POWER MOUNT

Giving back the power

The automated self-adjustetable headrest for powered wheelchair users

10 page summary

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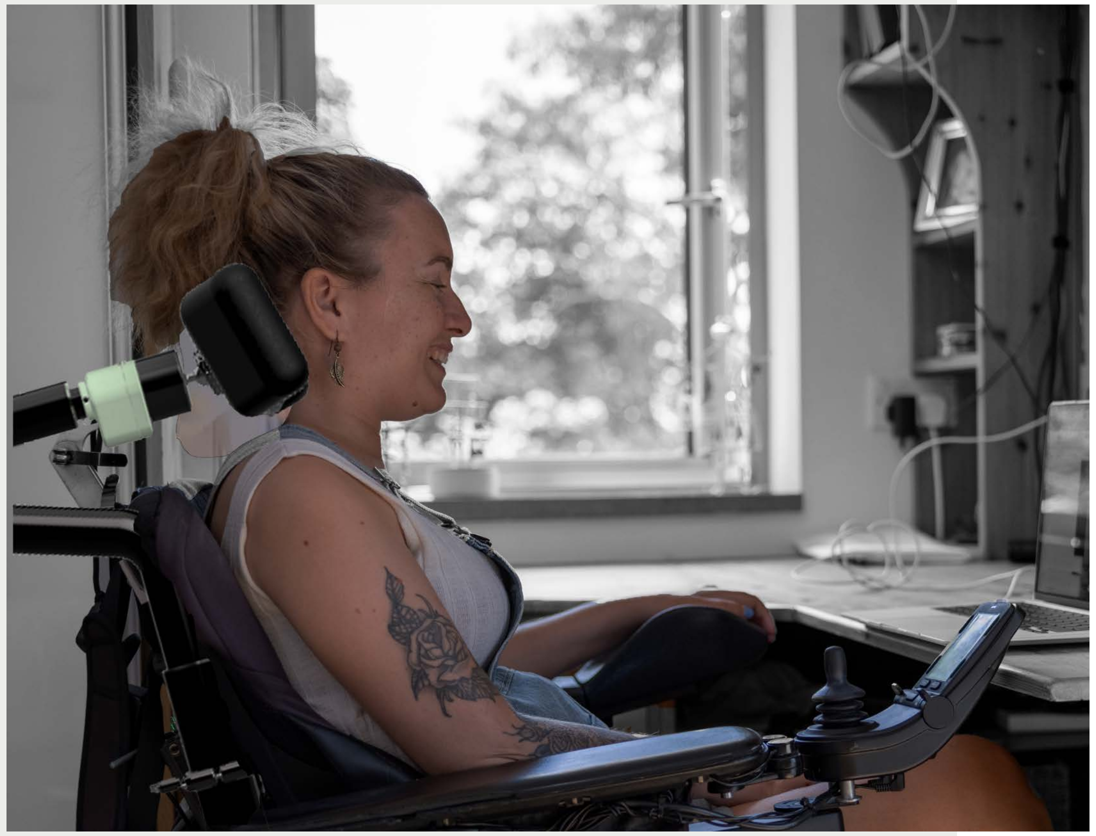
Designed Product

Who

Powered wheelchair users, with a particular focus on patients with Amyotrophic lateral sclerosis (ALS), Parkinson's disease and Cerebral palsy who have specific needs for a wheelchair headrest.



What

Power Mount offers the degree of freedom (DoF) illustrated below. The design is fully automated, wheelchair occupants have full control over the operation of Power Mount through the wheelchair joystick.

DEGREES OF FREEDOM

ROTATIONAL

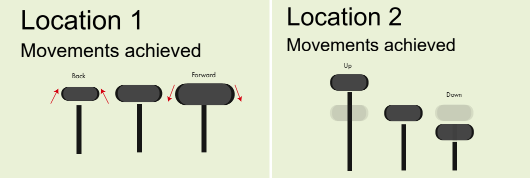
LINEAR

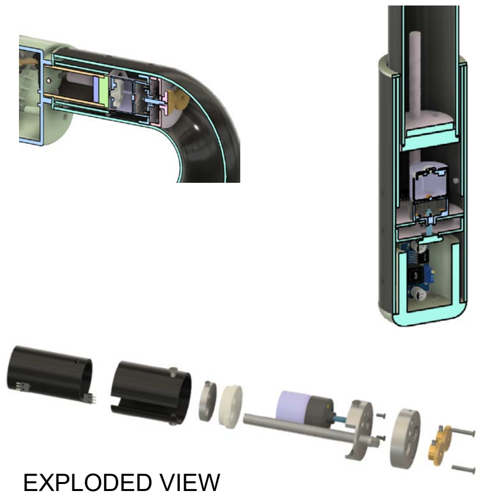
How

Mechanism guide

Integrated mechanisms are used in an external body made of aluminium and ABS to achieve the required DoF as shown.

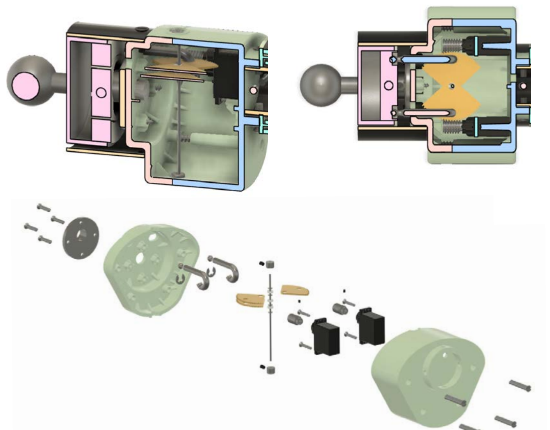
L LINEAR MECHANISM





EXPLODED VIEW

R ROTATIONAL MECHANISM



EXPLODED VIEW

The User

Who requires a wheelchair headrest?

Degenerative neurological conditions

Non-degenerative conditions

ALS

(Amyotrophic lateral sclerosis)

Muscles weakness

Difficulty speaking

Non-verbal

Difficulty swallowing

Difficultly walking/ standing

Fatigue (Due to muscles over working)

Difficulty breathing

Life expectancy 20-48 months

Parkinson’s Disease

Muscles stiffness

Dropped head · Lack of eye contact

Disparity in muscle strength (from side to side)

Difficulty swallowing

Tremors

Slow movements

Does not affect life expectancy

Cerebral Palsy

Movement disorder

Muscles too stiff or floppy

Tremors

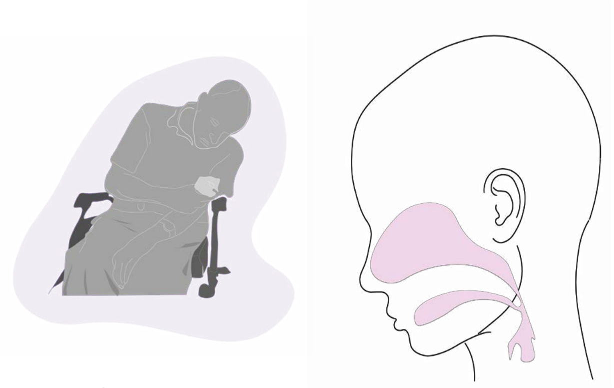
Difficulty swallowing, feeding and drooling

Random, uncontrollable movements

Does not affect life expectancy

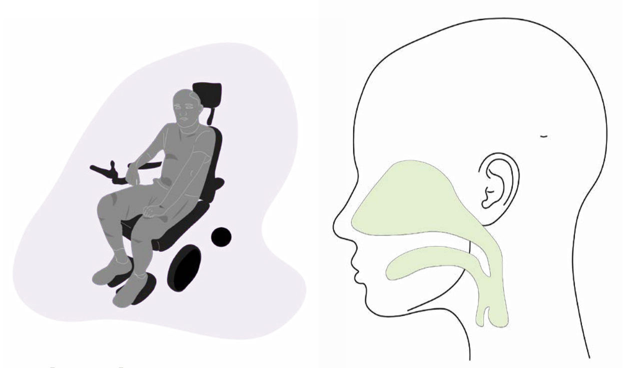
Headrest

Why do users have a wheelchair headrest?



