Design project 3

Mobility solution for Indian Army in Siachen region

Anshuman Dixit
176390005

Guided by :
Prof. Nishant Sharma

IDC
IIT Bombay

Mobility & Vehicle Design IDC School of Design
IIT Bombay

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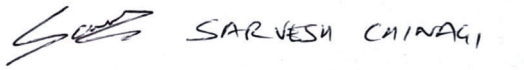
Name	Anshuman Dixit
Roll Number	176390005
Date	
Place	IDC School of Design, IIT Bombay, Mumbai
Signature	

Approval Sheet

This Mobility & Vehicle Design project report entitled “Mobility solution for Indian Army in Siachen region”, by Anshuman Dixit is approved in partial fulfilment of the requirement for Master of Design degree in Mobility and Vehicle Design.

Guide : Prof. Nishant Sharma 

Internal Examiner : 

External Examiner : 

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Anshuman Dixit
176390005
Mobility and vehicle Design
IDC, IIT Bombay

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INTRODUCTION

Motivation

Over the world's highest battlefield, military personnel faces a lot of problems while moving in the glacier terrains, apart from Cheetal and Cheetah choppers (only allowed for a very few regions) and HAL Dhruv helicopter ,no other vehicles are able to perform.

Siachen glacier presents a unique set of environmental challenges for the human body. These include low oxygen, partial pressure due to reduced barometric pressure at high altitude (HA), extreme cold, high levels of ultraviolet radiation and low levels of humidity.

Add to this, the constant threat of enemy action, which requires man and machine to be fighting fit and alert 24 X 7.

The extreme, harsh, cruel, body and mind numbing conditions at this height. Here, you are at risk of getting frostbite if your bare skin touches the trigger of your gun for more than 15 seconds.

A person's body cannot acclimatize to conditions over 5400 metres. If you stay at this height for long, you lose weight, stop eating and sleeping, and experience memory loss. Speech starts slurring. In short, the body just begins to collapse.

In the last 30 years, over 850 soldiers have been martyred at Siachen.

Source: Akhter, Z. (2016, Feb 13). The Strategic Importance of the Siachen Glacier for India .Retrieved from www.indiandefencereview.com: http://www.indiandefencereview.com/spotlights/the-strategic-importance-of-the-siachen-glacier-for-india

Scope of project

This device will ensure the safety and security of the soldiers. The project will encourage Indian military to send more soldiers in the region to guard which hopefully might lead the end of conflict eventually.
The vehicle will help the soldiers to sustain in the extreme conditions and could save a lot of precious lives
The device will allow the soldiers to move within the region and cover more than expected area in significantly less time , this will increase their frequency and efficiency and will give a huge advantage over enemy forces.

Siachen is strategically very important for India as long is India is in control in Siachen, there is no open passage to ladakh for Pakistan and Chinese forces , Pakistan army cannot link to china and pose a threat to India. Siachen stops both Pakistanis and Chinese army to attack India, a vehicle which eases the movement of soldiers will give a upper hand for Indian forces and can also lead to end of conflict in Indian favour

About Siachen

The Siachen Glacier is a glacier located in the eastern Karakoram range in the Himalayas just northeast of the point NJ9842 where the Line of Control between India and Pakistan ends. It is the longest glacier in the Karakoram and second-longest in the world's non-polar areas It falls from an altitude of 5,753 m (18,875 ft) above sea level at its head at Indira Col on the China border down to 3,620 m (11,875 ft) at its terminus.

Siachen Glacier lies in Northern Ladakh in the Karakoram, a mountain system originating from the Pamirs. This area is the most glaciated area outside the polar region comprising 22 glaciers. Troop deployment on the forward posts is from 18000 ft to 23000 ft. Temperatures dip down to below -55 degrees C and blizzards at 100 to 160 knots are a common phenomenon. In addition the area is criss-crossed by massive crevasses ranging from 40 ft in depth to practically bottomless ones. Besides, the confined glaciers have extremely unstable avalanche prone slopes. This terrain and the enemy shelling, restrict the area in which camps can be sited considerably and soldiers are advised to limit themselves to previously mapped routes only.

Source : Akhter, Z. (2016, Feb 13). The Strategic Importance of the Siachen Glacier for India . Retrieved from www.indiandefencereview.com: http://www.indiandefencereview.com/spotlights/the-strategic-importance-of-the-siachen-glacier-for-india/

Weather

“It was my fourth day at a post 21,000 feet high when the snow began pelting down in a blizzard lasting 22 days.
“It was a white-out,” which means zero visibility even at daytime.
What followed was severe rationing. “There was no communication, and our stocks were coming down. We had to use everything sparingly, especially fuel.”
From cooking food on a heater and melting snow for drinking water to lighting up the prefabricated snow shelters, kerosene is the magic substance. “It’s the lifeline, and you have to make it last till the next supply. You don’t know when it will come next because of the weather.”
There are only very small windows to stock up, because the weather changes swiftly and suddenly. Plus, there are very few places that a supply-carrying helicopter can land, and very little load that it can bring in.

Before being deployed to Siachen, soldiers undergo rigorous training at the Siachen Battle School, located near the base camp, and get acclimated to the conditions. They learn rock-climbing and how to handle ice walls as well as negotiate crevasses
- Major Saurabh Kaithat

Source : China, M. A. (2017, February 16). Everyday is a story: Army officers recall their time at Siachen Glacier. Retrieved from www.hvk.org: http://www.hvk.org/2016/0216/74.html

Living Quarters

“There are no beds. We sleep on makeshift beds which lie on top of supplies that we store in the shelter. There is no other place to keep them,”
“It takes three hours to heat up a bucket of water for a wash,” “Everything that we take for granted and normal down here does not exist there.”
- Col Manav Sharma, 35

In that freezing temperature, a wash should be the last thing on a soldier’s mind. But, as Sharma says, there is a reason behind it. “One should try to be as normal as possible in such desolation. The first task is to keep yourself fit, only then can you fight. Stick to your routine.”
While they bathe inside the pre-fabricated snow huts, crevasses usually serve as toilets, with a ladder leading down into them. The soldiers go a little distance from the post, so that the excreta does not get mixed up with the snow that has to be melted for drinking water.
When soldiers venture out, they tie themselves to each other so that they don’t drift apart if the weather changes and they are caught in a snowstorm or get plunged into a hidden crevasse.
- Col Samir Gupta

Source : Chhina, M. A. (2017, February 16). Everyday is a story: Army officers recall their time at Siachen Glacier. Retrieved from www.hvk.org: http://www.hvk.org/2016/0216/74.html

Medical care

Every post has a nursing attendant, and every company has a doctor which is a huge morale booster.“A doctor is a big psychological factor. When troops know there’s a doctor around, that’s reassurance,”
- Col Gupta

However, doctors themselves live in constant apprehension of a medical emergency. “The evacuation chain is very robust, provided the weather holds good. During my time, we had a soldier with splinter injuries due to enemy artillery shelling. We could not evacuate him for three days because no helicopter could land due to bad weather,”

There were situations, “where the weather packed up for four days and a patient suffering from high-altitude pulmonary oedema was lost because he couldn’t be evacuated to a lower altitude immediately”.
Col K V S Hari Kumar.

Source : Chhina, M. A. (2017, February 16). Everyday is a story: Army officers recall their time at Siachen Glacier. Retrieved from www.hvk.org: http://www.hvk.org/2016/0216/74.html

The Mind

The idea is to keep as busy as possible, so through those 22 days of the blizzard, he volunteered for whatever task came up — including fetching water and writing the operational log, just to keep active.
“You’ve to keep the team in good humour. I used to make the boys write letters home compulsorily,”
- Lt Col Sharma.

With everyone wearing the same clothes, eating the same food and sleeping in the same shared shelter, the line between an officer and a jawan is very thin, say the officers. Ten to 11 soldiers, including the officer in command of the post, generally share one fibreglass shelter.
Apart from one another, the one diversion that soldiers have from lurking inner fears, loneliness and depression are dogs. “Almost every post has a dog. We had one called Pisti (a mountain stray dog) whose specialty was that she would have breakfast at one post, then travel for lunch to another and have dinner at a third post. She knew exactly where her next meal was coming from, so we used to send letters tied to its collar,”
- Lt Col Manav.

Source : Chhina, M. A. (2017, February 16). Everyday is a story: Army officers recall their time at Siachen Glacier. Retrieved from www.hvk.org: http://www.hvk.org/2016/0216/74.html

RESEARCH

Experiences

In conversation with Major G. P. Singh
Flight Lieutenant Jhonson Jhon S

Siachen military region can be divided in three parts
- Base camp (12000 feet)
- Southern glacier (15000 ft)
- Northern glacier (18000-20000 ft)

Majorly training is about getting use to the situation and operate efficiently.
A period of 90 days is to be served at the post from the glacier
The march begins from the base camp towards the post

Soldiers march in a straight line harnessed to each other in a group of six with the experienced guide in the front leading, this soldier have got years of experience of Siachen.

Most critical part is crevasses which can show up in any season any where , therefore a defined path is followed strictly

Apart from the unidentified crevasses and avalanches, the most challenging task it to climb on extreme gradient which could be more than 45 degrees
White-out and hypothermia is the major physical issues that happens within the journey as the soldier exert, the sweat get crystallize due to low temperatures.
Once soldiers are at the post they majorly have got these few tasks that require considerable mobility
To collect the supplies dropped from the helicopters
Patrolling in the region
Answering the nature's call
Rescue fellow soldier
Construct the makeshift helipads to land
As mobility only helicopters like cheetah , cheetal are used and snow mobile is used that too at particular locations
Developments and testing of drones are in progress at base camps

Source : Chhina, M. A. (2017, February 16). Everyday is a story: Army officers recall their time at Siachen Glacier. Retrieved from www.hvk.org: http://www.hvk.org/2016/0216/74.html

Major Medical Problems

High Altitude Pulmonary edema (HAPE): is a life-threatening form of non-cardiogenic pulmonary edema (fluid accumulation in the lungs) that occurs in otherwise healthy mountaineers at altitudes typically above 2,500 meters (8,200 ft).

Acute Mountain Sickness: Other names for this condition are altitude sickness or high altitude pulmonary edema. It typically occurs at about 8,000 feet, or 2,400 meters, above sea level. Dizziness, nausea, headaches, and shortness of breath are a few symptoms of this condition.

Carbon Monoxide Poisoning : Carbon monoxide is a colourless, odourless gas. Cases of poisoning can take place. This is particularly dangerous because the symptoms are not immediately apparent. The men inside the tent or the hut will be found dead in the morning in case of severe carbon monoxide poisoning.

Disposal of Human Waste : This is a serious problem because maintaining suitable thermal environment at which the micro-organisms affecting degradation can survive is difficult. Chemicals are expensive for the amount of faecal matter to be degraded.

Acclimatised Reserves for Reinforcement : At times due to heavy casualties during operations reinforcements are to be rushed immediately to defend the posts. These are picked up from low lying areas and dropped on the forward location and most are non acclimatised, with inherent risk of AMS/HAPO.

Injuries due to Non Enemy Action (NEA): Crevasses are caused where the glaciers take turns on their outer sides and movement of glaciers. These crevasses have hard icicles formation at their bottom capable of piercing through the body like a spear and low temperatures of minus 200 degrees and below.

Source : en.wikipedia.org. (2019, May 15). Retrieved from Siachen conflict: https://en.wikipedia.org/wiki/Siachen_conflict

Training and Acclimatization

Only those who are certified medically fit can proceed to the next stage
Travel to high altitude exposes the human body to a variety of stresses, the most prominent being reduced available oxygen with increase in altitude due to reduced partial pressure of oxygen
Physiological and molecular readjustments encompassing acclimatization, namely, hypoxic ventilatory response, diuresis, increased cardiac output, improved oxygen carrying capacity and cerebral blood flow, Hypoxia

One main issue soldiers face is to climb the extreme heights with the angle of inclination could be more than 50-60 degrees.
Soldiers needed to carry special tools and gear to overcome this task like mountaineering boots , crampons, ice axe , climbing harness, etc.

One major task for the soldiers is to construct makeshift helipads for the helicopters to land for rescue and other purposes.
There are very few particular places on the glacier where these cheetah helicopters can land and take off.

Soldiers need to collect the air dropped supplies back to the post as soon as possible.

Extreme Cold Weather Clothing System (ECWCS)

The Army spends about ₹500 crore every year on basic personal items for soldiers.
The items include super high altitude clothing such as rucksack special socks, thermal insoles, snow goggles and High Altitude Pulmonary Oedema (HAPO) bag. These are currently imported and are quite expensive.

Lightweight Under-shirt & Drawers

Base Layer: Worn next to skin by itself or in conjunction with other levels for added insulation and to aid in the transfer of moisture. Constructed with Polartec Power Dry Silk-weight material, this layer is highly breathable, wicks moisture away from the skin and dries fast, providing evaporative cooling in warmer weather and insulating in cool weather – all with less weight and bulk than previous systems.

Mid-Weight Shirt & Drawers

Constructed with Polartec Power Dry grid material, this layer provides extra warmth in cooler conditions but still wicks moisture away and dries fast. The material offers stretch for increased comfort and is lighter weight with less bulk than previous systems.

High-Loft Fleece Jacket

Constructed with Polartec Thermal Pro® material the insulation on the Level III Jacket creates air pockets that trap air and retain body heat providing outstanding warmth without weight. With excellent breath-ability, the Level III jacket dries quickly with increased warmth while maintaining lower bulk and increased durability than previous systems.

Extreme Cold Weather Clothing System (ECWCS)

Wind Jacket

Shell Layer: Designed to be worn with base and insulation levels in transitional environments to provide wind and sand protection. Constructed from stretchable nylon with a water resistant finish, this full-zippered jacket provides wind and sand protection with low weight and bulk.

Soft Shell Cold Weather Jacket & Trousers

Constructed with stretchable and breathable water resistant materials, the Jacket and Trousers provide light-weight, low bulk and extreme comfort for movement.

Extreme Wet/Cold Weather Jacket & Trousers

Constructed with two-layer GORE-TEX and seam-sealed throughout, the Jacket and Trousers provide an outstanding light-weight, completely waterproof, wind-proof and breathable level of protection against the elements with 50% less bulk than previous systems. Level VI also incorporates near infrared signature reduction technology further enhancing soldier survivability.

