

### Motivation, Goal, Impact

#### MOTIVATION

The number of major abdominal surgeries, specifically C-sections, has grown significantly over the past couple decades. Modern abdominal compression wraps fail to provide adjustable, optimal compression that accommodates varying levels of user mobility.

#### GOAL

Our project aims to design an **adaptive compression wrap** for the **abdominal region** that varies **compression** and includes **heating** to aid in recovery and provide **optimal comfort** based on different mobility levels and posture positions.

#### IMPACT

- Increased comfort
- Improved mobility
- Medically approved for hospitals
- Affordable

### Requirements

#### CUSTOMER REQUIREMENTS

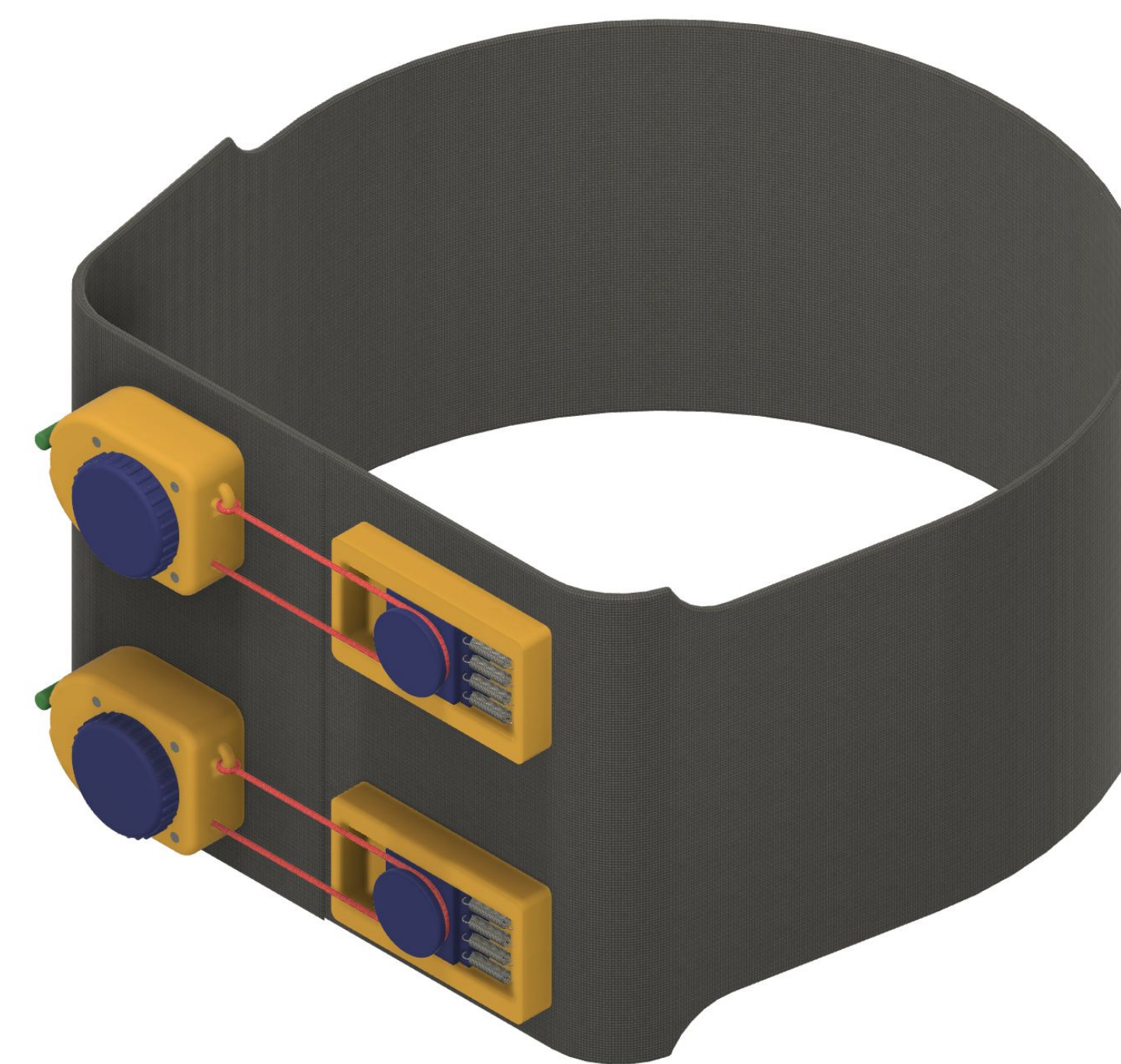
"The wrap must be"

- designed to avoid excessive compression
- skin protective
- manually adjustable with multiple settings
- adaptable to different types of users
- comfortable to wear during prolonged use
- thermally regulated
- capable of long-term maintenance
- portable

