a flexible wing wouldn't be able to provide the necessary stiffness to retain its shape to provide lift.

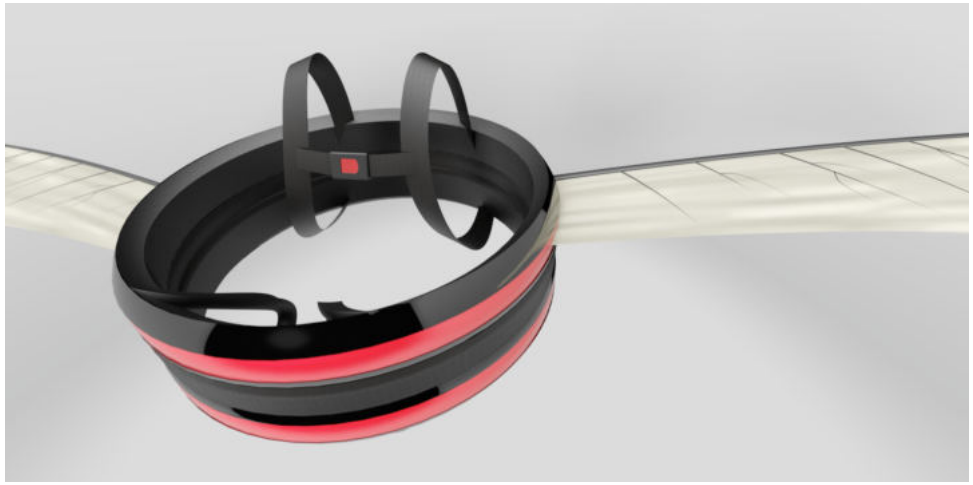
This can be solved by making the ribs of the wing out of flexible plastic tubes filled with liquid epoxy and a hardener/curing agent in separate chambers. When the wing is unfurled before use, the two liquids come in contact with each other and set quickly, creating a stiff rib needed for the wing to function.

