EML4501 – Spring 2020 – Group 23
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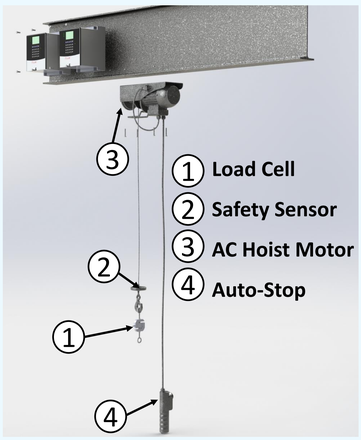
R.E.P.T.I.L.E KING
(Rehabilitative Eliptical Personal Trainer for Increased Limb Exercise)

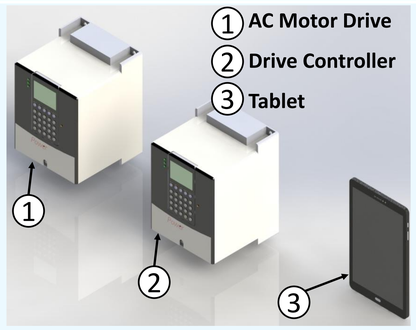
Figure 1. Full assembly of the R.E.P.T.I.L.E. King

Abstract:
The R.E.P.T.I.L.E King safely provides continuous support for the user with a very simple design. This design is cheaper than other designs because it takes advantage of OTS parts and uses existing structural I-beams for overhead mounting support. The user is lifted from their wheelchair and placed onto a mobile bench. Using a dolly-assist, the trainer can easily move the elliptical into place under the bench. The user can then comfortably strap into the trainer boots before being lifted to a full vertical position and the bench being easily rolled out of the way. An AC motor connected to an AC drive maintains necessary torque for the user while also providing the high rotation speeds necessary to account for the more sensitively tuned oscillatory offset. Motor operation is controlled by a user-friendly tablet application that is always within reach, mounted to the elliptical.



Weight Balance & Motor System:
- Motor is an AC Lift Electric Hoist Crane with 660 lb. capacity
- Motor includes a safety system that shuts off the motor if the rope touches an outside border, along with a stopper button that is accessible to the user and trainer
- The motor is attached to a spool with zinc-plated steel wire and a load cell

Figure 2. Assembly of the Motor Lifting system mounted to the middle I-beam including the AC motor drive and drive controller.



Control System:
- AC Controller will use an ethernet-enabled Compact Controller to communicate with the Tablet and a Low Voltage Variable Frequency Drive
- The driver will be configured with automatic safe torque off to ensure safety of PLD category 3, position control, and encoder feedback for weight offset adjustment.
- The tablet includes the interface used by the patient to adjust weight offset and controls

Figure 3. Full control system components, while the tablet connects wirelessly to the controller, this image shows that all components communicate with each other.

Narrative Summary:
The R.E.P.T.I.L.E KING will utilize ceiling and wall mounted I-Beams. A rehabilitative assistant will help the user equip the harness. A carabiner connected to the back of the harness will be attached to a load cell to calculate mechanical force applied on the motor from the weight of the user. The load cell connects to a galvanized cable that hangs from the I-beam-mounted motor. A fall safety strap will run between two outer I-beams with a dual pulley system and attach to the front of the harness. An AC controller and drive will be configured to the AC motor to control positioning and speed. The user will be raised to a height of 4 feet and a wooden bench on wheels will be pushed underneath the suspended participant. The assistant will use a hand truck to push the elliptical underneath the bench and user. Once properly strapped in, the motor will continue to run and reduce any slack in the cable. Once the user is fully suspended, the bench will be pushed away from the elliptical. The participant will use a tablet mounted to the elliptical to control the elliptical and motor. The driver will automatically adjust for the participant's weight offset. Once the participant is ready to end the exercise, the tablet will be used to turn off the elliptical, and the bench will be wheeled behind the user to comfortably unstrap from the elliptical. The user will be suspended again, the wheelchair will replace the bench, and the motor will slowly lower the user into the wheelchair. Finally, the carabiners will detach from the harness and the harness can be removed.