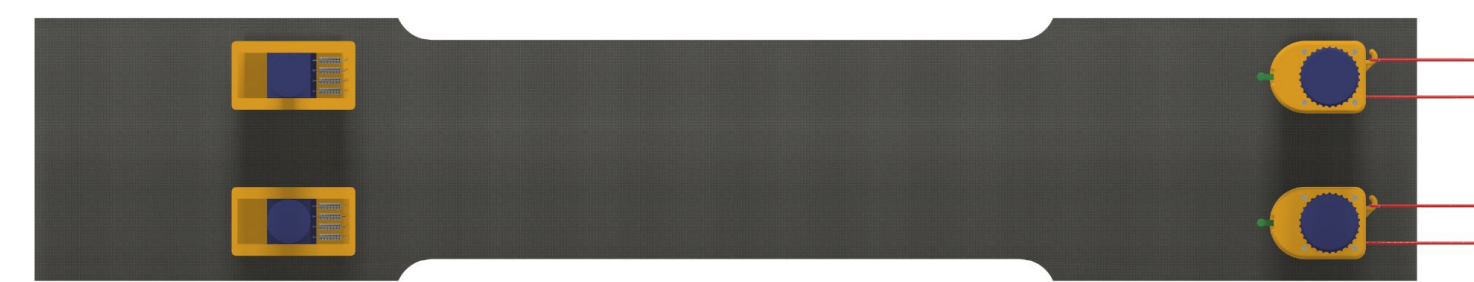
#### PRIMARY FUNCTIONS

- Control pressure levels in the abdominal region
- Regulate body temperature levels in the abdominal region
- Provide user freedom of movement

Assembly View (Wrapped)



Assembly View (Unwrapped)



**BASE LAYER** - The fabric is composed of a **75% Cotton**, **23% Polyester**, and **2% Spandex** blend to allow for moderate stretch while providing adequate support.

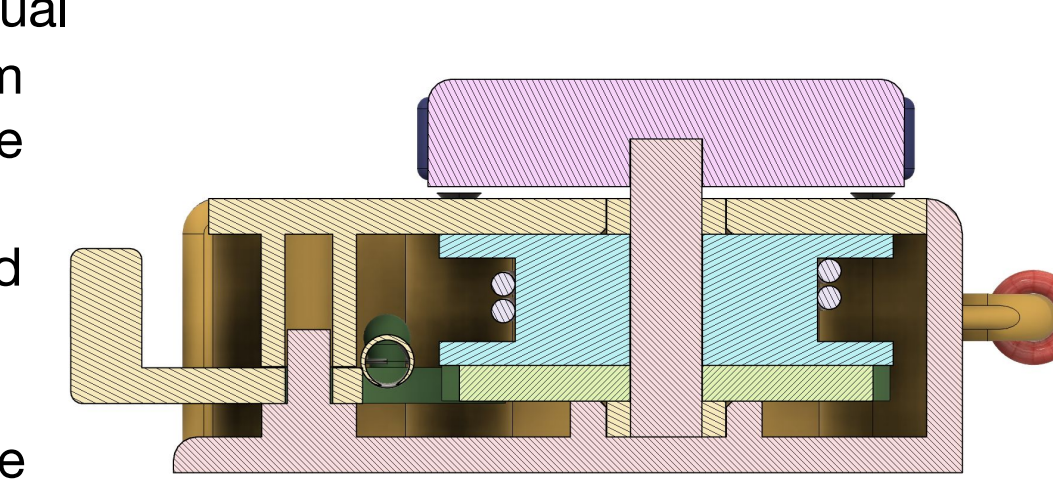
### Final Design

**WINCH** - this manual actuation mechanism applies tension to the fastening wires and maintains the desired level of abdominal compression across various regions of the wrap.

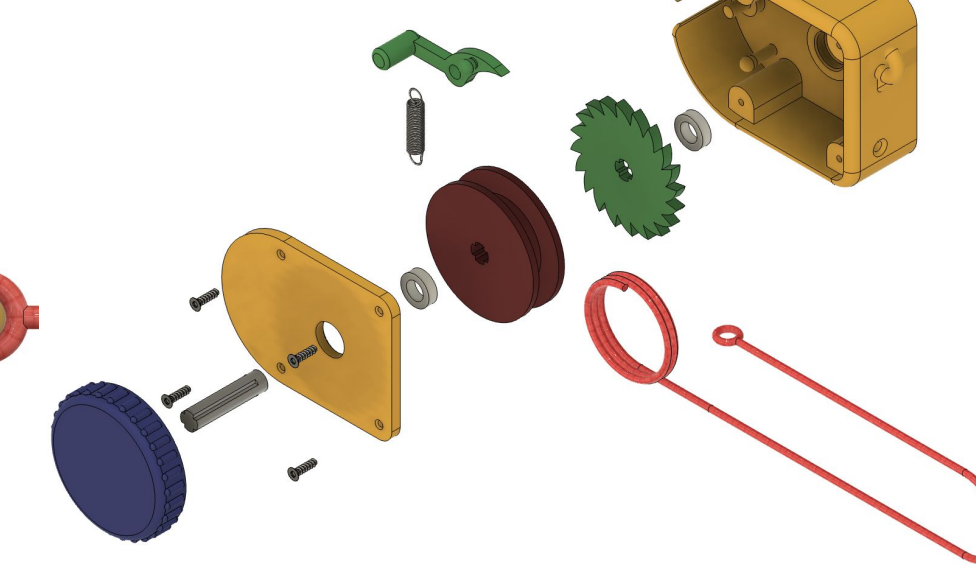
**PULLEY** - this passive actuation mechanism allows the wrap to expand or contract based on body posture changes while maintaining set compression at high loads.

