PEAK RESCUE

Mountain Rescue Universal Stretcher Wheel Unit

Project Summary

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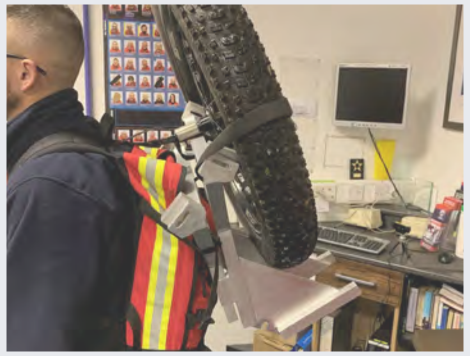
Final Year Project 22/23

+ The Problem

The need for an improved Stretcher Wheel Unit, was identified through a conversation with Jamie Greig, The Equipment Officer at Scottish Mountain Rescue. Stretcher wheels are a device that have been introduced to ease the process of transporting casualties. They allow the casualty to be wheeled down the mountain instead of carried, reducing the number of volunteers required per call-out and providing a smoother journey for the casualty. Current commercially-available Stretcher Wheel Units are a common pain point for teams across the country and there is a significant lack of uniformity in equipment amongst teams. While some units are more effective and easier to use, they come with a high cost (around £1500), whereas cost-effective options are cumbersome and complex to assemble. It should be considered that UK-based Mountain Rescue Team’s rely entirely on donations to finance their operations - the average team requires approximately £40,000 to operate annually.

1. Transporting

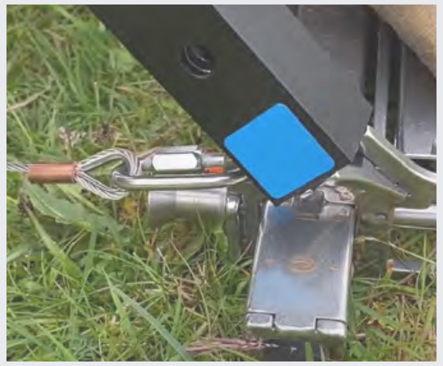
- The device needs to be carried up to the casualty site
- Current stretcher wheels are heavy and cumbersome (7-12kg)
- Volunteers’ already carrying their individual PPE and a significant volume of other equipment
- Incidents can often be above 600m, and can take around 3-4 hours+ to reach the casualty so the team can be carrying equipment for long durations




2. Assembling

- Lots of components - easy to lose on the way
- Fiddly parts - not glove friendly e.g. slings & locking pins
- Set orientations
- Generally over-engineered

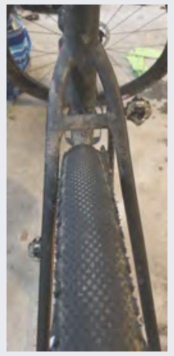




3. Fitting

- Loaded stretcher - casualty must be transferred on ground to minimise further injury
- Dark, cold, or low-visibility conditions aggravate the process
- Wheel positioning and alignment



4. Traversing

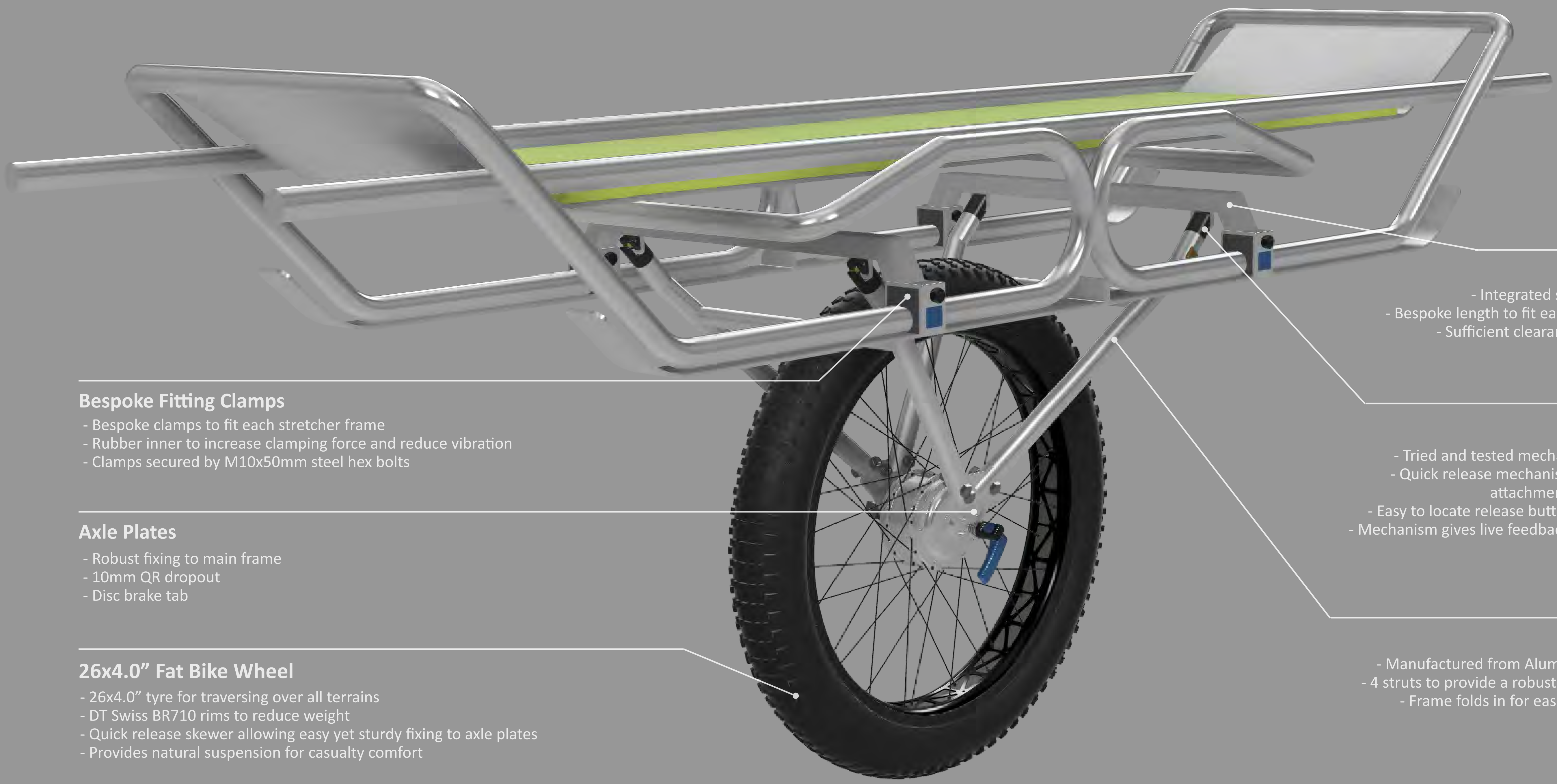
- Variety and diversity of terrain - large boulders to soft peatlands
- Time-consuming to dissemble at obstacles e.g. stiles, fences, rivers
- Lack of braking system
- Lack of comfort for casualty



