

THE GLASGOW SCHOOL OF ART

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Background

Inspiration

Since I moved to Glasgow, I have experienced a lot of fire drills and wrong-triggered fire alarms. To understand why it is so different from Taiwan, I found that it was because of the tragic accident of the Grenfell Tower Fire which cost the lives of 72 people. The British government implemented new policies regarding fire incidents, such as building fire regulations, fire alarms, fire drills, etc. This was how I decided to choose fire as the theme of my final design.



Wrong-triggered fire alarm and evacuation that I experienced at my accommodation.



The Grenfell Tower Fire

While the Grenfell Tower Fire claimed the lives of 72 people, 40% of whom were disabled. Most tenants with disabilities were forced to live at Grenfell Tower due to financial difficulties; they had no other option. Additionally, they were not allowed to choose their residence floor and were even put in dangerously higher floors. The community committee's reaction to their complaint that their living arrangements are not accessible for those with disabilities was, "If you don't want to live on this level, you can choose not to live in this building." They were forced to compromise and consent to living in such an unfavorable atmosphere because they had no better options. Such a biased phenomenon happens not just in Grenfell but throughout the world. As a result, those with disabilities have a substantially lower chance of surviving a fire than others.

How to face a fire

Step 1:

Find a room with an external window.

Step 2:

Close the door, open the window to allow air circulation in the room.

Step 3:

ask for help, and wait for rescue.

One of the unique contents is a fire accident in Taiwan. There was a severe fire accident in a house, and six people were killed. They were found in the toilet, living room, and other places. However, after the investigation, it was found that there was almost no trace of smoke intrusion in one of the closed rooms, which means that closing the door and staying in the room can actually improve the probability of survival. **To face a fire, the thing that should be done is to try to survive rather than evacuate.**



Fire Development

A normal fire incident can be divided into four phases.

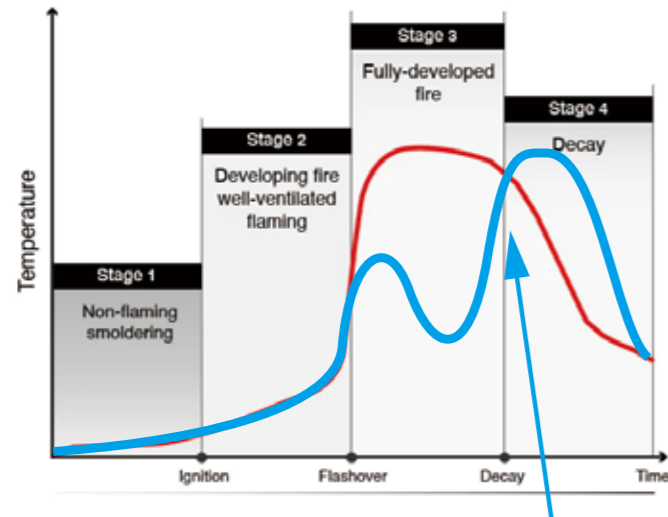
1. The first phase begins when a cause leads to unwanted fire.
2. The heat and smoke trigger the fire alarm, which automatically initiates a call to the emergency service.
3. Residents become aware of the fire and begin evacuation.
4. Firefighters arrive to extinguish the fire and rescue the residents trapped in the building.

Fire alarms play a major role, however, First Local Government indicates that one in ten homes does not have a working smoke alarm, and more than 22 percent of households never test their smoke alarm. As a result, there are design opportunities in phase 3 and 4, because if the user miss the first and second phases, the user can not evacuate on his/her own. The main goals of the design are to lengthen the survival time of the victims until help arrives and also helping the firefighters to locate the survivors.

Regulation

- EN 14604:2009 (Standard for Domestic Smoke Detector Safety)
- NFPA 1982 (Standard for Personal Alert Safety Systems)
- NFPA 75 (Standard for the Fire Protection of Information Technology Equipment)
- NFPA 76 (Standard for the Fire Protection of Telecommunications Facilities)

Environment

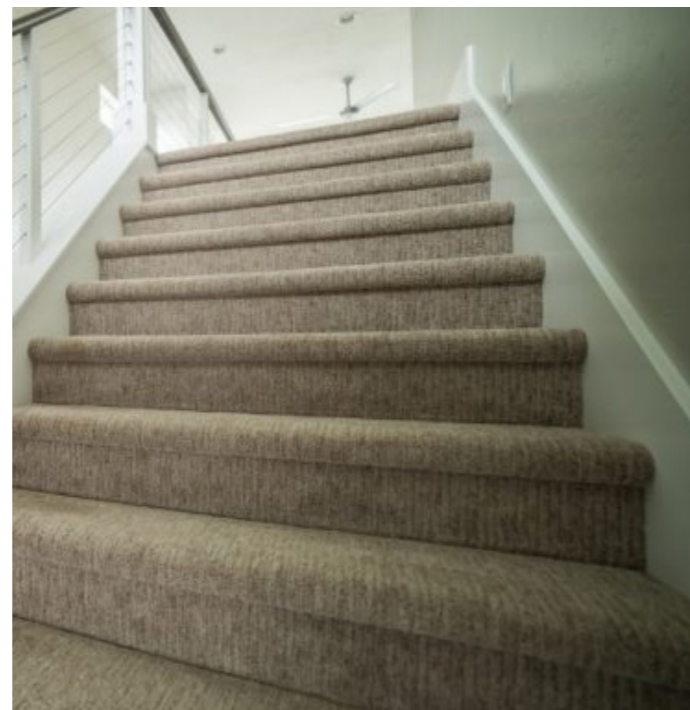


Flashover

Target Environment

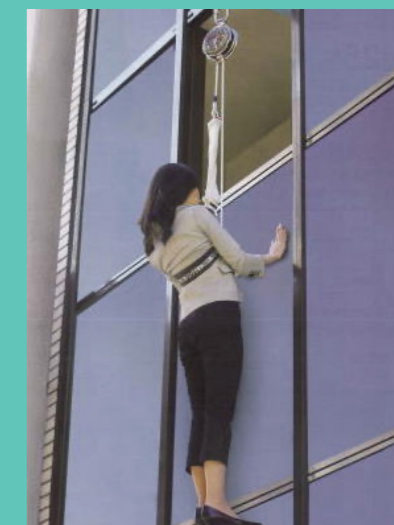
Multi-story residential buildings are designated to be the target environment for this design. The changes in the environment during the fire can be represented by the fire growth diagram. As shown in the figure, the fire growth can be roughly divided into four stages. It only takes 30 seconds for a fire to develop from stage one to stage two and a few minutes into stage three. After the "flashover" occurs, the fire is fully developed, at which point smoke, heat, and visible exterior flames are severe and fatal, and the temperature can reach 700 to 1200 degrees C. Hot air and smoke gather on the ceiling and then move to the ground constantly. Therefore, the closer to the ground, the longer people can survive. Moreover, according to the actual combustion experiment of NFPA, when the temperature outside the door is as high as 150 degrees Celcius, the temperature in the room is only 25 degrees Celcius if the door is always closed. It means that the door can effectively block the rapid rise of the ambient temperature.

All in all, breathing problems, vision sense, and high temperature are the main three difficulties needed to be overcome while trying to survive in a fire, especially considering the limited bodily functions of disabilities. These latter two phases are the most important.



