

# McKRUMAN TECHNOLOGIES

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# The Project

Our objective was to design and fabricate a High-Speed Treadmill that is capable of measuring the horizontal and vertical forces exerted by human and non-human subjects sprinting up to their top speeds.



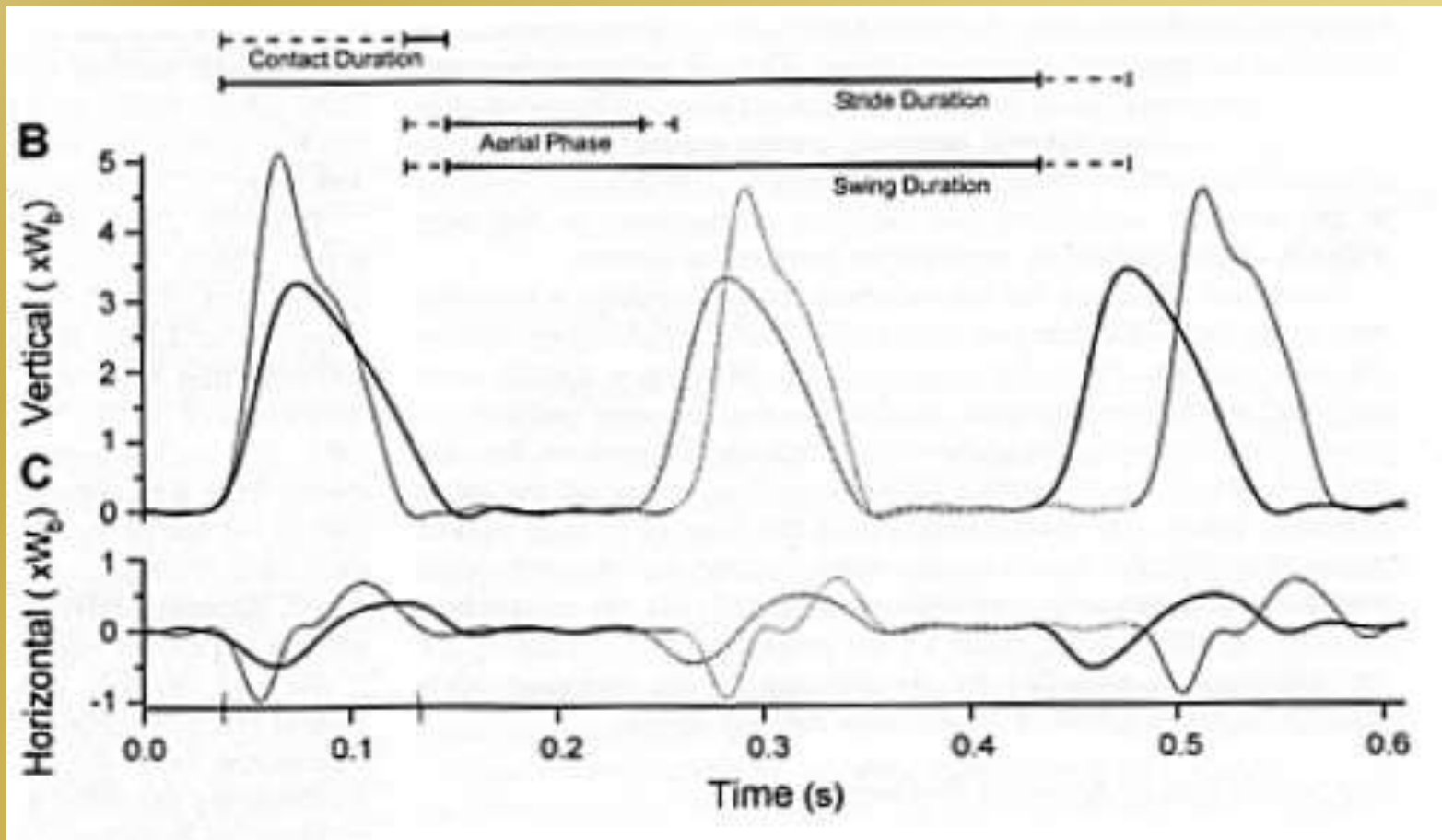
# Why Design a High-Speed Treadmill

- ▣ Dr. Matt Bundle of the Kinesiology Department asked us to build a treadmill to aide him in his research studies
  - Difficult to measure forces of sprinters on a track
  - The treadmill will be used to investigate leg function in individuals with intact and prosthetic limbs
  - Use data to analyze muscle functions
  - Animals sprinting characteristics can also be compared to human's