5. Lack of Uniformity

- Split usage of commercially-available stretcher wheels
- Many teams opting to custom-build their own unit
- All but one unit are not compatible with more than one stretcher model (many teams own several stretchers and stretcher wheels)

+ Product Overview



Support Struts
- Integrated steel Isofix anchors
- Bespoke length to fit each stretcher model
- Sufficient clearance for use of skids

Bespoke Fitting Clamps
- Bespoke clamps to fit each stretcher frame
- Rubber inner to increase clamping force and reduce vibration
- Clamps secured by M10x50mm steel hex bolts

ISOFIX Latch
- Tried and tested mechanism up to 6000N
- Quick release mechanism allows for quick attachment and detachment
- Easy to locate release button in all conditions
- Mechanism gives live feedback and reassurance

Axle Plates
- Robust fixing to main frame
- 10mm QR dropout
- Disc brake tab

Main Frame
- Manufactured from Aluminium 6061 tubing
- 4 struts to provide a robust and reliable frame
- Frame folds in for ease of transportation

26x4.0” Fat Bike Wheel
- 26x4.0” tyre for traversing over all terrains
- DT Swiss BR710 rims to reduce weight
- Quick release skewer allowing easy yet sturdy fixing to axle plates
- Provides natural suspension for casualty comfort

WHO

Mountain Rescue Teams in the UK.

WHAT

A universal, quick release stretcher wheel to allow casualties to be wheeled down the mountain side.

WHEN

For use on casualty call-outs when an injured or in need member of the public cannot descend independently .

WHERE

All outdoor environments - designed to traverse over all terrains.

WHY

Current stretcher wheels are a pain point as they are fiddly to assemble or at an inaccessible price point.

+ Research

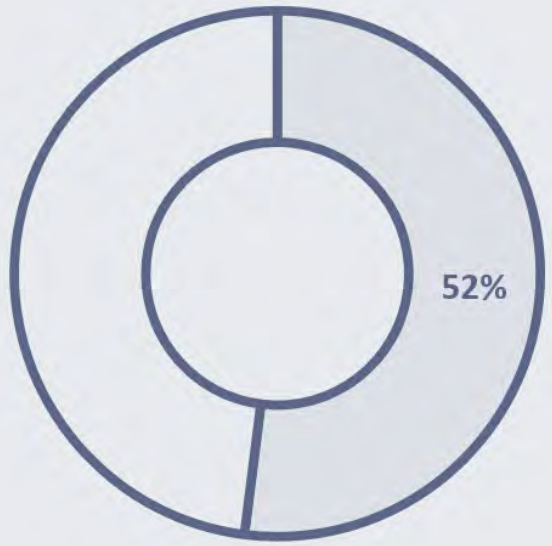
Stretcher Comparison

Each of the four stretcher models was studied in detail to identify each of their features and the similarities and differences between them. This included highlighting potential attachment points on each stretcher frame. A key notable difference between stretchers was the presence or absence of skids as this impacted on the clamp used and it's placement.

Stretcher Model	Safe Working Limit	Mass	Length Open	Frame Material
Bell Tangent	136kg	20kg	192cm	Stainless Steel
Ferno Titan	1134kg	15.1kg	212cm	Titanium
MacInnes Mk6	159kg	18kg	203cm	Aluminium Alloy
SAR Alpine Lite	300kg	12.5kg	210cm	Mild Steel

Current Assembly Processes

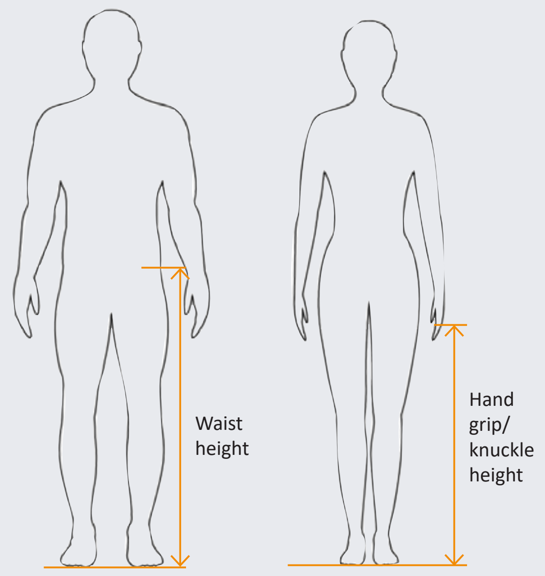
Through visits to local teams and watching video recordings, a picture of the current assembly process for each stretcher wheel was built up. From this, key pain points and time-consuming parts of the process were noted. Through a survey carried out, which was sent out to all 76 teams, 52% of team's reported that they found the current ease of use of their stretcher wheel unacceptable. A further 13% said that it was satisfactory.



5/22 steps in the assembly process of the Lyon Stretcher Wheel Unit.

Human Factors

An important consideration was the overall height of the unit. It should be comfortable for a wide range of users and minimise stooping of volunteers or them having to reach upwards. From speaking to mountain rescue volunteers and cross-referencing their views with ergonomic guides, I found that the ideal handle height should be between standing knuckle height and waist height (this is also taking into account the thickness of shoes worn). Different heights were marked out and tested with users to find the optimal handle height of 880mm.



September 2022

Initial Problem Identification
Conversation with Jamie Grieg, Equipment Officer @Scottish Mountain Rescue

Visit & Interview: Lomond MRT
Observation of stretcher wheel assembly process (Ferno Titan) with Tom Percival and Martin McCallum.

Mountain Rescue Training Session
General Equipment Usage and Protocols

Peak District Mountain Rescue Organisation Equipment Officers Meeting
Comparison and evaluation of each teams current wheel setup.

The Female Perspective
Conversations with female volunteers to identify unique challenges.

Visit & Concept Evaluation: Arrochar MRT
Observation of stretcher wheel assembly process (MacInnes Mk6) and concept discussion with Mark Leyland.