Current Fire Equipment

There are various fire types of equipment in the market, and they are already installed in many buildings, such as escape ladders, inflatable rescue airbags, and descent rescue device. However, most of them cannot be used by people with disabilities even though they are considered products without user restrictions.



Target User

People in wheelchairs who can live independently.

People in wheelchairs

40% of people who lost lives in the Grenfell Tower Fire were mostly in wheelchairs.

Live independently

People in wheelchairs need to deal with much more difficulties in an emergency compared with those who have flatmates, in which they will not be able to get help from others.

Current Fire Equipment

According to the analysis of current fire equipment that I mentioned previously, most of the product can only be used by healthy adults, while children, pregnant women, elderly, as well as the disabled are not able to use it.



Interviews

Jimmy and Nina

They are the people that I met on the street, and they showed me how to transfer from the wheelchair to the stairs.

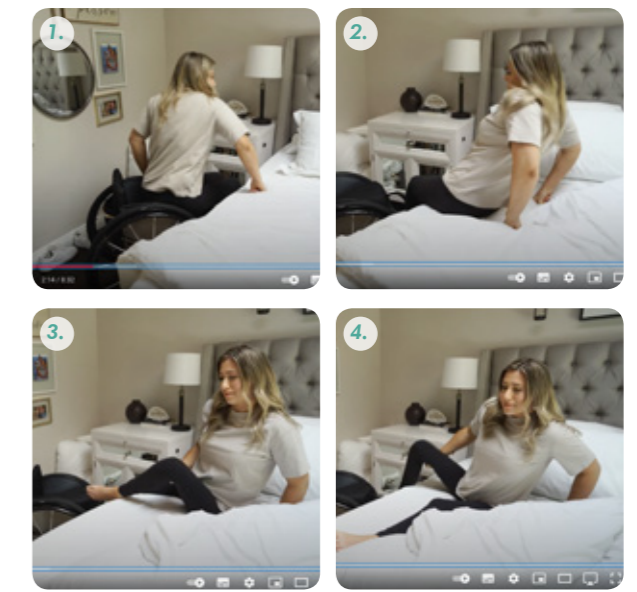


Youtube Videos

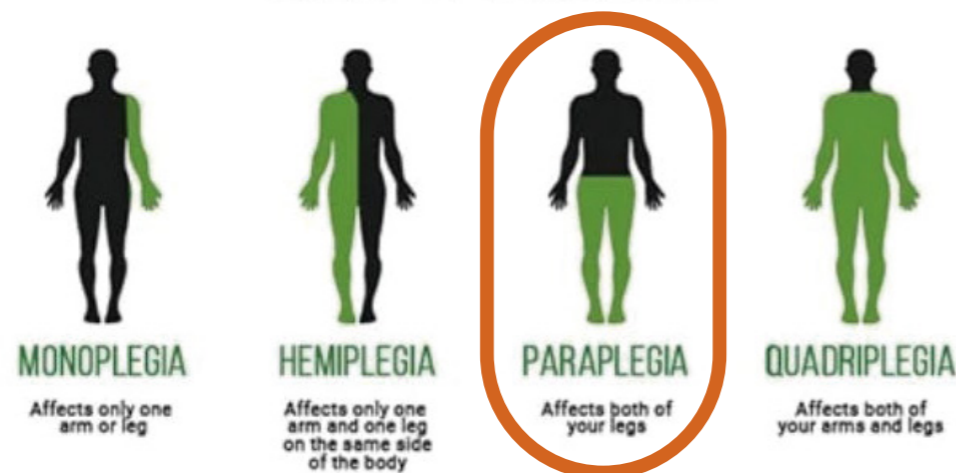
There are so many videos about the lives in wheelchairs, and I have learnt a lot from them. Especially how they transfer to beds and wheelchairs.

Youtube Channel:

Finding Ren, Wheels2Walking, Wheelsnoheels - Gem Hubbard and Chelsie Hill



TYPES OF PARALYSIS



Paralysis Types

Since I decided to focus on people on wheelchairs living independently, I have searched for information on this user group, finding that there are several different types of paralysis, such as monoplegia, hemiplegia, paraplegia, and quadriplegia. The one that meets my target user statement is **paraplegia**.



Lorie, 23 years old. Born in Italy, now living in the USA.

She had a severe accident when she was 19, almost taking her life. Fortunately, she survived but needs to spend the rest of her life in a wheelchair. Her paralysis type is paraplegia, which met the target user statement. Nevertheless, she is a positive woman and passionate about life. So when I contacted her through Instagram, she was the one that replied to me immediately and was interested in my project. After having a zoom meeting with her, I have known more about the target user.

Essential Points:

1. Sensitive skin on their legs because of muscle atrophy causes a lack of protection for their legs.
2. They can slightly use the muscle on their legs but can not support their weight.
3. Have muscular upper body strength such as core and arm muscles to move their body within a limited space.

Key Points Summary



User Journey Map

1. Because most fire accidents occur at night, so the User journey Map begins at night. And it is also the reason that I design to place the Mobile Fefuge close to the bed.
2. Due to the lack of fire alarm installation, there is a high probability that the user may not be aware of the fire until they hear the sound of burning furniture, which leads them to the deadliest killer in a fire: the smoke.
3. the refuge point, which is a relatively safe space for the disabled to wait for help, is only designed for commercial buildings.
4. Even if the disabled reach the exit stairs, they would not have the ability to go downstairs by themselves.



Problems

- Heavy smoke
- Breathing problems
- Visual problems
- Communication/positioning (relex panic emotion, be found faster, be helped efficiently)
- Fall from wheelchair/couldn't get into wheelchairs with panic emotion
- Can not go down stairs by themselves
- Don't know how to survive

Opportunities

- What if they can go downstairs by themselves
- What if they can get out of the building without going downstairs
- What if they can create a refuge space to survive until firefighters come

Target User

- People in Wheelchairs
- Live in the residential building with stairs
- Reality makes them have no choice but to live in upper floors
- People who already lived at upper floor before needing wheelchairs

Environment

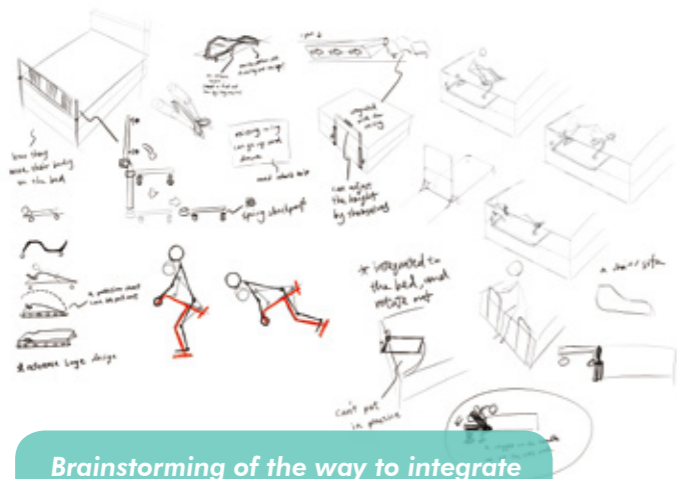
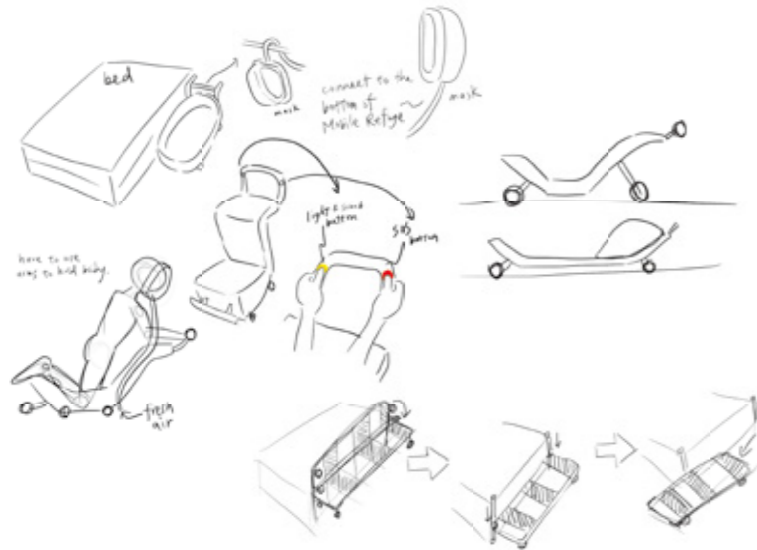
- Residential buildings
- Mutple floors
- stairs
- no flatmates nor roomates