Lack of neck support

Bad posture leads to airways getting blocked



With neck support

Good posture is an essential prerequisite for:

Eating · Swallowing

Breathing

Speaking

Eye contact · Social inclusion

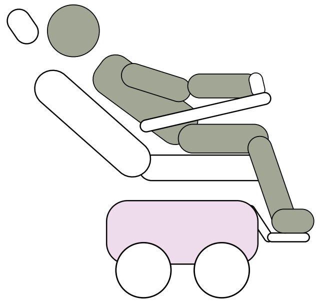
These problems already exist due to weak muscles in the neck and throat. Poor head positioning aggravate this further.

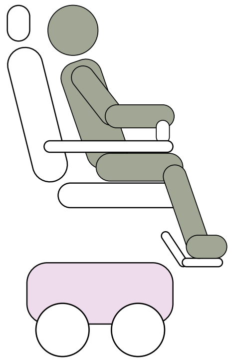
Current powered wheelchair use

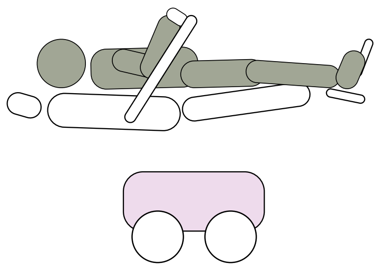
What adjustments do users currently have?

An external study showed that the addition of adjustable features is useful and popular for comfort and reliving pressure sores. Use of the features illustrated below went UP the longer the ownership of the wheelchair. For a person occupying a wheelchair at least 14 hours a day, the number of adjustments made to each feature is as shown

Seat tilt	Seat elevate	Recline
6-20	6-10	3-5
per day	per day	per day







The Need - *for a self-adjustable headrest*

Requirement

Why an automated SELF-adjustable headrest?

Better quality of life

Having the ability to achieve their exact desired position will result in better comfort and social interactions for the user

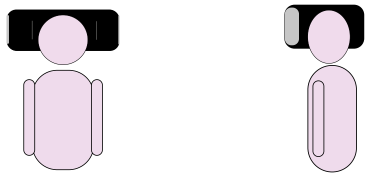
More independence

Retaining good neck mobility

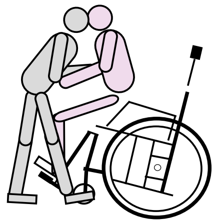
When would a user want to adjust their headrest?

Sleeping or sunbathing

Social activities, watching TV, self-grooming



After being hoisted into wheelchair



Eating, drinking

Prevention of general discomfort, pressures sores, feeling stiff

Pain points

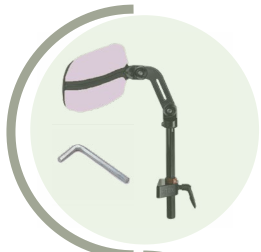
What are the pain points with a manual headrest?

The main paint points were gathered from

- *Carers (Glasgow college boccia club)*
- *3 NHS Biomedical engineers*

Lack of communication between patient and carer

Communication difficulties may prevent users alerting carers to the need to adjust the headrest for them

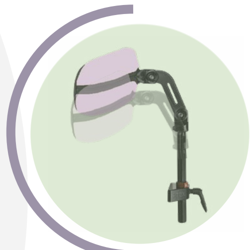


Additional tools are required for adjustments

The current way to adjust a headrest's position is to loosen the screws with an Allen key and move the headrest manually

This is undertaken by a carer

This tool may get Lost or Forgotten



Screws may get worn

Multiple adjustment, over time, causes the screws to loosen and the headrest can slip out of position

Multiple adjustments cause wear and tear to the screws, rendering them unusable

Trips to clinicians are required to fix the issue

Lack of independence

Users want to feel independent and to have a sense of freedom

Carers' and users' views

Why would a user want to adjust their headrest themselves?

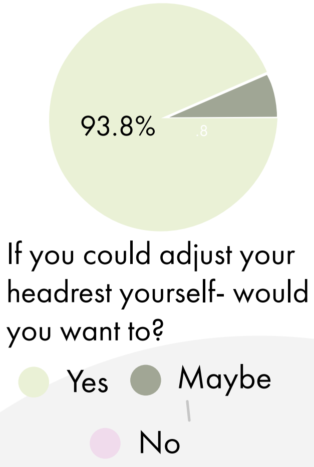
This survey was designed and sent out via user forums
A mix of patients and carers responded, n=32

> "Keeps my muscles from stiffening up"
> - Anonymous survey respondent

> "Not to bother caretaker"
> - Anonymous survey respondent

> "I want to see the sunshine!"
> - Jill Clarke

> "Nobody can adjust it exactly the way I would like it"
> - Anonymous survey respondent



If you could adjust your headrest yourself- would you want to?

> "What if the power wheelchair batteries go flat?"
> - Boccia Carer

> "Could the limits be adjusted if it is deemed unsafe to move in that direction"
> - NHS Physiotherapist

Design brief

"Design a powered headrest mounting system that users can adjust themselves without any need to alert carers."

Product Design Requirement

USER

As a user I want to have a sense of freedom and independence

As a user I want to make fine adjustments rotation and linearly

As a user I want to have the ability to adjust the headrest myself

MEDICAL

As a user and medical professional I want the headrest to be retro fitted to existing wheelchairs

As a user and medical professional I want the headrest to be controled using the exiting on board joystick

As a medical professional I should be able to calibrate the range of adjustment for each patient using the existing software

CARER

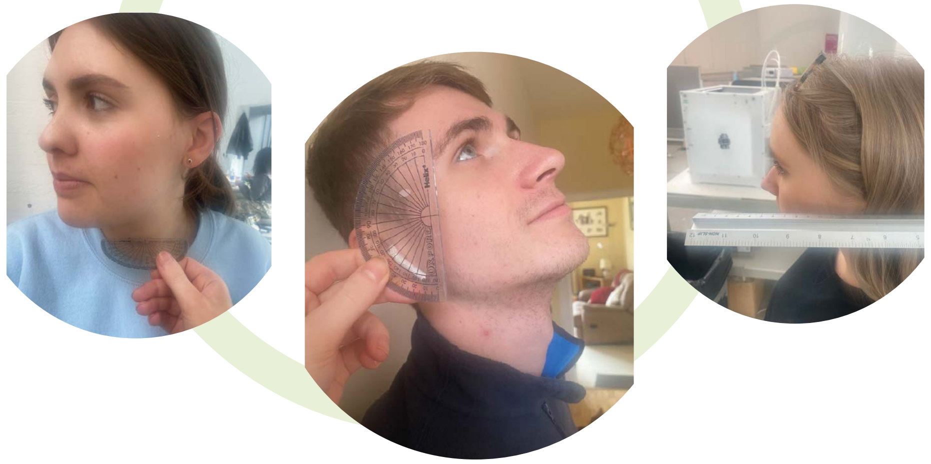
As a carer I want the ability for a manual backup if the wheelchair batteries go flat

Design Parameters

Parameter No.	Parameter Name	Parameter Value
1	Angular step increment	3°
2	Linear step increment	3 mm
3	Total rotational range (yaw and pitch)	(+/-) 40 °
4	Total vertical linear range	80mm
5	Total horizontal range	40mm
6	Time for mechanism to get from a-b (where a-b = total range)	20-25 seconds
7	Maximum force to move a user's head	50N
8	Maximum torque to move a user's head	7.2Nm

Parameters 3-5

These parameters were measured by asking users with healthy necks to move to whatever they deemed to be a 'comfortable position'. The distance from neutral position was measured



Parameter 6

- *An external study showed that patients with ALS move 52% slower than people with healthy necks when completing the extension movement of their neck*
- *I then carried out a study to find the time taken for a person with a healthy neck to complete the range of movement set out in parameter 3. This was recorded and values adjusted by 52% for a person with ALS.*

	1	2	3	4	5	6	AVERAGE
Recorded Time (s) (Healthy Patients)	10	12	12	8	13	15	11.67
Estimated Time (s) (Patient with ALS)	19.2	23.04	23.04	15.96	24.96	28.8	22.4

A range of 20-25 seconds was selected for Power Mount to complete its full range of movement in the various directions

Parameter 7

Users were asked to lean horizontally against the scales and push slightly to replicate the 'maximum force scenario' against the headrest of a user reclined 180° in their wheelchair, lying on their headrest.