Interview & Concept Evaluation: North East Wales Search & Rescue
Mike Jones, Volunteer

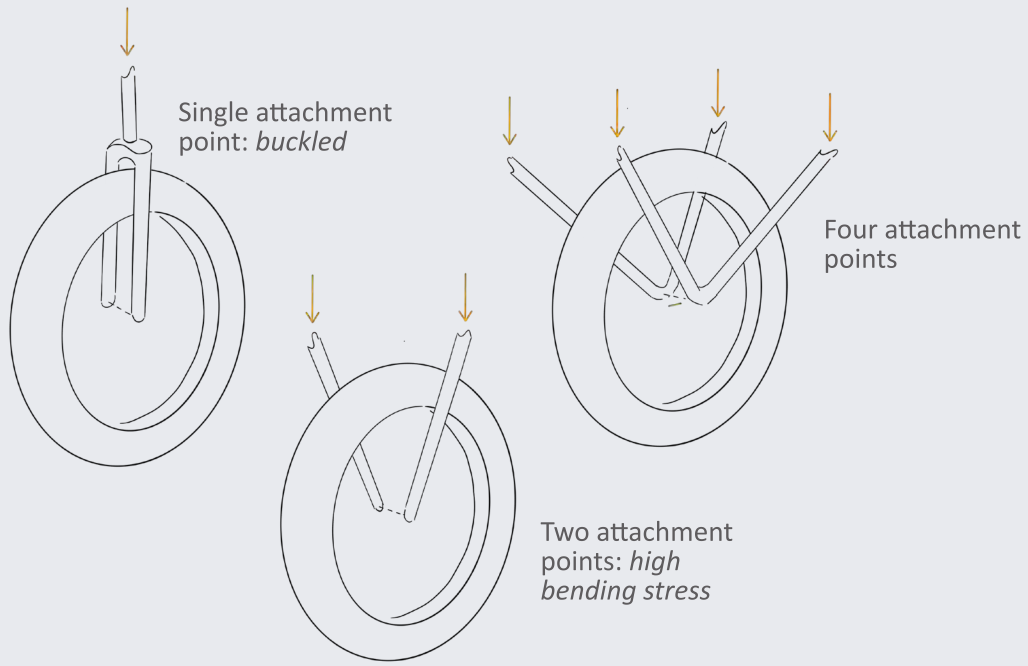
Wheel Evaluation & Build Process
Conversations with GAMMA Transport Division, Glasgow Bike Hive & Biketrax

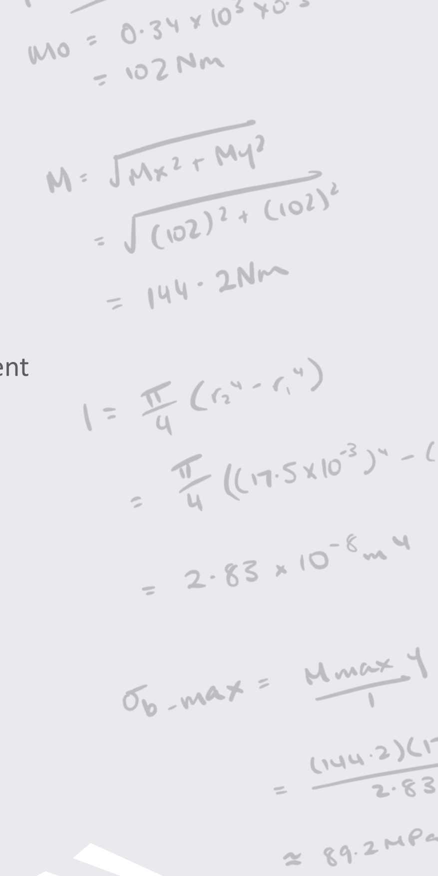
April 2023

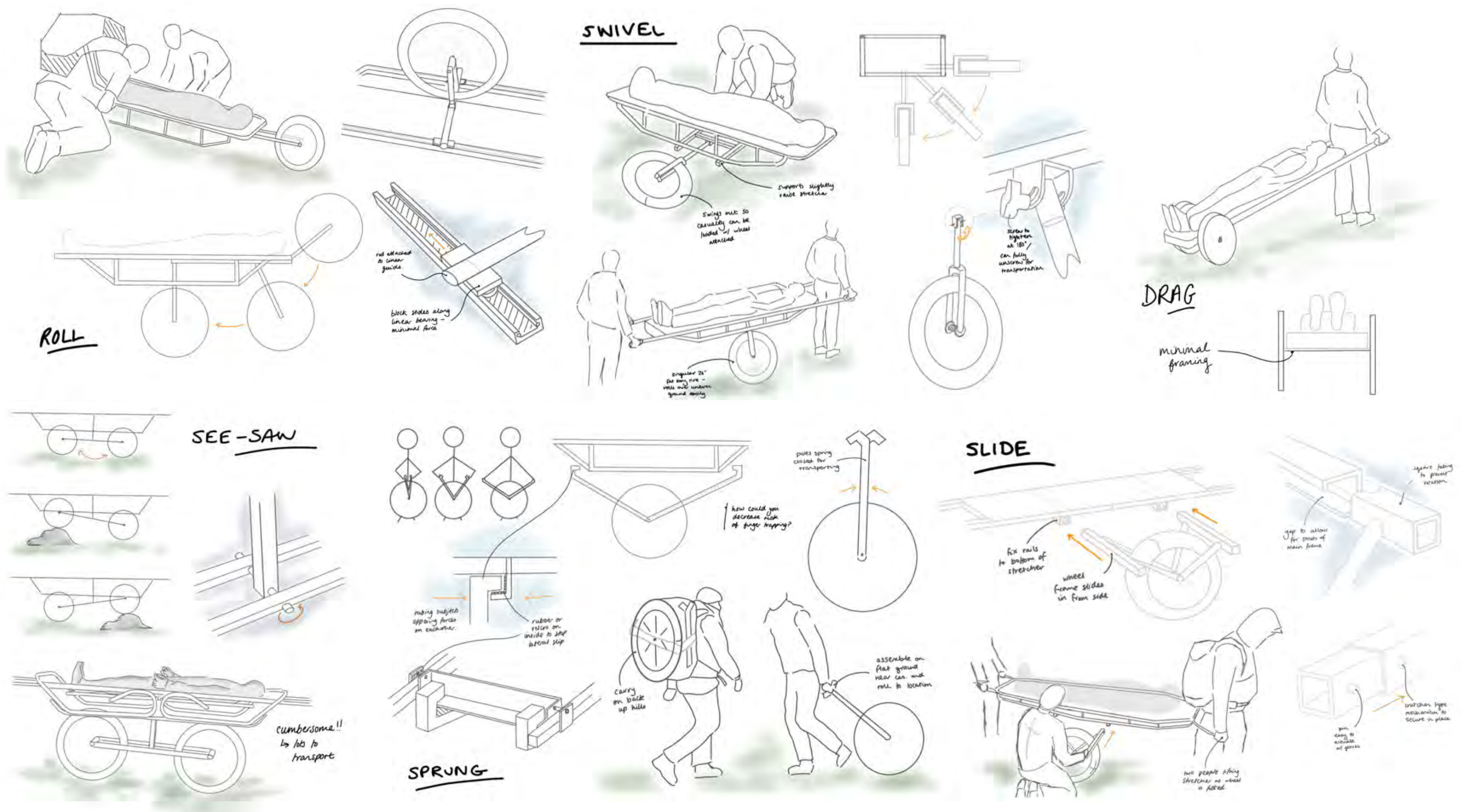
+ Design Process 1

Initial concepts were generated, these mainly focused on the problem of attaching the wheel, after the casualty has been loaded, as this was deemed to be one of the most fiddly parts of the assembly process. A selection of these concepts were presented at the interim presentations and to mountain rescue personnel to gain feedback. Simultaneously, rudimentary calculations were done to assess how different frame geometries would behave under the anticipated load.