Concept

Initial Concept

Three concepts are created:

1. The first concept is going downstairs without any help. Some products already exist in the market to help the disabled go downstairs, so the design opportunities are relatively limited.
2. The second concept is getting out of the building without going through stairs. After brainstorming, the ideas were too unrealistic to put into practice.
3. The third concept is creating a refuge space to wait for rescue, which is the chosen concept for further design.



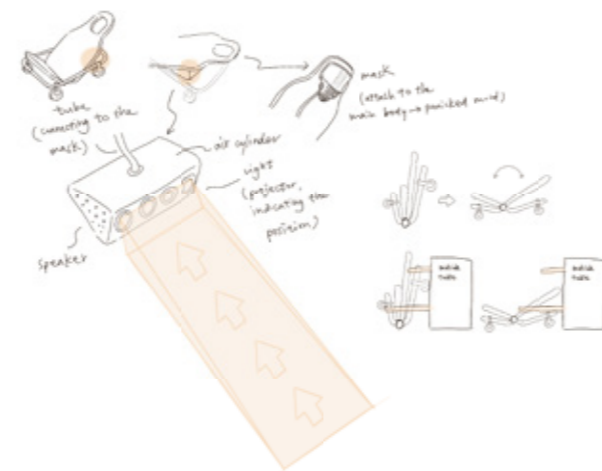
Brainstorming of the way to integrate the Mobile Refuge into bed railings.

Key Insights

People with disabilities need extra time to get into wheelchairs, so when the fire breaks out, they easily miss this best time to evacuate. Not all multi-story residential buildings have a refuge point for disabled people, so they may not find a place to be rescued. In this circumstance, how can they survive in the fire until someone comes to help? Moreover, they can not even do a specific pose to avoid toxic smoke.

What if Question / Identified Opportunity

What if they don't need to leave their bed and can still be safe until getting help?



Concept Description

The storyboard (figure 7) shows the concept about creating the Mobile Refuge.

1. The fire occurs.
2. The sound of broken glasses awakens the user.
3. The user realizes the fire and wants to get into the wheelchair. However, the wheelchair cannot help the user to stay in a space with smoke.
4. The user gets into Mobile Refuge.
5. The user puts on the air mask and presses the button that triggers calling the emergency center, turning on the light, and making the sound.
6. The firefighter arrives and notices the light and the sound, so the user is found.
7. The firefighters carry the Mobile Refuge to evacuate the user.
8. The user survives.

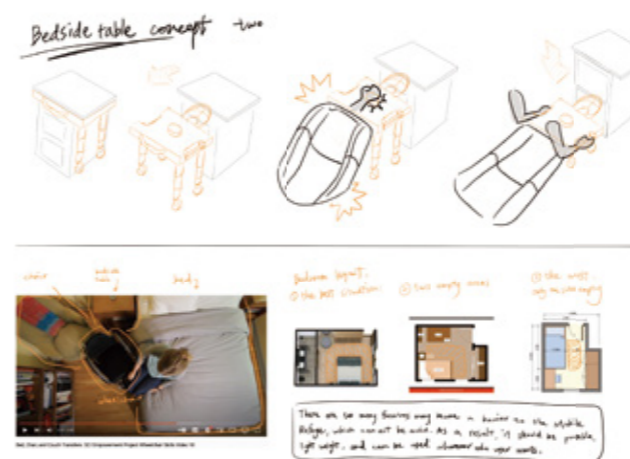
Ideations and Sketches

As the target user is defined as people sitting in wheelchairs and living independently, investigating how the target user transfers between the bed and the wheelchair in an emergency is significant. There are three problems:

1. Failing to reach the wheelchair.
2. The person can not do the lie-down pose in a wheelchair.
3. The transfer time is inefficient.



Different ideas of deployments.

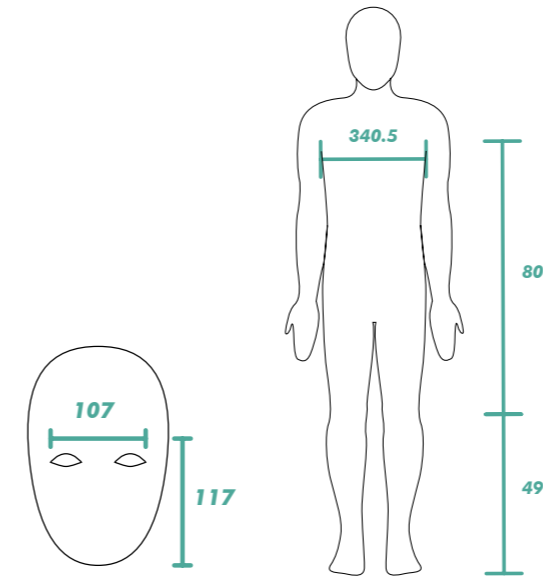


Concept Verification

Gordon and Chris with 17 years experience working as firefighters.

Key points of this interviews with firefighters:

1. Refuge points normally are only designed for commercial buildings, and normally there is no refuge point in a commercial building.
2. There is a fire equipment, evacuation chair, used to evacuate the disabled in an emergency. However, Gordon and Chris said that they never had used an evaluation chair before, this is only used by the building staff before the firefighters arrive.
3. They evacuate people who are trapped in a fire by carrying them directly without any equipment, and two firefighters help one at a time.
4. They advised me to add an air cylinder on the button of my design. The air cylinder contains air rather than oxygen. And it can help the victim to breathe for an extra hour.
5. They are trained to rescue in the low visibility environment. Even though they are not able to see anything in the environment filled with smoke, the light may be visible close to the ground that they may notice.
6. The handles on the product are possible for them to use to evacuate the victim.
7. Before they start a mission, they will receive a note with all the information they need and highlighting certain fire products used in the building. As a result, if my design is able to work in reality, the firefighters will train to use this product and be notified before rescue.



Face Down v.s. Face up

Face down:

1. Get closer to the ground
2. Feeling safer
3. To transfer from bed to the Mobile Refuge, facing down is a more reasonable solution.