**HEATING LAYER** - A detachable layer; it includes a grid of patches to generate heat by running electricity (current) through wires embedded in the patches. Constructed with polyimide tape (adhesion) and microfiber cloth (insulation).

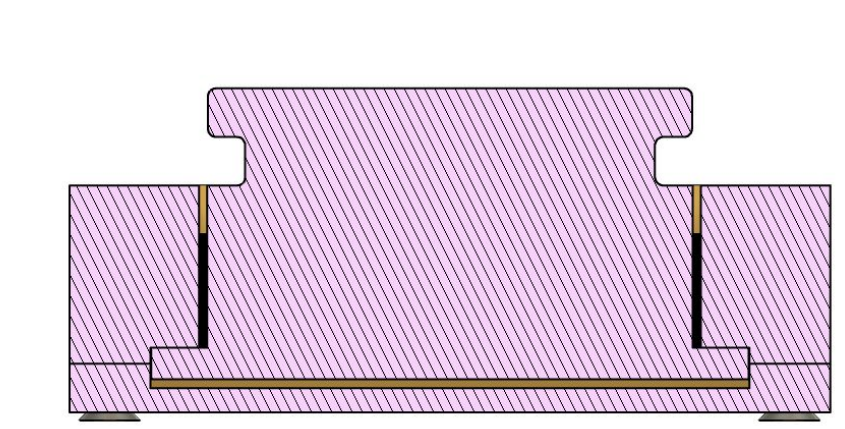
Section View



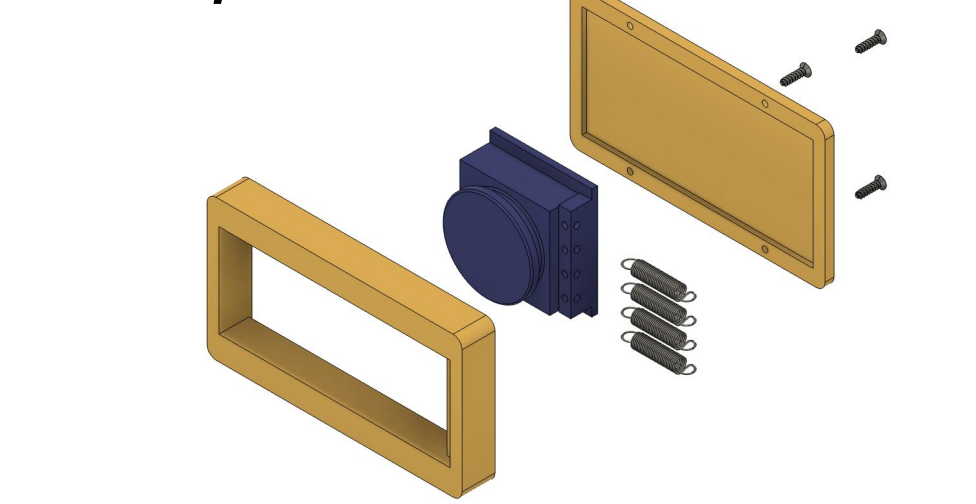
Exploded View



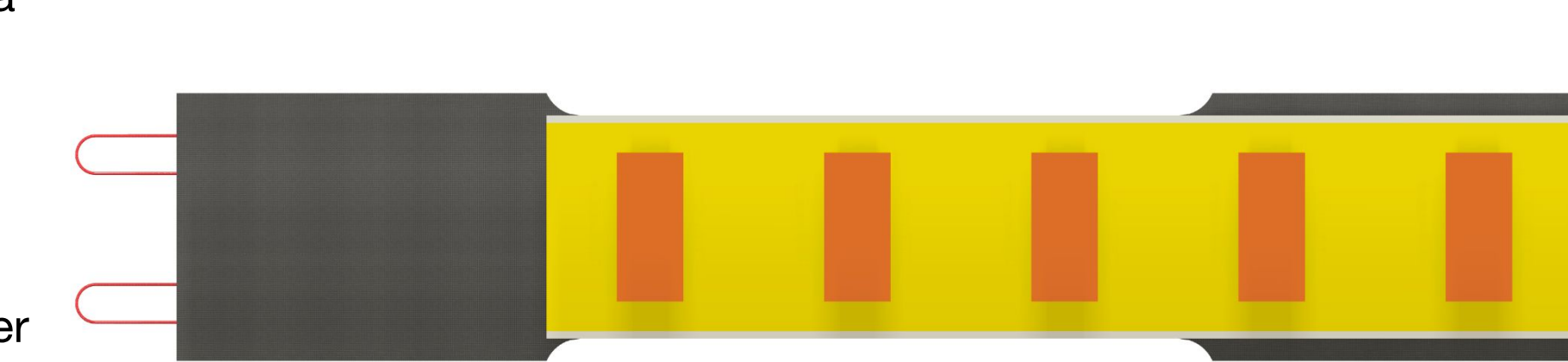
Section View



Exploded View



Inside View of Wrap with heating layer



### Design Calculations & Decisions

#### FORCE CALCULATIONS

- Free Body Diagrams (FBD)
- Stress analysis
- Material selection
- MATLAB
- Finite Element Analysis (FEA)

**Wire Diameter and Material**  
**d = 2mm | Kevlar**

$$d_{wire} = \sqrt{\frac{4F}{\sigma_{wire}\pi}} = \sqrt{\frac{4T}{\left(\frac{S_y}{SF}\right)\pi}}$$