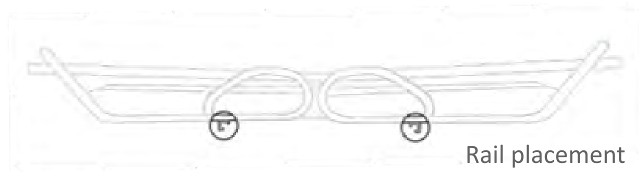
After feedback from volunteers, a slide-in concept was originally selected as the most favourable. This allowed volunteers to slide the wheel in from the side instead of attaching the wheel from underneath.







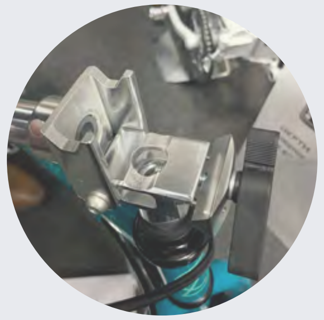
After 3D modelling and user testing of this concept, the design took a change in direction. Some of the stretcher models feature skids on the bottom and therefore no rails or fixtures could fall below the skids as this would void their use. Debris, such as mud and dirt getting inside the rails also made it difficult to maintain and restricted the slide in motion - this would result in the user exerting more force than necessary.

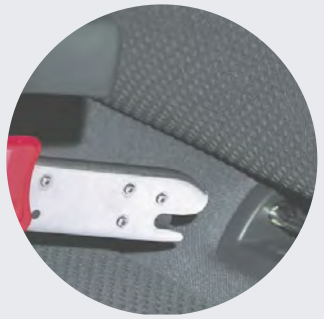


Rail placement

Stretcher's skids in use

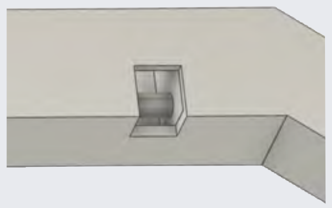
+ Design Process 2




Existing mechanisms were explored for transferability to mountain rescue applications - in particular, quick-release mechanisms. Thule roof racks provided valuable inspiration with their approach of providing customised rails, depending on the car make, and a universal attachment.

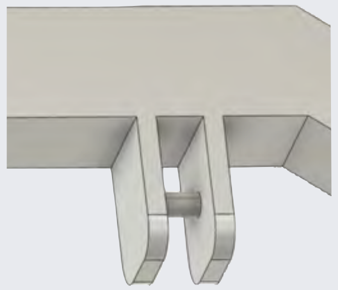
Additionally, the Isofix mechanism achieved all the requirements set out for an effective attachment method. This mechanism was selected and applied due to its effectiveness, ease of use, and high-impact resistance, having been tried and tested above the intended load. Firstly, the anchorage points required for the Isofix latch to connect to were developed.



Anchor V1

Metal bar embedded inside support strut.

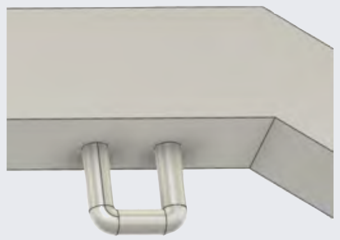
+ Sleek, does not protrude out from strut
+ Gap provides easy method of locating anchor
- Difficult to manufacture
- Ingress could obstruct the Isofix latch



Anchor V2

Metal bar secured between plates on exterior of strut.

+ Plates eliminate lateral movement
- Plates act as obstruction to locating anchor point
- Difficult to manufacture as anchor is steel (cannot weld to aluminium strut)



Anchor V3

Metal bar bent to shape and secured to exterior of strut.

+ Simple
+ Easy to clean debris out of
+ Can be mechanically secured

Testing

Simulations

Concerns were raised about the structural integrity of concept 2 as a cut in the supporting strut would introduce an area of weakness. A brief simulation was run on the concepts to evaluate how each concept performed under the intended load. The simulation results showed that all three designs presented a very similar stress and deformation profile. Therefore, the anchor design depended on user preference and ease of use in the environment.

User-based

A user test was set up where the fixings were attached to the underside of a table. Users were then asked to try and locate the anchor point blindly and connect the Isofix latch to it. User testing concluded that concepts 1 and 2 were both easy to use, however, users found that on concept 3 the plates acted more as barriers rather than guides especially when trying to connect the fixing blindly.

Through user testing, it was also concluded that the anchorage points should be placed as far out on the supporting struts as possible to minimise the user's reach underneath the stretcher.

Environmental

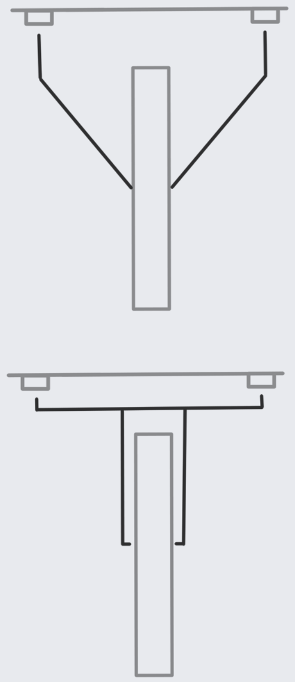
Testing was carried to out to verify that the Isofix mechanism would still function in the presence of debris and snow. The Isofix latch was filled with mud and proved that it was still able to engage upon contact with the anchor point. However, when Anchor V1 was compacted with mud it obstructed the latch from fitting in the gap. Anchor V3 performed the best in this test as the debris was able to fall out easily.