Extreme Cold Weather Parka & Trousers

Constructed with an outer shell fabric that has a water resistant finish and with PrimaLoft Sport thermal bonded high-loft insulation, Level VII is highly durable and breathable. The Parka and Trousers maintain warmth even when wet and provide protection in extreme cold conditions during static operations.

Source: Peri, D. (2017 , May 17). Indigenous gear for Siachen soldiers. Retrieved from www.thehindu.com: https://www.thehindu.com/news/national/indigenous-gear-for-siachen-soldiers/article18469169.ece

Load consideration

The Indian army deploys more than one hundred thousand soldiers in the high-altitude border areas. They are routinely subjected to load carriage operations in this difficult terrain.
Siachen is the highest battle zone in the world hence it offers tremendous challenges for the soldiers weather it is climate, altitude, pressure or terrain , all eventually adds to the load carrying challenge for a soldier.
It is strategically important for a soldiers to reduce the risk of morbidity and mortality among this population.
It is hypothesized that the maximum aerobic capacity of soldiers will be significantly reduced with increasing altitude compared to sea level. The amount of load to be carried by Indian soldiers will also be reduced with increasing altitude for a given walking speed.

The load carried by Indian soldiers in Siachen region is more than the soldiers in other parts of the country as soldiers in Siachen needs to carry the fuel as well, this fuel is the lifeline because even to make the food edible it is needed to be boiled which requires fuel to be burnt.
A good amount of kerosene is needed to carry to make sure survival if stuck in between the trek which is very common in Siachen due to unpredictable weather conditions.

Each soldier carries an ice axe, his weapon and a colossal battle load of 20-30 kg.

Keeping this in mind and increasing the load index with 10 kg more (for more backup fuel), further the research is done based on the consideration for a soldier to carry 40 kg of load.

Source : Chatterjee, T. (2017). Soldiers' load carriage performance in high mountains: a physiological study. Military medical research .
Sandhu, V. (2016 , February 20). Life in Siachen. Retrieved from www.business-standard.com: https://www.business-standard.com/article/specials/life-in-siachen-116021900798_1.html

Design Direction

In Siachen region the environment and surface is highly unpredictable, hence the solution must not demand any added assistance or responsibility from the soldier
During the interviews it was evident that any device which needs to be operated or need ant kind of assistance is highly not recommended.

However autonomous vehicle is one direction which could be a solution but , the uneven terrains, unpredictable weather and extreme temperature would require a technology which is not yet developed to provide any kind of autonomy.

Considering the facts and recommendations from the interviews, development of an walking assist device have high potential to work in such conditions.

Design direction of developing a walking assist exoskeleton system not just demands to understand the technologies but also the wearability and form of the product.

Problem identification

To proceed further it is important to freeze one distinct problem to address in a wide range of challenges Siachen offers .
In many problems like low pressure and temperature and extreme terrains, the major problems a soldiers faces is the extreme gradient on which they trek with heavy load of 25 kg on their back from base camp to the post.
The primary focus is to design a device which could help them perform this task in a more convenient and efficient manner.

Task

To better understand the problem a task was performed where similar physical activity was involved.

A Weight of 40 kg was to be carried over different terrains with different configurations to better understand the behaviour and ability of body to move under such circumstances.

Three different types of terrains were taken in consideration along with one obstacle task.
Load distribution was also done in three different manners

Weight Distribution

S. No.	Load distribution	Discription
1	Load Distribution 1	Here entire load of 40 kg was carried on the back in the rucksack
2	Load distribution 2	In this , major load (25kg was on back and 15kg at front)
3	Load distribution 3	Here load was evenly distributed all over the body

Task Terrain

S. No.	Type	Discription
1	Terrain 1	Staircase
2	Terrain 2	Staircase
3	Terrain 3	Slope
4	Obstacle	A 2 ft Obstacle

Terrain 1

Terrain 2

Terrain 3

Obstacle

Observations based on different types of load carrying experiments

Experiment 1

As the entire weight was on the back, the load was pulling the body to the back, to counter that while maintaining balance the upper body bends to change the CG to a desired position.

Due to this bend , issues of cramps and pain happened on the lower back.

Hence it is very important to adjust load on other body parts

Experiment 2

Here the weight was distributed to front and back due to this it was a bit easy to maintain the bend as the front load was helping to pull the body forward.

However while coming down the staircase the front load was pulling the body eventually increasing the speed of the movement (specially on slopes)

Hence it required slow and steady movement while coming down.

Experiment 3

When the load was distributed all over the body the bend to the body was not required to keep anymore however load on the legs were restricting to take steps.

Whereas load carried on the hands was not obstructing the flow of moment.

As there was no huge load on the upper body hence there were less jerks on the waist, however jerks on the ankles were very high as weight was directly above the ankle.

	Positive	Negative
Load distribution type 1	- Load segregation was closer to CG - Less time to prepare - Freedom of limbs	- Point load triggered to vertebrate - Bad posture - Less balance in movement
Load distribution type 2	- Load segregation was closer to CG - Load is balanced on torso - Equal load division	- Compromised posture - Too much weight on shoulders - Hands engagement
Load distribution type 3	- No segregated point load - Load doesn’t trigger one body part - Good posture	- Lack of free movement - Slow body reflexes - Significantly slow movement

Analysis and Considerations

To further analyse the different experiments to get a productive insight which help in defining the brief further it is important to consider different environments and weight distribution methods against each other according to specific considerations which define the demands this exercise in almost all aspects.

Following are the considerations taken in to analyse the different forms of excersises with each other to get a satisfactory conclusion.

Mental demand : How much mental and perceptual activity was required (Eg.thinking, deciding, calculating ,remembering, looking searching, etc)

Physical demand : How much physical activity was required (Eg. pushing, pulling , turning controlling etc)

Performance : How successful do you think you were in accomplishing the goals of the task set. How much satisfied ?

Frustration : How insecure irritated discouraged, stressed annoyed versus secure gratified content relaxed and complacent did you feel during the task

Time : How much time did it take for the preparation and execution of the task ?

Freedom of movement : How much freedom of movement did it felt while performing the task ?

Posture : How correct the deal human body posture was maintained

Physical demand

The Borg Scale takes into account your fitness level: It matches how hard you feel you are working with numbers from 6 to 20; thus, it is a “relative” scale. The scale starts with “no feeling of exertion,” which rates a 6, and ends with “very, very hard,” which rates a 20. Moderate activities register 11 to 14 on the Borg scale (“fairly light” to “somewhat hard”), while vigorous activities usually rate a 15 or higher (“hard” to “very, very hard”). Dr. Gunnar Borg, who created the scale, set it to run from 6 to 20 as a simple way to estimate physical effort.

How you might describe your exertion	Borg rating	Examples (for most adults <65 years old)
None	6	(for most adults <65 years old)
Very very light	7-8	Tying shoes
very light	9-10	Chores like folding clothes that seem to take little effort
Fairly light	11-12	Walking through the grocery store or other activities that require some effort but not enough to speed up your breathing
Somewhat hard	13-14	Brisk walking or other activities that require moderate effort and speed your heart rate and breathing but don’t make you out of breath
Hard	15-16	Bicycling, swimming, or other activities that take vigorous effort and get the heart pounding and make breathing very fast
Very hard	17-18	The highest level of activity you can sustain
Very very hard	19-20	A finishing kick in a race or other burst of activity that you can’t maintain for long

Source : The Borg Scale of Perceived Exertion. (n.d.). Retrieved from www.hsph.harvard.edu: https://www.hsph.harvard.edu/nutritionsource/borg-scale/

Mental Demand

Rating 5
Highly engaging : Here immense mental engagement is done in order to complete the task. Even a second of mental disturbance compromise the entire task .
Rating 4
Majorly engaging : A lot of mental work is been done to achieve desired goal, disturbances affect the task adversely
Rating 3
Fairly engaging : Significant mental engagement is done to accomplish the task, disturbances does not cost much.
Rating 2
Very light : Here a very limited mental engagement is done
Rating 1
None : Not at all engaging

Performance

Rating 5
Performance far exceeded expectations due to exceptionally high quality of work performed in all essential areas
Rating 4
Performance consistently exceeded expectations in all essential areas and the quality of work overall was excellent. Goals were met.
Rating 3
Performance consistently met expectations in all essential areas, at times possibly exceeding expectations, and the quality of work overall was very good. The most critical annual goals were met.
Rating 2
Performance did not meet expectations – performance failed to meet expectations in one or more essential areas, and/or one or more of the most critical goals were not met.
Rating 1
Performance was consistently below expectations in most essential areas, and/or reasonable progress toward critical goals was not made. Significant improvement is needed in one or more important areas.

Frustration

Rating 5
Extremely frustrating : Extreme level of frustration where it is not at all possible to perform the task.
Rating 4
Discomfort : In cases of high level of mental discomfort leading to adverse effects on the performance of tasks
Rating 3
Moderately frustrating: In cases where the frustration is annoying enough to hamper the quality of the task.
Rating 2
Unpleasant : In cases when there is mild mental discomfort.
Rating 1
None : In these cases the posture is not at all bearable to be kept, this is the last stage after which a person falls on the ground

Time pressure

Rating 5
Extreme : Here most important part of the task is to complete it in particular preset time.
Rating 4
High : In this case there is a very high importance of time. Wastage of time here leads to major negative impact on the task
Rating 3
Significant : Here time is one major concern.
Rating 2
Less : In this case the pressure of time is very less
Rating 1
None : No pressure of time

Freedom of Movement

Rating 5
Extreme : In this case a person is able to freely move anywhere he/she wants. No force is acting upon him/her to restrict the desired movement except gravity.
Rating 4
High : In this case a small force is acting against the free body movement (Gravity)
Rating 3
Significant : Here Freedom of movement is been limited to distinct body parts like hands and legs (Limbs)
Rating 2
Low :Here a major force is acting on the entire body to restrict a desired movement.
Rating 1
None : This case represent the freedom of movement to be nil, where a person is not able to move any part of the body

Posture

Rating 5
Ideal (highly maintained) :This rating represents the ideal posture of human body for efficient walking.
Rating 4
Satisfactory posture : This represents the posture which is not ideal but can be termed as a good posture, the angles might not be exactly meeting the ideal demand , however there is no problems in keeping this posture.
Rating 3
Unpleasant : In cases where the posture is somewhat unpleasant but still does not directly hampers walking or other movements of walking or others movements of body.
Rating 2
Poor : In cases when the posture is not easy to maintain and creates unbalance and body pains in different parts of body.
Rating 1
Unbearable : In these cases the posture is not at all bearable to be kept , this is the last stage after which a person falls on the ground.

Source : Sullivan, G. M. (2013). Analyzing and Interpreting Data From Likert-Type Scales. Journal of Graduate Medical Education . Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3886444/

Analysis chart 2

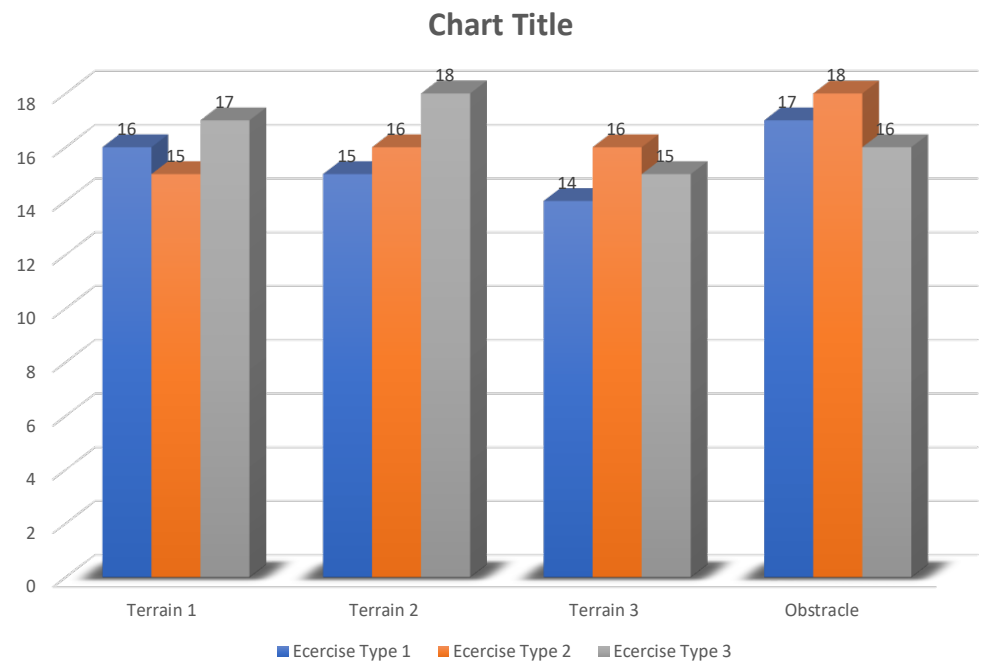
To further analyse the observations a detailed chart was made.
This chart shows the 7 considerations taken in account against the different types of exercises performed, these exercises are been further subdivided into four parts based on the types of terrains.
Based on the scale description for different considerations shown previously, ratings were marked against each type.

S. no.	Considerations	Escersise type 1				Escersise type 2				Escersise type 3			
		Entire load on the back				Load distribution front and back				Evenly load distribution			
		Terrain 1	Terrain 2	Terrain 3	Obstacle	Terrain 1	Terrain 2	Terrain 3	Obstacle	Terrain 1	Terrain 2	Terrain 3	Obstacle
1	Physical demand	16	15	14	17	15	16	16	18	17	18	15	16
2	Mental demand	3	4	5	5	3	3	5	5	2	3	4	4
3	Performance	3	2	3	2	3	2	2	2	3	3	2	2
4	Frustration	3	4	4	4	2	3	3	4	1	2	2	3
5	Time pressure	2	3	2	1	2	3	2	2	4	4	3	3
6	Freedom of movement	3	3	2	3	3	2	2	3	2	2	2	2
7	Posture	2	1	2	1	2	1	2	1	5	4	3	2

These ratings were further analysed differently according to particular consideration taken one at a time.
Doing this will show how different considerations were affected due to the terrain and load distribution type.
This will eventually lead to the important insights directing to the most important factors which must be taken in account while designing the system.