**Material of Wrap**

**$\sigma_{wrap} = 34.2$  KPa**

$$\sigma_{wrap} = \frac{F}{A_{wrap}} = \frac{T}{w_{wrap} h_{wrap}}$$

$$\sigma_{wrap} < \frac{S_y}{SF}$$

**Tension in Wrap**

**$T_{Max} = 54.44$  N**

$$T = \frac{PCW}{4620n}$$

**Spring Constant (PULLEY SUBSYSTEM)**

**$k = 533.33$  N/m**

$$k \geq \frac{F_{applied}}{x} = \frac{2F_{wire}}{x}$$

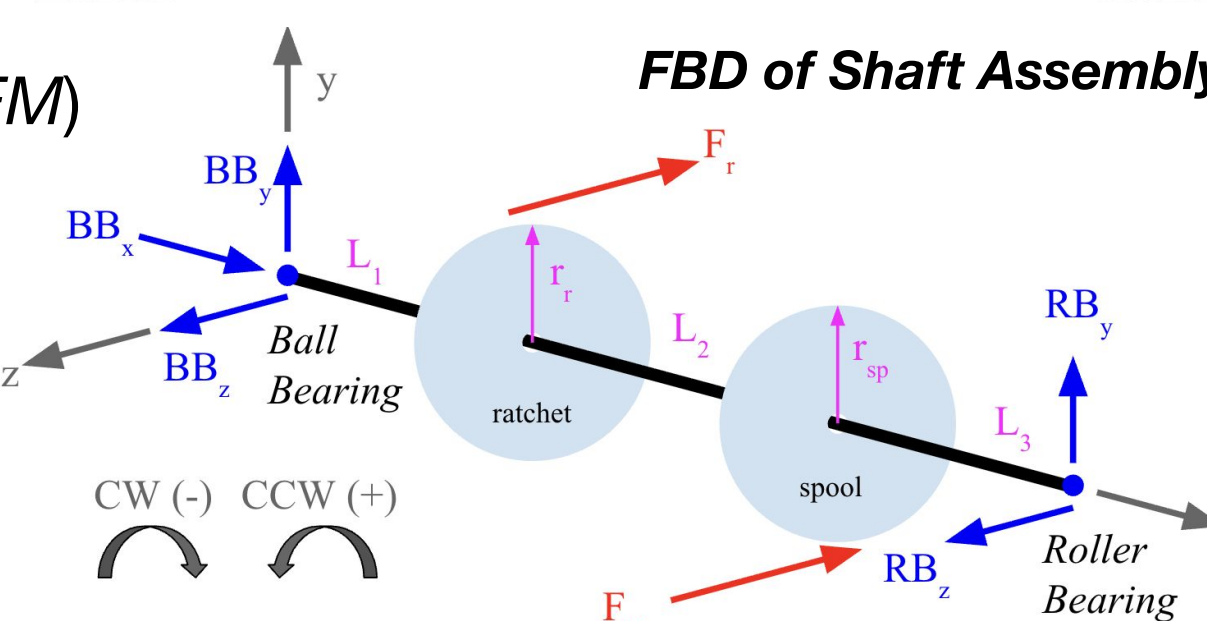
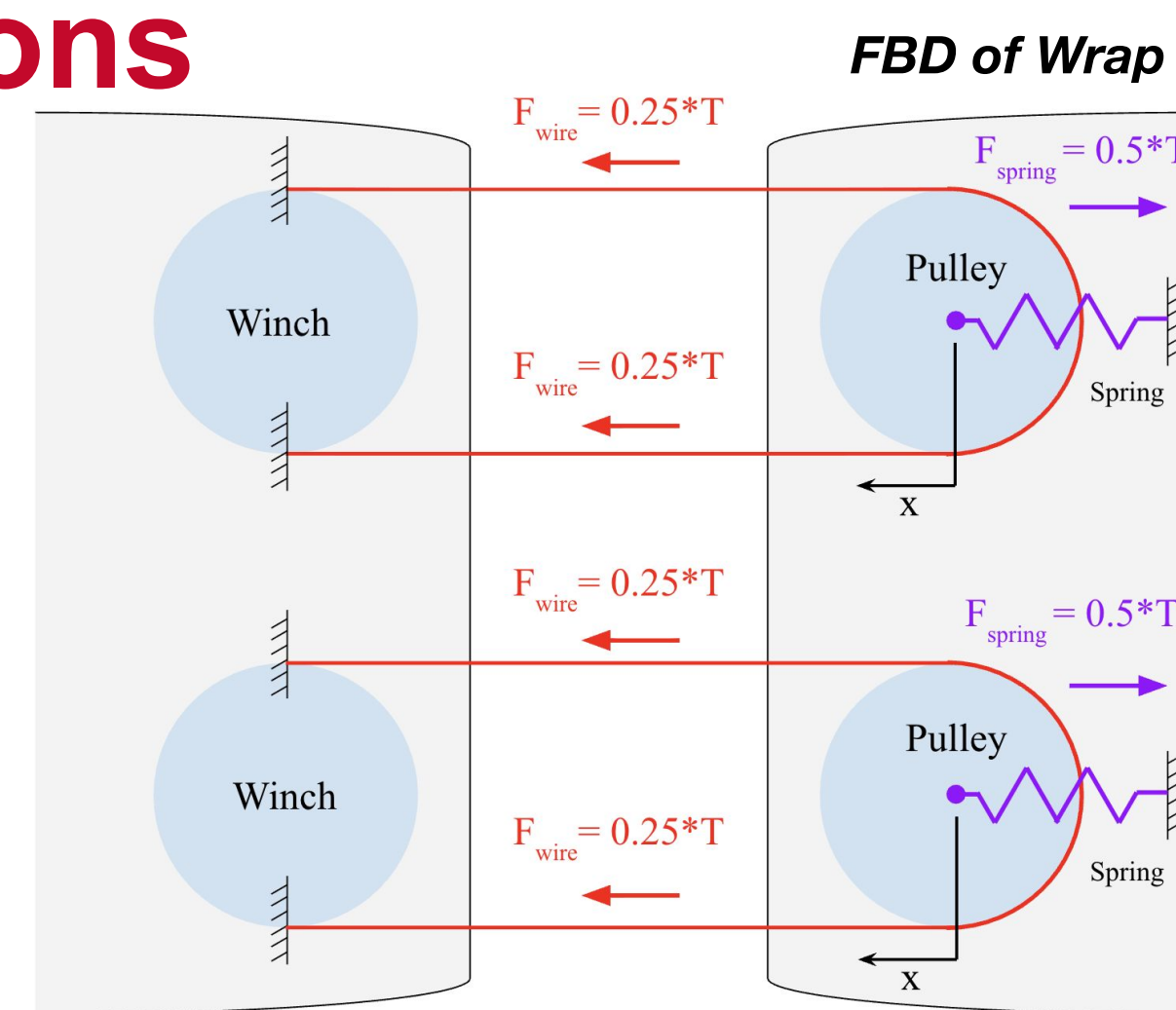
**Shaft Diameter and Material (WINCH SUBSYSTEM)**

