S.P.A.R.
Strut Pulley Active Reduction System

EML 4501 – Group 15
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Narrative Summary

The lifting system shown here is a very adaptive system. The frame is supported by locking caster wheels that allow the entire system to be moved over the patient, and over the elliptical that is going to be used. The patient is connected to the system with clips that attach to the harness. These clips run to a set of springs, that are connected to a winch cable. The winch enables the patient to be lifted and stabilized for rehabilitation to occur. The winch is directed by a controller connected to a sensor, which reports the force on in the system to help keep the patient in proper position, so no injuries occur during the process.

Frame

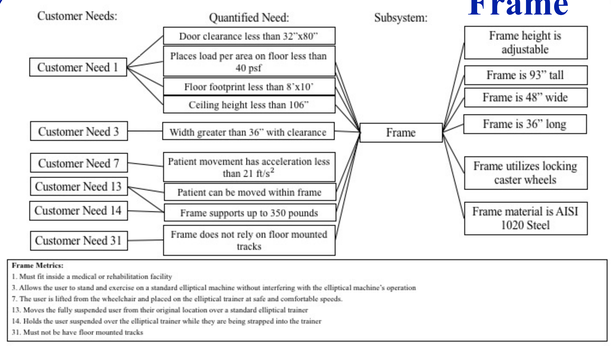


Figure 1. Customer Needs mapping for the Frame

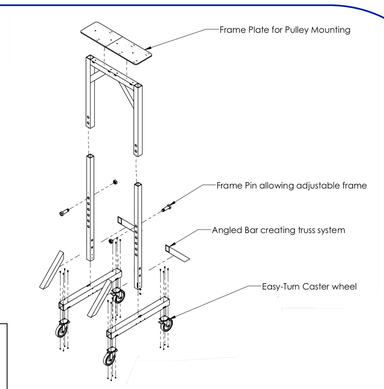


Figure 2. Exploded view of the Frame

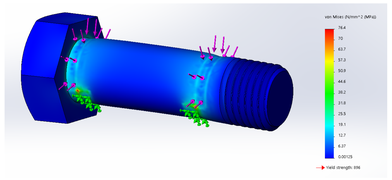
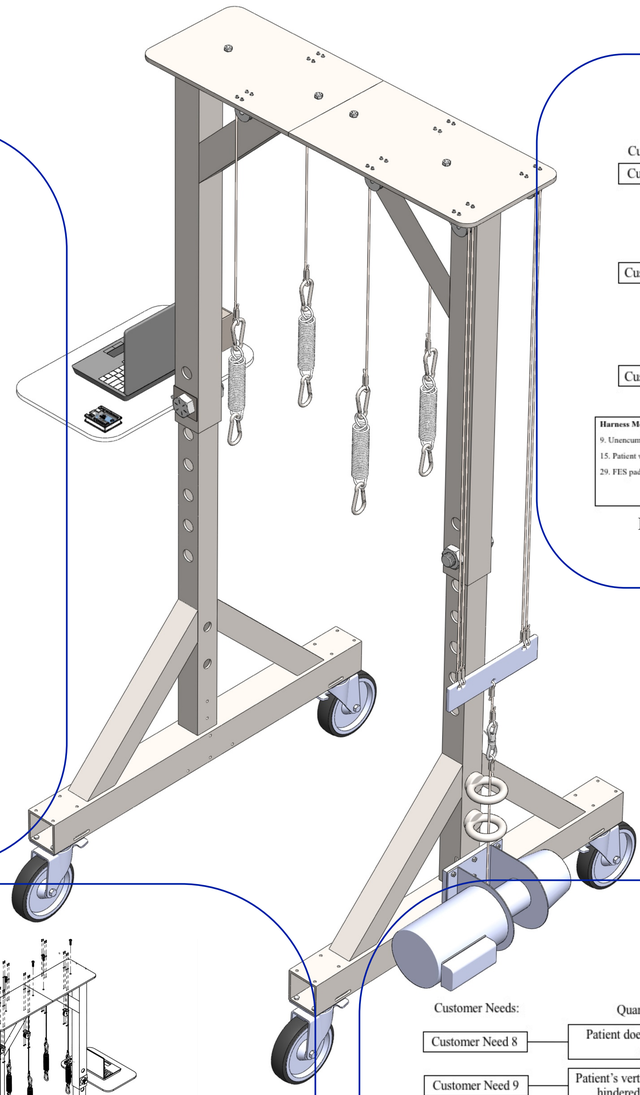


Figure 3. FEA of frame bolt. Analysis shows that bolt can withstand Von Mises stresses associated with frame loads during operation with a factor of safety of 16.

Design Highlights

- Double pulley system allows for easy cable alignment
- Telescoping Frame-Pin system allows for variable height adjustments
- Locking Caster Wheels make patient movements easy



Harness

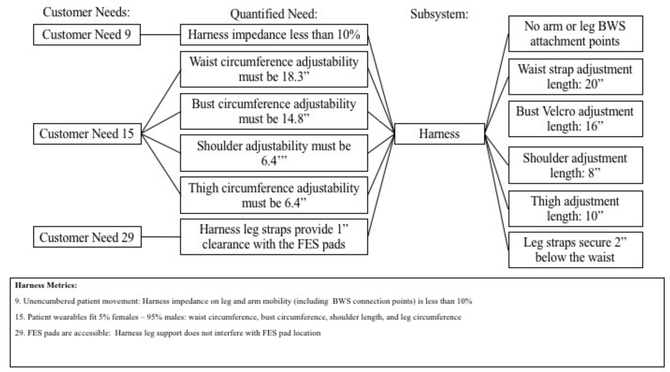


Figure 10. Customer Needs mapping for the Harness

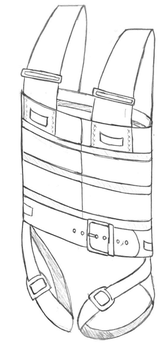


Figure 11. Drawing of the Harness

Cost Overview

Category	Cost
Raw Material	$1290.97
OTS Parts	$2016.05
Manufacturing	$136.00
Assembly	$44.00
Total	$3487.02