User no.	1	2	3	4	5	6	7	8	9
Mass (g)	4300	3700	5000	5000	4500	3900	4800	4100	4800

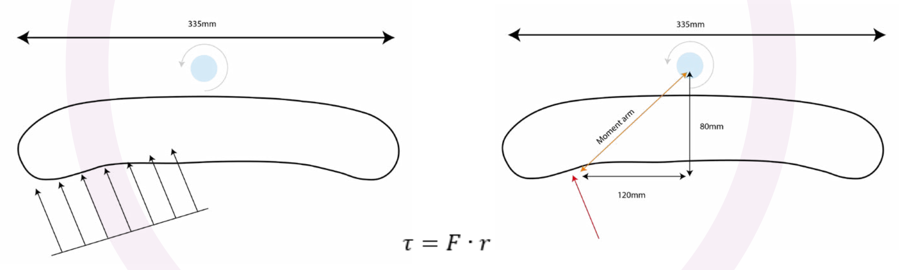
$$Maximum\ Force = m \cdot g$$

$$Maximum\ Force = 5 \cdot 9.81$$

$$Maximum\ Force = 49.05N$$

Parameter 8

The mximum torque required to move a user's head would be when a user is lying horizontally against the headrest pad, slightly off centred, for example if they were sleeping.
The calculated force of 50N would evenly distributed 124mm from the point

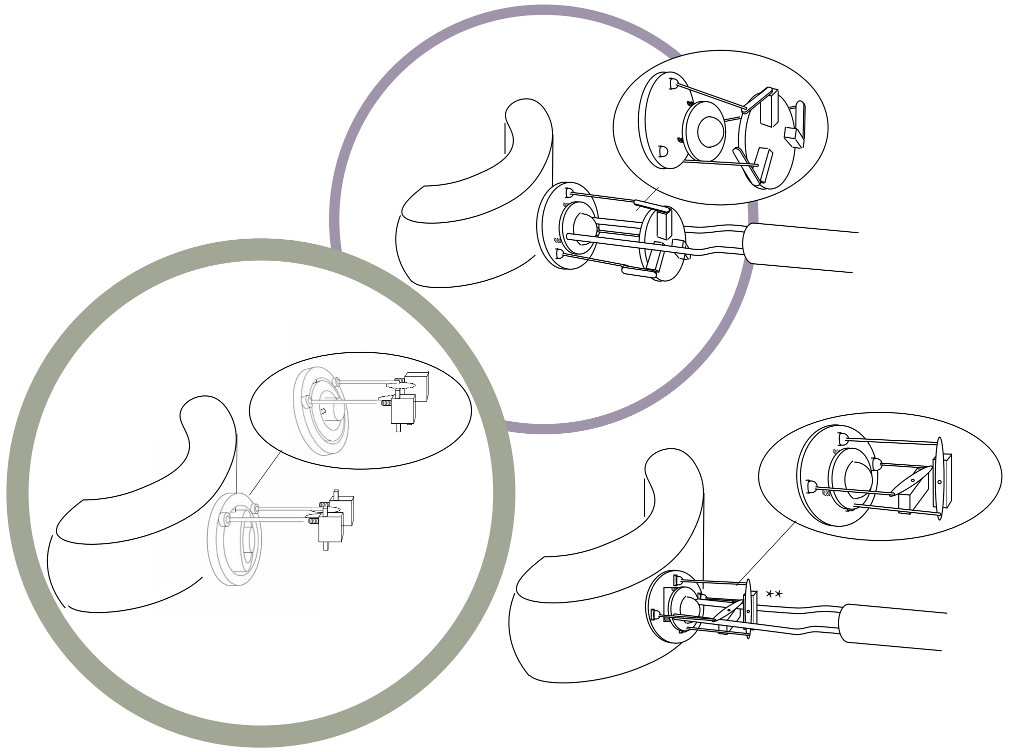


$$\tau = F \cdot r$$

$$\tau = 50(N) \cdot 0.124$$

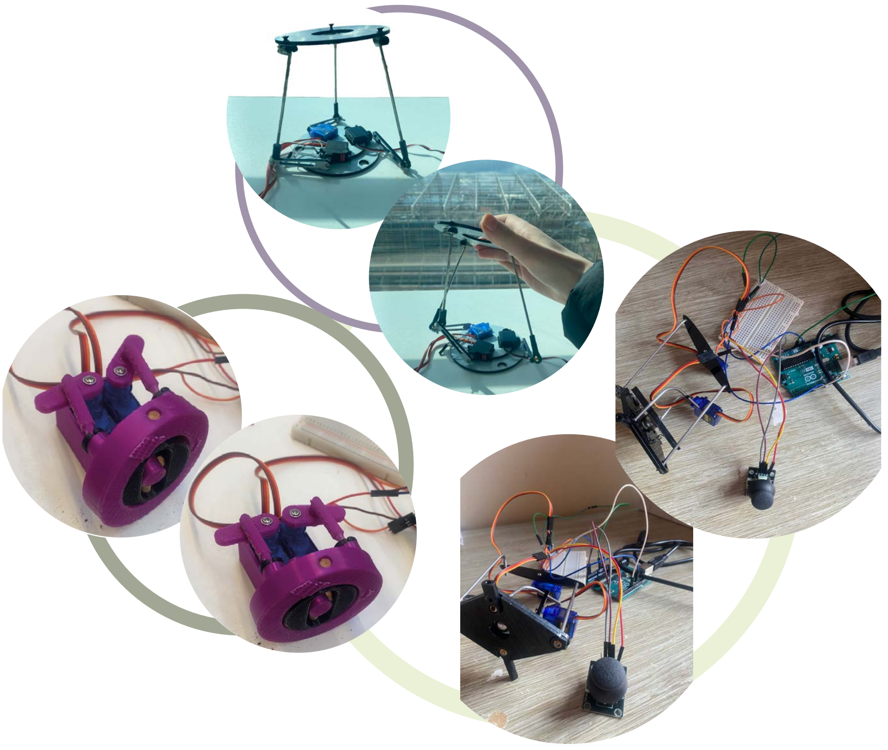
$$\tau = 6.2N \cdot m$$

Rotational mechanism



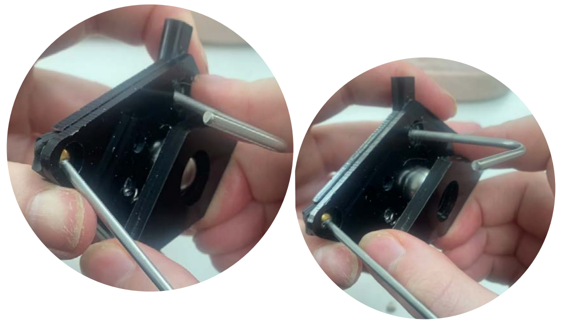
Initial concepts were informed from the examination of other technologies such as:

- Inner mechanism of a Power Car wing mirror
- Flight simulator, which uses a Stewart Platform



