**EML 4501-Group 17**
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# Easy-Weight Elliptical Exercise (EEE)

**Abstract:** An innovative body weight support system was designed to aid a patient in recovering from impaired leg movement. This primarily ceiling-mounted system lifts the patient from a wheelchair and suspends them above an elliptical. The winch-like support system is guided along steel rails that mount to any ceiling's structural beams. Track rollers smoothly translate the patient along the rails. The Easy-Weight Elliptical Exercise (EEE) system is comprised of a single electrical motor coupled with a gear train that turns a shaft which spools a steel rope offsetting the patient's weight by a specified amount. The user-friendly remote interface makes therapy programming fast and easy. The EEE system includes a reliable backup failsafe system that is just slack enough to catch the patient mid-air in the case of any electrical failures. A lightweight aluminum suspension and an ergonomic nylon harness makes a previously burdensome therapy process less tiresome. The user will be mounted onto an elliptical trainer equipped with boots that use functional electrical stimulation to rehabilitate the mind-to-muscle connections that the patient is lacking.

**Frame:** The foundational concept of the EEE is a ceiling mounted rail system with rollers that translate the vertical lift system as shown in Fig. 1. Solenoid actuated spring locking pins fit into a series of holes along the rails to anchor the system in place.

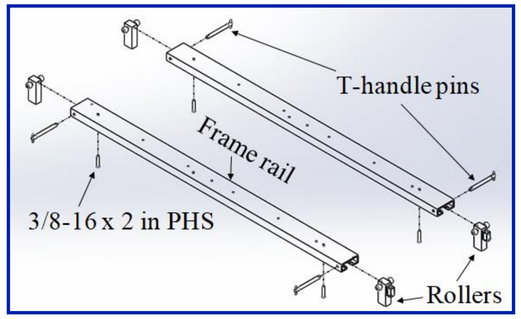


Figure 1. Exploded view of the Frame System

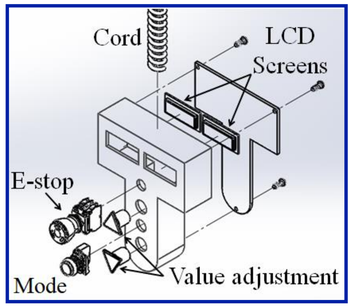


Figure 2. Exploded view of the Interface remote

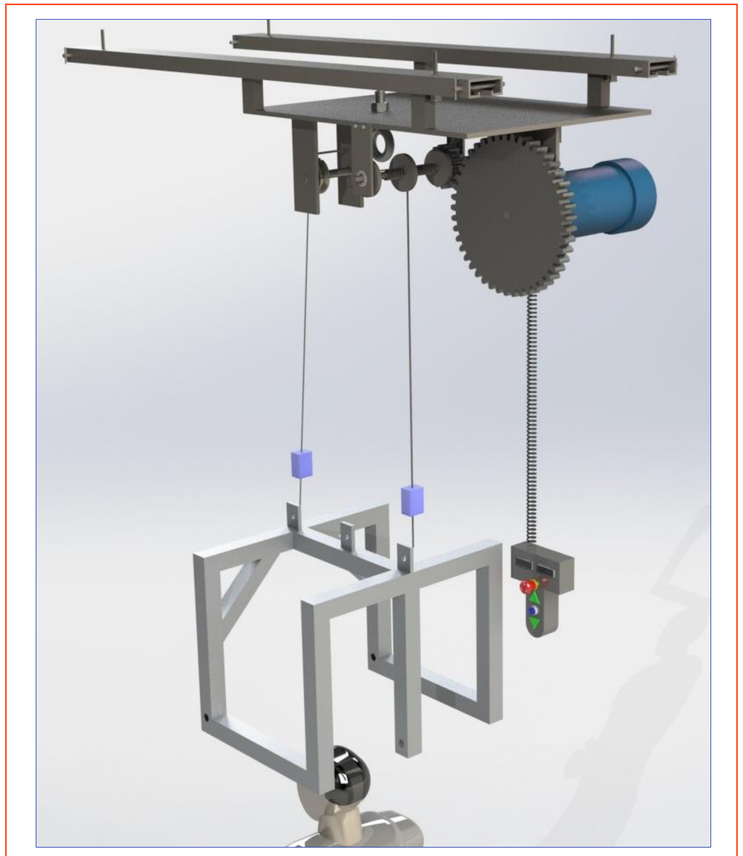

Figure 5. A full system view of the Easy-Weight Elliptical Exercise

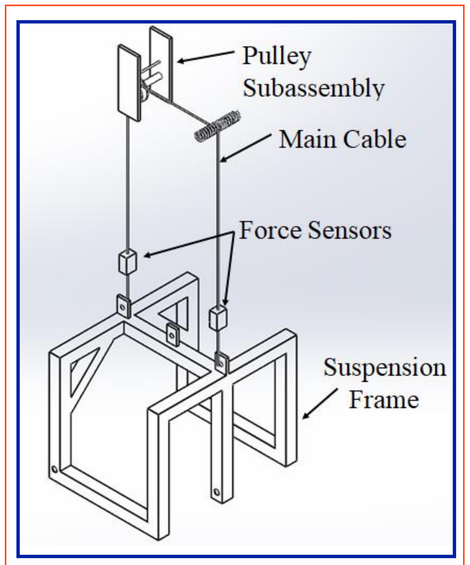


Figure 4. View of the Suspension System

**Suspension System:** Two cables from the offset system and an additional rope from the fail-safe attach to a frame made of square tubing as shown in Fig. 4. The suspension frame is the structure which the three ropes that go to the harness clip into.

## Cost Overview

- OTS Parts: $3080.76
- Raw Materials: $909.78
- Manufacturing: $88.85
- Energy: $18.74
- Assembly Labor: $141.89

**Total Cost: $4240.02**

**Fail-Safe:** A secondary rope attaches to the suspension frame from an eyelet on the top plate which holds the motor up. The secondary rope is configured to be taut at the lowest point of the exercise cycle.

**Interface:** The user adjusts different system parameters through an intuitive remote. The remote translates along with the user, so it is always within arms reach. Fig. 2 shows an exploded view of the interface.

**Harness:** A modified OTS climbing harness is used to secure the user into the system. Ropes from the suspension frame attach to the harness in three locations.

**Offset System:** A variable speed motor coupled with a gear train makes it possible to offset a desired value of the users weight during assisted elliptical exercise. The offset system is capable of lifting up to 1,050 lbs and operating at a max linear lift speed of 10 in/s. A dual spool is used to supply two cables to attach to the suspension frame as shown in Fig. 3.