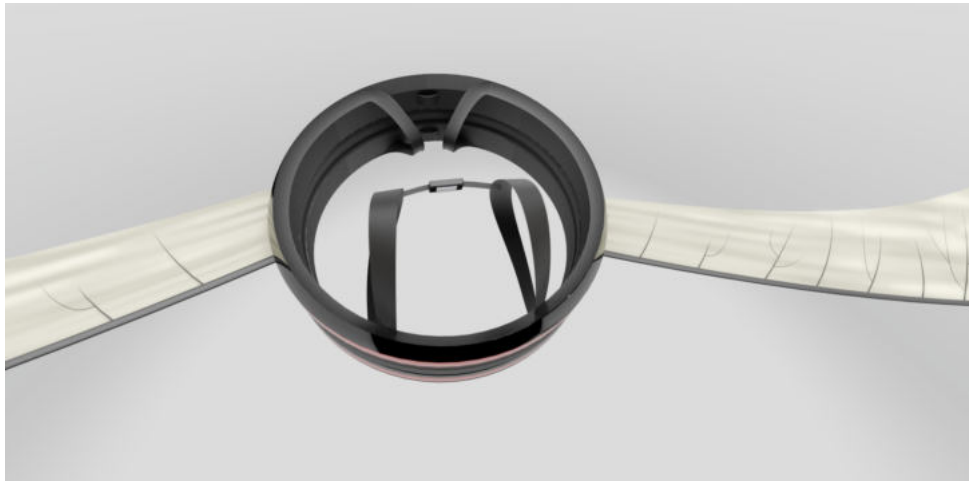


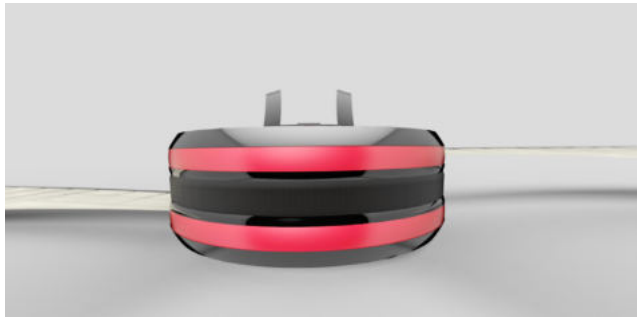


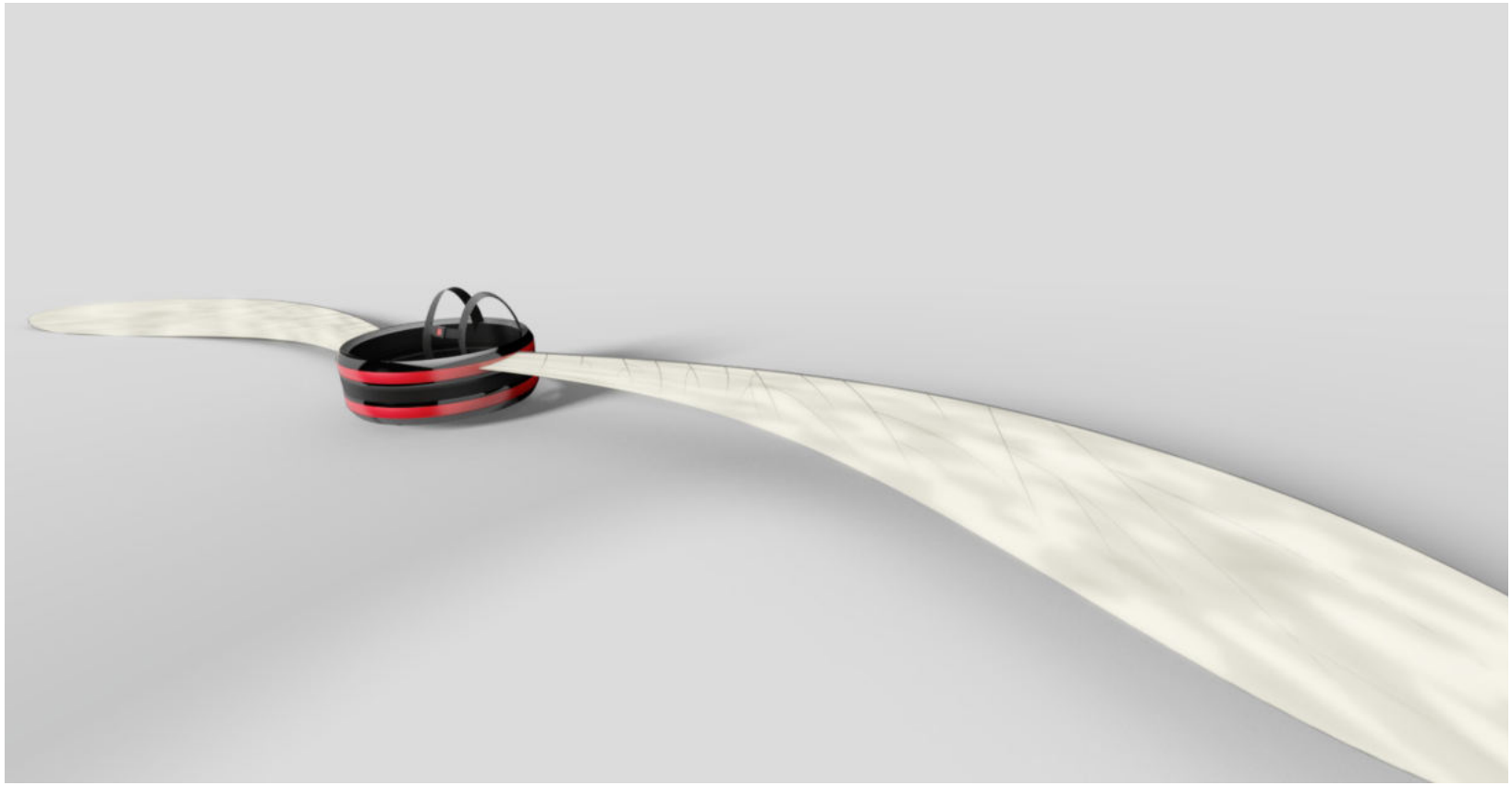