Physical demand Analysis

	Exercise 1	*Exercise 2*	*Exercise 3*	*Recommendation*
Terrain 1	*16*	*15*	*17*	*Exercise 2*
Terrain 2	*15*	*16*	*18*	*Exercise 1*
Terrain 3	*14*	*16*	*15*	*Exercise 1*
Obstacle	*17*	*18*	*16*	*Exercise 3*

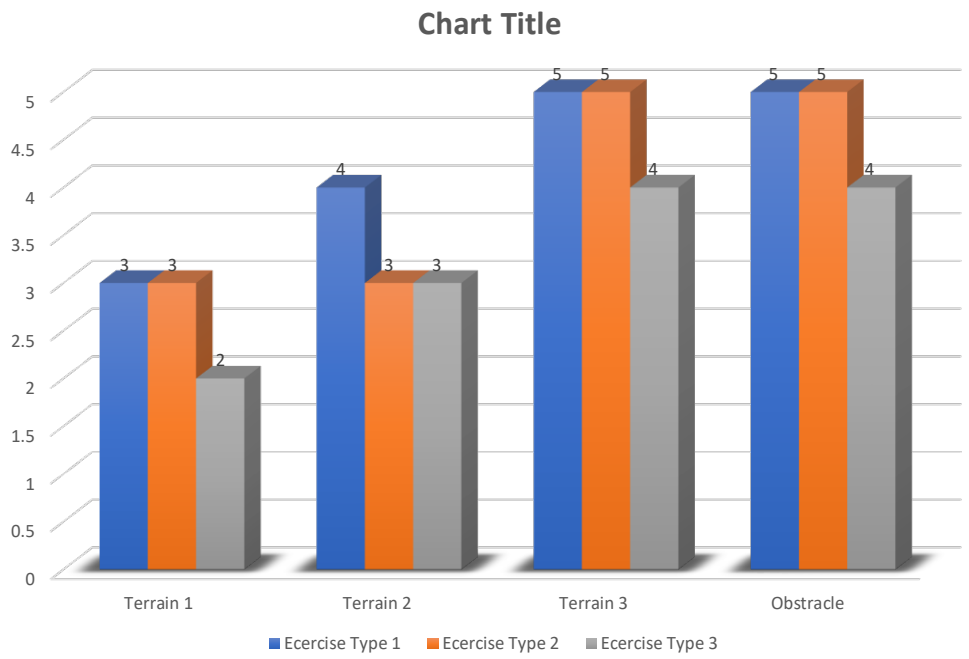


How much physical activity was required (Eg. Pushing, pulling , turning controlling etc)

Here exercise type one apparently is recommended one as compared to other two types as in experiment 1 limbs were not loaded with weight and were free to move, however concentrated load disturbs the balance of the body.

Mental demand Analysis

	Exercise 1	*Exercise 2*	*Exercise 3*	*Recommendation*
Terrain 1	*3*	*3*	*2*	*Exercise 3*
Terrain 2	*4*	*3*	*3*	*Exercise 2-3*
Terrain 3	*5*	*5*	*4*	*Exercise 3*
Obstacle	*5*	*5*	*4*	*Exercise 3*

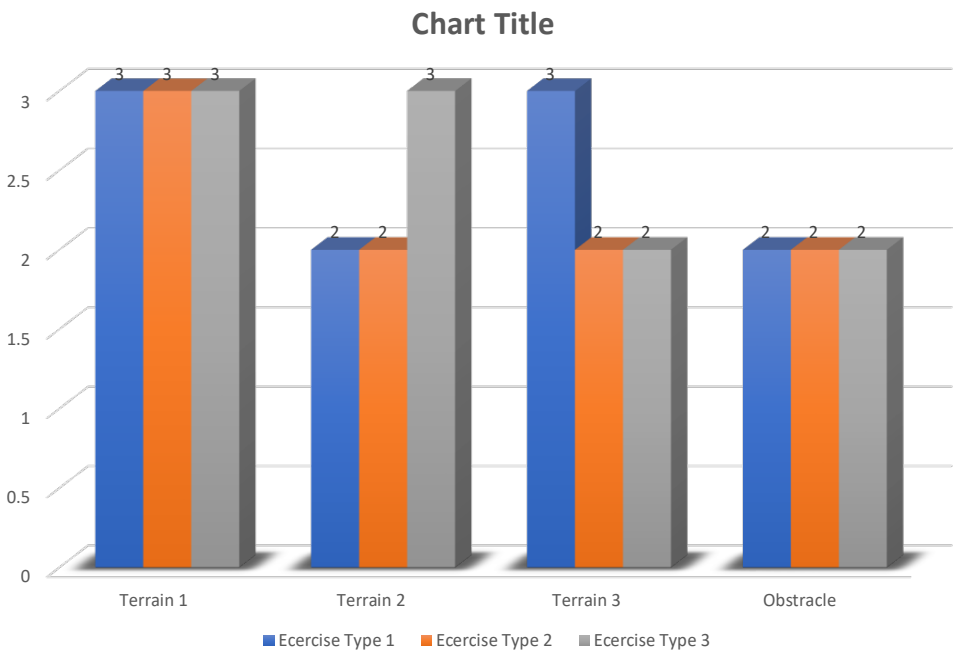


How much mental and perceptual activity was required (Eg.thinking, deciding, calculating ,remembering, looking searching, etc)

Here exercise type three appears to be the most recommended one as compared to other two types as the concentrated load requires high-mental alertness to make sure the load does not get imbalanced.

Performance

	Exercise 1	*Exercise 2*	*Exercise 3*	*Recommendation*
Terrain 1	*3*	*3*	*3*	*Exercise 1-2-3*
Terrain 2	*2*	*2*	*3*	*Exercise 3*
Terrain 3	*3*	*2*	*2*	*Exercise 1*
Obstacle	*2*	*2*	*2*	*Exercise 1-2-3*

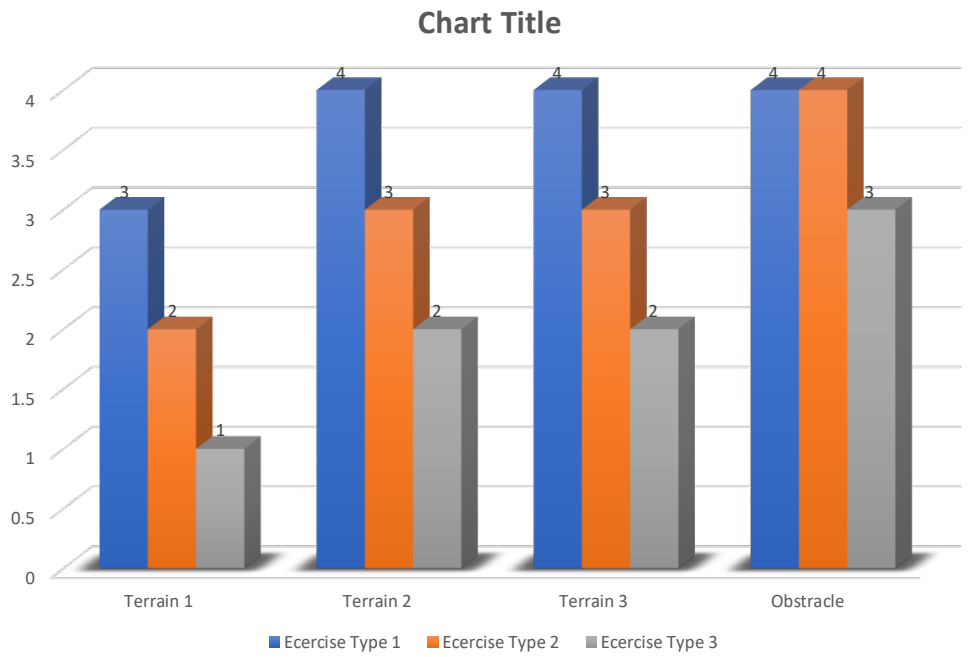


How successful do you think you were in accomplishing the goals of the task set. How much satisfied ?

Here exercise type 3 is the most recommended one as in this exercise the load was segregated hence less mental effort was required.

Frustration

	Exercise 1	*Exercise 2*	*Exercise 3*	*Recommendation*
Terrain 1	*3*	*2*	*1*	*Exercise 3*
Terrain 2	*4*	*3*	*2*	*Exercise 3*
Terrain 3	*4*	*3*	*2*	*Exercise 3*
Obstacle	*4*	*4*	*3*	*Exercise 3*

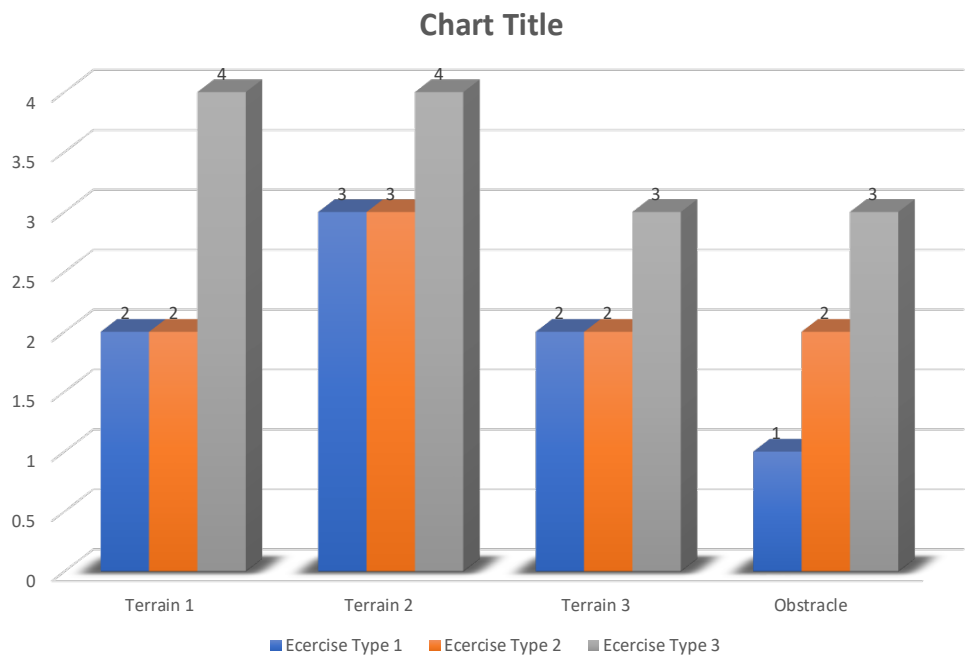


How insecure irritated discouraged, stressed annoyed versus secure gratified content relaxed and complacent did you feel during the task ?

In third case the level of frustration is least as compared to other two exercises, as the only load is evenly distributed due to which bending is not required.

Time Pressure

	Exercise 1	*Exercise 2*	*Exercise 3*	*Recommendation*
Terrain 1	*2*	*2*	*4*	*Exercise 1-2*
Terrain 2	*3*	*3*	*4*	*Exercise 1-2*
Terrain 3	*2*	*2*	*3*	*Exercise 1-2*
Obstacle	*1*	*2*	*3*	*Exercise 1*

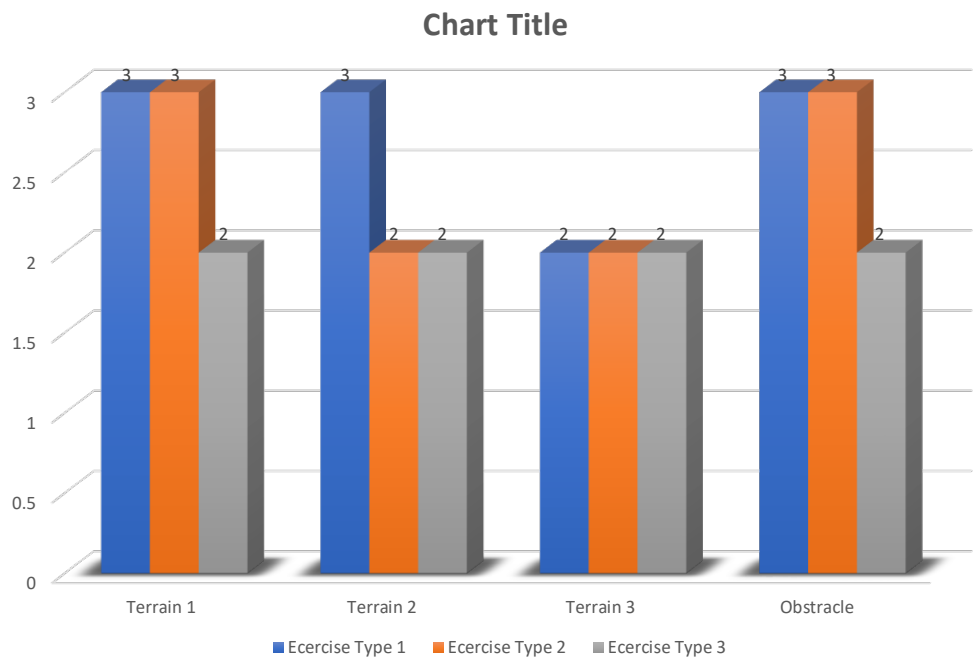


How much time did it take for the preparation and execution of the task, How mush time pressure did you felt ?

Here it is evident that the time pressure was highest for the exercise type 3 as load was evenly distributed at all body parts making the movement very slow.