## Table 1: Mapping customer needs to design features

| Need | Parameter | Quantification | Subsystem | Features |
|---|---|---|---|---|
| 1 | Clearance through door | < 36 in x 80 in | All subsystems | Ceiling mounted frame rails are compact, fit within 30 in x 18 in |
| 1 | Ceiling Height | <80 in | All subsystems | BWS total assembled height is 18" |
| 2 | Compatible with wall outlet | 120 V | Offset System | System can be powered with 120 V source, cord plugs into standard wall outlet |
| 3 | No interference with elliptical operation | 0 points below user's knees | Harness | Harness secures around waist and upper body, no attachments below knees |
| 4 | Load capacity | >350 lb | All subsystems | An electric motor coupled with a gear train combine to make the offset system. This system is capable of lifting 1052 lb. |
| 5 | Factor of Safety | 2.5 | All subsystems | Lifting motor FOS of 2.63; Frame FOS of 5 and lifting cables FOS of 10; Suspension arms FOS of 7 |
| 6 | Fall distance | Not fall past the lowest position | Failsafe | Ascender allows the length of the rope to be adjusted. When the user is in the lowest point, the rope should be taut. |
| 7 | Lift and descent rate | 2 in/s | Offset System | Variable speed motor combined with gear train |
| 8 | Prevention of patient swinging into elliptical | 5° | Harness | Suspension and harness subsystems synergize to form a pendulm, reducing forward movement |
| 9 | Translate unencumbered in the vertical direction | 3 in. of vertical displacement | Offset System | Harness and suspension allow for user to traslate freely in the vertical direction. |
| 10 | Prevents sagittal fall | <25° vertical, <15° in dorsal | Interface | Suspension and harness subsystems synergize to form a pendulm, reducing lateral movement |
| 11 | Prevents transverse fall | Constrains body within ±15° | Harness | Harness has attachments at the shoulders as well as locations such as the hips. |
| 12 | Lifts user from seated position | Bent knee (90° +/- 5°) to | Suspension | Suspension has three attachment points, two across the chest and one on the back |
| 13 | Horizonal translation distance | >36 in | Frame | User is translated up to 41 in by ceiling mounted rail system |
| 14 | Vertical lift distance | 15 in. | Offset System | Cable is coiled around the spool to lift the user. |
| 15 | Harness torso circumference | 39.2 - 58.0 in | Harness | Adjustable climbing harness style harness, fits almost all body types |
| 16 | Smoothly transition to offset weight | 0.5 - 2 lbs/s | Offset System | Load cells feed data into control system so offset weight is transitioned smoothly |
| 17 | Distance to interface | 36 in | Interface | Remote is attached to translating rail system by a cord such that it is always within reach of the user. |