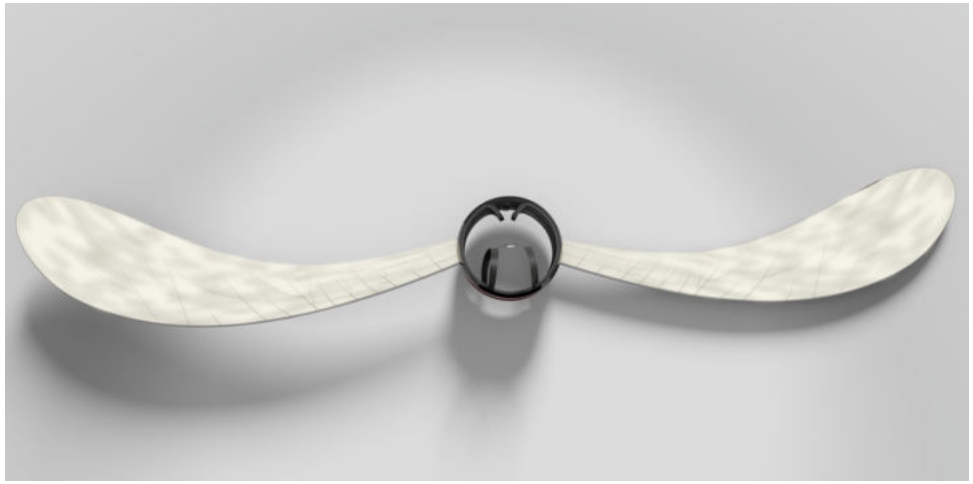
Final Design

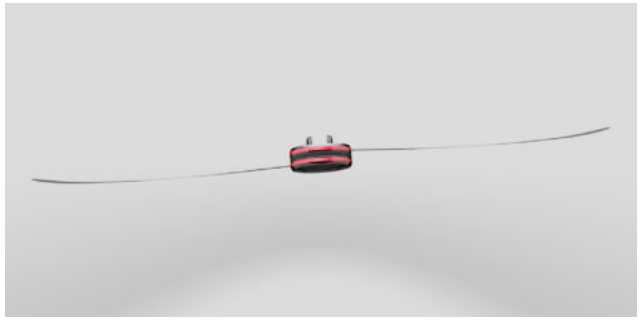