Freedom of Movement

	Exercise 1	*Exercise 2*	*Exercise 3*	*Recommendation*
Terrain 1	*3*	*3*	*2*	*Exercise 1-2*
Terrain 2	*3*	*2*	*2*	*Exercise 1*
Terrain 3	*2*	*2*	*2*	*Exercise 1-2-3*
Obstacle	*3*	*3*	*2*	*Exercise 1-2*

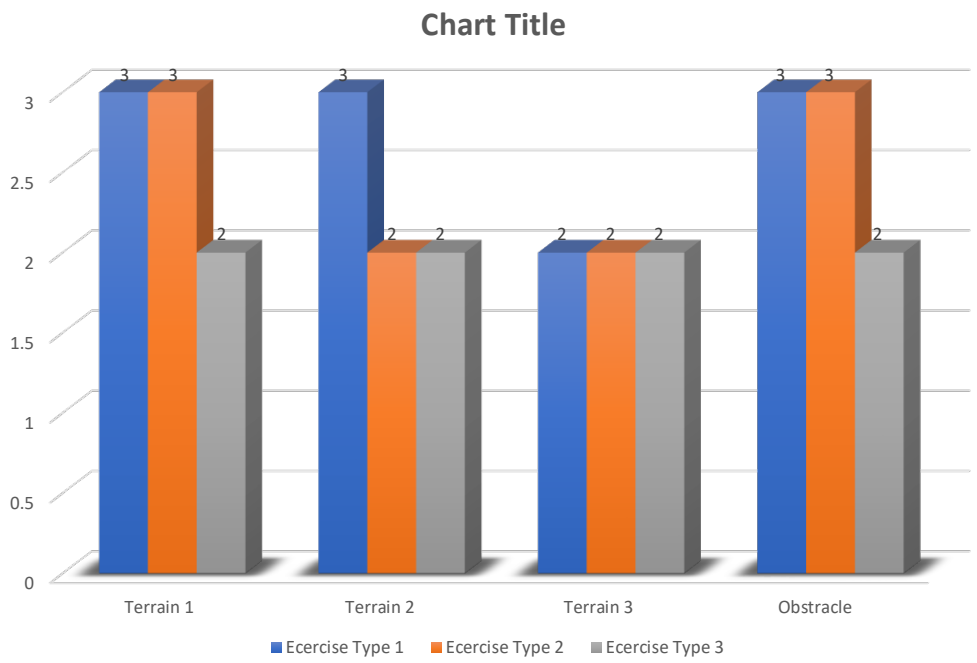


How much freedom of movement did it felt while performing the task ?

Exercise type 1 is distinctly seen to have high ratings in freedom of movement as the load is concentrated at a point allowing the limbs to move.

Posture

	Exercise 1	*Exercise 2*	*Exercise 3*	*Recommendation*
Terrain 1	*2*	*2*	*5*	*Exercise 3*
Terrain 2	*1*	*1*	*4*	*Exercise 3*
Terrain 3	*2*	*2*	*3*	*Exercise 3*
Obstacle	*1*	*1*	*2*	*Exercise 3*



How correct the deal human body posture was maintained

In case of posture exercise type 3 is most effectively proven , this certainly proves that the even load distribution is the most favourable case to keep the posture ideal in any terrain condition.

Insights

Posture
It is very important to keep the posture correct, as incorrect posture for longer duration may cause severe injuries. Even load distribution provides a correct posture.

Mental demand
Concentrated load at one point at the back makes the movement unbalanced for all terrain. This demands heavy mental effort to keep steps firm and balanced.

Frustration
In even load distribution the level of frustration is least as compared to other two exercises because the body and movement was automatically balanced.

Freedom of movement
Freedom of movement is very important for the movement, at least the limbs must be free to perform balanced movement safely.

Brief

Design of wearable walking assist system for the soldiers serving in high altitude and ice mountain areas.
The primary focus is to design a device which could help them move and carry heavy load with minimal strains on the body and have following basic requirements.

Function must be to
- Provide assistance for the person to move on different terrains.
- Reduce musculoskeletal injuries due to heavy loads.
- Ensures weight does not shift to the soldiers body hampering his movement.
- Quick and easy wearability for single individual.

Being part of the system which have following characteristics:
- Withstand significant low pressure of 8 psi and temperatures up-to-50 degree centigrade.
- Different types of terrain ranges at a height of 17000 ft : hard ice, soft snow, rocky and flat grounds.
- War zone readiness.

Considerations

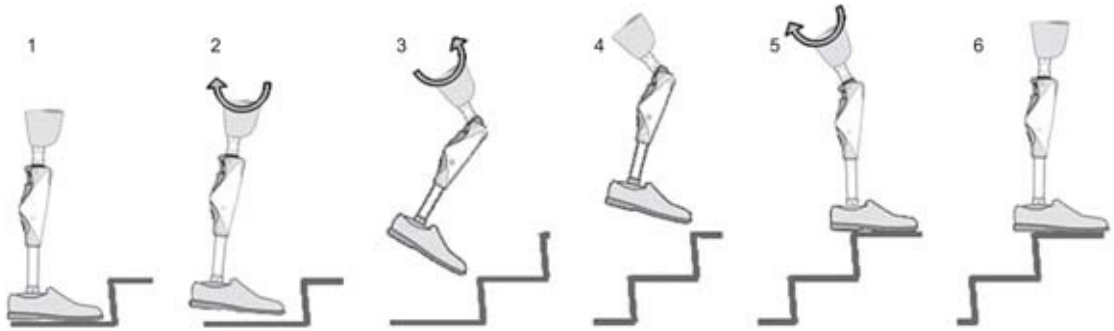
Before starting the concept ideation and the mechanisms it is important to define considerations along which a concept can be built.
These considerations ensures the workability and sustainability of the product.

- Freedom of limbs for movement.
- The posture needed to be ideal to minimize cramps and other physiological disorders.
- Maximize freedom of movement to minimize frustration.
- Balancing concentrated load.
- Load must be directed on ground , it must lift its own weight.
- Automatically sense the movement and reflex.
- Jerks must me absorbed.

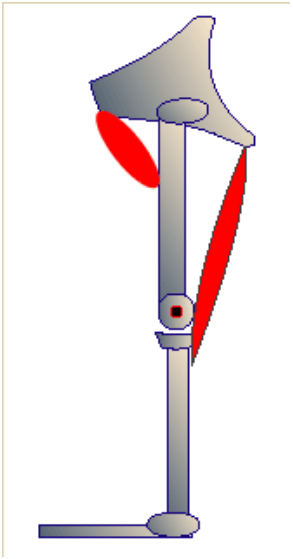
Concept Biomimicry (Synthetic musculature) Orthosis

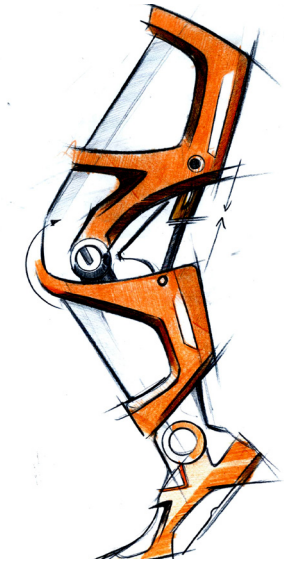
About : In cases of running and walking with a huge amount of load the most important muscle responsible for moving the leg up and down is a group of muscles and their tendons at the rear of the upper leg aka hamstring.
Therefore the idea is to mimic the hamstring in a manner it follows similar function and helps to move in a efficient manner

Here a basic step wise analysis of climbing a staircase is been done.
The most important step involved in the cycle is the part where the step is been taken and the entire body is now to be lifted upwards on the next step. Shown in step 5-6.



The idea is to find out the particular muscle which is significantly involved in the major walking /running exercises and to mimic it in a manner that the system helps to perform the similar function with ease.





Process

The mechanism used in this is a suspension system which is attached to the lower thigh in place of hamstring which is further connecting to the upper calf region.
This setup helps the individual to move the knee and bend in desired manner.
The entire system can be explained in four steps :

Sensing : Sensors receives the muscle engagements data and sends it to the central processing unit.

Processing : The CPU takes the data from the sensors and predicts the next movement of the body. It further commands the actuators to process further.

Actuation : An actuator is a component of a machine that is responsible for moving and controlling a mechanism or system

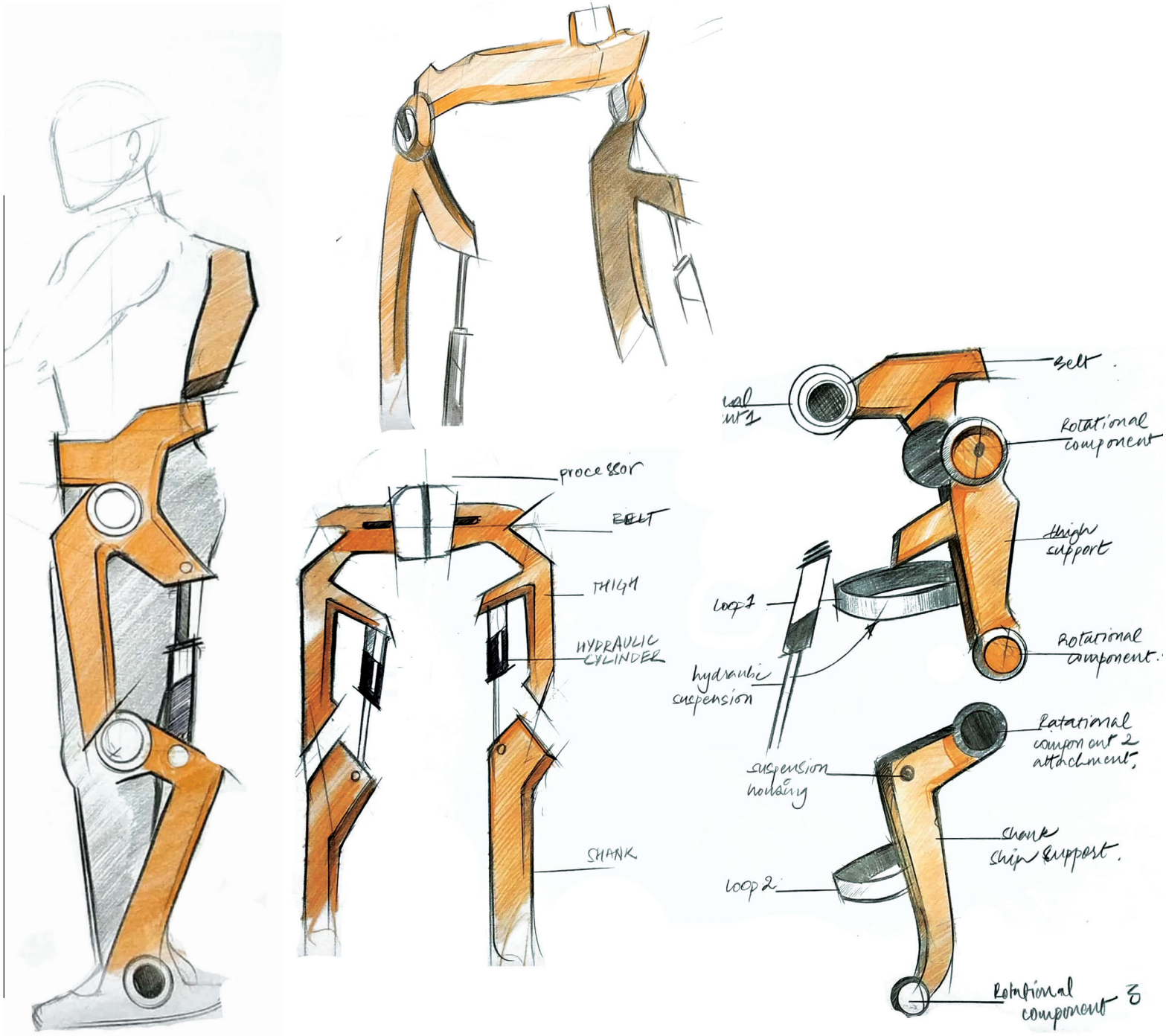
Execution : The suspension contracts and expands and provides the movement in a manner exactly similar to the hamstring helping the individual to move the leg and bend or straighten the knee.

Wearability Explorations

The system have primarily four components respectively
- Belt
- Thigh support
- Calf support
- Shoe

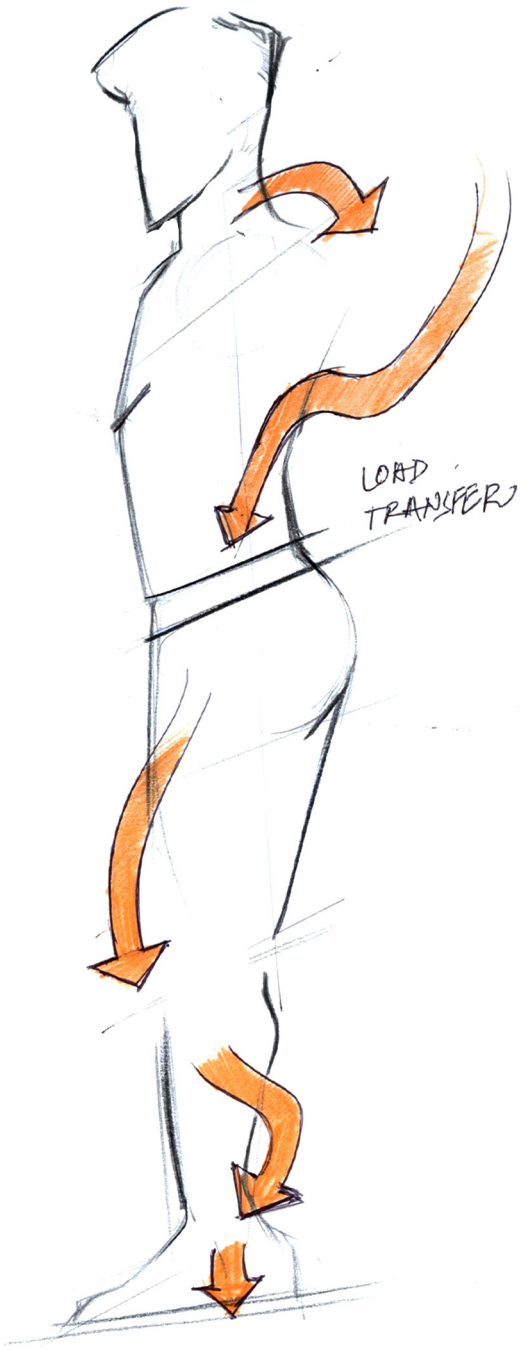
Every component engage each other on a joint , therefore a specific bearing is been installed at all joints to make sure the body movement does not restrict.