+ Design Process 3

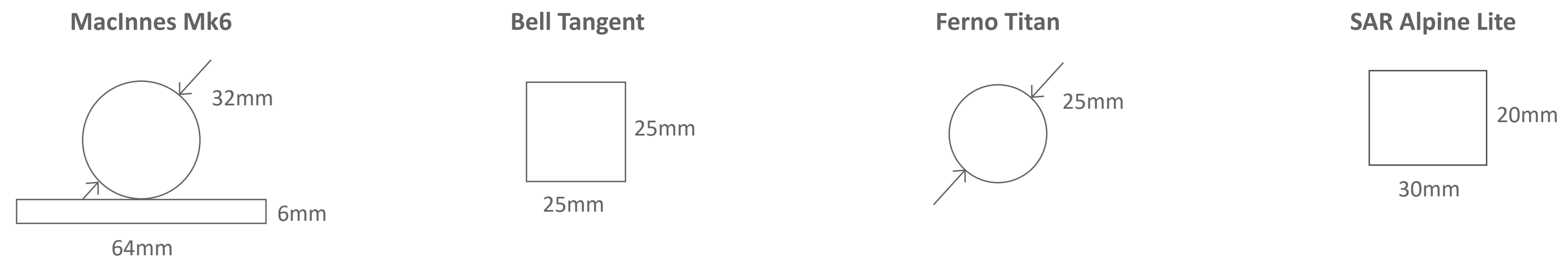
Frame Refinement

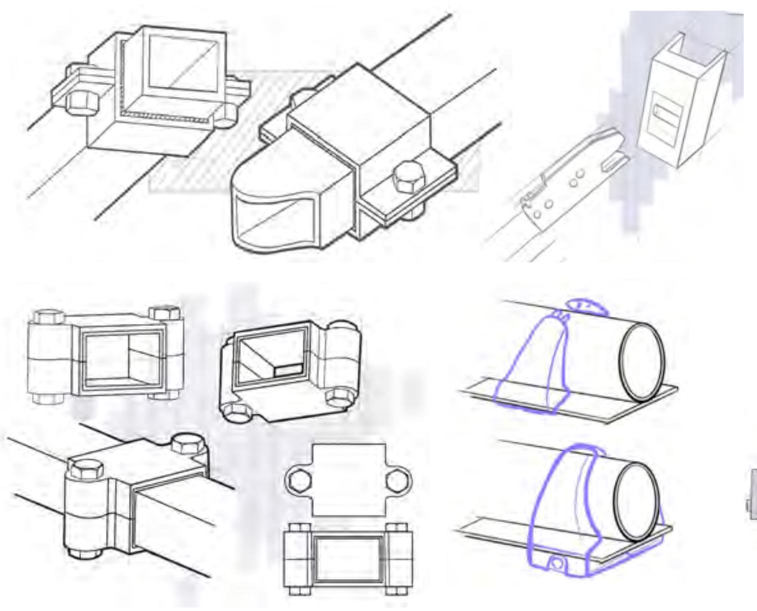
Aspects of the frame design were explored further including the frame geometry and height adjustment. In particular, the amount of splay was considered - splaying the frame ensured the unit would still be able to function if the wheel was to become unstable and not perfectly balanced.

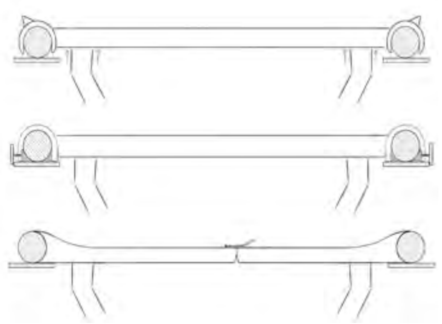
Height adjustment was considered as a method of altering the height of the frame depending on the stretcher model and also to give teams some flexibility in the height of the stretcher depending on the volunteers guiding it. Ultimately, it was decided that changing the angle to alter the height resulted in fewer touch points and less time being wasted on the hill.

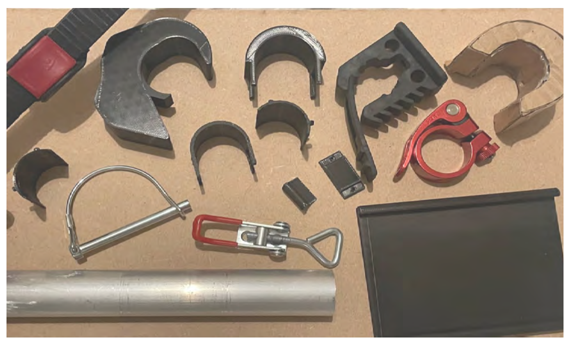


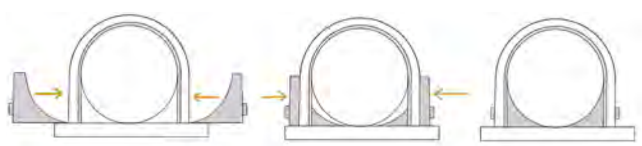
User Testing of Height Adjustment

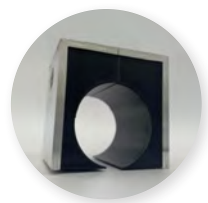












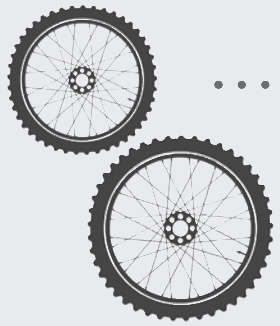
Clamp Development

The bespoke clamps for each stretcher model were developed through 2D and 3D modelling. The clamp required for each stretcher varies as each stretcher's framing has a different cross-section. Despite this, the aesthetics and method of assembly between clamps was kept as consistent as possible.

Initially, the anchor and bolt to tighten the clamping system were combined. These were later separated into separate components in order to reduce the clamp size and allow the clamp geometry to be refined.

The final clamp design for the MacInnes Mk6 stretcher comprises of an aluminium outer shell and rubber inner to absorb vibrations and increase the clamping force. Through development, the clamp size was sized down to 50.8mm in height so that standard aluminium channel could be used for the outer shell. Standard channel provided a much higher level of structural integrity and ensured consistency between parts. Additionally, switching to standard aluminium channel, reduces the time and cost of the process as it is less labour intensive.

+ The Wheel



Wheel Size
A 26x4.0" fat bike tyre was selected. The large diameter is designed for low ground pressure to allow easier rolling on soft, unstable terrain, such as snow, sand, bogs and mud. Additionally, a greater diameter wheel, means less framing was required to achieve the desired height.