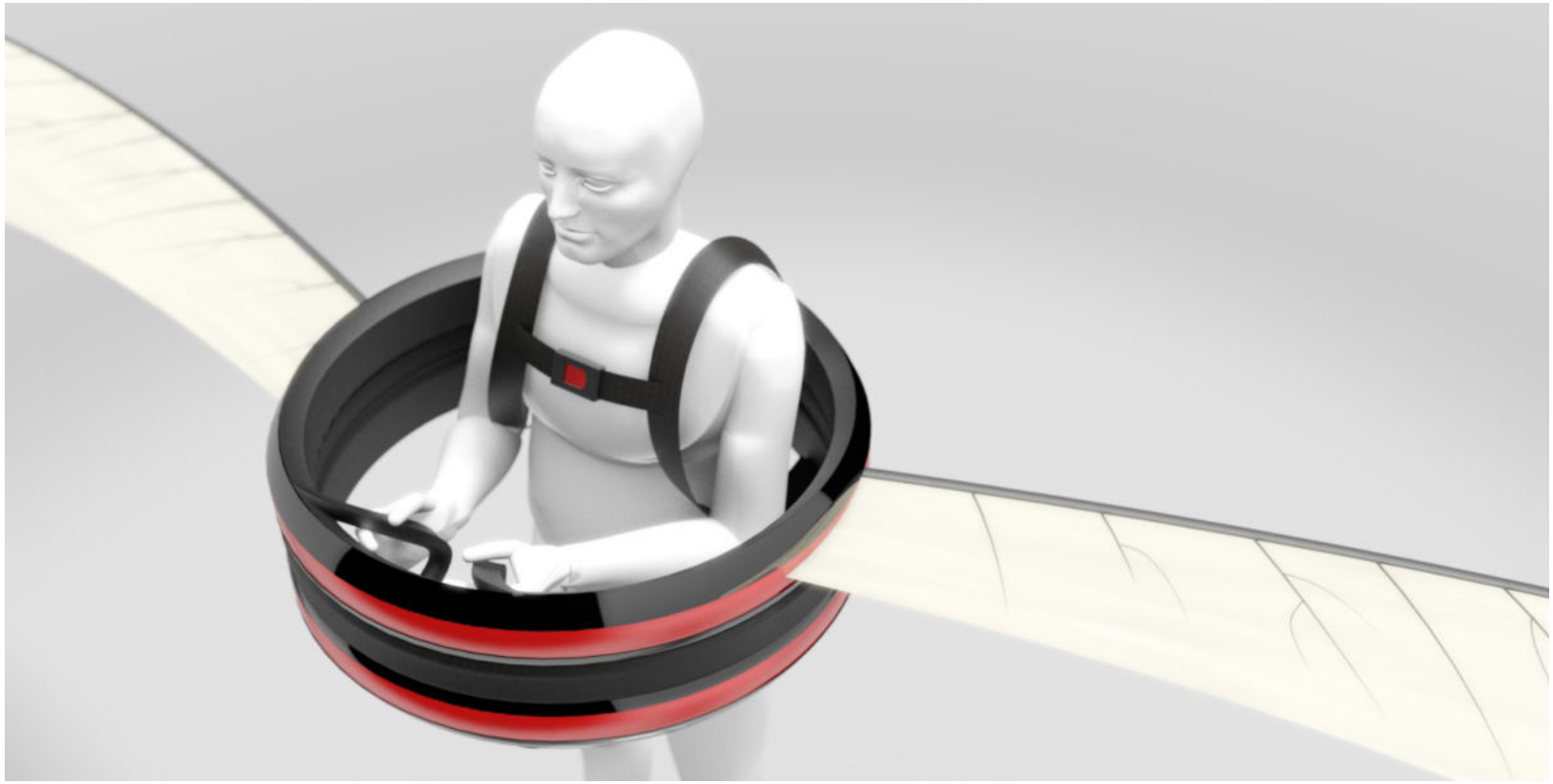


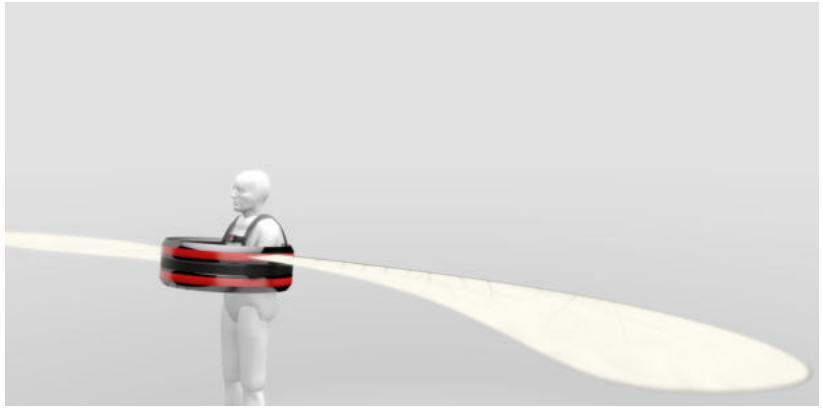


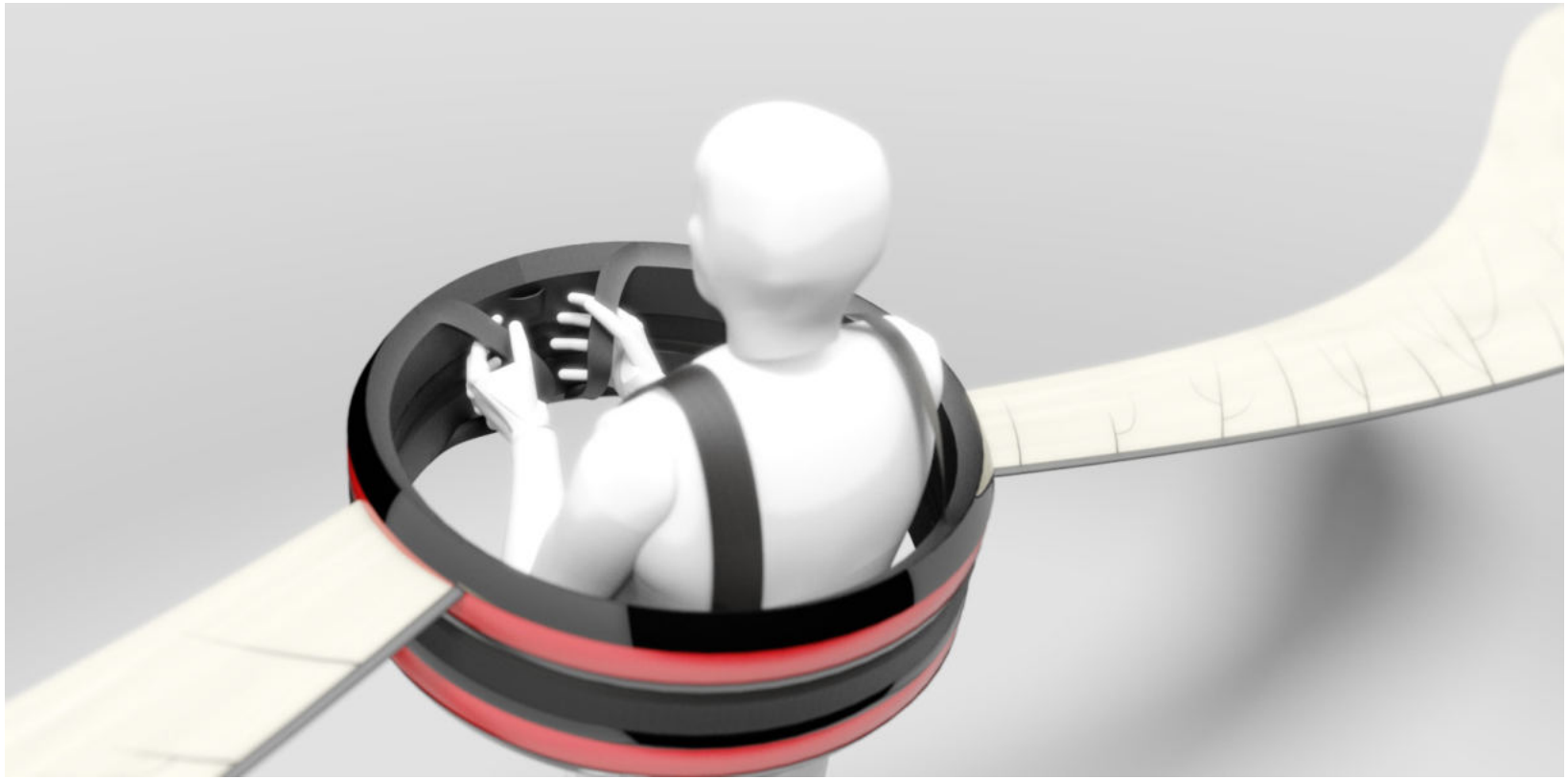


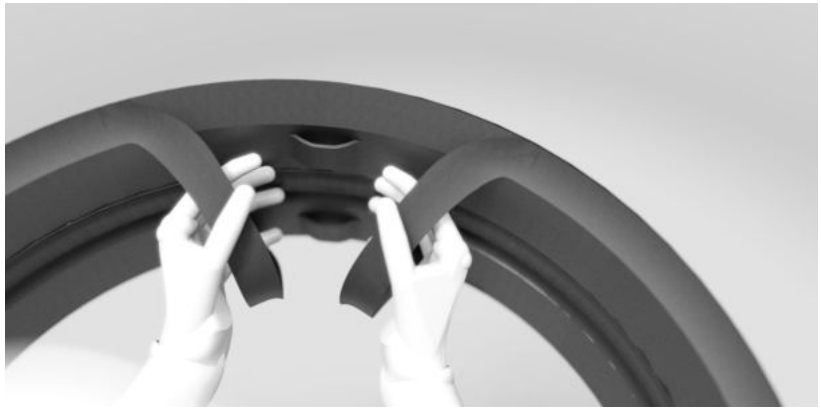












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