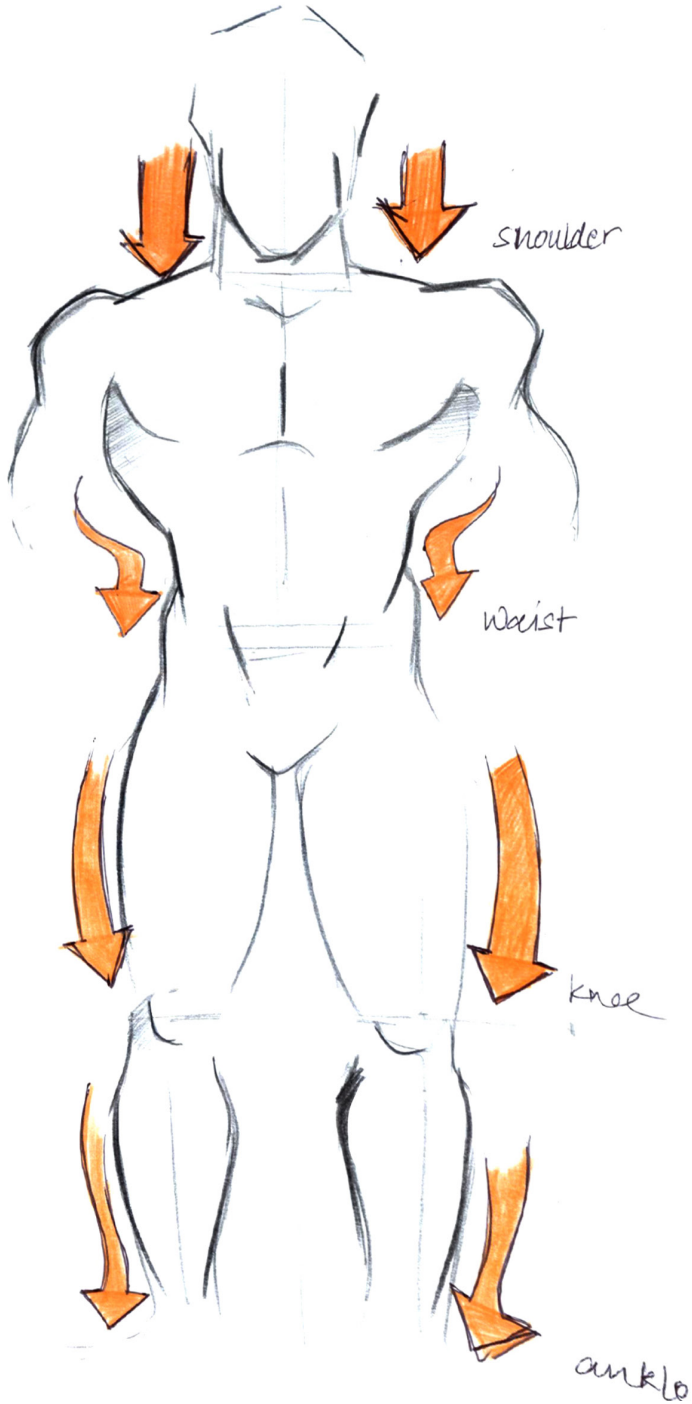
Belt holds the microprocessor in which the motion data is been further analysed.



Load Distribution

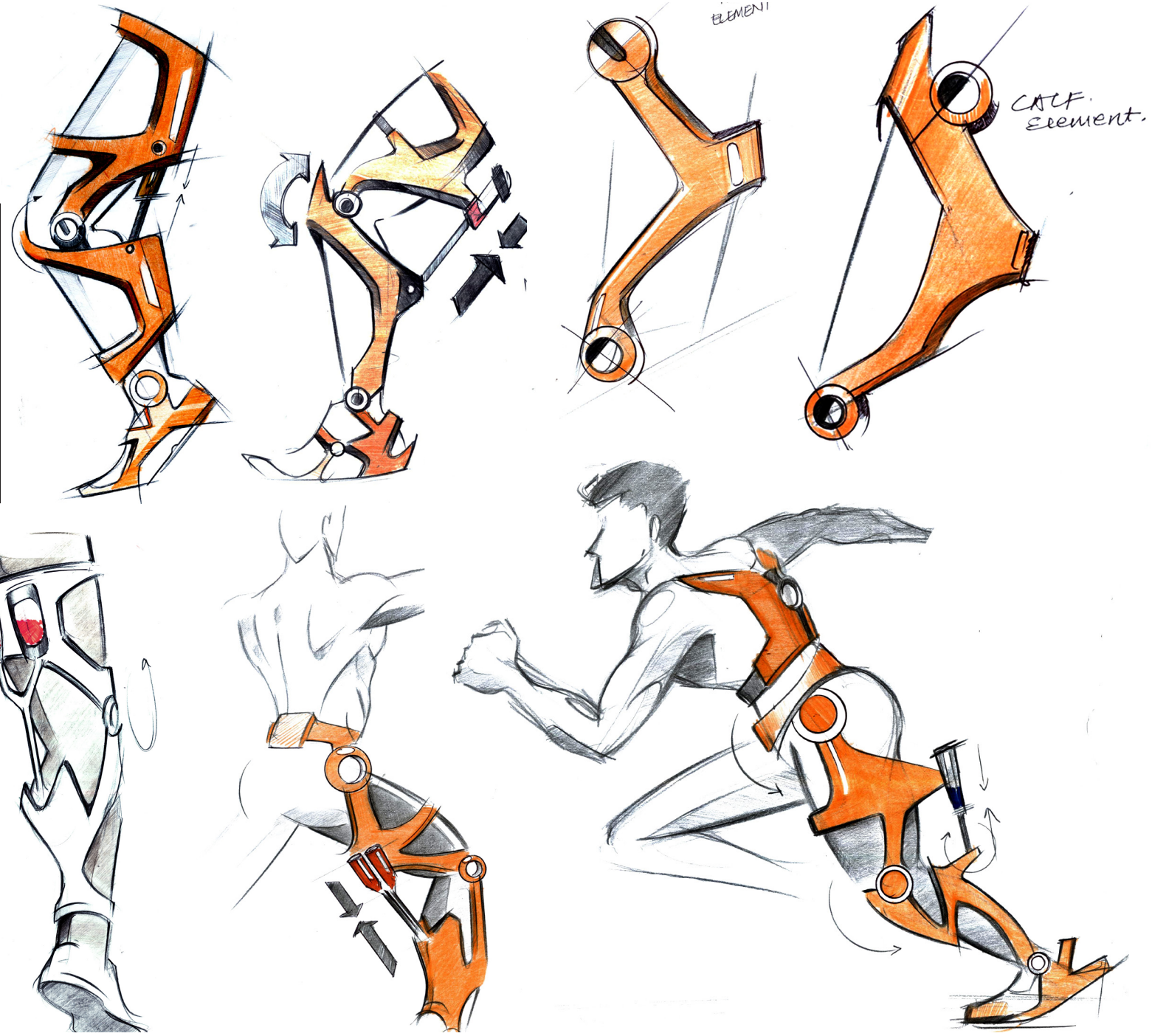
The sketch shows how the load of the backpack is been diverted though the ground . Majorly the load is been distributed over both shoulders in conventional cases , the concept shows how the load is been diverted to the ground





Wearability Explorations

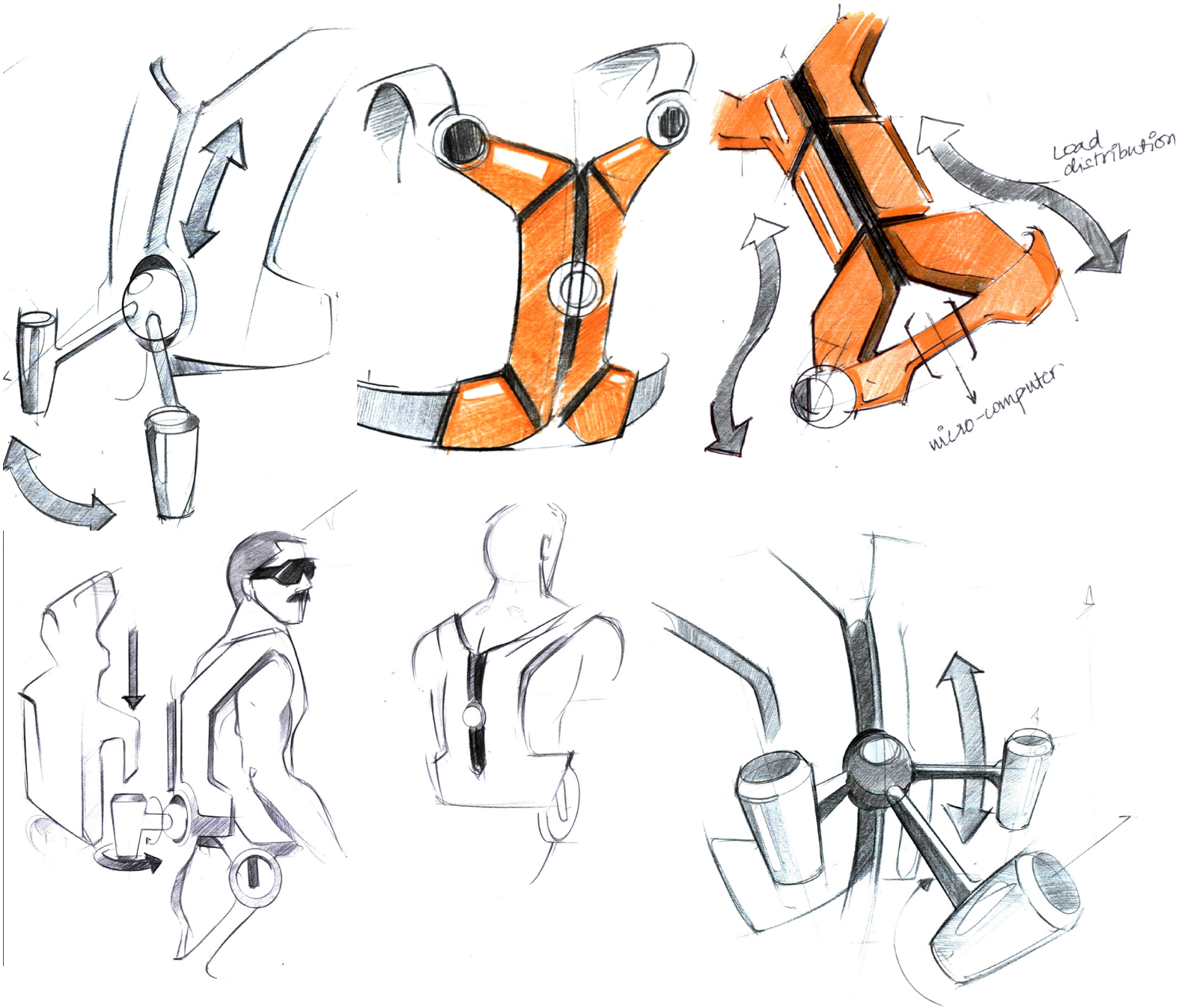
Here the concept shows the suit components to be more efficiently wearable as compared to the previous one



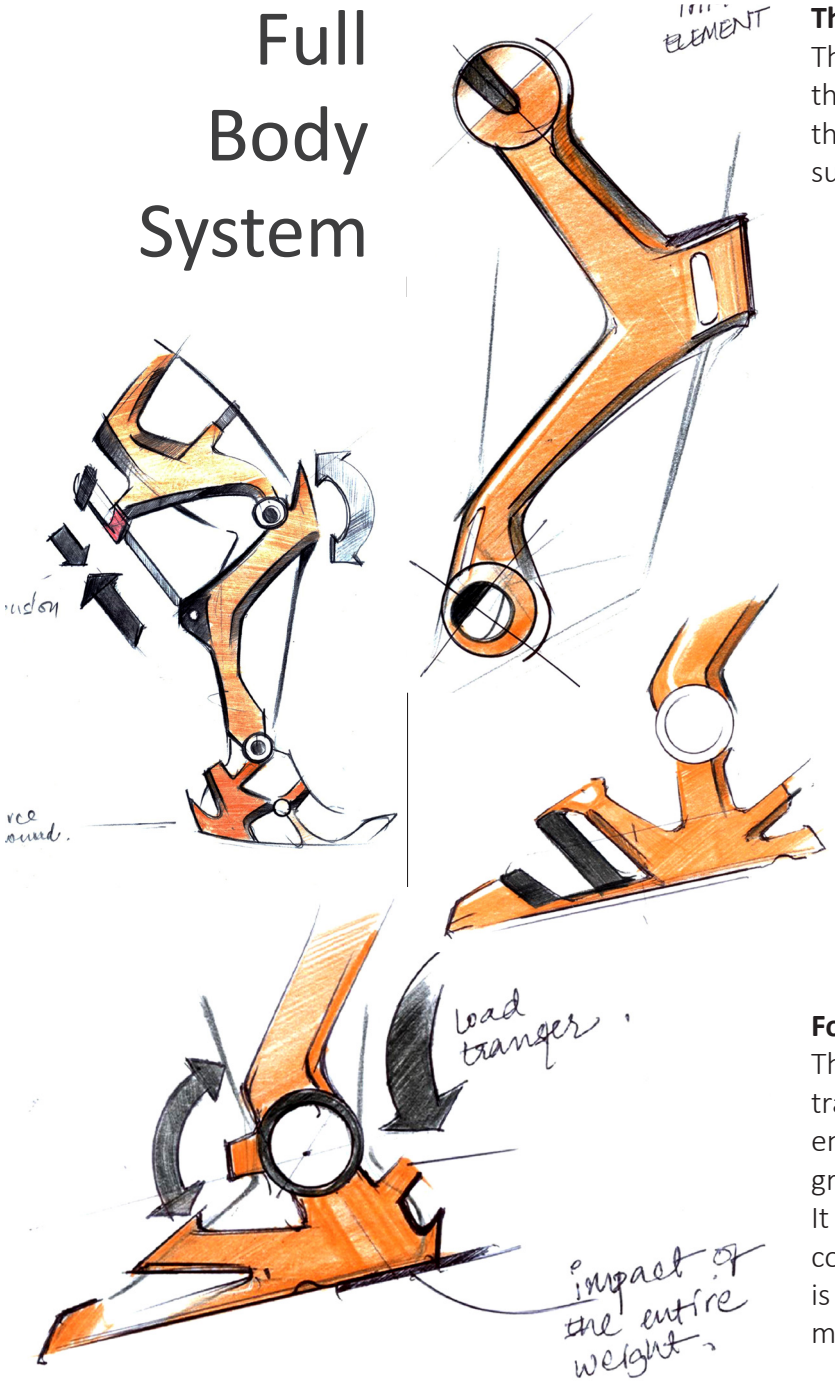
Upper Body System

The upper body system is been attached with the lower body through belt, the system contains a spring loaded hinge suspended out from back to provided backpack to be attached.
Through the movement this hinge consumes the jerks and the load of the backpack is been spread out on the ground through the bottom assist system.

