U-Cube: Spider Cage for Traumatic Brain Injury Patient

Jon Elicson, Jake Kanack, Jon Leja, and Sam Mešanović

Client: Matt Jahnke Advisor: Dr. Kris Saha

Abstract

Every year, millions of people worldwide suffer a traumatic brain injury (TBI). Often, these injuries interfere with the strength and motor skills of those affected. Physical therapy is essential in restoring muscle strength and control for many people affected by a TBI. The proposed U-Cube provides a solution for anchoring the customizable supports utilized in intensive physical therapy programs. These physical therapy programs use targeted support or resistance of specific sections of a patient's body to enhance the value of physical therapy sessions. The U-Cube hopes to improve upon prohibitively expensive commercial systems by providing a low cost alternative. For evaluation of the U-Cube System, a patient suspension system was designed utilizing a commercially available harness. The harness and U-Cube are to be used in conjunction with one another in order to provide a dynamic physical therapy experience for individuals of all ages.

Background

- TBI affect roughly **2.5 million people** in the US
- The two kinds of TBI are closed (concussive) and penetrating (gunshot, stabbing)
- Symptoms include seizures, confusion, and loss of coordination
- Incurs roughly **$76.5 billion** in US annualy (1)

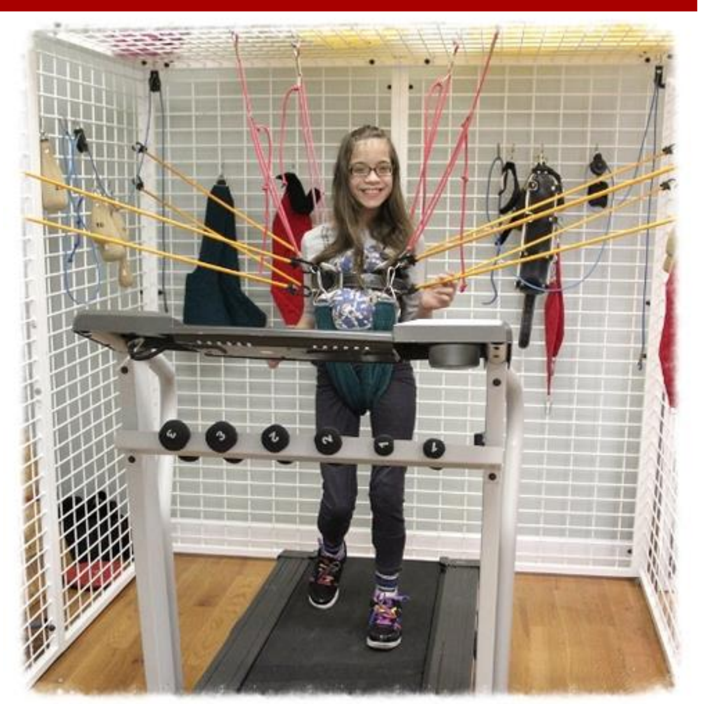

Figure 1&2: 1) Picture of TheraSuit (left) and 2) commercial fenced cage (above). (3,4)

- Current designs include fencing unit, rock climbing harness, and bungee cords connecting harness fence. (2)
- Commercial cages **can cost upwards of $7000**
- The TheraSuit is another alternative therapy option
- However, TheraSuit training **costs $1600** (3)
- It is geared toward children and only offers one adult size

Motivation & Design Specifications

The U-Cube is intended to act as an intensive physical therapy unit that can help patients regain mobility and motor function. A variety of diseases that affect coordination can be treated with this device, not just TBI's. The cage will be designed at a fraction of the cost and open-sourced to allow a wider population to have access to its benefits. The cage should:

- Allow targetable support of specific areas on patients of any age & size
- Support up to 200 lb. (1112.5 N) with a 1.6 factor of safety
- Withstand 2 hour therapy sessions at least 5 times a week without wear
- Accommodate common therapy equipment like a treadmill and Hoyer lift
- Have simple fabrication process with easily obtainable tools and materials
- Include instruction manual and parts list uploaded to UCPdane.org

Future Work

- Collect materials from supplier (3-4 weeks)
- Construct cage in clinic and help implement its use
- Provide recommendations for harness and its integration
- Upload instructions manual to UCPdane.org

References & Acknowledgements

Kris Saha, Ph.D.; Amanda Miller, OT; John Puccinelli, Ph.D.; Bill Koepcke; Elizabeth Meyerand, Ph.D.; Matthew Jahnke, Joseph Towles, Ph.D.