Prototypes were tested against the PDR

- By hand with manual movement
- With microprocessor controlling servo motors



Degrees of freedom

- How many DoF the prototype could achieve

Aesthetics

- Reduce overall footprint of the headrest to be less bulky

Safety

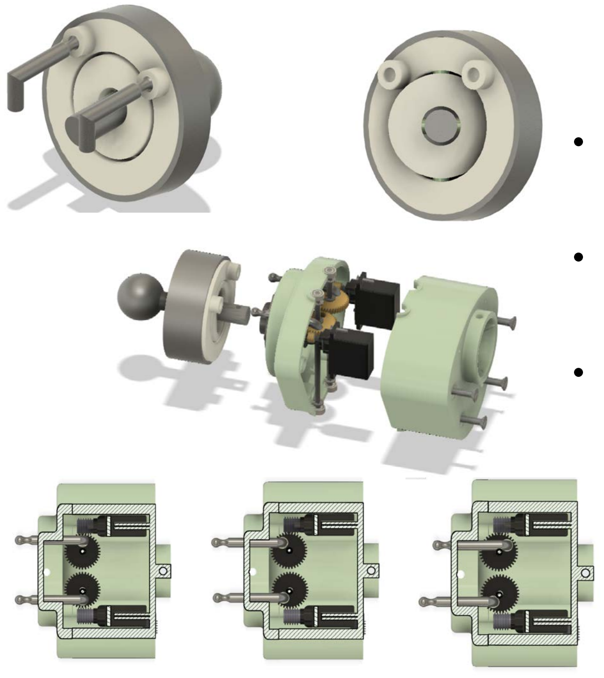
- Could the mechanism withstand worse case loading scenario?

Concept Generation

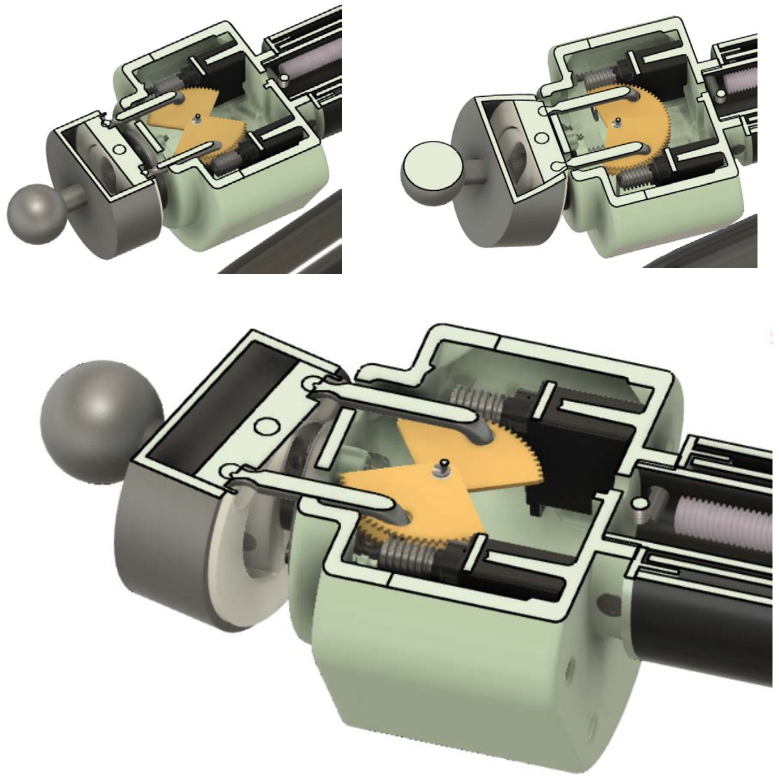
3D modelling / Developing code

Testing/Evaluation

Concept Iteration

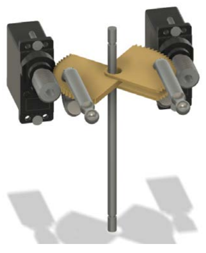


- Gimbal is used to restrict DoF to 2 axis
- Two separate gears control push rods
- Push rods difficult to integrate into the designed motor casing



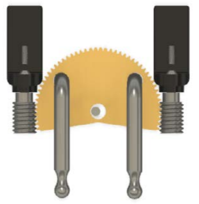
Concept solution

The final solution uses 3 quadrant gear with two quadrant gears at 180° This it to create a gap during maximum rotation



Worm Gear

A worm gear at end of motor shaft used as a locking mechanism, to prevent back drive during extreme loading scenarios.

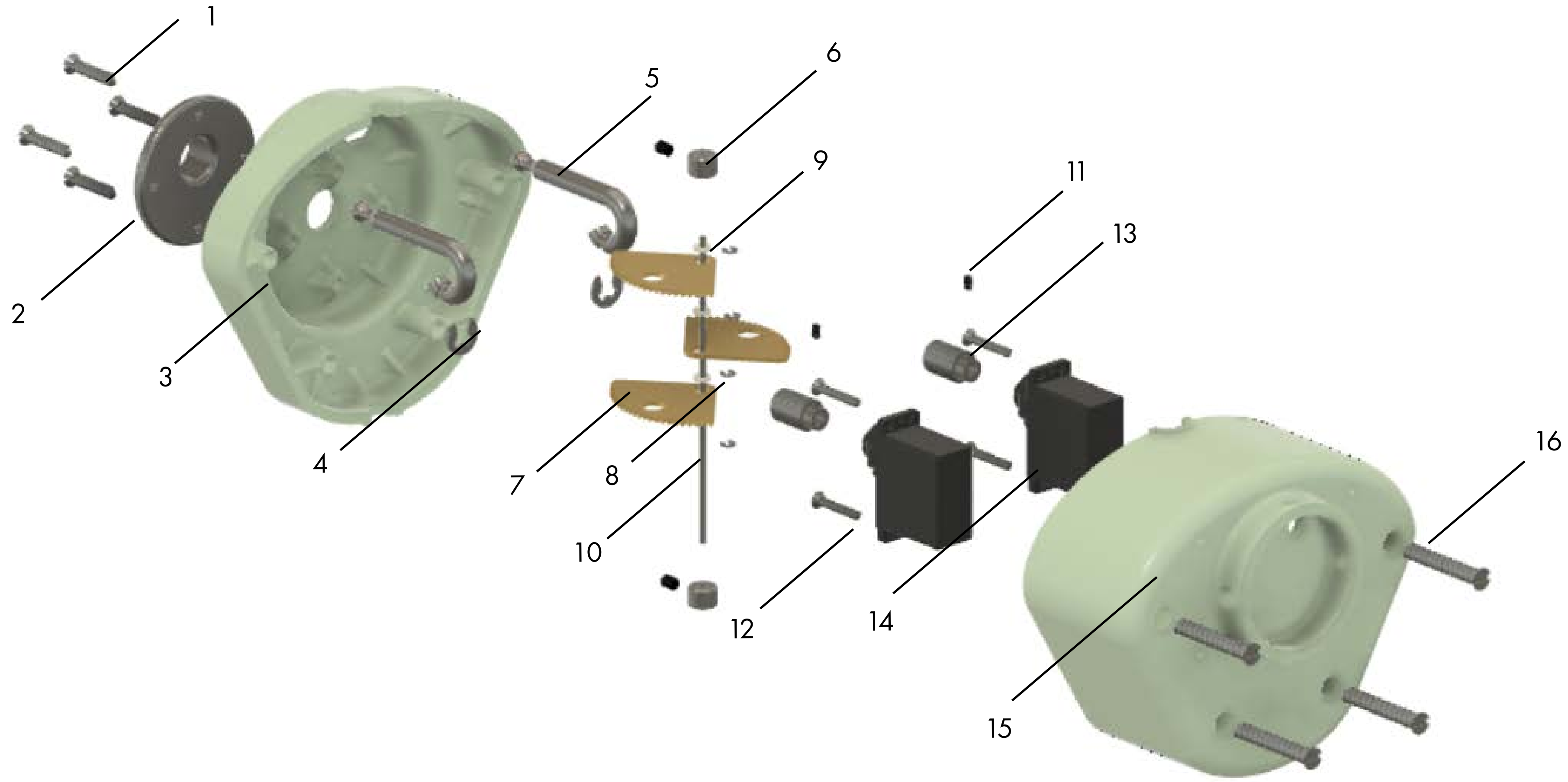


Quadrant gears

Intersecting quadrant gears creates a compact solution.