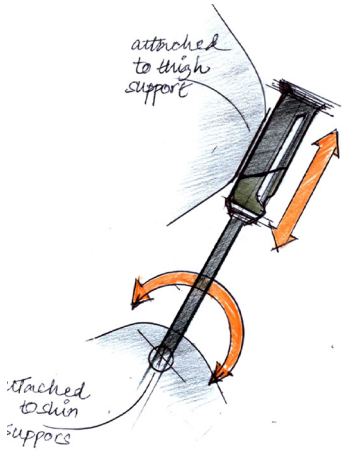
sorbothane padding is been used as an vibration insulation substance between the body and brace
The brace provides the movement of the bag in different angles and directions as shown, which is connected to gyro making it balanced



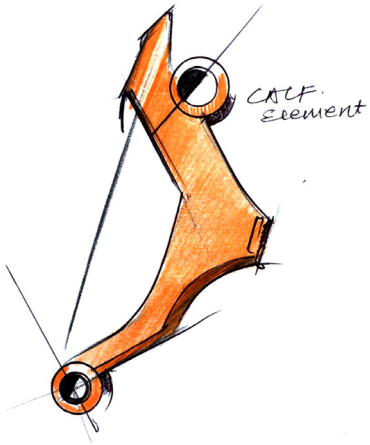
Full Body System

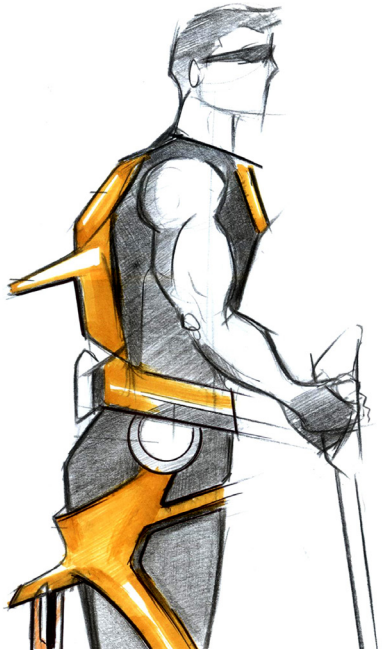


Thigh Support unit :
This element supports the thigh it is connected to the belt and the lower leg support

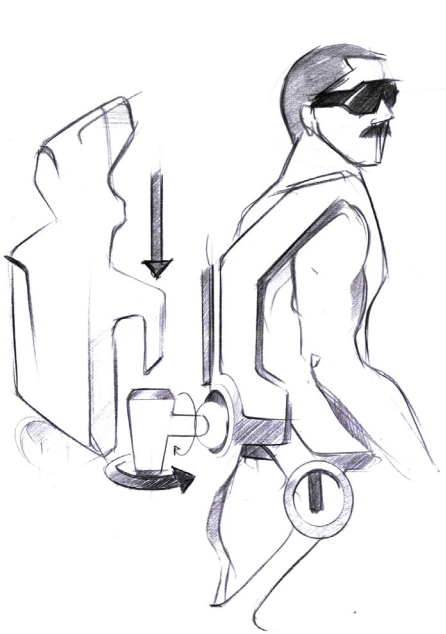


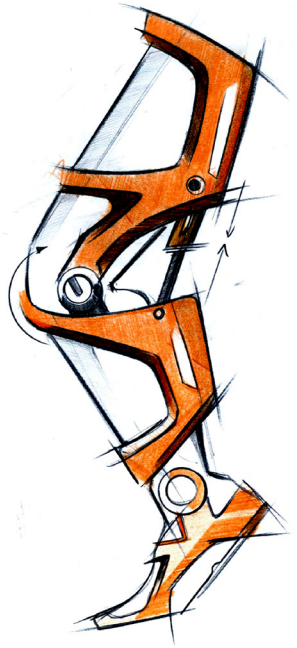
Calf Support unit :
This element supports the lower leg it is connected to the thigh support element and the shoe



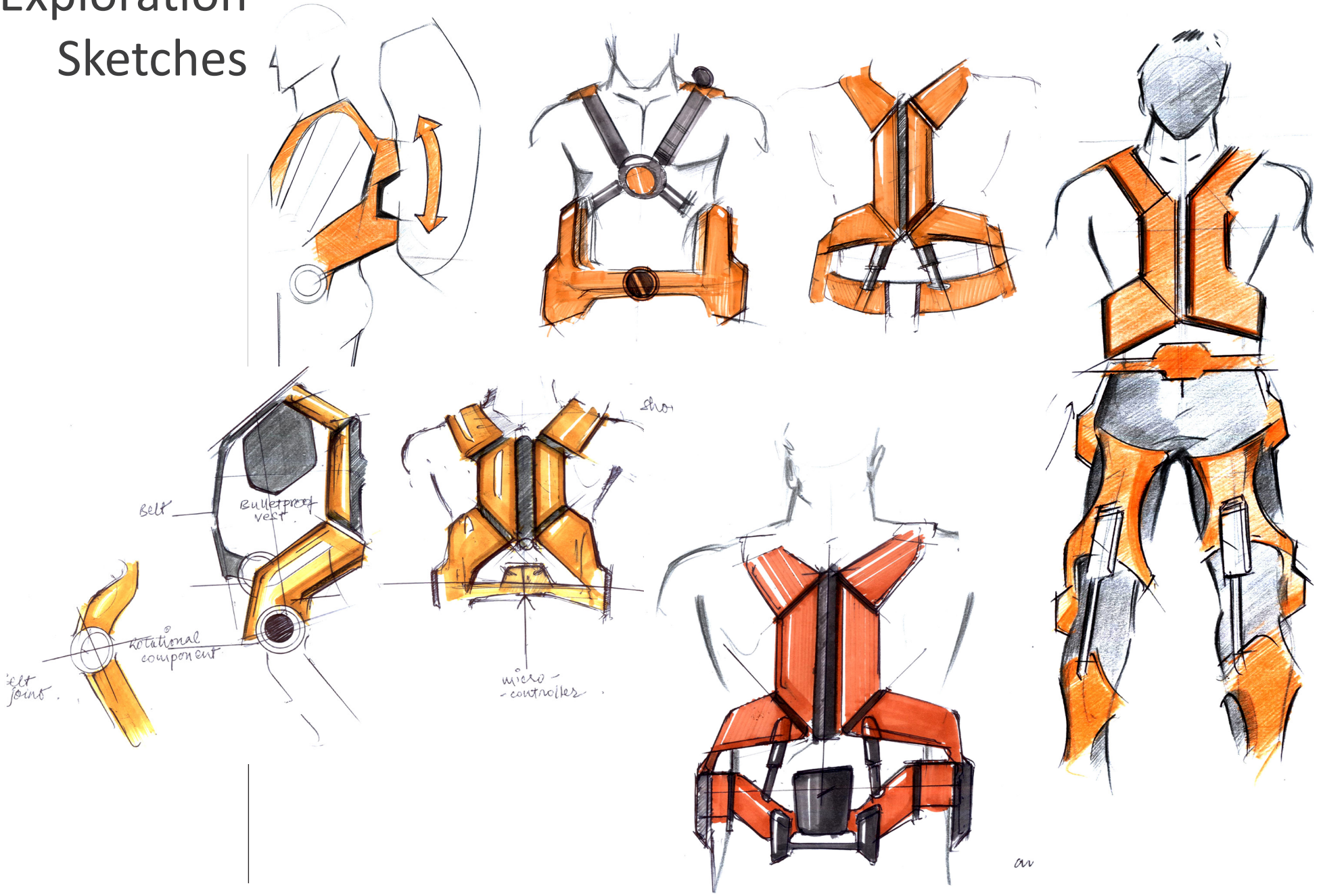


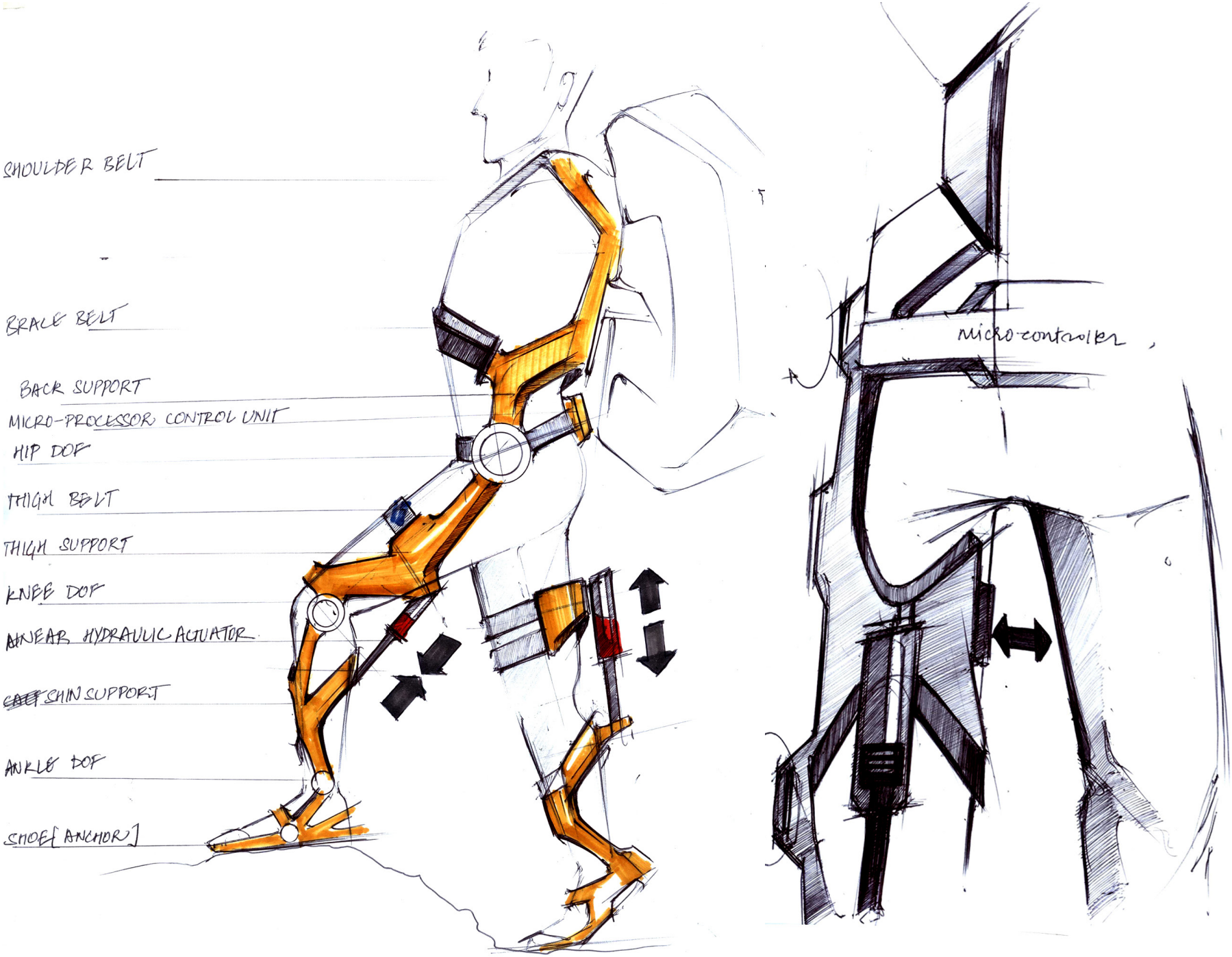
Foot support unit :
The shoe provides to transfer the load of the entire system to the ground.
It have two rotational component which helps is desired freedom of movement.