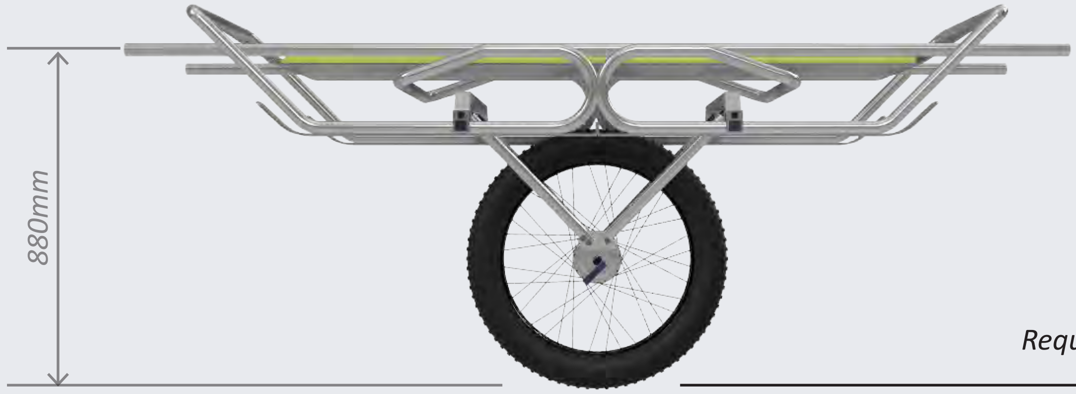
Suspension
The low tyre pressure also offers an element of natural suspension. This provides a more comfortable descent for the casualty down the mountain side. Suspension systems offer better shock and vibration absorption however, add significant weight and are typically heavier and require more maintenance than a fat bike tyre.

Brakes
The axle plate that connects to the wheel has a disc brake tab allowing teams to add brakes to the wheel to provide better control over the stretcher. This is a feature that is absent from many of the commercially-available units.

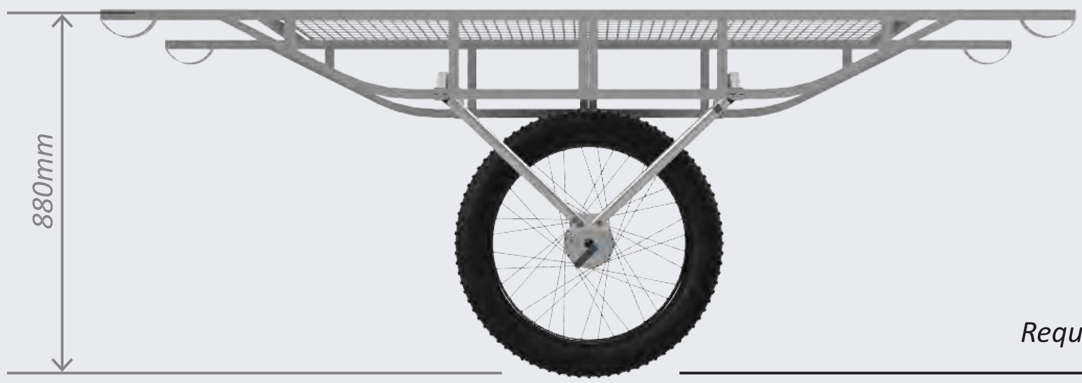
Puncturing
The wheel would arrive slimed to help protect against punctures. Slime is a cost-effective, tyre sealant which consists of fibres, binders and other substances that are suspended within a liquid. The slime is typically injected into the tyre and upon puncturing, the liquid mixture fills any punctures or leaks and dries into a rubber-like, flexible substance. This helps seal the hole to prevent air from escaping and extends the tyre lifetime.

One wheel, several possibilities

For each stretcher model, the clamps have a different spacing specification. This is so that the frame attaches at the correct angle to give the ideal handle height of 880mm. A jig would be provided to help achieve this spacing.

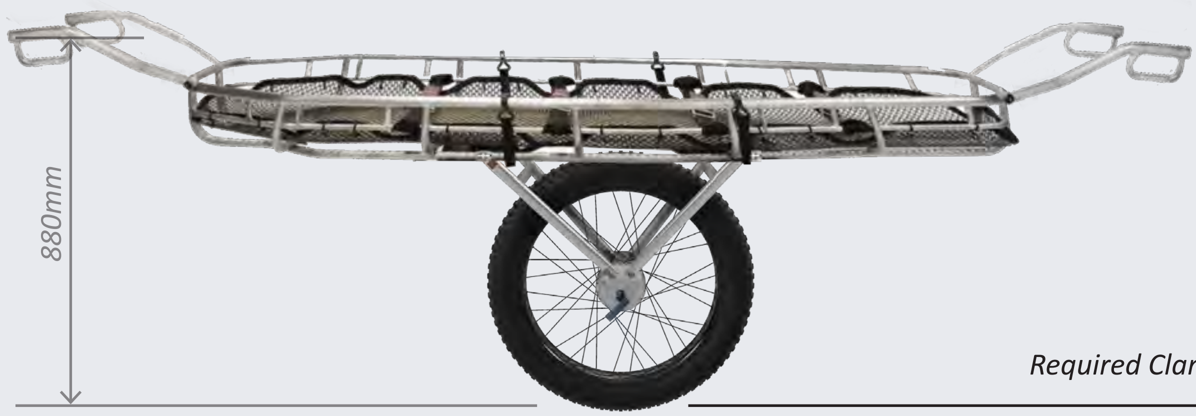


MacInnes Mk6
Required Clamp Spacing: 680mm



Bell Tangent
Required Clamp Spacing: 735mm

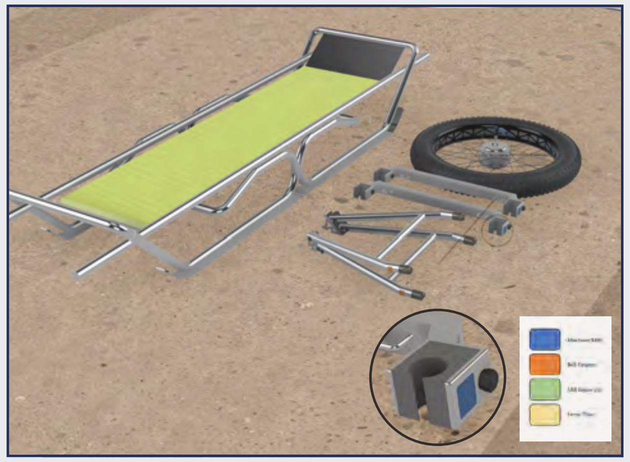
SAR Alpine Lite
Required Clamp Spacing: 560mm