Face up:

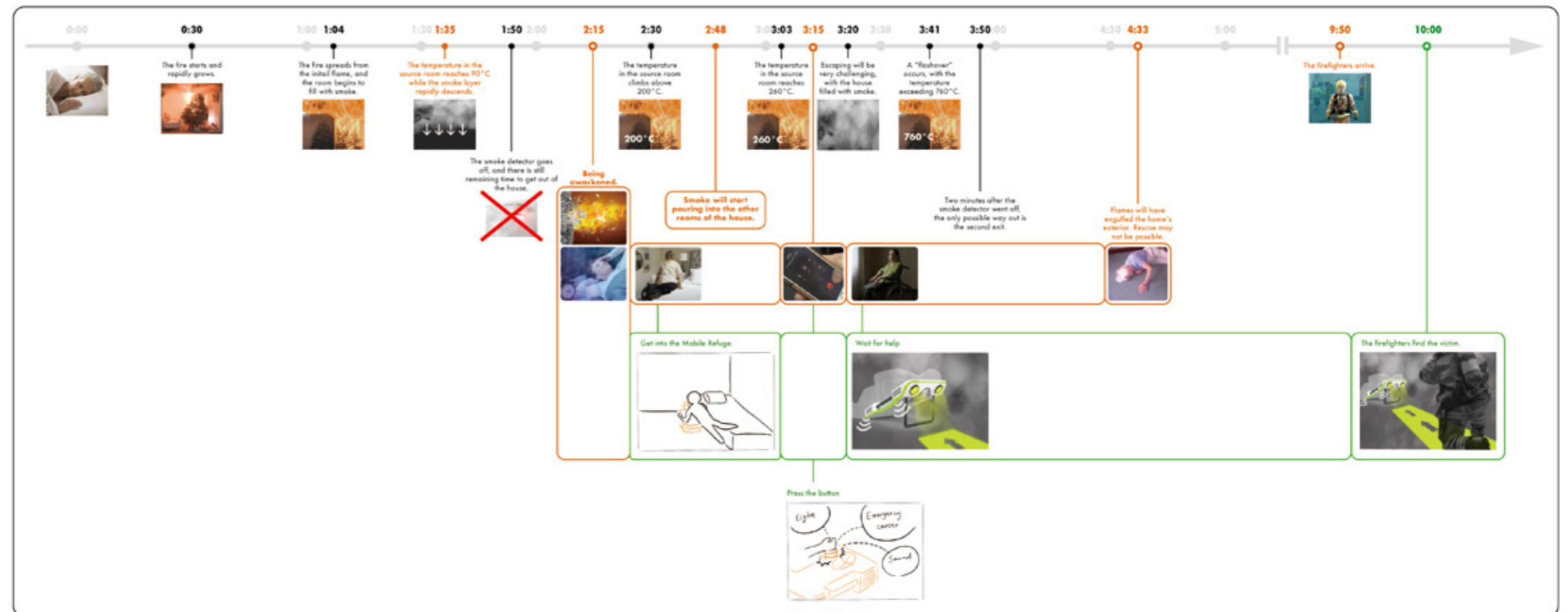
1. The rescuer can quickly infer the victim's life status
2. But in the environment of smoke, the rescuer is not able to see and infer anything, so in fact, face up is not beneficial to this situation.

Anthropometric Analysis

Peoplesizes Software is used to collect anthropometric data to define the size of Mobile Refuge. The data was set to be British males and females aged 25-50, and the dimension percentile is 1-99%. There are five dimensions I need to know, eye width and eyebrow to chin length, which are used to determine the size of the holes in the Mobile Refuge to place the face and provide fresh air. Secondly, the length and width of this product, so the data of body length, width, and calf-length also need to be collected. (Appendix)

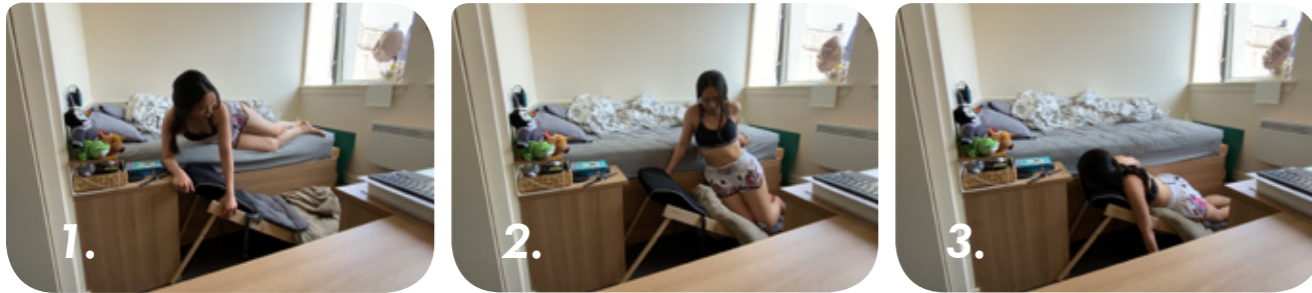
Timeline

After interviewing Gordon and Chris, I integrated their professional advice and data from the UK website to create this timeline. This timeline highlights the value of Mobile Refuge. The timeline compares an extreme fire incident with and without the use of Mobile Refuge. Usually, it only takes about five minutes to generate enough smoke to cover an entire room, and because the disability limits mobility, one can not escape by him/herself. Furthermore, according to the UK government website, on average, firefighters take about seven minutes to arrive at the scene after being notified, which is at the tenth minute, which is too late to rescue. On the other hand, one can stay alive until rescued, as highlighted in green.

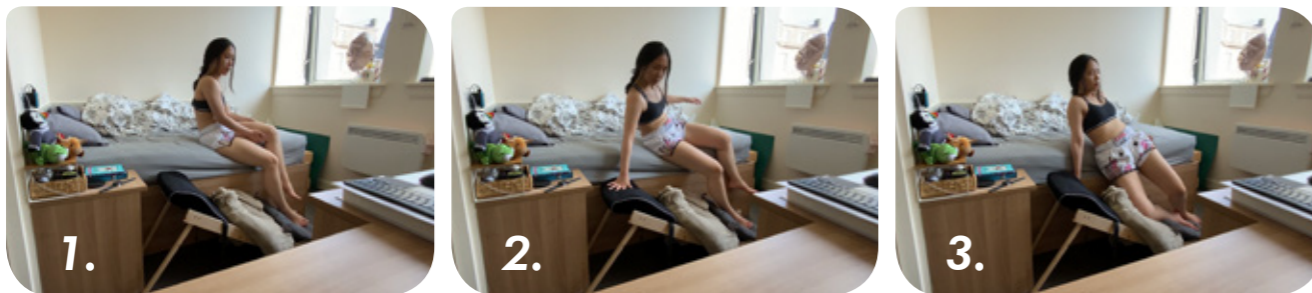


Prototyping & Sketches

Face down



Face up



1st Prototyping & Role-playing

The first prototype was made to have a specific understanding of the actual size. However, since this prototype was not very strong, I could not fully exert pressure on it during role-play, so the user experience was not entirely realistic.