| 18 | Mount to structural member | Exert less than 50 psf | Frame | Frame mounts distributes weight to ceiling over a large area with a max load of 25 psf; attaches to ceiling joists |
| 19 | Provides continous user defined offset weight | ±5lb Offset Error | Offset System, Interface | Interface allows user to select offset weight. Load cells have fast sampling rate so control system can adjust appropriately |
| 20 | Offset weight support feels continous, despite adjustments | <15° tilt from vertical | Offset System, Harness | Use of an electric motor, a speed controller and a gear train to maintain the offset speed |
| 21 | Provide offset over vertical and horizontal range | ±20° abdominal, -10° - +45° Vertical | Harness | The offset subsystem provides the vertical range of motion. The track system provides the horizontal range of motion. |
| 22 | Is programmable | 2 inputs | Interface | The remote takes the user's weight and height as inputs so the controller has initial data. |
| 23 | Interface colors | ≥ 2 | Interface | Mode button, value up/down buttons, and emergency stop button are all different colors |
| 23 | Actions to execute task | 2 | Interface | (1) Select the mode (2) Adjust the value |
| 24 | Raw material cost | $4,000 | All subsystems | Harness: $90, Suspension: $825, Frame: $554, Fail-Safe: $305, Offset: $1977, Interface: $177 |
| 25 | User activated E-stop | Activate with 1 hand | Fail-safe, Interface | Two e-stop buttons, one on the remote and one on elliptical dashboard. Both can be activated with a single hand. |
| 26 | Automatic force based safety shutoff | Activates at 120% of | Failsafe, Suspension | Controller coupled with load cells in suspension system detect when safety limits are hit |
| 27 | Visual Indicator that shows function | 6 lumens | Interface | Two LCD screens depict system parameters |
| 28 | Operational lifetime | >1500E6 cycles | Offset system | Motor and cable spool lasts for >1500e6 rotations |
| 29 | Body surface area covered | < 50% | Harness | Harness covers 28% of the users body, enough to stablize the user but also allow them to exercise freely on the elliptical |
| 30 | System footprint | 8 ft x 10 ft | Frame | The system has a footprint of 30in x 72in |

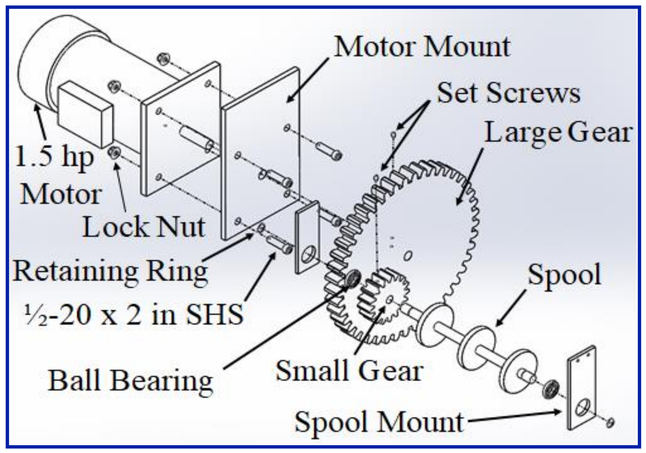


Figure 3. Exploded view of the Offset System

## Offset Speed and Torque Analyses

Target linear lift speed: 10 in/s
Target rotational lift speed: 4.255 rev/s
Motor rotational speed: 1 rev/s

**Gear ratio:**

$$\frac{n_1}{n_2} = \frac{r_2}{r_1} = \frac{1}{4.255} \approx \frac{200}{850} = \frac{4}{17} = \frac{d_2}{d_1}$$

Motor gear pitch diameter, $d_1$ : 17 in
Spool gear pitch diameter, $d_2$ : 4 in

**Factor of Safety:**

$$FoS = \frac{\text{Torque of Motor}}{\text{Torque of Load}} = \frac{44.47\ \text{Nm}}{16.91\ \text{Nm}} = 2.63$$