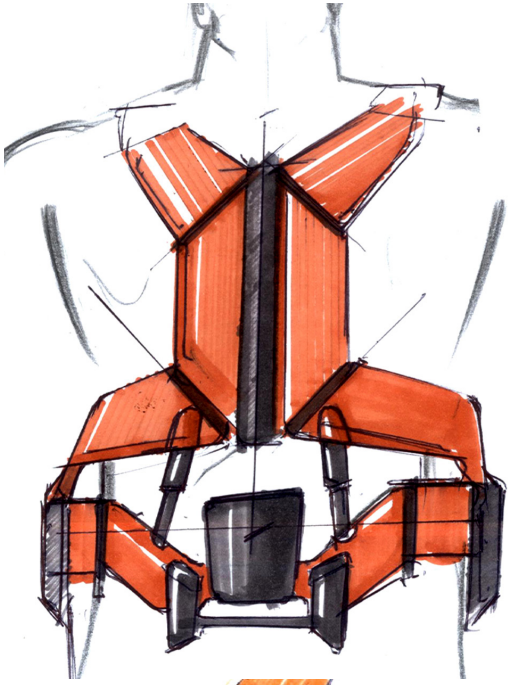
Exploration Sketches

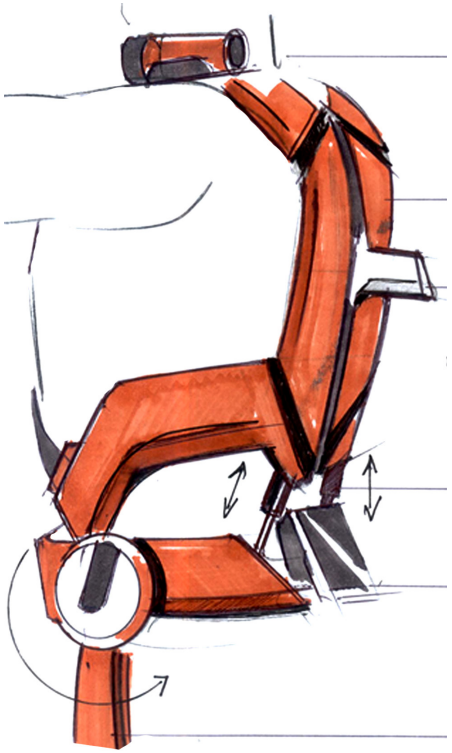


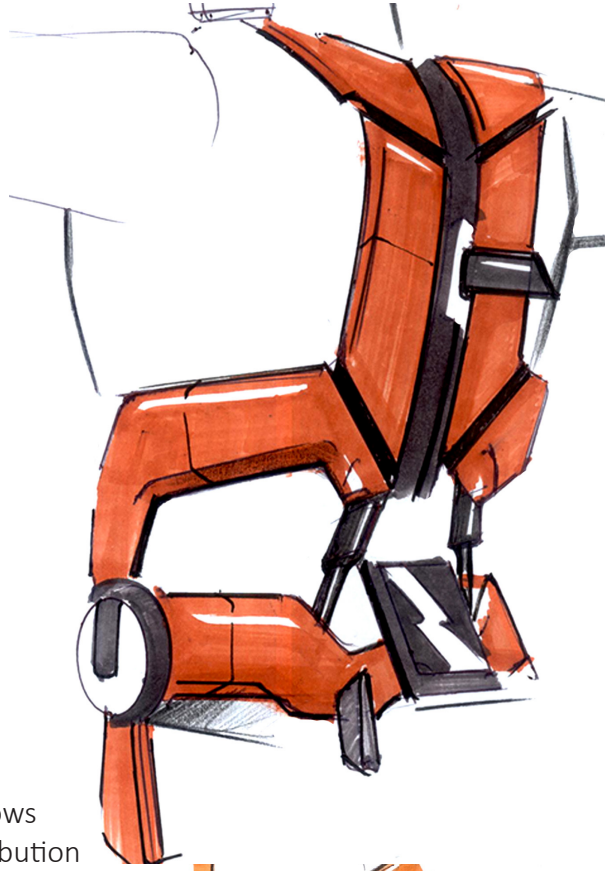

SHOULDER BELT
BRACE BELT
BACK SUPPORT
MICRO-PROCESSOR CONTROL UNIT
HIP DOF
THIGH BELT
THIGH SUPPORT
KNEE DOF
LINEAR HYDRAULIC ACTUATOR
SHIN SUPPORT
ANKLE DOF
SHOE[ANCHOR]
micro-controller

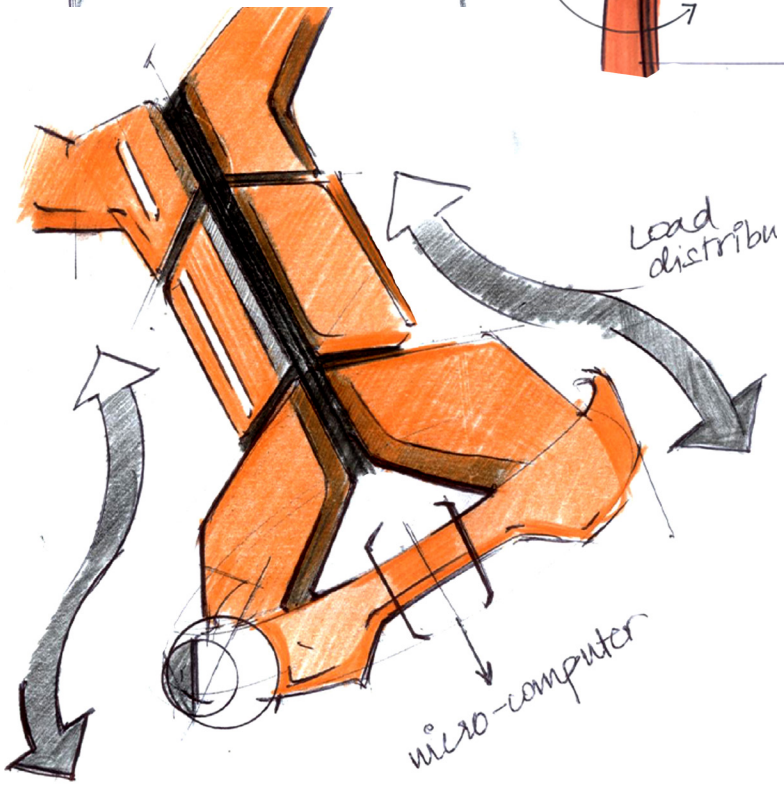
Final concept Upper Body unit

The final concept of upper body unit is been shown attached with two shock absorbing units attached to belt-line from bottom of the brace.
The microprocessor sits between these two shock absorbers.

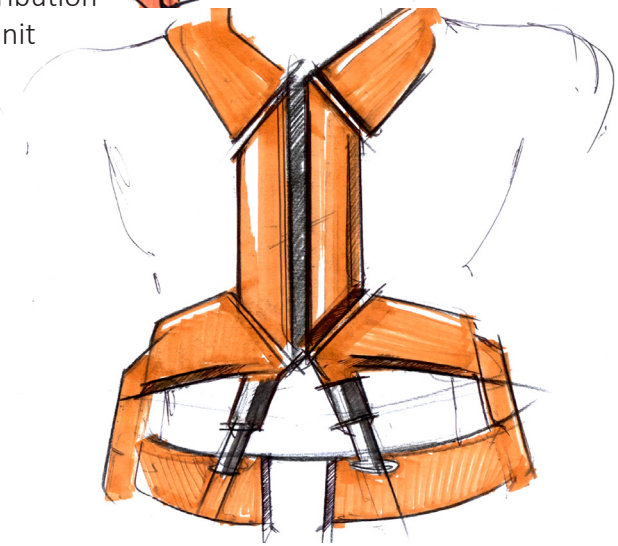








The figure shows the load distribution on the belt unit



MECHANISM

Human Intention Detector

Sensors are used to capture information or intentions from humans to be sent to the exoskeleton controller. The sensors can be categorized into two main groups: cognitive based sensors and physical-based sensors

Cognitive

Cognitive-based sensors read intentions by measuring the electric signals from the nervous system or musculoskeletal system of humans. For example, muscular activity can be measured by means of electromyography (EMG) and mechanomyography using a muscle stiffness sensor (MSS), muscle tenseness sensor, and ultrasonic muscle activity sensor, while brain activity can be detected by means of an electroencephalogram (EEG).

Physical

Physical-based sensors read intentions by measuring the motions of human limbs using position, force, motion or pressure sensors. For instance, position and motion can be measured by means of an encoder, potentiometer, accelerator and inclinometer.Likewise, force and pressure can be measured by a force/torque sensor, pressure sensor, strain gauge and piezoelectric sensor.

Aliman, N. (2016). Design and development of lower limb exoskeletons: A survey. Robotics and Autonomous Systems.
Soumya K Manna. (2017). Comparative study of actuation systems for portable upper limb. Medical Engineering and Physics.

Sensors

The sensing unit primary function is to gather the necessary information about the leg muscle movements and send it to the microprocessor.
Typical sensors are been placed on the particular body parts to get the vital information about intramuscular movements , stretch and strains.
This information is very important to further analyse the force required by the particular muscle to carry out a desired movement in an efficient manner.
New sensor systems that are easy to integrate with textiles and soft components are required in order to properly control and evaluate the exosuit. Shelf sensor technologies (e.g. gyro, pressure sensor, IMU) that can be used to detect key events in the gait cycle

Accelerometer
An accelerometer is an electromechanical device used to measure acceleration forces. Such forces may be static, like the continuous force of gravity or, as is the case with many mobile devices, dynamic to sense movement or vibrations. Acceleration is the measurement of the change in velocity, or speed divided by time.
A dynamic accelerometer measures gravitational pull to determine the angle at which a device is tilted with respect to the Earth. By sensing the amount of acceleration, users analyse how the device is moving. Accelerometers allow the user to understand the surroundings of an item better.

Rate gyro
A rate gyro is a type of gyroscope, which rather than indicating direction, indicates the rate of change of angle with time. If a gyro has only one gimbal ring, with consequently only one plane of freedom, it can be adapted for use as a rate gyro to measure a rate of angular movement.

Encoders sensors
An encoder is a sensor of mechanical motion that generates digital signals in response to motion. As an electro-mechanical device, an encoder is able to provide motion control system users with information concerning position, velocity and direction. There are two different types of encoders: linear and rotary.

Source : Asbeck, A. T. (n.d.). Stronger, Smarter, Softer: Next Generation Wearable Robots. Next Generation Wearable Robots.

Control Strategy

There are 3 levels of hierarchical controllers. First, the high-level controller acts to understand the locomotion intent of subjects through a combination of activity mode detection and direct volitional control.

Perceive

First, the high-level controller acts to understand the locomotion intent of subjects through a combination of activity mode detection and direct volitional control. There are many strategies to perceive the locomotion intent of subjects, namely,

1. Sensitivity amplification control
2. Gait trajectory
3. Model based
4. Fuzzy controller
5. Predefined action based on Gait cycle
6. Hybrid assistive strategies

Translation

Second, the middle-level controller acts as an intent-to-state translation layer. It maps the locomotive intent from the high-level controller to the desired device sequence for tracking by a low-level controller. The middle-level controller also manages the controller between multiple actuated joints, whether contained within one device or across multiple devices. The phase-based controllers in and non-phase-based controllers in are examples of middle-level controllers.

Low level

Third, the low-level controller or joint level controller acts as a specific control layer device from which is derived the actuator that tracks the state in the middle layer. This level serves as the force, torque and position or angle of the exoskeleton joint. There are many types of controller strategies for each level,

Source : Aliman, N. (2016). Design and development of lower limb exoskeletons: A survey. Robotics and Autonomous Systems.

Processing

The sensing unit primary function is to gather the necessary information about the leg muscle movements and send it to the microprocessor.
Typical sensors are been placed on the particular body parts to get the vital information about intramuscular movements , stretch and strains.
This information is very important to further analyse the force required by the particular muscle to carry out a desired movement in an efficient manner.

Sensitivity amplification
Sensitivity amplification is a current best-in-class control strategy. The exoskeleton shadows the user and uses exoskeleton data for joint angle, velocity, and acceleration and the exoskeleton model to minimize torques experienced by the human torque. The process and hardware are relatively simple yet effective.

EMG Data assessment
Electromyography (EMG) is an electro-diagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles. EMG is performed using an instrument called an Electromyography to produce a record called an electromyogram.

Source : KAZEROONI, A. Z. (2005). Design of an electrically actuated lower extremity. Advanced Robotics.
EBME & Clinical Engineering Articles. (n.d.). Retrieved from /www.ebme.co.uk: https://www.ebme.co.uk/articles/clinical-engineering/electromyography-emg

Actuation type

Since actuator and actuation mechanism used in exoskeletons are the key factors for making a portable system, different types of actuator are considered with respect to the anatomical joints
There are some new types of actuators such as artificial muscle, shape memory alloy (SMA), electro-active polymer (EAP), and piezoelectric motor which are also being adopted in exoskeleton designs.

Active :
Active actuators comprise electric, pneumatic and hydraulic actuators.

Passive :
Passive assistive actuators comprise non-powered components or elastic components such as springs, which can store energy, and are based on the principles of gravity for balance. Passive orthoses depend solely on the physical effort of the patient and allow for very slow walking speeds.

Quasi passive :
Quasi-passive actuators are passive devices that work in conjunction with viscosity devices such as clutches, dampers or clutch–damper combinations

Hybrid :
Hybrid actuators are a combination of more than one type of active–passive or active–quasi-passive actuators in LLE joints.

Source : Aliman, N. (2016). Design and development of lower limb exoskeletons: A survey. Robotics and Autonomous Systems.

Actuation

Active actuation

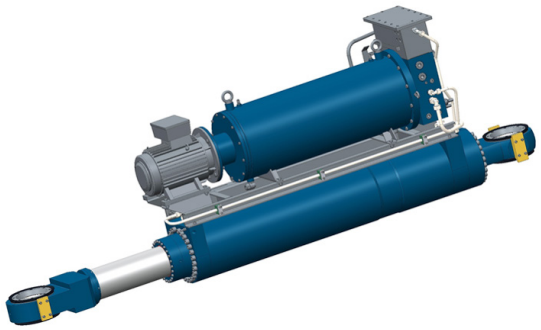
Enhancing the performances is most important for the development of wearable robots, such as active orthoses, prosthesis and body extenders. Indeed more compact actuators allow to reduce the mass of the device and the energy requirements and also to improve its aesthetic and hence the user acceptability.
Here are the few existing technologies which are used in muscle data assessment and actuation which can be used for the purposes needed here to move the mechanism.

Hydraulic actuators

Actuator efficiency is an important factor in design of powered legged robots. A continuously variable series-elastic actuator is presented as an efficient actuator for legged locomotion. The CV-SEA implements a continuously variable transmission (CVT) between a motor and series elastic element. The CVT reduces the torque seen at the motor, allowing the motor to operate in speed regimes of higher efficiency, while the series-elastic element efficiently stores and releases mechanical energy, reducing motor work requirements for actuator applications where an elastic response is sought.

Source : Williamson, G. A. (n.d.). Series Elastic Actuators .
KAZEROONI, A. Z. (2005). Design of an electrically actuated lower extremity. Advanced Robotics.

Hydraulics



Various hydraulic fluids has been developed to serve in the extreme colder conditions which can be applied in this device , few examples are given below :
Cryogenic Hydraulic Oil

SCH #60 is a synthetic low temperature hydraulic oil that was created especially for long-lasting oxidation resistance against sludging. SCH #60 meets the needs of systems that operate over very wide temperature ranges, as it offers a very wide application temperature range of-110°F (-78°C) to 300°F (148°C). SCH #60 offers low pour points and doesn't congeal

Minus 70 Hydraulic Oil is a special anti-wear hydraulic oil designed for extreme low temperature operations where high fluid mobility is of utmost importance. This oil has an extremely high viscosity index which guarantees excellent fluidity and very low torque under these adverse cold conditions.