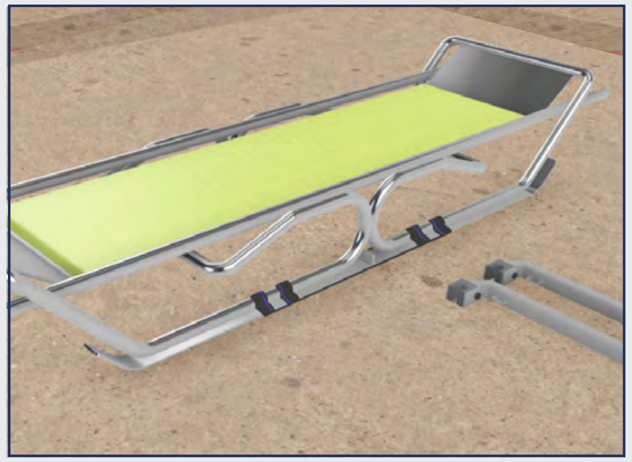
Ferno Titan
Required Clamp Spacing: 635mm

+ User Journey

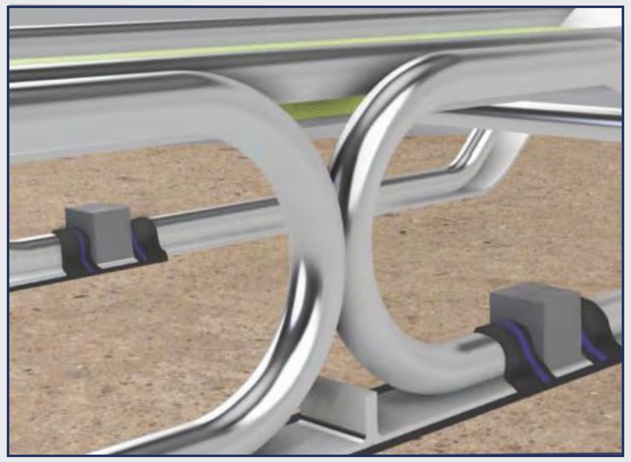
Set-up



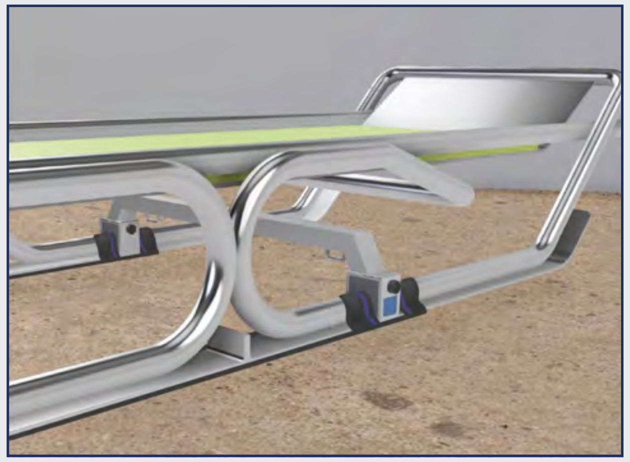
The team's stretcher and Peak Rescue stretcher wheel kit is laid out. It is checked that the right clamps have been provided by checking the colour code on the side.



The jig is attached to the stretcher - this is to help align and position the clamps correctly.



The inner clamp part is fixed around the stretcher frame first. Volunteers' check it has a snug fit and is correctly positioned and aligned within the jig.



Volunteers' fit the clamp's outer shell and support struts on top and secure in place with the M10 nuts and bolts provided. Now the support struts are fitted to the stretcher and ready to use.

Transportation

Volunteers' unload the frame and wheel unit from the team vehicle before walking to the casualty site.

Volunteers' fold the frame in to make it more compact for transporting.

Volunteer's secure the stretcher wheel frame to the exterior of their backpack using its existing straps and bungee cord.

Volunteers' carry the unit disassembled up to the casualty site on their back. One volunteer should take the frame, whilst another carries the wheel to spread the load.

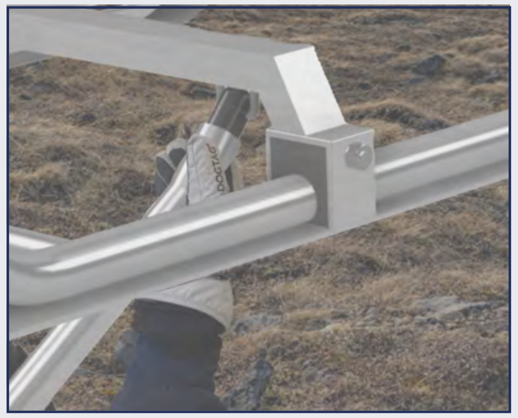
Attachment

The team load the casualty onto the stretcher at ground level to prevent further injury.

Volunteer's prepare the stretcher wheel unit by folding out the frame and attaching it to the wheel using its quick release.

Volunteer's align and secure the isofix latches to the anchorage points. The Isofix makes a loud click once it has been engaged and is ready for use.

Detachment



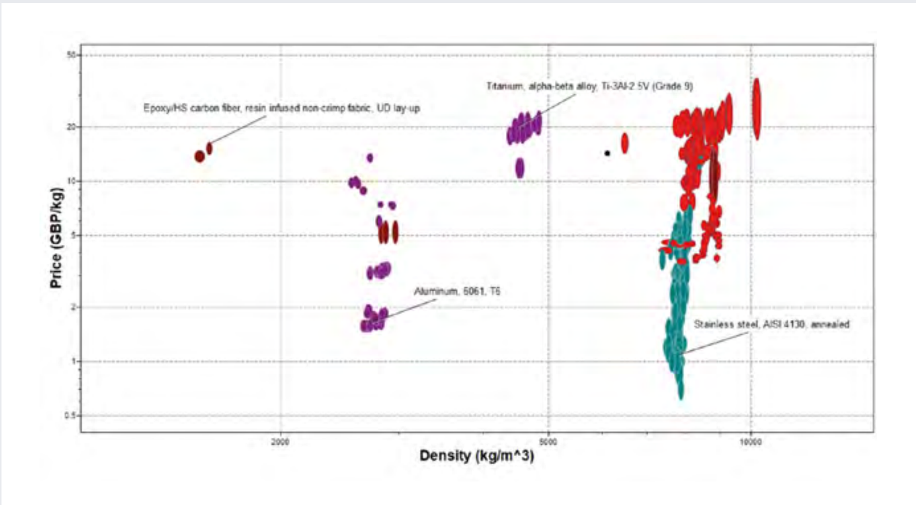
To detach the frame, volunteers' can simply press the large red button, located at the frame bend, to disengage and release the frame from the stretcher.