# Design Objectives

- ▣ Treadmill was designed to exceed human sprinting capabilities
  - Speeds up to 28 mph
  - Duration of sample: 8 step count
  - Olympic runner's foot on ground for 87 ms with step frequencies larger than 5 Hz
  - Maximum vertical force is 5 times the runners body weight
  - Maximum horizontal force is 1 times the runners body weight
  - Sprinter's Safety

# Sample Step frequency



# Specifications

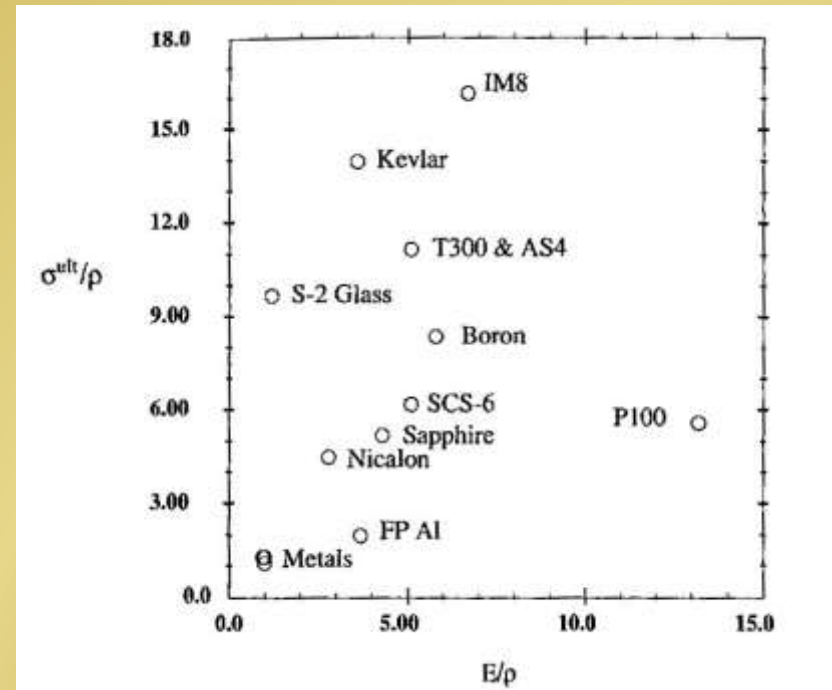
- ▣ Reach a velocity of 14 m/s (31 mph)
- ▣ 2.46 m in length
- ▣ 0.76 m in width
- ▣ Dynamic coefficient of friction <0.1
- ▣ Weight sitting on load cells <200 lbs
  - Bed should be light with high stiffness
  - The natural frequency should be large

# Provided Materials

- ▣ Baldor Electric Motor – 5.83 kW- 4000 rpm
- ▣ 2 - 6" Aluminum rollers
- ▣ 4 Bearings
- ▣ Tread belt
- ▣ Steel for outside safety frame
- ▣ 4 Load Cells - multi-axial