Source :https://www.superior-industries.com/products/synthetic-lubricants/synthetic-oils/cryogen-ic-low-tempeWWWWrature-oils/hydraulic/sch-60.html.
Gannon, M. (22, May 2016). Low-temperature hydraulic fluids. Retrieved from www.fluidpowerworld.com: https://www.fluidpowerworld.com/low-temperature-hydraulic-fluids/

Power supply

Wearable battery systems are been made and modified to be wearable for the soldiers

Unlike civilians who may only need one or two devices at a time and can easily access electrical outlets to recharge their devices when needed, soldiers regularly use a multitude of peripheral network devices. Further, they are often in remote and austere environments for extended periods of time without the guarantee of convenient electricity.
The conformal wearable battery was a result of our mission to deliver soldiers with a sustainable battery pack fit for their extremely demanding and varied environments.

Furthermore there are few exceptional modifications in wearable batteries like ballistic compliant and provide power supply for almost 24 hours .

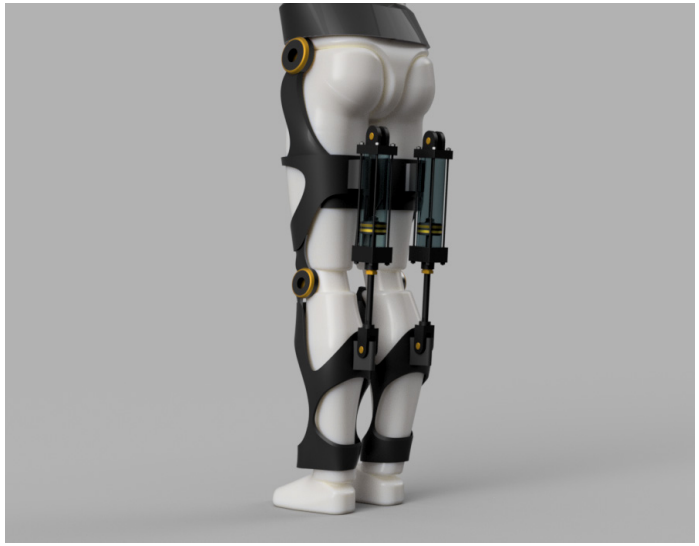
Battery power has improved over the years, the invention has brought about more compact and higher capacity batteries which are capable of sustaining the exoskeleton during the course of its service.

The HAL suit is powered by battery packs of lithium and bickelmetal hydride origin, which currently is capable of sustaining the lower and upper part of the exoskeleton for 2 hours and 40 minutes on a single full charge.

Source :https://www.superior-industries.com/products/synthetic-lubricants/synthetic-oils/cryogenic-low-tempeWWWWrature-oils/hydraulic/sch-60.html.

Helping Solve the Portable Power Needs of Today's Warfighter. (2016, May 16). Retrieved from inventuspower.com: https://inventuspower.com/helping-solve-portable-power-needs-todays-warfighter/
THE ENERGY CIRCUIT. (n.d.). Retrieved from asc.army.mil: https://asc.army.mil/web/access-log-the-energy-circuit/

Wearability Explorations

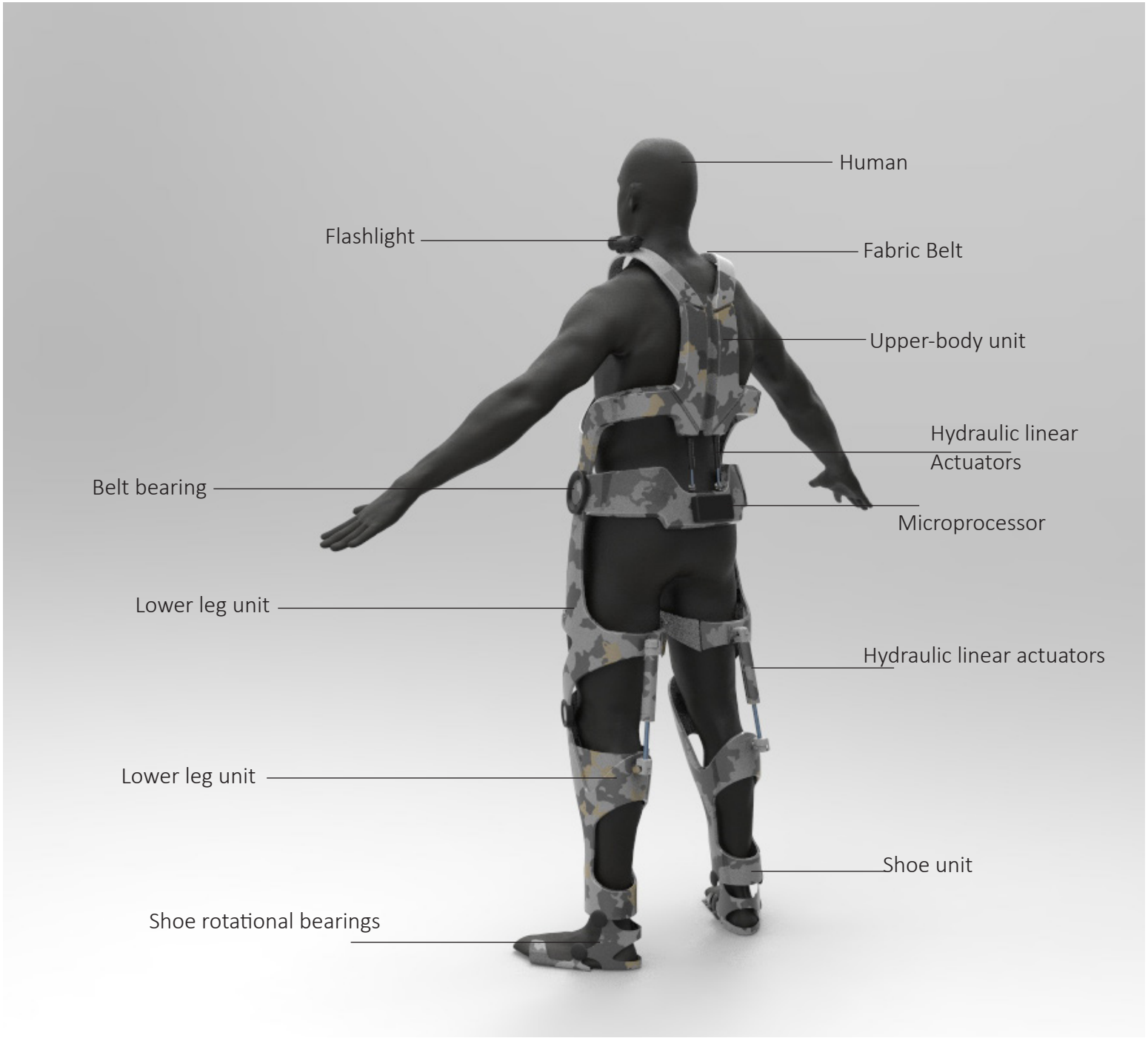


Wearability Explorations

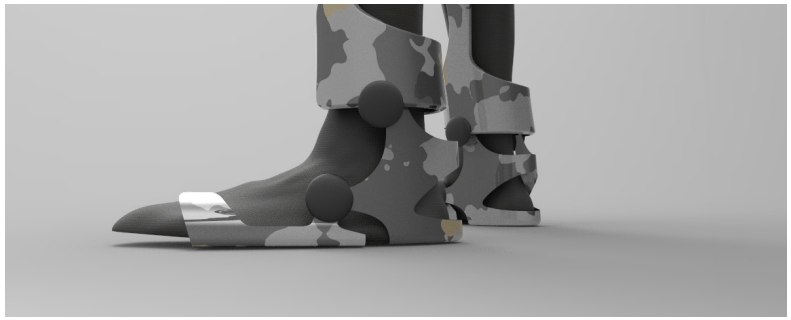
Here the concept shows the suit components to be more efficiently wearable as compared to the previous one

Explorations

Final Concept



Final Concept



Final Concept

Physical Model

Conclusion

Scope

There is an increasing number of applications for an exoskeleton, such as to decrease fatigue and increase productivity whilst unloading supplies or to enable a soldier to carry heavy objects (40–300 kg) while running or climbing stairs. Using exoskeleton, soldiers could presumably wield heavier armour and weapons while lowering or maintaining their metabolic rate with more carry capacity.

The device will help the soldiers to keep on the trek going without tiring , this will help them to save a lot of valuable time and eventually lead to a significant advantage over enemy forces.

For those particular areas where helicopters does not reach, any rescue operation is been carried out by soldiers only. In such difficult situations this device can take heavy loads and still able a soldier to walk.

With the development of automation and artificial intelligence there is a huge potential of modification of the suit to be self sustainable and automatic , reacting according the environments and individual.

In extreme cases of natural disaster like avalanche the suit is also equipped with the avalanche signal transmitter to send out the signal for help.

Limitations

Adding to this there are few limitations of the project which is needed to be further analysed like Power supply, the most limiting factor but of great importance in the exoskeleton design. The lithium ion batteries which are proposes to be used in the concept provides a limited amount to operation time for the system, however research and new technologies are been under process of development to further improve the operation time.

Furthermore at the time of ambush or a sudden attack this suit must react and act according to the situational needs ,this needs a specific testing before implementations.

The process of putting suit on and off has to be very well defined and this is open for explorations.

Also the technologies and materials proposed in these concepts are expensive and very rare because of which its very difficult to analyse the cost of the product.

Bibliography

1. (2017, December 30). Retrieved from The real enemy on the world's highest battlefield: https://www.bbc.com/news/world-asia-41432568
2. Akhter, Z. (2016, Feb 13). The Strategic Importance of the Siachen Glacier for India . Retrieved from www.indiandefencereview.com: http://www.indiandefencereview.com/spotlights/the-strategic-importance-of-the-siachen-glacier-for-india/
3. Chhina, M. A. (2017, February 16). Everyday is a story: Army officers recall their time at Siachen Glacier. Retrieved from www.hvk.org: http://www.hvk.org/2016/0216/74.html
4. Cryogenic Hydraulic Oil. (n.d.). Retrieved from https://www.superior-industries.com/products/synthetic-lubricants/synthetic-oils/cryogenic-low-temperature-oils/hydraulic/sch-60.html
5. en.wikipedia.org. (2019, May 15). Retrieved from Siachen conflict: https://en.wikipedia.org/wiki/Siachen_conflict
6. Extended Cold Weather Clothing System. (2018, June 28). Retrieved from en.wikipedia.orgc: https://en.wikipedia.org/wiki/Extended_Cold_Weather_Clothing_System
7. Extreme Cold Weather Parka and Trousers. (n.d.). Retrieved from ciehub.info: https://ciehub.info/clothing/CW/ECWCS/GEN3/Level7.html
8. Gait training. (2, April 2019). Retrieved from en.wikipedia.org: https://en.wikipedia.org/wiki/Gait_training
9. Helping Solve the Portable Power Needs of Today's Warfighter. (2016, May 16). Retrieved from inventuspower.com: https://inventuspower.com/helping-solve-portable-power-needs-todays-warfighter/
10. Herr, H. (2009). Exoskeletons and orthoses: classification, design challenges and. Journal of NeuroEngineering and, 3-9.
11. Hooda, D. (2018, July 11). High Altitude Warfare School: Where Indian jawans are trained to survive in Siachen. Retrieved from economictimes.indiatimes.com: https://economictimes.indiatimes.com/news/defence/high-altitude-warfare-school-where-indian-jawans-are-trained-to-survive-in-siachen/articleshow/50968653.cms?from=mdr

Bibliography

12. Jindal, A. (2011 , July 21). The Highest Battlefield of the World : Medical Problems and Solutions. Retrieved from www.ncbi.nlm.nih.gov: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4921426/
13. Jones, O. (11, May 2019). Walking and Gaits. Retrieved from teachmeanatomy.info: https://teachmeanatomy.info/lower-limb/misc/walking-and-gaits/
14. Justin Greisberg, M. (2019, March 3). Biomechanics of Walking. Retrieved from footeducation.com: https://footeducation.com/biomechanics-of-walking-gait/
15. LAND ACTIVITIES. (n.d.). Retrieved from www.indianarmy.nic.in: https://www.indianarmy.nic.in/Site/FormTemplete/frmTempSimple.aspx?MnId=GwI1LjDYTnKv6cdcpgW3vQ==&ParentID=dSlRP/mU/0kUDWLiRQ5GpA==
16. Lubricant Challenges in Extreme Cold Environments. (n.d.). Retrieved from file:///C:/Users/Tharki/Desktop/P3/Cryogenic%20Hydraulic%20Oil%20_%20Extreme%20Low%20Temperature%20_%20Superior%20Industries,%20Inc..html
17. OP MEGHDOOT. (n.d.). Retrieved from http://indianairforce.nic.in: http://indianairforce.nic.in/content/op-meghdoot
18. Operation Meghdoot. (2019, May 8). Retrieved from en.wikipedia.org: https://en.wikipedia.org/wiki/Operation_Meghdoot
19. Peri, D. (2017 , May 17). Indigenous gear for Siachen soldiers. Retrieved from www.thehindu.com: https://www.thehindu.com/news/national/indigenous-gear-for-siachen-soldiers/article18469169.ece
20. Staff, A. A. (2015, February 16). THE ENERGY CIRCUIT. Retrieved from asc.army.mil: https://asc.army.mil/web/access-log-the-energy-circuit/
21. Types of Orthoses (Lower Extremity). (n.d.). Retrieved from www.fior-gentz.de: https://www.fior-gentz.de/en/orthotics/orthosis/types-of-orthoses.html
22. Walsh, C. J. (2006). Development of a lightweight, underactuated exoskeleton. 3486-3489.
23. Williamson, G. A. (n.d.). Series Elastic Actuators .
24. Soumya K Manna. (2017). Comparative study of actuation systems for portable upper limb. Medical Engineering and Physics.
25. Aliman, N. (2016). Design and development of lower limb exoskeletons: A survey. Robotics and Autonomous Systems.
26. ChaChatterjee, T. (2017). Soldiers' load carriage performance in high mountains: a physiological study. Military medical research .
27. ds Sandhu, V. (2016 , February 20). Life in Siachen. Retrieved from www.business-standard.com: https://www.business-standard.com/article/specials/life-in-siachen-116021900798_1.html