Sub Assembly - Materials and Manufacture

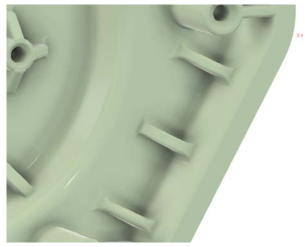
General Arrangement



Part No.	Quantity	Part Description	Part Material	Part manufacture
1	4	No.4 Self tapping screw. L12.5mm	Stainless Steel	Bought in: accu.com
2	1	Steel Bushing	304 Stainless Steel	CNC Turned
3	1	Motor casing cover	ABS	Injection moulded
4	2	E-clips ø4mm (Suitable for 5-7mm shaft)	Stainless Steel	Bought in; accu.com
5	2	Push rods	Stainless Steel	Turned and bent
6	3	Shaft collar (with M3 Grub screw included)	Stainless Steel	Bought in: conrad.com
7	3	Quadrant gear wheel (40mm pitch diameter module 0.5)	Brass	Die-cast
8	4	E-clips ø1.2mm (Suitable for 1.4-2.1mm shaft)	Stainless Steel	Bought in: accu.com
9	3	Nylon plain bearing	Stainless Steel	Pultruded and hole machined
10	1	1.5mm shaft	Stainless Steel	Grooving lathe
11	2	M2 x 2mm Grub screws	ABS	Bought in: accu.com
12	4	No.2 Self tapping screws L12.5mm	Stainless Steel	Bought in: accu.com
13	2	Worm gear for motor shaft	Brass	Outsoure to company, lathe
14	2	Macgregor Servo motor M1203DS	N/A	Bought in: macgregors.com
15	3	Main body for motor casing	ABS	Injection moulded
16	1	No 4. Self tapping screws L25.5mm	Stainless Steel	Bought in: accu,com

Selected Details

Motor casing



Gussets

Designed to be 0.5 x thickness in width and 2x thickness in height and length

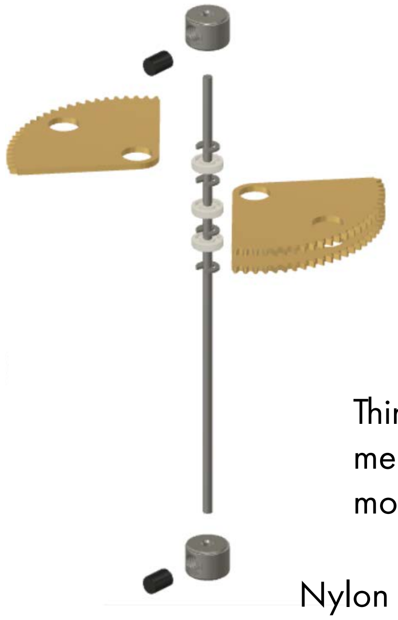
Crush Ribs

1mm radius crush ribs for push fit shaft collar

Screw bosses

Designed to have inner diameter equal the pilot hole of self-tapping screw and outer diameter is two times the screws nominal diameter

Gear and shaft assembly



Tolerances

Bearing and Gears are designed to H7 k6 interference fit standard

Manufacture

Thin gears with precise tolerances means laser cutting brass sheet is the most effective method of manufacture.

Nylon bushing to be pultruded from ø5mm rod to for interference tolerances required for a nominal diameter of 4mm.

Servo Motor

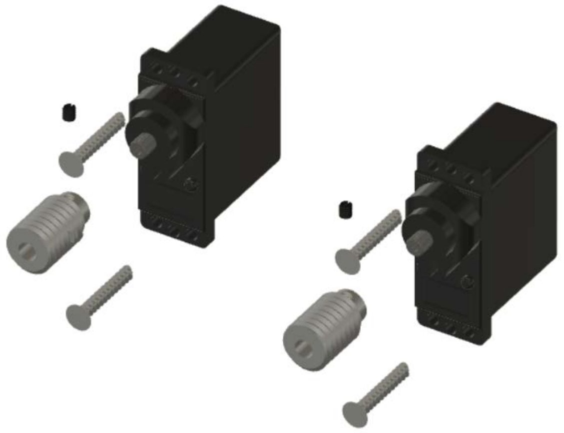
Headrest required to move headrest (+/-40°) in 20 second
0.75