[1] Traumatic Brain Injury in the United States: Fact Sheet. (n.d.). Retrieved February 19, 2015, from http://www.cdc.gov/traumaticbraininiury/get the facts.html

[2] Intensive Suit Therapy — the most powerful and innovative therapy method for Cerebral Palsy and Brain Injury. (n.d.). Retrieved February 24, 2015, from http://www.revivo.ca/suittherapy/

[3] TheraSuit Method. (n.d.). Retrieved October 8, 2014, from http://www.suittherapy.com/

[4] Universal Exercise Unit. (n.d.). Retrieved October 8, 2014, from www.believetherapv.com/cage/

Final Design

Structure Specifications

- 7' (2.13 m) cube
- Open face for entry by patient and therapist
- Fits Hoyer lift, therapy table, treadmill, etc.
- Easy to assemble/disassemble
- 7/16" (1.1 cm) holes every 1" (2.54 cm) for suspension attachment
- Cross bracing for added stability

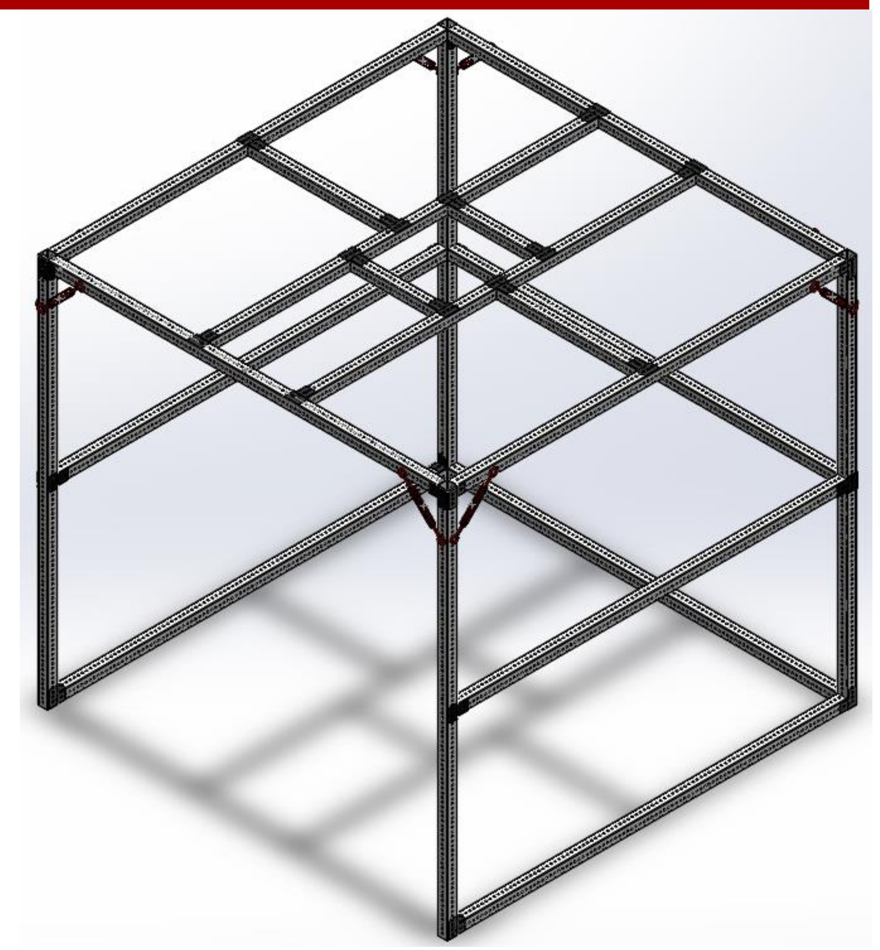

Figure 3: Picture (left) of the recommended harness (DLX) to use in the complete two component therapy system.
Figure 4: Picture (top right) of final design.

Table 1: Table (below) displaying size and quantity of all parts as well as total cost.