**d = 6mm | Acetal (POM)**

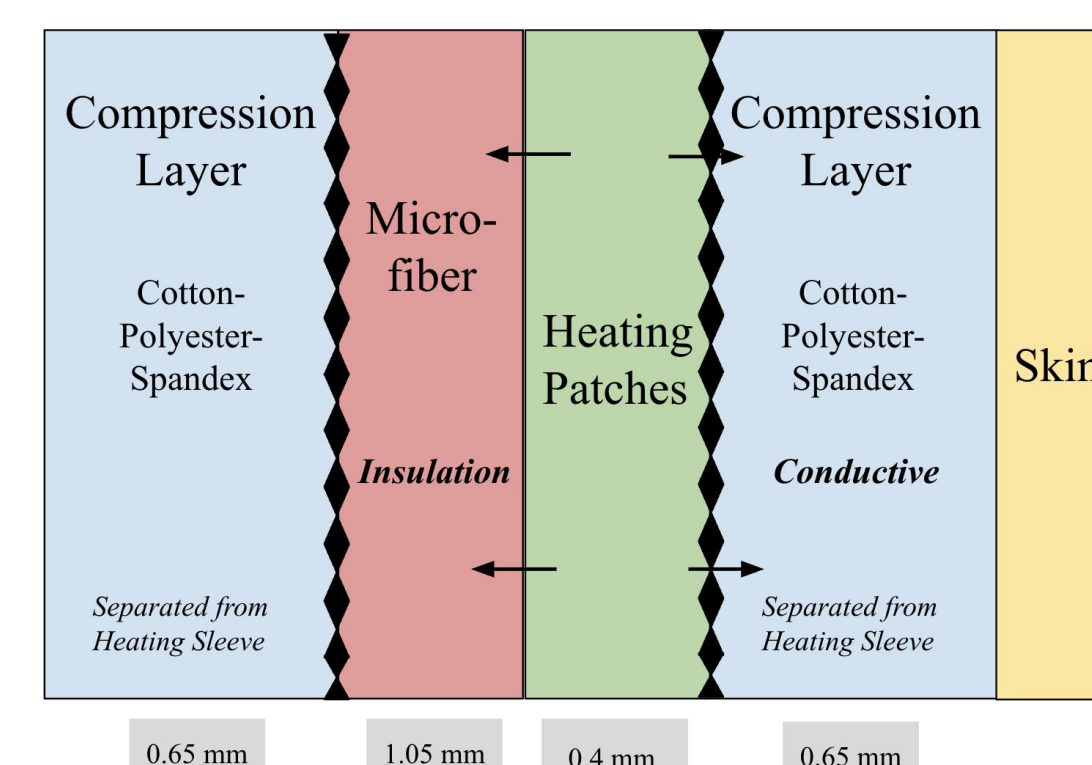
$$d_{shaft} = 2 \left( \frac{\sqrt{16M_{max}^2 + 12T_{max}^2}}{\pi\sigma_{vm}} \right)^{1/3}, \sigma_{vm} = \frac{S_y}{SF}$$

**Parameters:**

Pressure (P) = 15 - 30 mmHg  
Circumference (C) = 950 mm  
Width (W) = 180 cm  
No. of Layers (n) = 2