Figure 4. Hand Truck

Figure 5. Mobile Bench

Translational Components:
- The mobile wooden bench provides the user with a comfortable way to strap on to the elliptical
- The bench is built with clearance to roll over the elliptical base
- Locks on the caster wheels will secure the bench
- The hand-truck provides the trainer an ergonomic way moving the elliptical with less effort. The elliptical is pushed under the wooden bench to allow the user to strap on.

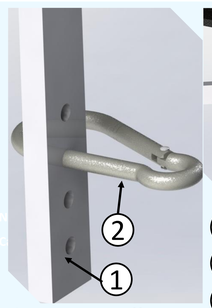
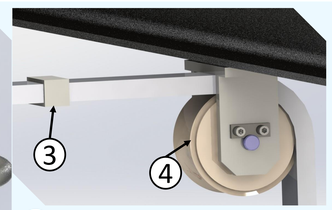


Figure 5. Pulley System showing rubber stopper



1 Nylon Strap
2 Carabiner
3 Stopper
4 Pulley
5 Harness

Figure 6. Carabiners that attach to the harness

Figure 7. Harness

Safety:
- One continuous strap attached by carabiners to both ends on the front side of the user provide the user with seamless motion
- Rubber stoppers are placed on the inside ends of the pulleys to prevent the user from moving too much to one side and therefore losing balance
- The straps have multiple attachment points on each side which will depend on the height of the user.
- Safe Torque Off (SIL2/PLD3) embedded Driver

Cost:

OTS Parts	$3204.97
Raw Materials	$37.31
Manufacturing and Labor	$40.00
Energy Consumption (1 Year Est.)	$260.00
Assembly Labor	$33.28
TOTAL COST	**$3575.55**

Design Specifications:

Lifting Speed	6.6 in/s
Footprint	5.27 x 5.75 ft
Weight	210.14 lbs
Motor	120 V/AC 10.7 A 1.676 HP
AC Controller	GuardLogix 5380
AC Drive	PowerFlex 525 2HP

C1: Fits inside medical facility

C2: Runs power from standard wall outlet

C3: User does not interfere with elliptical operation

C4: Supports full weight of user

C5: Acceptable factor of safety

C6: Include failsafe to catch user

C7: User lifted at comfortable speed

C8: User will not swing and hit anything while suspended

C9: User unencumbered in vertical direction during exercise

C10: Prevents user from losing balance in a sagittal fall

C11: Prevents user from losing balance in a transverse fall

C12: Lifts user from seated position to fully suspended

C13: Moves suspended user over elliptical

C14: Holds user over elliptical trainer to strap in

C15: Accommodates body sizes from 5% female to 95% male

C16: Slowly transitions to offset weight

C17: User can select any offset from 0-100% of body weight

C18: Mounts to structural members or sits on floor

C19: Provides continuous user-defined offset weight support while exercising

C20: Offset weight support feels continuous

C21: Provides offset weight support in all directions

C22: Is programmable

C23: Has an intuitive user interface

C24: Total cost < $4000

C25: Includes a manual emergency shut off

C26: Includes a force limit emergency shut off

C27: Has a visible indicator

C28: Lifetime exceeds 3X lifetime of elliptical

C29: FES electrical stimulation pads accessible

C30: Overall footprint cannot exceed 8’ X 10’

M1: Minimize Height X Width [ft^2] (Disassembled system must be < 7’ X 3’)

M2: Minimize System Weight [lbs]

M3: Required system voltage < 120 [VAC]

M4: Required system current < 15 [Amps]

M5: Minimize relative percent interference by hanging components [%]

M6: Maximize Load Capacity [lbs]