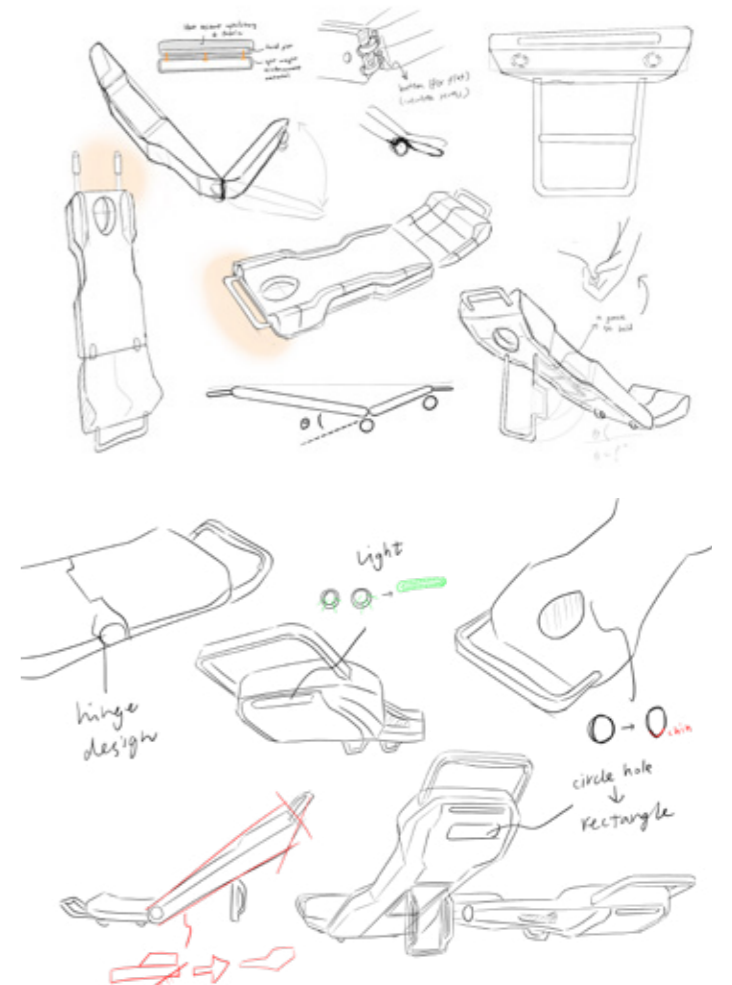
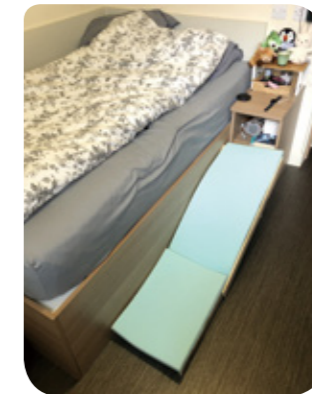
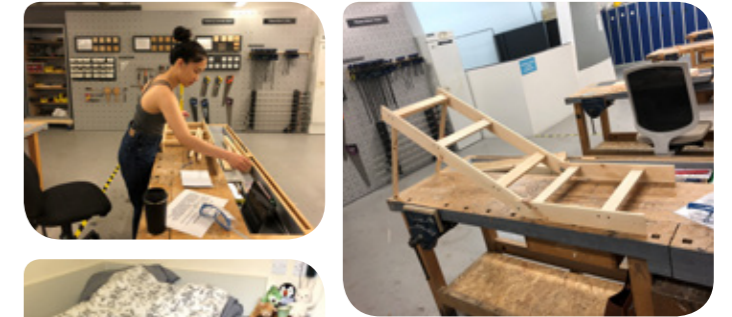
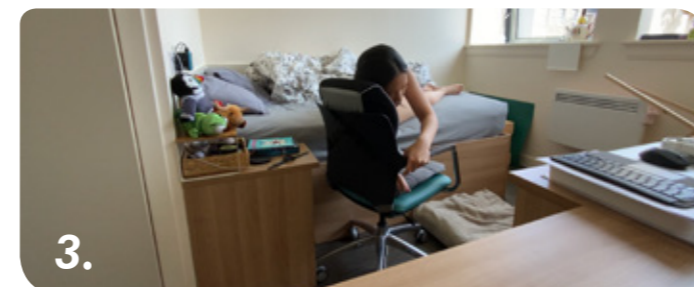
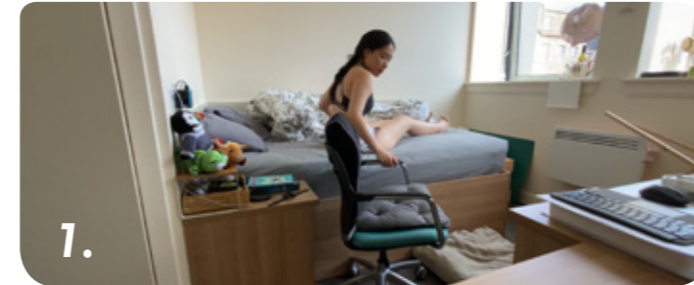
I tried two ways to transfer from the bed:

Face down

The concept of this transferring method was similar to the first try on the chair. Moreover, after the interview with Lorie, this transfer process was verified to be feasible. Target users have strong core muscle and upper body strength. They can easily perform this but only with a soft cushion on the product.

Face up

When I role-played the face-up process, I found it impossible not to use my leg muscles to support my body weight.



Before I made the prototypes, I used a chair and blanket to experience and test how target users would transfer to the Mobile Refuge. And this was also the first thought of “face down.” My intuition behavior led me to a face-down pose, which is also similar to the advised pose in a fire accident.

2nd Prototyping & Role-playing

The second prototype was the airbag concept.

1. The hole for the face: When the face is leaning against the oval hole, it is not very comfortable, so it is changed to a slightly sharper design at the bottom.
2. There is insufficient support for users when transferring, although the airbag can easily solve the big-size problem.

Where to put the product is actually not a problem. Each wheelchair user has different preferences for placing the wheelchair, and also, the wheelchair is able to be pushed away even if the brake is on. So The Mobile Refuge can be placed on the edge of the bed.

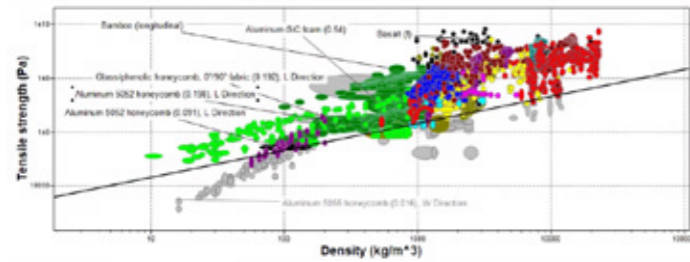
Detailed Design

Mainbody

The main body is composed of the frame, fabric, and cushion. The selection of fabrics and cushions needs to be fireproof following the British Standard 5867:Part 2:1980-Type B.