# Bed Design

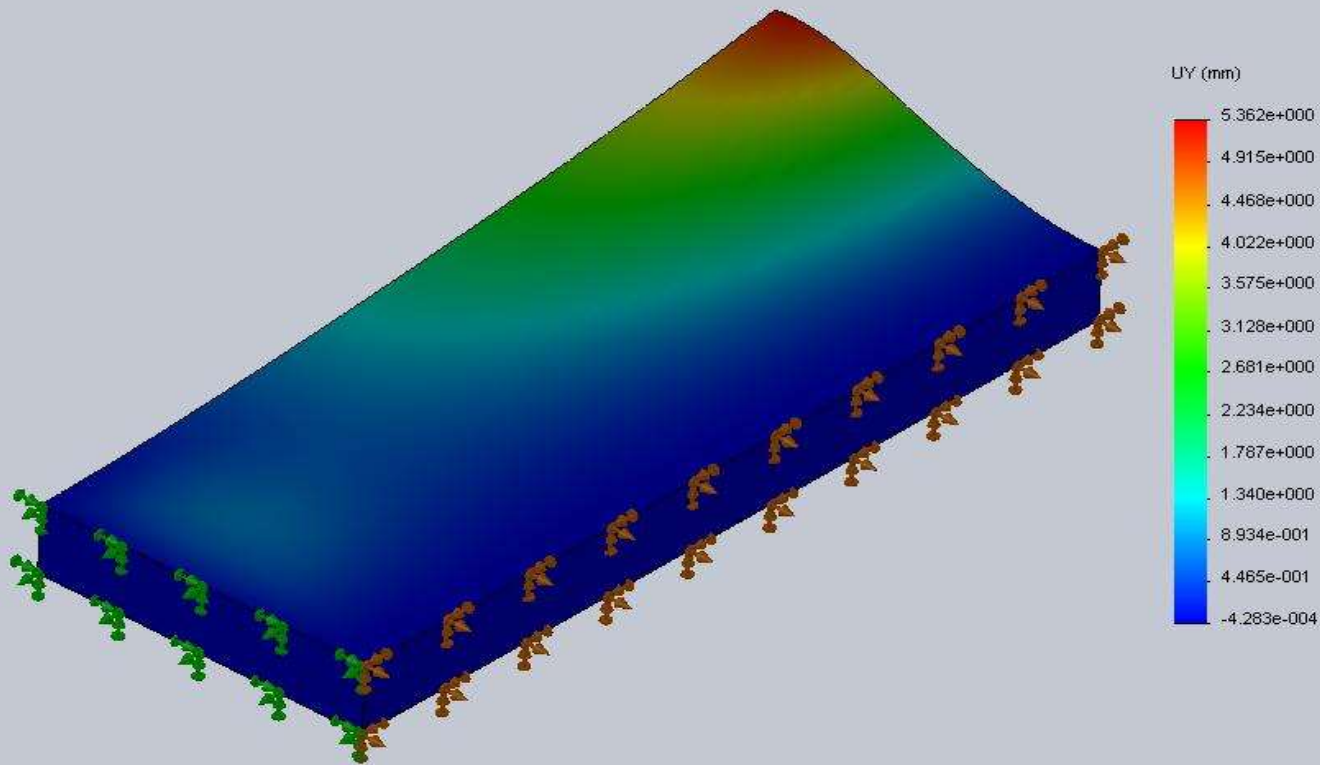
- Aluminum or Composites for bed material?
- Polyurethane foam core
  - 3.5" thick, 34" wide, and 87" long rectangular slab
  - Light weight - 6 lbs/ft<sup>3</sup>
  - Will not contribute to material properties of bed
- Composite materials
  - High specific strength and high specific stiffness
  - Two layers of 18oz Fiber glass, one layer of 6 oz fiberglass and a top layer of 6oz carbon fiber





# Bed Deflection

Model name: Multi lay-up model  
Study name: Study 2  
Plot type: Static displacement Displacement1  
Deformation scale: 20.842



Educational Version. For Instructional Use Only

# Composite Layup



# Teflon

- ▣ Teflon secured on top to reduce coefficient of friction and wear
- ▣ Tests were performed to determine the coefficient of friction
  - $\mu \approx 0.10$