M7: Minimize degrees of freedom of system [#]

M8: Minimize complexity of system [Rank]

M9: Minimize fall time [ms]

M10: Optimize system lift speed [ft/s]

M11: Radial freedom of movement [ft]

M12: Maximize vertical clearance [ft]

M13: Minimize sagittal angular freedom of movement [degrees]

M14: Minimize transverse angular freedom of movement [degrees]

M15: Minimize lift time [ms]

M16: Minimize translation time [ms]

M17: Minimize degrees of freedom while strapping in [#]

M18: Maximize height range of functionality [Rating]

M19: Maximize optimization of transition speed [Rating]

M20: Maximize weight offset sensitivity [lbs]

M21: Minimize permanent connection points [#]

M22: Minimize weight offset error caused by user movement [Rating]

M23: Maximize offset weight reaction of system [lb/s]

M24: Maximize dimensions of support [#]

M25: Maximize number of programmable buttons [#]

M26: Minimize required commands to full set up [#]

M27: Minimize cost [$]

M28: Minimize distance to manual shut-off [ft]

M29: Minimize response time [Ranking]

M30: Maximize freedom of indicator placement location selection [Rating]

M31: Maximize lifetime [yr]

M32: Minimize surface area of legs inaccessible [ft^2]

M33: Minimize Length X Width [ft^2] (must be under 8’ X 10’)

Weight Balance Subsystem

Fall Safety Subsystem

Translation Subsystem

Mounting Support Subsystem

Controls Subsystem

F1 (C1): All individual components are less than 7x3 ft.

F2 (C1): Weight of combined subsystems is 210.14 lb.

F3 (C2): AC motor requires less volts than a DC motor.

F4 (C3): No interference from ceiling-mounted cables/motor components.

F5 (C3): No interference from tablet mounted to elliptical.

F6 (C3): Bench has 1.5 ft clearance above elliptical pedals.

F7 (C4): Motor capacity is 660 lb.

F8 (C4): Galvanized steel cable can withstand 660 lb.

F9 (C4): Fall support leash can support 400 lb.

F10 (C4): Beams can support 23 ksi.

F11 (C5): Minimum 1.5 S.F.

F12 (C6): Fall safety straps

F13 (C7): User is slowly lifted onto bench since main translation is the dolly cart used to move elliptical.

F14 (C8): Pulley breaks on continuous safety strap limit right/left movement.

F15 (C8): Front straps and back cable limit forward/backward movement.

F16 (C9): Vertical clearance is 1 ft.

F17 (C10): Less than 20° of freedom in sagittal direction from tri-connection configuration.

F18 (C11): Tri-connection limits all 4 degrees of freedom in transverse plane (translations/rotations).

F19 (C12): Motor/cable spool suspends user onto bench and then suspends user to vertical.

F20 (C13): Elliptical is moved under bench using dolly cart.

F21 (C14): Bench straddles elliptical while user straps boots.

F22 (C15): Harness has variable length buckles.

F23 (C15): Fall safety straps have multiple loop heights.

F24 (C16): AC motor drive controller can slow down lifting speed.

F25 (C17): Motor drive is controlled to maintain selected offset.

F26 (C18): System mounts to existing structural I-beams.

F27 (C19): Load sensor between harness and motor cable.

F28 (C20): Maximum motor speed is 6 in/s.

F29 (C21): Main lift force originates behind user but safety straps keep user upright in a natural manner.

F30 (C22): Tablet is programmable.

F31 (C23): Tablet is user-friendly.

F32 (C24): Total cost: $3575.55

F33 (C25): OTS motor contains emergency stop button.

F34 (C26): Programmable motor driver.

F35 (C27): Tablet mounted to elliptical is visible to user/trainer.

F36 (C28): Simple design means parts can be replaced with wear.

F37 (C29): Harness only covers part of upper-thigh.

F38 (C30): Total footprint: 5.27x5.75 ft