+ Materials and Manufacturing

Material Section: The Main Frame

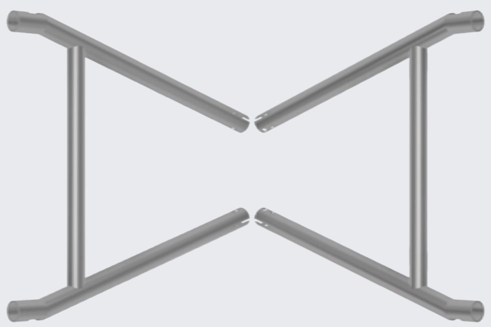
Using the calculated material indices for the specific problem, GRANTA was employed to aid the material selection process. This software was used to ensure a wide range of materials were considered for the product and several requirements were applied to the material selection process including: suitable yield strength and Young's modulus values, excellent resistance to fresh and salt water, and good machining and welding capabilities. As expected, the software suggested typical bike frame materials as the most viable options.

GRANTA CES Material Selection Tool
Key Trade-off: Weight vs. Cost

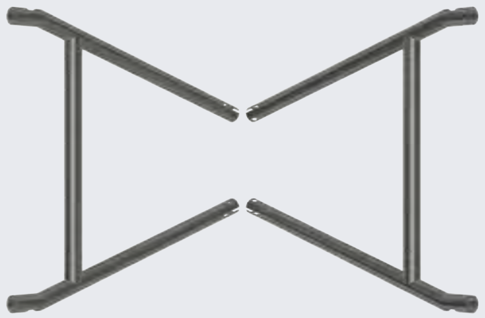


The options were narrowed down to Aluminium 6061-T6 and Titanium 3Al-2.5V due to manufacturing cost and weight considerations. Some readily-available tubing sizes for these materials were collated and analysed to assess whether they would yield under the intended load with a safety factor of 3 applied. The most appropriate tubing sizes, for each material, was modelled and compared for overall mass and cost. Aluminium 6061-T6 was chosen due to it being capable of providing the required strength at a lower cost and weight.

	d2 (m)	t (m)	d1 (m)	r2 (m)	r1 (m)	y (m)	I (m^4)	M (Nm)	σ_y (Pa)	Yield?	Frame Mass (kg)
Al	3.2E-02	3.2E-03	2.6E-02	1.6E-02	1.3E-02	1.6E-02	3.0E-08	4.3E+02	3.1E+08	No	1.92
Ti	2.7E-02	2.2E-03	2.3E-02	1.4E-02	1.1E-02	1.4E-02	1.4E-08	4.6E+02	6.2E+08	No	2.37

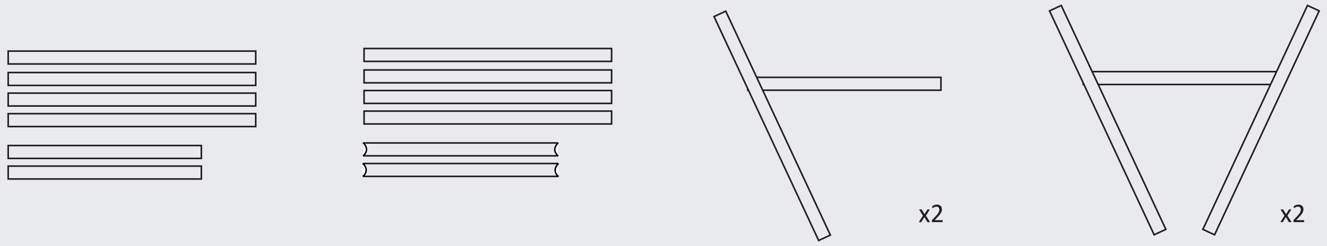


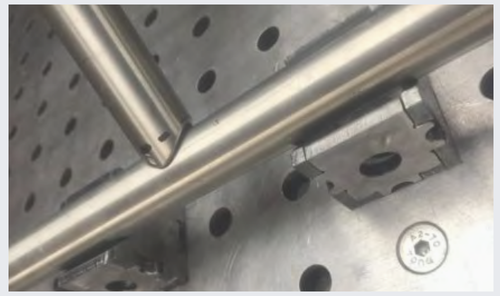
Aluminium Frame: *Top View*
Tubing Outer Diameter: 32mm
Tubing Inner Diameter: 25.6mm



Titanium Frame: *Top View*
Tubing Outer Diameter: 27.2mm
Tubing Inner Diameter: 22.8mm

This product will be manufactured on a small scale, therefore a lot of the components will be produced manually to reduce high set up costs. The aluminium tubing of the main frame is to be cut, with a horizontal band saw to specific length pieces and milled to cut curved edges before being welded together. A full bead weld is required at each joint.





The supporting struts are also to be cut and welded with the metal bars for the Isofix anchorage points mechanically secured. The anchor points must be secured parallel to the wheel axle in accordance with EU regulations.

The Isofix anchors are to be bought-in along with the 26x4.0" fat bike wheel. The increased diameter of the wheel means that less framing is required to achieve the correct height. Small plastic components, such as the Isofix casing, are to be 3D printed as this is most cost-effective manufacturing method due to the small batch size. Around 20 stretcher wheel units are currently sold within the UK per annum.

+ Assembly

The wheel unit would arrive with three main components, the support struts, the main frame and the wheel. The supporting struts are to be clamped to the stretcher framing, and are intended to be left attached long-term. The main frame is to be secured to the wheel using the axle plate's 10mm drop-out and the wheel's quick release skewer. This assembly can then be attached to the supporting struts at the casualty site using the Isofix mechanism. The Isofix mechanism allows for an efficient and easy method of attachment and detachment.

Support Struts

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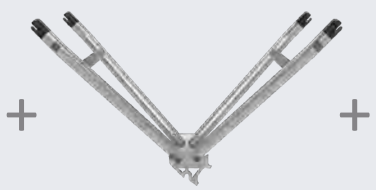

Main Frame

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Wheel

PART NO.	PART NAME	DESCRIPTION	QTY.
1	Clamp Shell	Aluminium 6061-T8	4
2	Clamp Inner	EPDM Rubber	4
3	ISOFIX Latch	Steel	4
4	Isofix Casing	3D Printed PLA	4
5	Supporting Struts	Aluminium 6061-T7	2
6	Main Frame	Aluminium 6061-T6	2
7	Axle Plate	Aluminium 6061-T6	2
8	Maxxis Minion FBR 26 x 4.00 Tyre*	Sealant-compatible Rubber	1
9	DT Swiss BR710 26"x81mm Rim*	Aluminium Alloy	1
10	Wheel Hub*	Aluminium 2014-T6	1
11	Quick Release Skewer*	Aluminium Alloy	1
12	M10 Steel Lock Nut*	Zinc Plated Steel	4
13	Steel Hex Bolt M10x50mm*	Stainless Steel	4
14	M10 Washer*	Zinc Plated Steel	8
15	M6 Steel Lock Nut*	Zinc Plated Steel	4
16	Steel Hex Bolt M6X40mm*	Stainless Steel	4
17	M6 Washer*	Zinc Plated Steel	8

* Bought-in Components