Frame Material Analysis and Selection

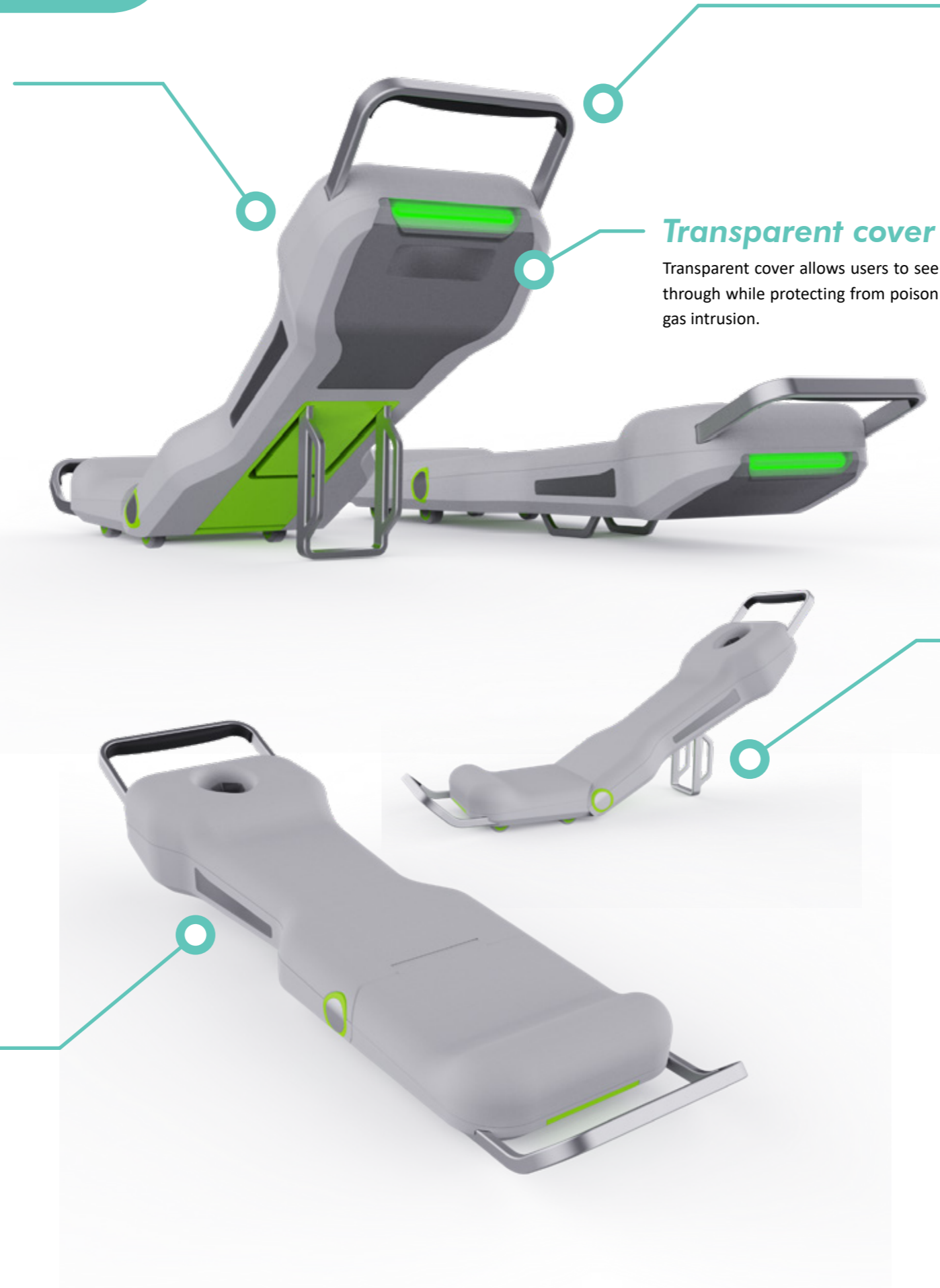
The following three materials are searched from the GRANTA EduPack for comparison. Basalt has the best maximum service temperature and tensile strength, yet the high density makes the product too heavy. The densities of Aluminum 5052 and bamboo are both within the acceptable range. Although Aluminum 5052's tensile strength is slightly lower than bamboo, the service temperature of Aluminum 5052 is better than that of bamboo. Furthermore, in the fire incident circumstance, the service temperature is the crucial factor in selecting **Aluminum 5052** as the material of the frame.



Alert

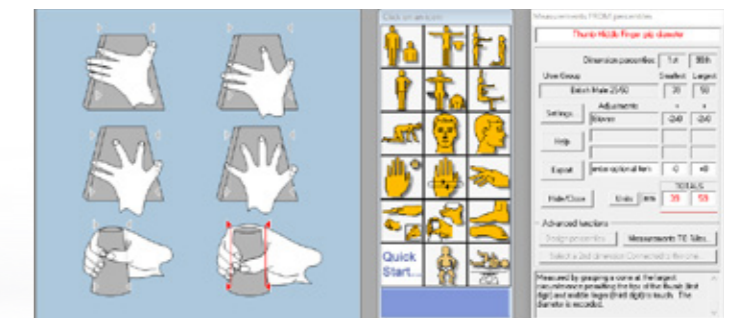
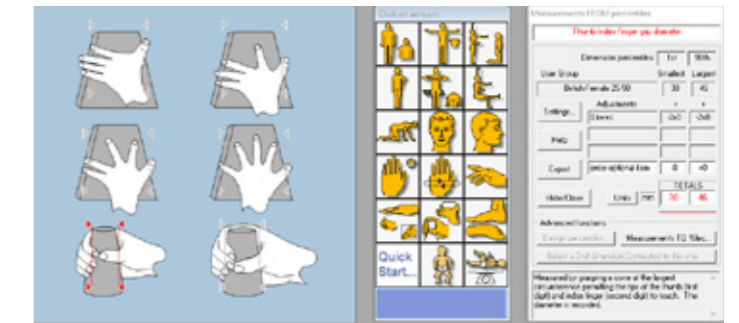
This feature is designed to give rescuers audible clues to find victims faster in environments with limited visibility. The audio's volume and frequencies are followed by the Standard on Personal Alert Safety Systems (Appendix).

Volume	(93 dB/W)
Rated Power	3 (W)
Frequency	150 (Hz) - 20 (kHz)



Handles

Using Peoplesizes software, the ideal diameter for a tool handle is calculated to be **33 (mm)**, which is also the finding that validates an existing biomechanical model of the hand.

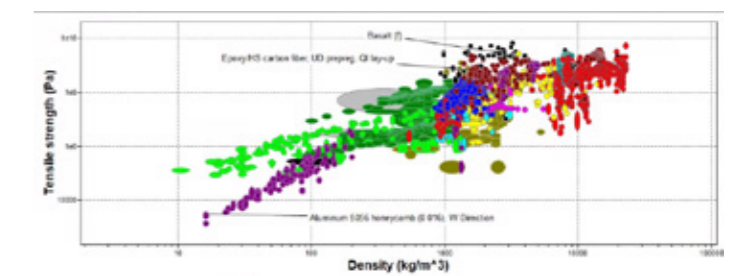


Transparent cover

Transparent cover allows users to see through while protecting from poison gas intrusion.

Handles & Foothold Material Analysis and Selection

Basalt has high tensile strength and the best heat resistance, yet its density is the highest of the three materials. Aluminum 5056 is the lightest material, but the tensile strength is too low. Epoxy/HS carbon fiber's heat resistance is slightly better than aluminum 5056. However, after calculation, the price of this product is almost ten times that of the other two materials, so it is not taken into account first. One of the necessary conditions for the handles and foothold is to bear the weight, so the Aluminum 5056 with a minor tensile strength was removed. Basalt was the final choice.