Headrest requires maximum torque of
7.2Nm

Required reduction ratio
1: 100

Motor meets the requirement
Resulting torque: 18N.·m
Resulting RPM: 0.72

Motor sub assembly



Chosen motor spec.
Macgregor Servo motor
M1203DS

RPM= 72
Torque= 0.18 N.·m
Voltage: 4.5V

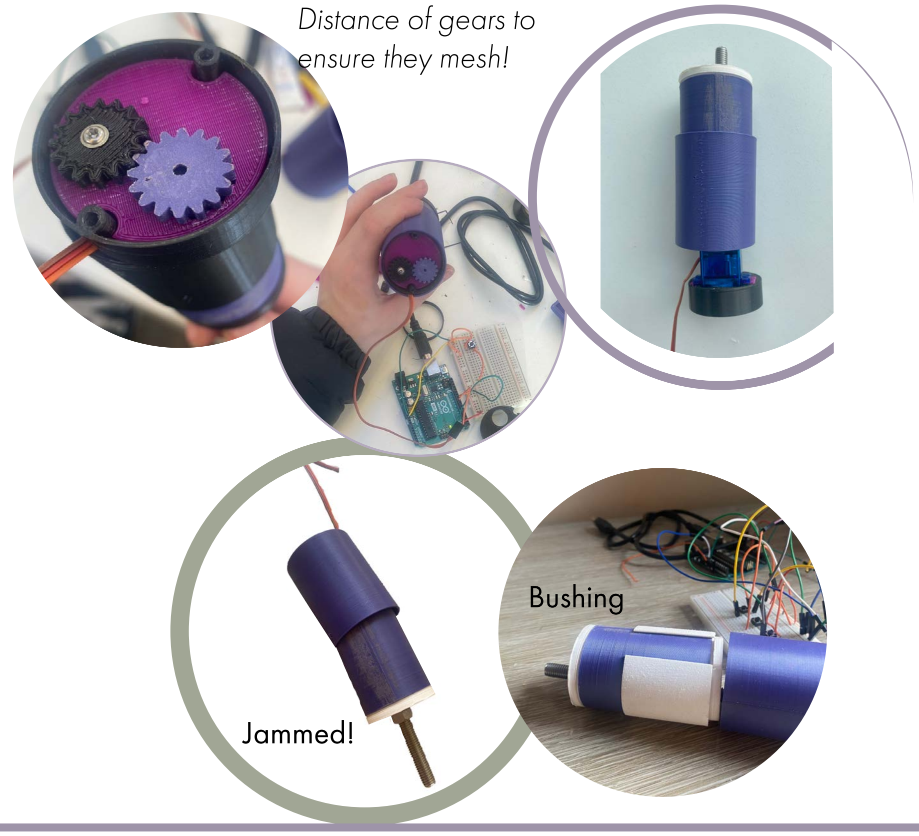
Linear Mechanism

Concept Generation

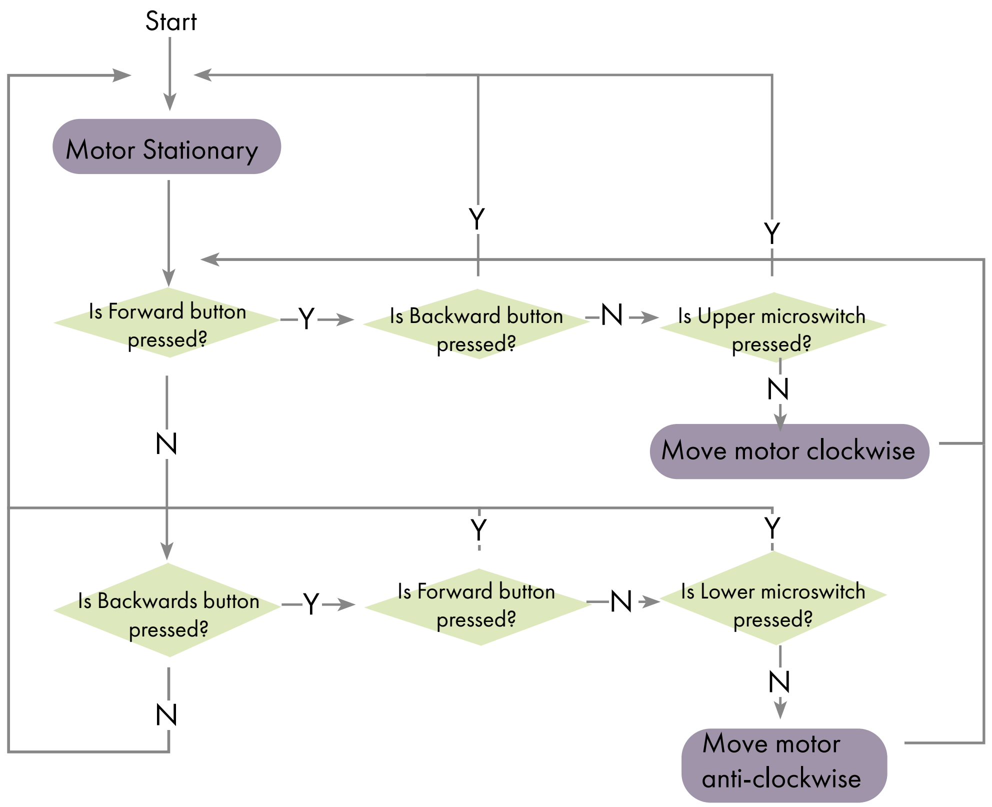
Initial concepts were informed from the examination of other technologies such as:

- Linear actuators
- Rack and pinion

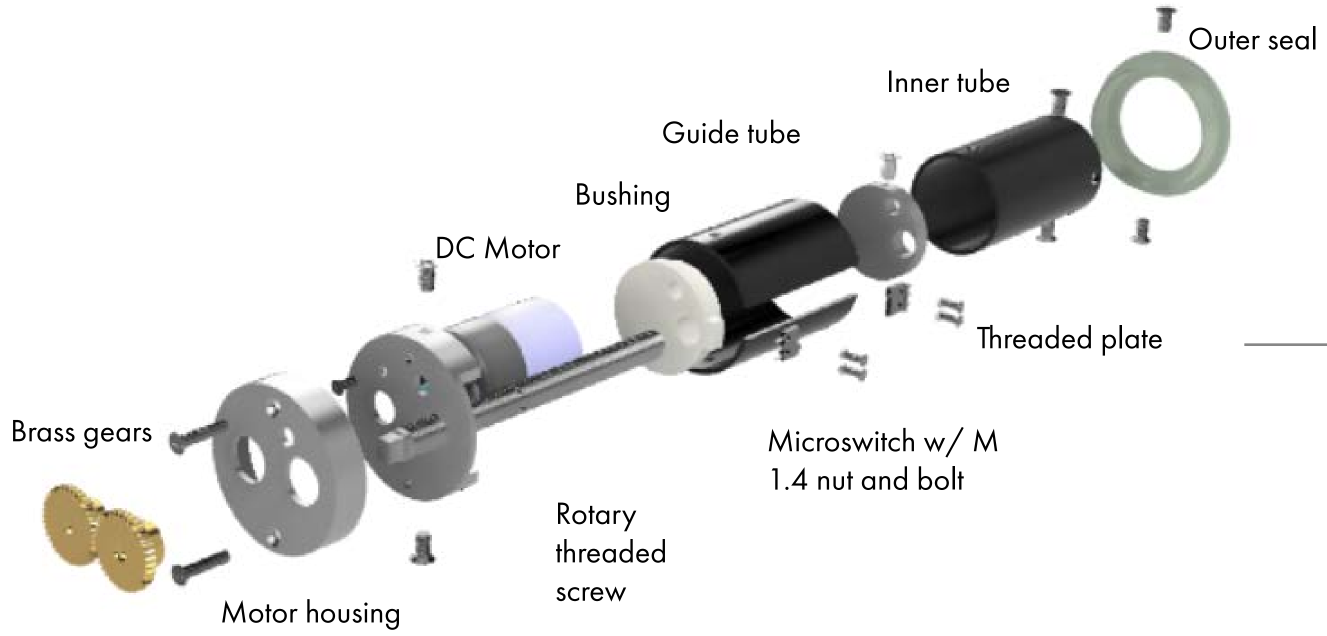
Iterations/testing/evaluation

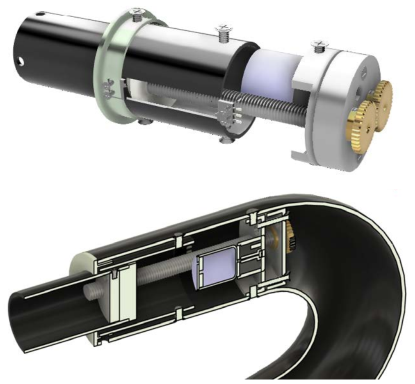


Developing code



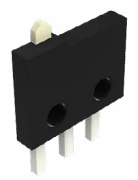
Concept solution





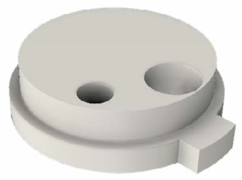
Micro-switches

Micro switches bolted onto the inside of the main body tube to limit the range of motion.



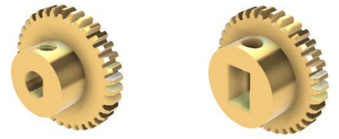
Bushing

- Bushings are used to stop inner tube jamming and create linear only motion
- Nylon selected for it's sliding wear and low friction when in contact with metal



Gears

Gears and rotary shaft to be machined to easily fit together, and connected with a grub screw



User journeys

Prescription of Power Mount to Bill

User cycle 1

At the clinic

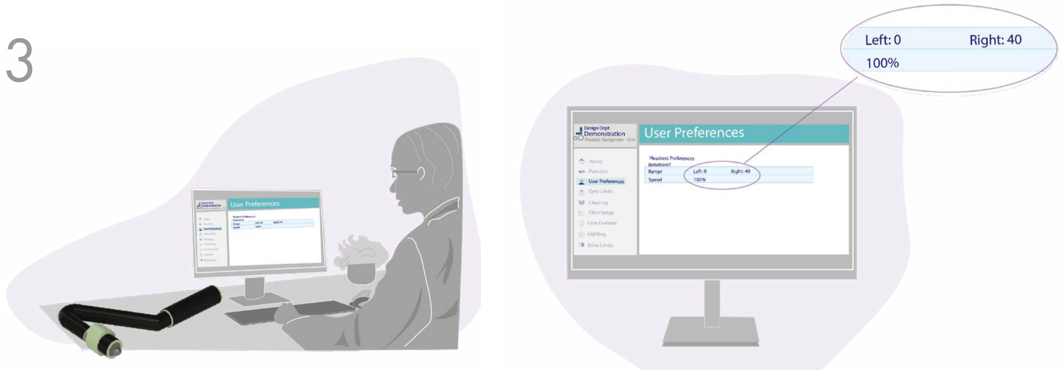
1

Bill has Parkinsons disease and has a tendency to lean to one side. He is non verbal

2

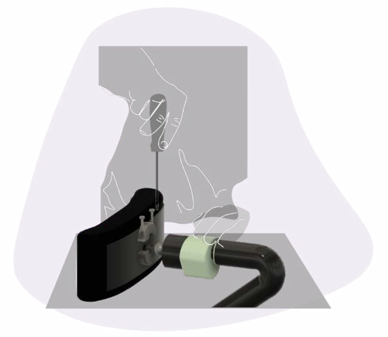
The physiotherapist asks Bill whether he would like to purchase The Power Mount.