Body Weight Support System

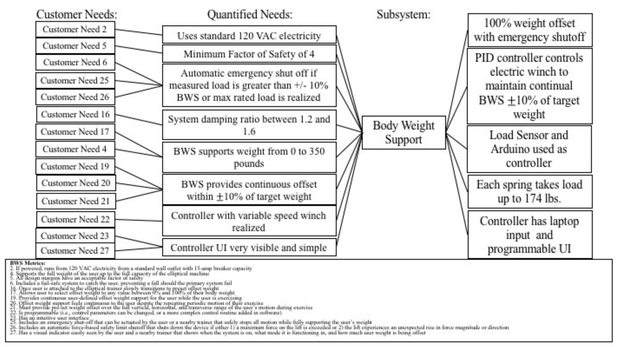


Figure 4. Customer Needs mapping for the BWS System

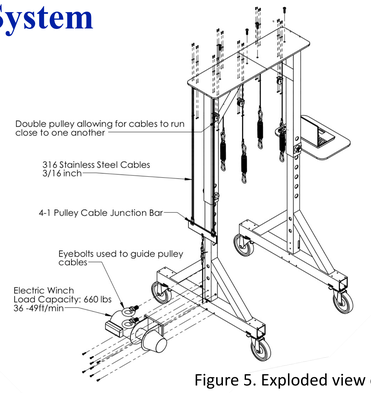
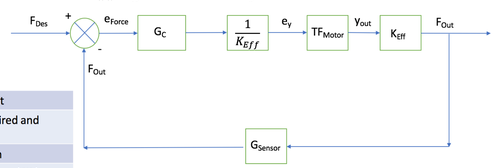


Figure 5. Exploded view of BWS System



F_{Des}	Desired Force Input
e_{Force}	Error between desired and measured force
G_C	PID Controller Gain
K_{Eff}	Effective Spring Force ($4K_s$)
e_y	Error in linear displacement
TF_{Motor}	Transfer Function of the Motor
Y_{Out}	Linear Displacement
F_{Out}	Force Output of System
G_{Sensor}	Gain of Load Cell Sensor

Figure 6. System Block diagram and Legend. This shows how the system would keep weight offset within +/- 10% of the target

- Fail Safe Verification
  - Worst Case Weight: **385 lb**
  - Position in cycle: Bottom Dead Center
    - This means that the system must travel up a full 4" range of motion to keep up with the patient motion before any additional displacement takes place
  - Winch Velocity: **51.8 ft/min (10.36 in/sec)** good for weights below 429 lb
  - Spring Constant: $K_{eff} = 4 * K_{spring} = 100$ lb/in

$$y = \frac{F}{K_{Eff}} = \frac{385[lb]}{100[\frac{[lb]}{[in]}]} = 3.85[in] \qquad t = \frac{y}{V} = \frac{3.85 + 4[in]}{10.36[\frac{[in]}{[sec]}]} = 0.76[sec]$$

- This shows that in a perfect control scheme using maximum rated velocity, the system can respond to an emergency stop situation in <1 second

Stabilization

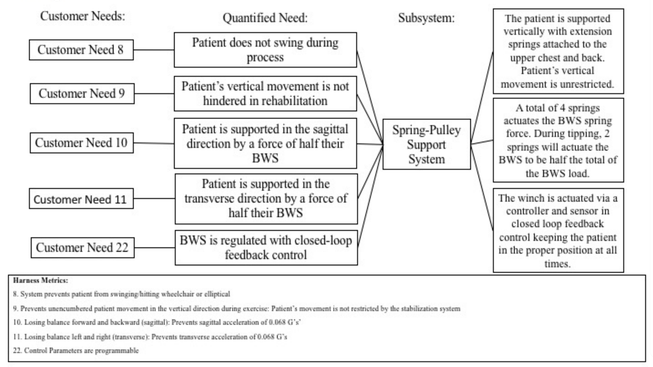


Figure 7. Customer Needs mapping for the Stabilization System

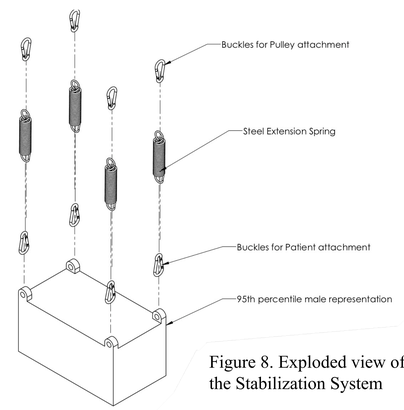


Figure 8. Exploded view of the Stabilization System

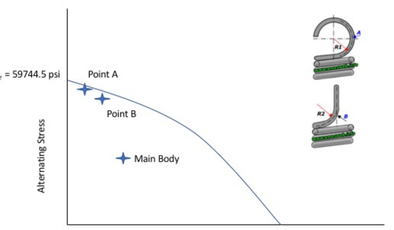


Figure 9. Gerber Diagram for the Stabilizing Springs. This shows that cyclic loading under operating loads will not cause failure in the springs

Frame Tipping Stabilization

$K_{F,\,Max} = 174$ lbs. => $K_{T,\,Max} = 4(K_{F,\,Max}) = 696$ lbs.

Maximum total spring force is **696 lbs**. at a maximum deflection of **6.3 inches**

The generated spring force is well above the maximum weight of the patient and well below the magnitude of the tipping length