Layer Diagram



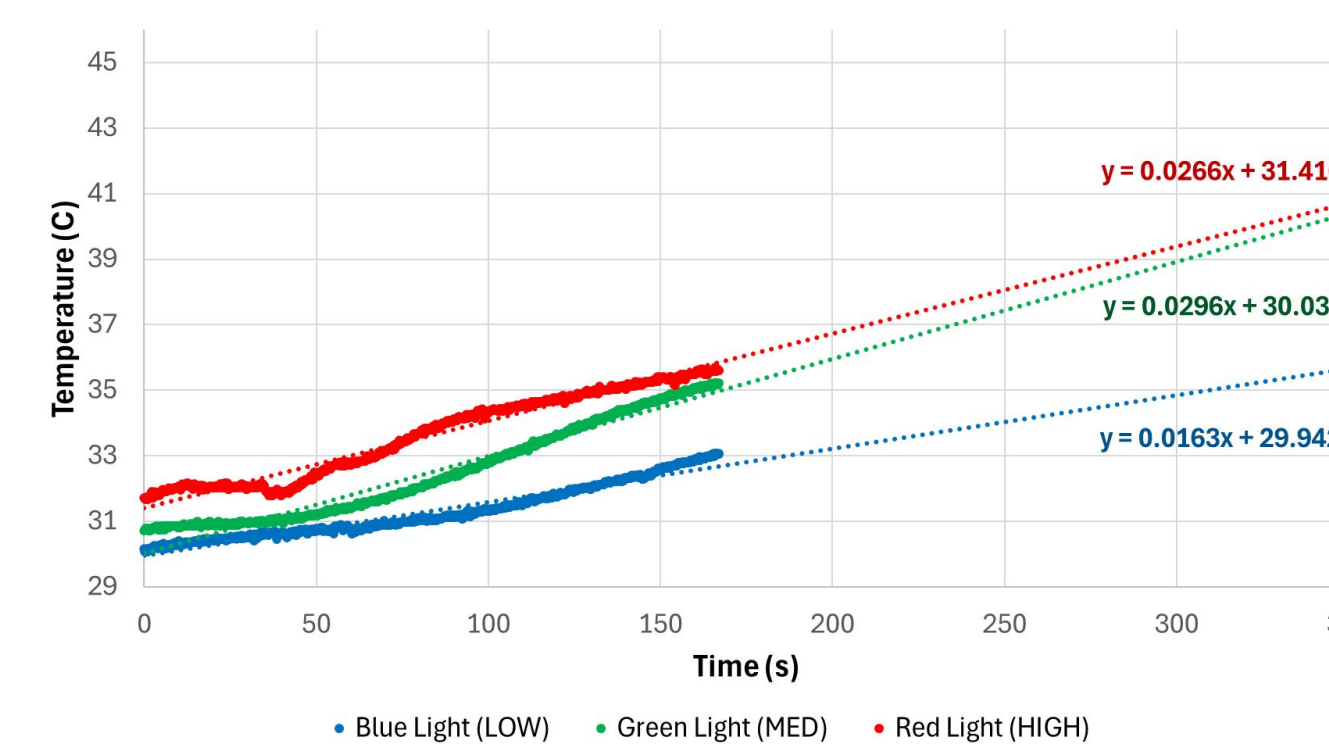
### Prototype & Test Results

#### COMPRESSION TEST

**Setup:** Pressure was measured using three force sensors at the front and back under stationary and mobile conditions. The wrap was tightened to a snug-fit (two-finger rule).

**Procedure:** Sensor data was recorded and repeated three times for each condition and