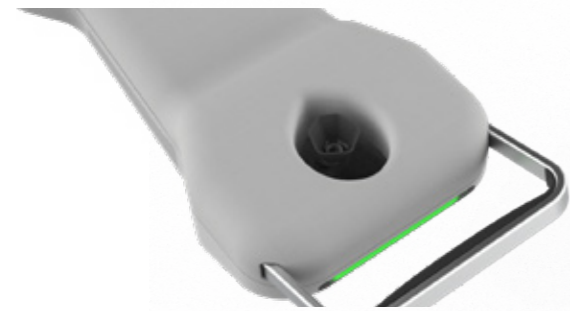


SCBA

The **open-circuit SCBA** is selected in this design because the close-circuit contains pure oxygen, which is unsuitable for fire circumstances. The SCBA should provide fresh air to **breathe for an hour** to achieve the PDS, and the volume is calculated as 11.34 (L). (Appendix)

Material of the Air Tank

The material of the air tank is typically made of aluminum, steel, or composite construction. The composite construction has the lowest density and the lowest lifespan that must be taken out of service after 15 years. Hence, the second priority material is **aluminum**. Besides, the shape of the air tank is different from the existing products, which are designed to fit the Mobile Refuge. Both features and materials of the existing air tank are applied to the design.



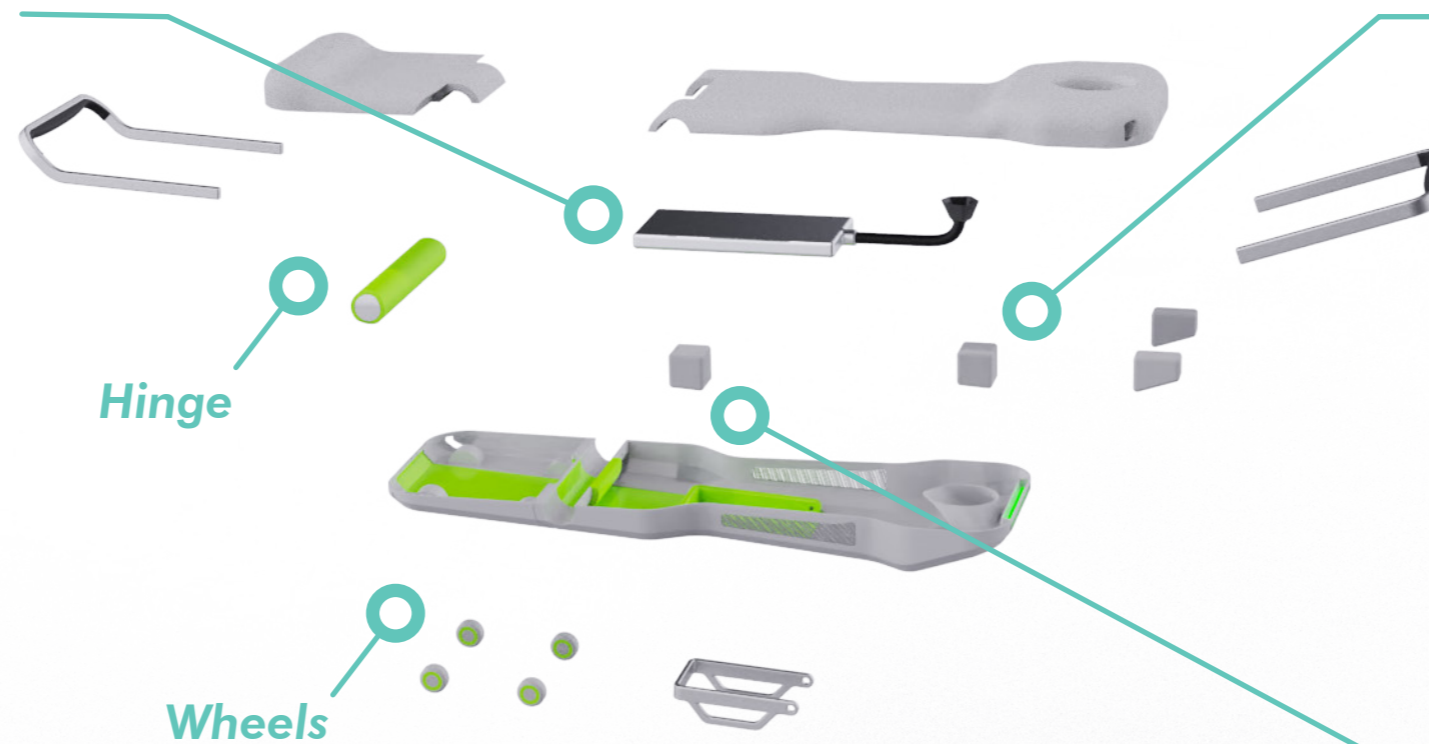
Hole for Breathing

The design of the sharp corners under the oval shape enhances the user experience. In addition, in an emergency, just lying directly on the Mobile Refuge and getting fresh air in a thick smoke environment without additional actions. An air mask is included in the hole.



Foothold

The foothold in the bottom is vital to support the weight, and also, when it is rotated out, it triggers to turn on all the features, including calling the emergency center, light, and alert. The user need only one move to use the product, considering the panic emotion in an emergency.



Hinge

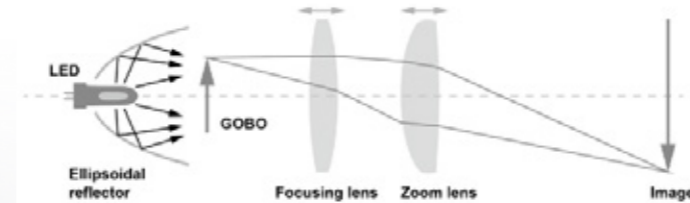
Wheels

Light

This light's design aims to increase the possibility for the victim to be located within a particular radius in an area with a lot of smoke and poor vision. The light projects arrows on the ground leading the victim toward themselves using **green LEDs**. The arrow projected on the ground can be fulfilled with the light glass projection principle.

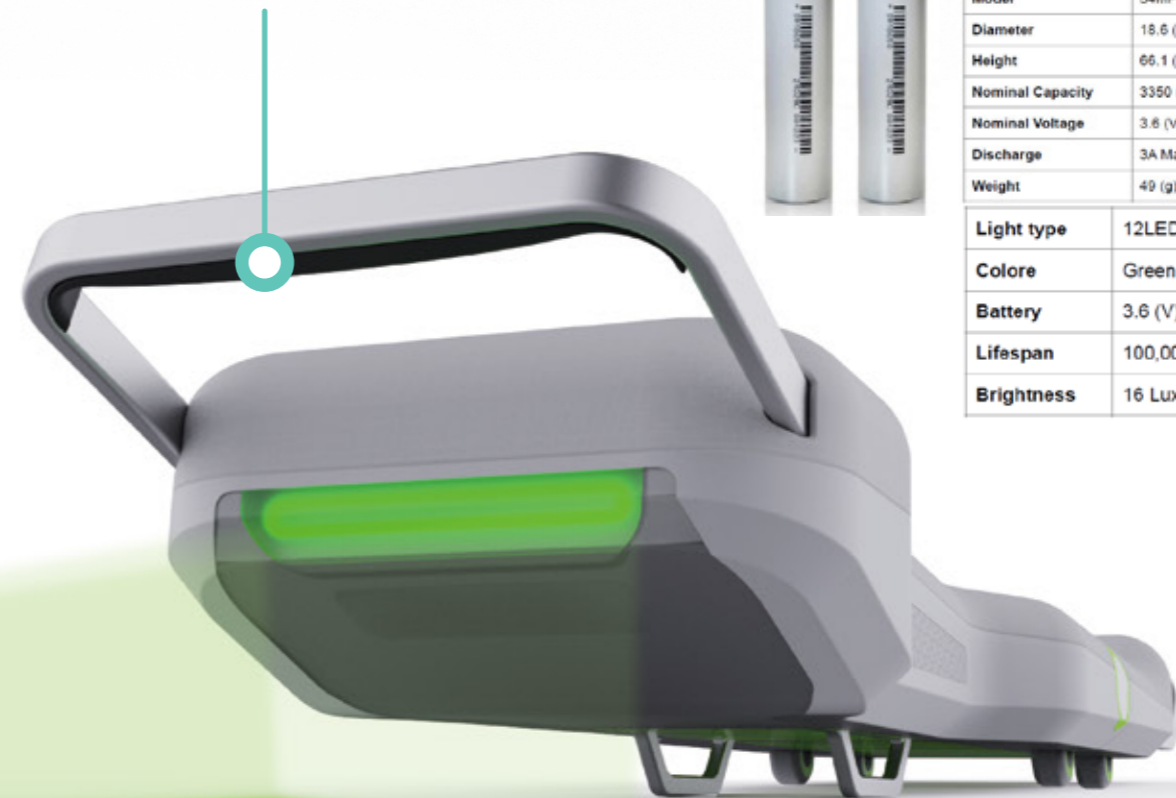
Why Green?