3



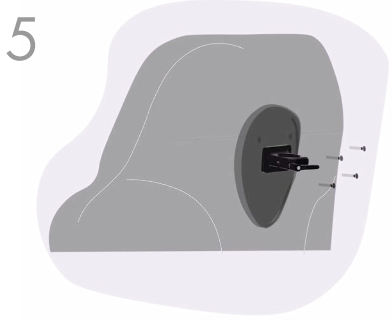
The biomedical engineer adjusts the limits using the software package Linx to remove the limits on the side which Bill tends to lean to.

4



The workshop engineer attach on an external head pad onto the mount, using the ball joint. This is clamped together.

5

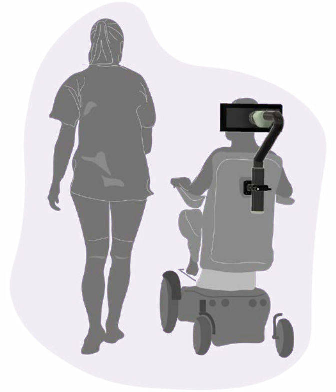


The mounting bracket is connected via screws to the universal mounting plate on the back of the wheelchair

6

The headrest is clamped into the mounting bracket and plugged into the power module located at the bottom of the chair

7



Bill leaves the clinic and need a review appointment for a few weeks

Limits can be adjusted based on the patient's presenting symptoms and current range of movement

Headrests pads of different shapes can be attached onto the mount to suit patient's needs

Patients don't need to return to the clinc to fix slipping issues as the adjustments are not based on the use of screws which reduces numbers of vists required

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User cycle 2

Day in the life

User can move their headrest at times when they may not have done so if the adjustments were manual

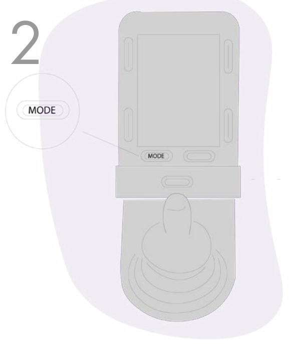
It is predicted users will move their headrests 3-5 times a day. This should lead to more comfort, better social interactions and an improved quality of life.

The design assumes joystick control as per wheelchair standard and medical professional recommendation. Alternate control systems could be integrated later by a biomedical engineers

1

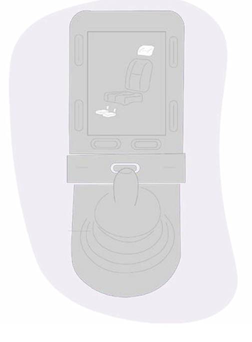
In the morning Mary, his wife, hoists Bill into the wheelchair. but the headrest is digging into him. He can't tell her as he is non-verbal

2



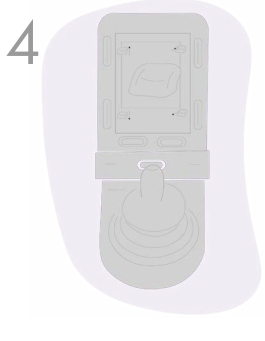
Bill clicks 'mode' on his wheelchair joystick

3



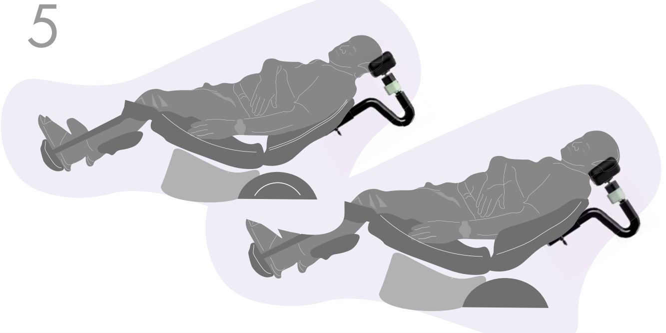
At the adjustment menu, he moves the joystick until the headrest is highlighted

4



Bill can now use the joystick to make fine adjustments to the headrests position

5

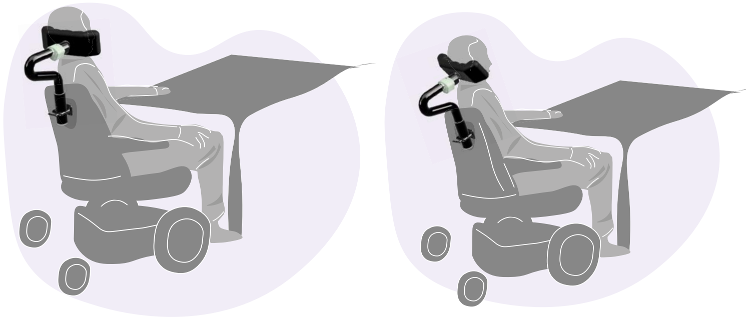


Later Bill is sleeping so reclines back 150°. The headrest is too high, so using the joystick module he moves it down and rolls it back.

6

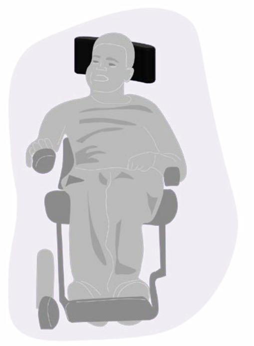
The wheelchair batteries go flat on the wheelchair but Bill wants the headrest rolled back. His son Ben can do this by releasing the headrest pad from the ball joint and manually moving it

7

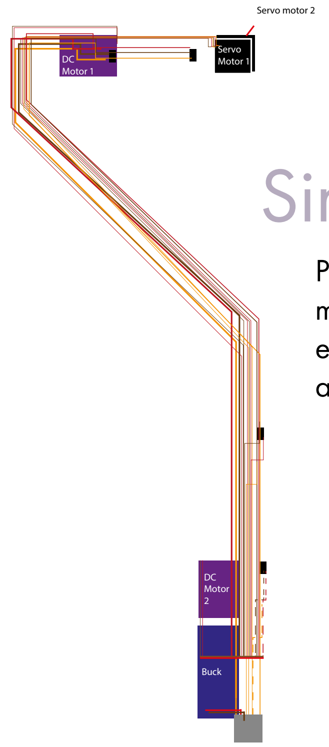


The wheelchair is now fully charged At the dinner table Bill rolls his head back slightly. This is more comortable for Bill while eating

7



Before bed Mary is sitting to the right of him. He moves the headrest around to gain better eye contact while she is talking to him



Control system

Simple integration

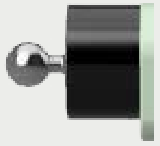
Power mount will be plugged into the wheelchairs power module, located at the bottom of the wheelchair, which is where existing actuators are already plugged in. This supplies power and receives control inputs

Micro-proccessor control

Control wires would be connected to the Power Module, which is a microprocessor, and is used to control the motors for precise movements via the wheelchair joystick using the code developed in this project.

Ball joint

The ball joint on Power Mount can be used to clamp on many current wheelchair headrests

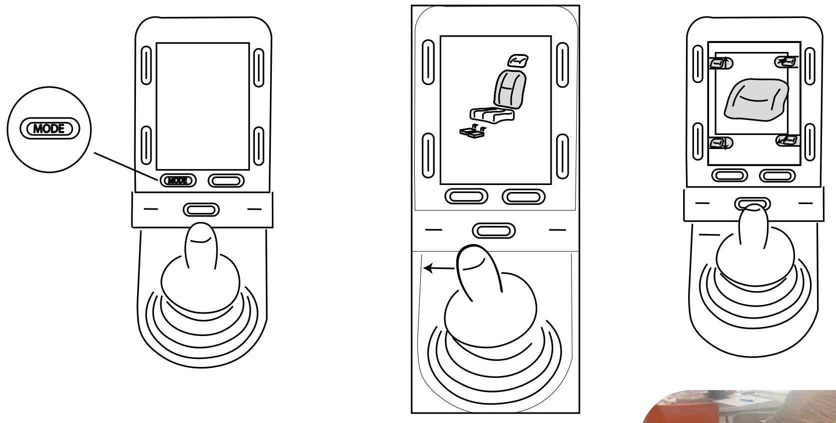


This also serves as a manual backup for carers should the wheelchair batteries go flat. Carers can un-clamp the headrest and move it around the ball joint.