location. The wrap was removed and reapplied between trials to ensure consistency.

Temperature Settings Over Time

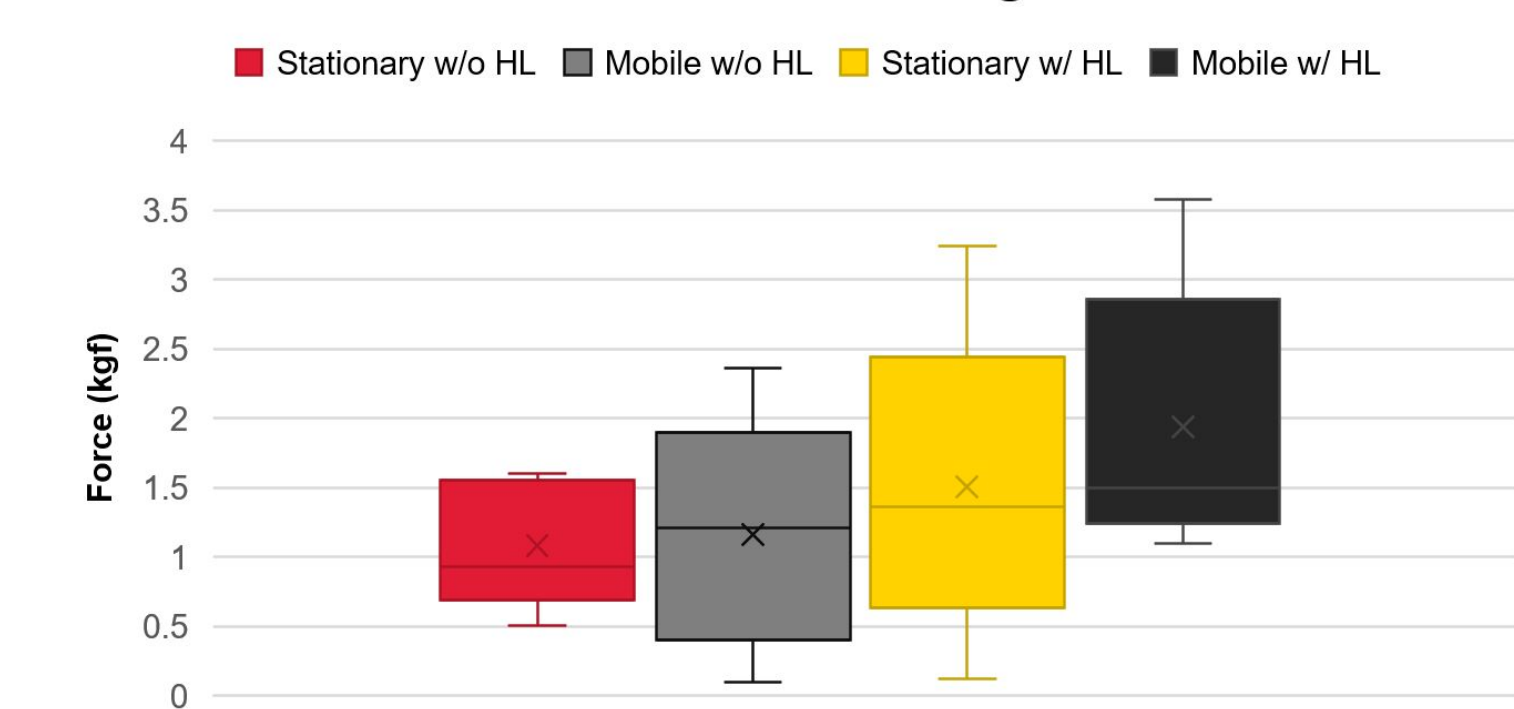


#### COMFORT TEST

**Setup:** Users wore the wrap on their bare abdomen or over thin clothing to a snug-fit (two-finger rule). An initial survey assessing comfort, softness, irritation, and expected wear duration was taken.