1. Green light performs less distortion when it is diffracted and scattered by smoke
2. People typically interpret green as "safe".



Handle Cushion

high-temperature resistance, increasing friction, improving the experience when holding



Communication System

Once the foothold has been rotated out, and calls may be placed, the communication system is activated to establish a connection to monitoring centers. This feature may make use of the Tunstall brand's existing system. Tunstall's product is called "The Lifeline Smart Hub," which connects to monitoring centers using IP technologies and VOIP over a 4G connection.



Voltage	3.3 (V)
Current	1.5 (A)

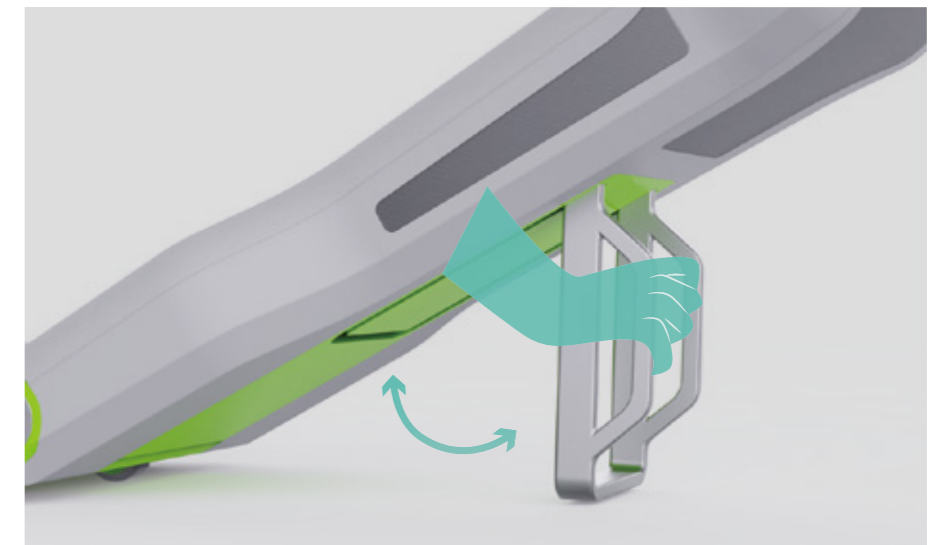
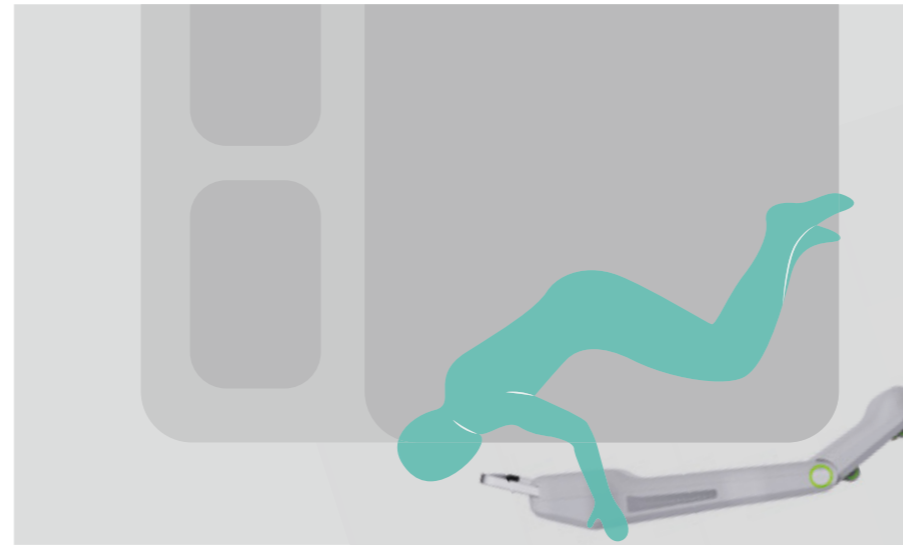
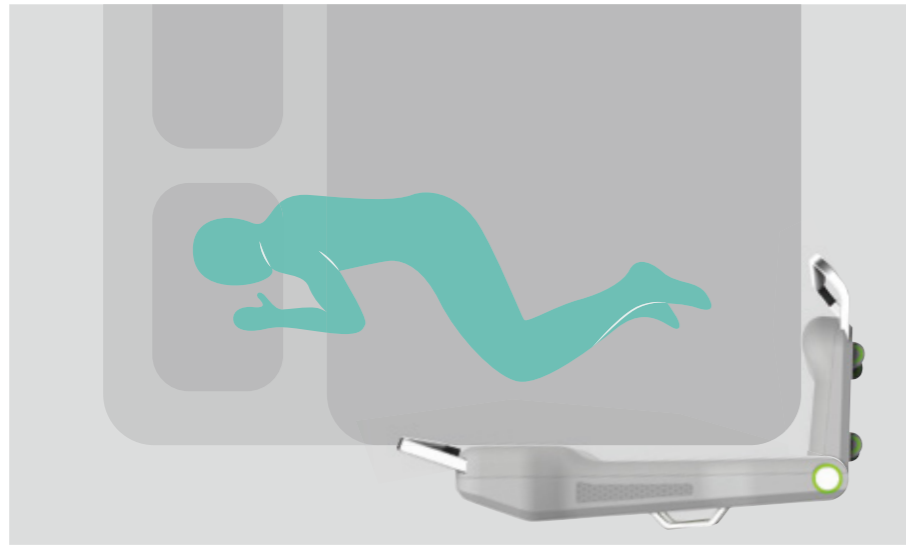
Batteries

The battery provides energy to lights, the alert, and the communication system. The product has to be used continuously for at least an hour, using the specifications to calculate the needed power of each feature. The total energy needed is 12.99 (Wh). **18650 battery** is selected to apply in this product and to provide enough energy, the product needs at least two 18650 batteries, which is 24.12 (Wh).



Brand	Sinowatt
Model	34MP
Diameter	18.6 (mm)
Height	66.1 (mm)
Nominal Capacity	3350 (mAh)
Nominal Voltage	3.6 (V)
Discharge	3A Max Continuous
Weight	49 (g)
Light type	12LED*2
Colore	Green
Battery	3.6 (V) 700 (mAh)
Lifespan	100,000 hours
Brightness	16 Lux

Usage Scenarios



Scale Model