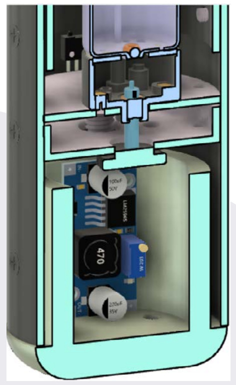
There is a range of headrest for patients with different mobility needs that can to be attached to Power Mount

On board controls

Power Mount has been design to be operated with the existing on board wheelchair controls, which is usually a joystick This was feedback that was received from wheelchair users and medical professionals alike.
The design of Power Mount is adaptable and Bio-medical engineers will be able to adapt to different control methods.

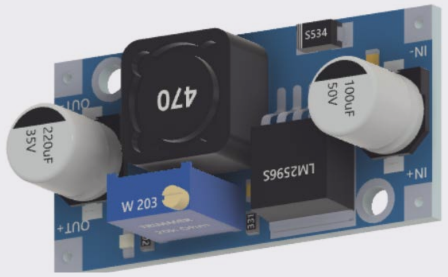


Battery supply



Internal buck

The internal buck is used to supply 4.5 V to the motors from the 2x 12 V wheelchair batteries



Charging

Wheelchair batteries are charged via a socket in the joystick module. The batteries are used to control the headrest

Battery useage

Estimated that headrest is adjusted 3-5 times every day (from survey above)

Total power used for 5 adjustments:
1.25W everyday

5 adjustments taking 30 seconds each
Amp hours: 0.01Ah (every day)

Wheelchair has a 50 Ah
Additional actuator is negligible battery consumption

User testing joystick

User testing was carried out to evaluate how users would intuitively want to interact with the joystick to achieve the desirable movements

Mounting Bracket

A clamping mount is use to attach the Power Mount the back of wheelchair. It is screwed onto the universal mounting plate, or the back of the wheelchair frame.

Loading scenario 1: Sudden deceleration

Crash testing: Deceleration of 10m/s^2 in accordance with British Standards

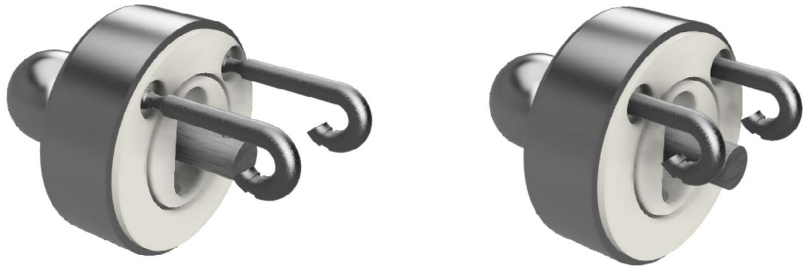
Design implications

Steel plate with ball joint

Steel plate would be manufactured from pressed sheet metal with a ball joint screwed into it

This is used to

1. Protect users head from the push rods breaking through nylon gimabl in event of extreme loading
2. Allow headrest pads to be attached on



PDR No. 8

Moving pad around the ball joint would serve as a manual backup for users.

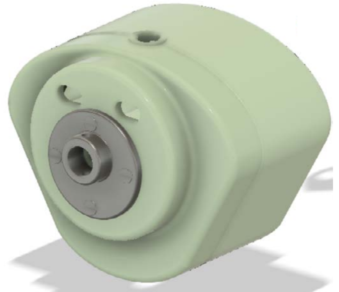
Loading scenario 2: User leaning on the end of the headrest

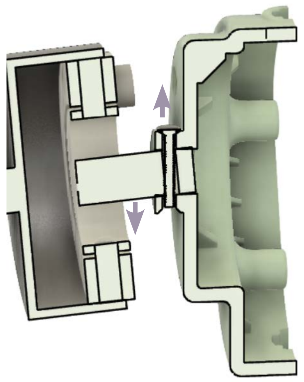
Mass of 100kg at the end of a cantilever beam

Design implications

Steel plate/bushing

ABS is not strong enough on it's own and so the addtion of a steel plate resists moment due to the connection of the headrest to the motor casing. Size of bushing plate resists moment at the point it connects to the motor housing





$$Moment = Force \ x \ distance$$
$$Moment = (101.2 \ x \ 9.81) \ x \ 0.12$$
$$Moment = 120Nm$$

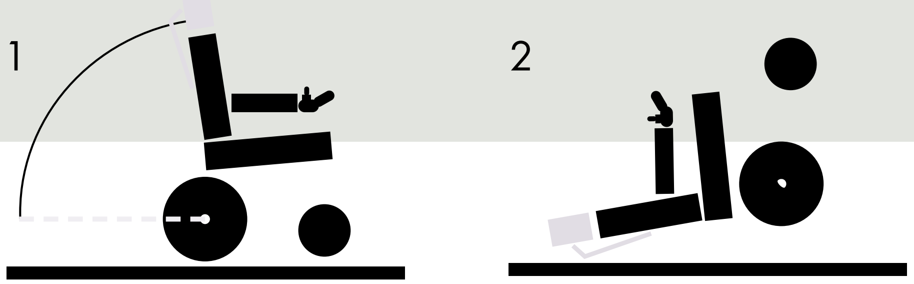
$$Moment = Force \ x \ distance$$
$$120 = Force \ x \ 0.005$$
$$Force = 24kN$$

$$\sigma = \frac{Force}{area}$$
$$\sigma = \frac{24{,}000}{0.00017}$$
$$\sigma = 141MPa$$

Loading scenario 3: Wheelchair tipping

Material needed to protect the internal components .

Height of wheelchair falling = 1m
Weight of person and components above pivot point = 73 kg



Design implication

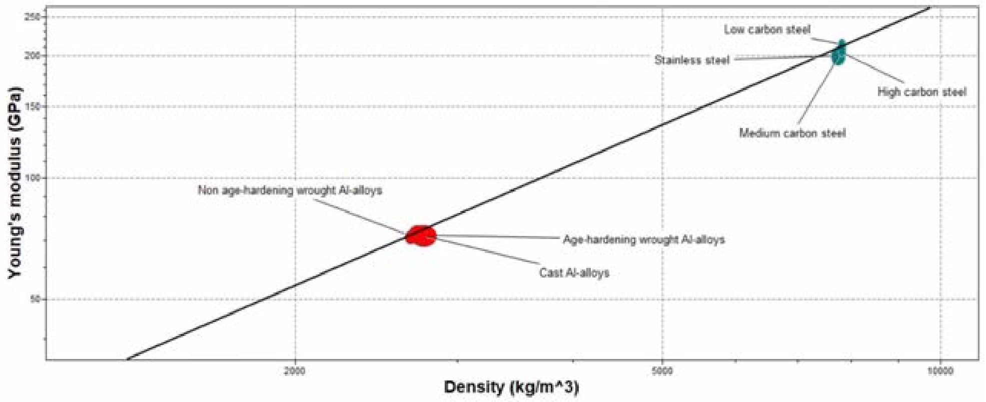
Material Choice

Impact force on the main body of Power Mount
Energy of the weight of the person and wheelchair components that land on the headrest mount during a rotational tip

$0.5v^2$=mgh 4.42 m/s

F= mv/ Δ = 32,266N

Shear stress (on hollow clyindrical beam) = 2F/a = 152.2MPa



Aluminium 6061

Meets strength requirements
Lightweight for less battery consumption
Not brittle (BS- Standard)
Good resistance to fresh water
Already commonly used in wheelchairs

Final user feedback

"Can I get a free one when it comes out"
- Scottish Boccia Player

"It would be great if I didn't have to do anything for him"
- Carer of Boccia Player

"You should show this to wheelchair company brands"
- Scottish Boccia team

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