**Procedure:** The user performed different movements (walking, sitting/turning, standing, and picking up an item) and rated comfort on a scale of 1-10. A final survey was issued to evaluate any changes in comfort, irritation, and wearability.

Forces Under Various Testing Conditions

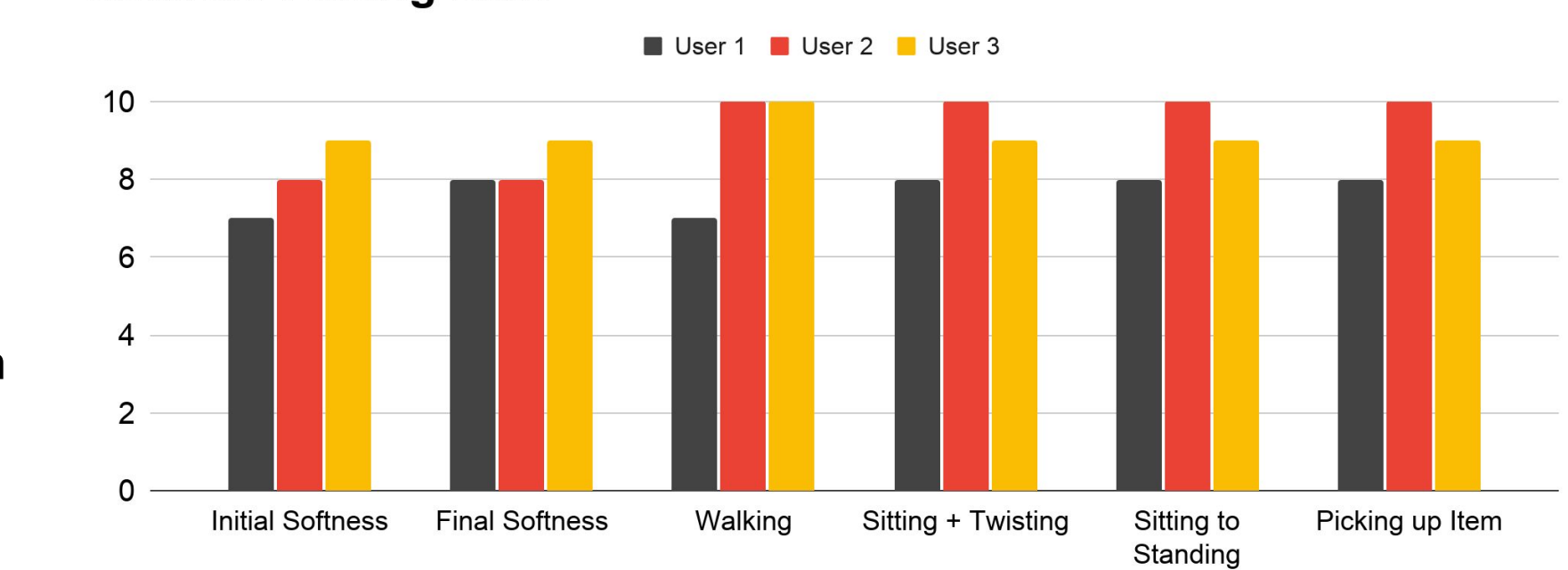


#### TEMPERATURE TEST

**Setup:** A thermistor was placed inside the wrap while on user. The wrap was tightened to a snug-fit (two-finger rule) and the sensors were calibrated for data collection.

**Procedure:** Temperature data was recorded three times at each heating level (low, medium, high). Labeled trendlines estimate heat patch behavior.

Comfort Testing Data



#### ENERGY CALCULATIONS

- 1D Fourier Law of Conduction
- Ohm's Law
- Electronic circuit analysis
- MATLAB Simulink
- FEA

**Heat Flux on the Skin**

**Heat Flux ( $q''$ ) = 3265 W/m<sup>2</sup>**

**$T_{range} = [40, 45]$  °C**

$$q'' = \frac{Q}{A} = \frac{\Delta T}{RA_{wrap}}$$

$$R = \frac{t}{kA_{wrap}}$$

**Battery Specifications**

**Current (I) = 2.5 A**

**Capacity (C) = 2500 mAh**

**$P_{Max} = 30$  W |  $V_{range} = [7, 12]$  V**

$$I = \frac{P}{V} = \sqrt{\frac{P}{R}}$$

$$C = It$$