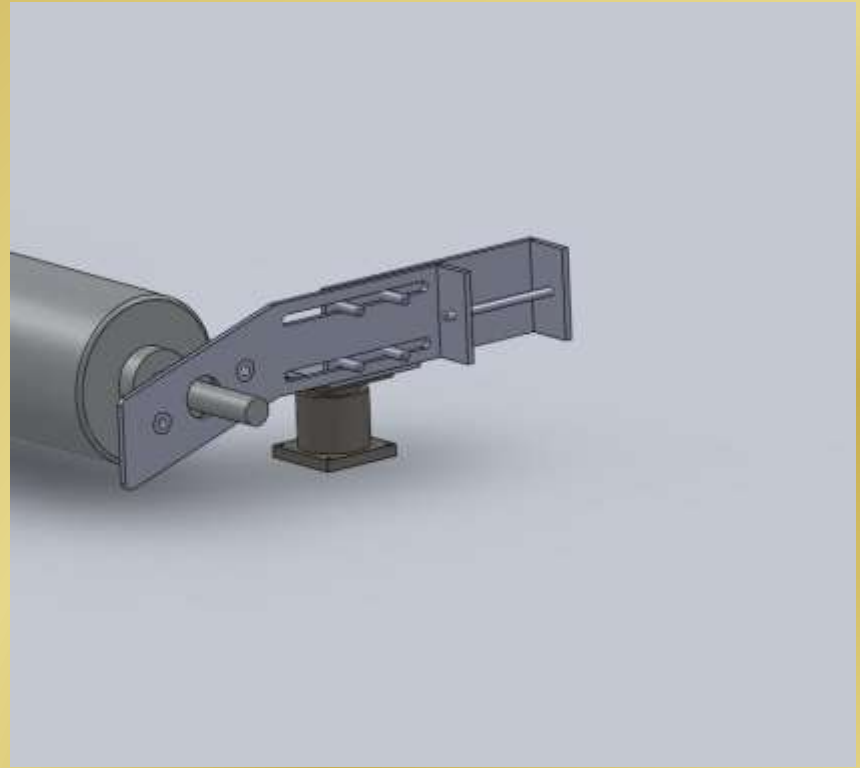
# Brackets

- ▣ Brackets were made specifically to support the rollers and to transmit all loads through the load cells
- ▣ Made of 1/4" carbon steel cut on water jet machine for precision
- ▣ Threaded holes for attachments (no bolts)



# Tensioning System

- The front brackets were designed to provide tracking adjustability and tension in the belt
- This system also allows for the belt to be put on or taken off with minimal disassembly
- The system is a simple device that uses 3/8" all-thread and a nut to control the distance the brackets move



# Method of Attachment

- ▣ Can be difficult to attach parts to composite
  - Support loads
  - Bolt through
  - Rivets
  - Epoxy adhesives
- ▣ High strength epoxy adhesive was used to hold brackets in plates
- ▣ Rivets were used to hold Teflon



# Flexible Coupling

- Removal of the motor's 75.5lbs off the load cells
  - Use flex couple so that the weight of the motor is off the load cells
  - Flex couple does not transmit any transverse forces but is stiff in torsion
  - Allows for 5 mm of parallel misalignment



# Load Cell Leveling

- ▣ In order for the load cells to accurately measure forces, the load cells x and y axis must be parallel with one another
- ▣ Swivel mounts were used to accomplish this
- ▣ To ensure a level mounting surface, self leveling epoxy is used





# Safety

- ▣ Hand Railing
- ▣ Overhead Railing for safety harness
  - Aircraft cable ran the length of the frame
  - Harness attaches to sprinter
- ▣ Steel tubing and beams for railing
- ▣ Decking on all sides of bed to cover wiring and mechanical parts



# Testing

- ▣ Composite samples were made prior to the fabrication of the bed
  - Familiarized ourselves with composite manufacturing process
  - Cyclic loading
    - ▣ Performed at 5 Hz
    - ▣ 100 lb load
  - Failure loading
    - ▣ Failed in shear at 1700 lbs.



# Testing

- ▣ Bed deflection
  - A Matlab code was used to obtain a Modulus of Elasticity (E) for the composite material
  - The modulus was then used in Solidworks to model the maximum bed deflection
    - ▣ Using Solidworks modeling, maximum deflection is roughly 5 mm
  - For verification a 250 lb person jumped on the bed and a 4 mm deflection was recorded

# Cost Analysis

Baldor Electric Motor	\$5,844.00
Four Load Cells	\$16,852.00
R&W Driveshaft	\$1006.00
Bearings	\$267.64
Belt	\$438.42
Rollers	\$804.00
Teflon Plates	\$479.72
Composite Materials	\$1500.00
Other Materials	\$1000.00
Machine Shop	<b>Priceless</b>
<u>Total</u>	\$28,191.88

# Finishing Touches

- ❑ The servo-controller configuration was not compatible with the motor that was purchased
- ❑ The cabling for the load cells was not available
- ❑ The self leveling floor has yet to be finished
- ❑ Rhino lining needs to be applied to safety frame
- ❑ Safety harness has not been purchased

# Acknowledgements

Dr. David Walrath

Dr. Matt Bundle

Dr. Dennis Coon

Machine Shop

Composite Manufacturing Class

Chris Sundberg

**Questions ???**