Qty	Size	Part	Cost
18	7' (2.13 m)	2.5" (63.5 mm) 12 Ga. Perforated Tubing	697
2	7' (2.13 m)	2.25" (57.15mm) 12 Ga. Perforated Tubing	54.2
120	7/16" (50.8 mm)	Bolts (Grade 8+)	108
120	7.16" (50.8 mm)	Nyloc Nuts	30
120	7.16" (50.8 mm)	Fender Washers	18
25	-	L brackets	104
25	-	T brackets	104
25	-	90 degree brackets	49
8	9" (203.2 mm)	1/2" Eye/Eye Turnbuckle	16
6	7/16" (50.8mm)	Eyebolt	6
		Total Cost - Cage	1186.2
1	-	DLX Harness	500
		Total Cost - Cage & Harness	1686.2

Testing Procedure

Computer Modeling

- Modeled in 7' (2.13 m) cubic space in SAP 2000
- Applied vertical 400 lb. (1780 N) load – representative of 200 lb. (890 N) load and FOS
- Additional 150 lb. (667 N) lateral load to simulate dynamic exercise
- Modeled truss layouts in ANSYS for overhead deflection minimization

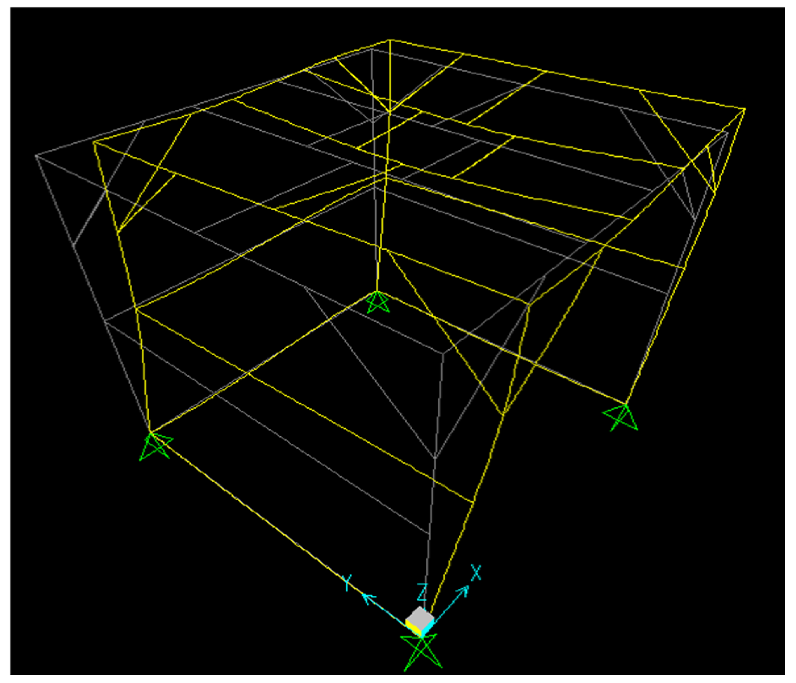

Figure 5: Prototype simulation in SAP2000 under vertical and lateral loading

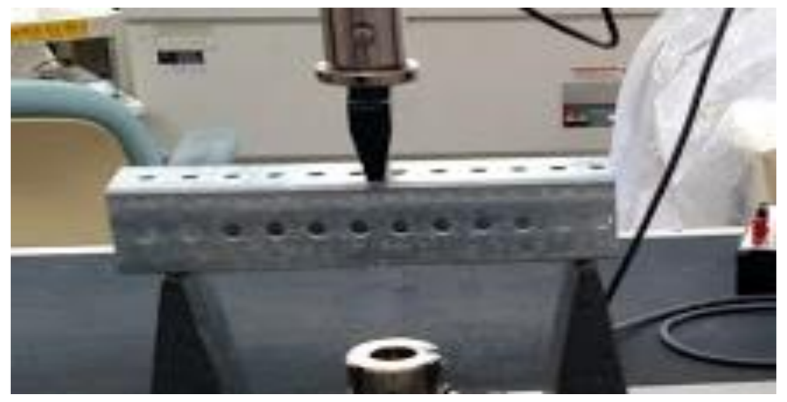

Figure 6: Picture of MTS machine and sample being deformed

Physical Modeling

- 3 point bending test performed on MTS
- Tested 2.5" (63.5 mm) and 2.25" (57.15 mm) samples three times
- Loaded to plastic deformation
- Balsa wood modeling for initial analysis of truss layouts

Results & Discussion

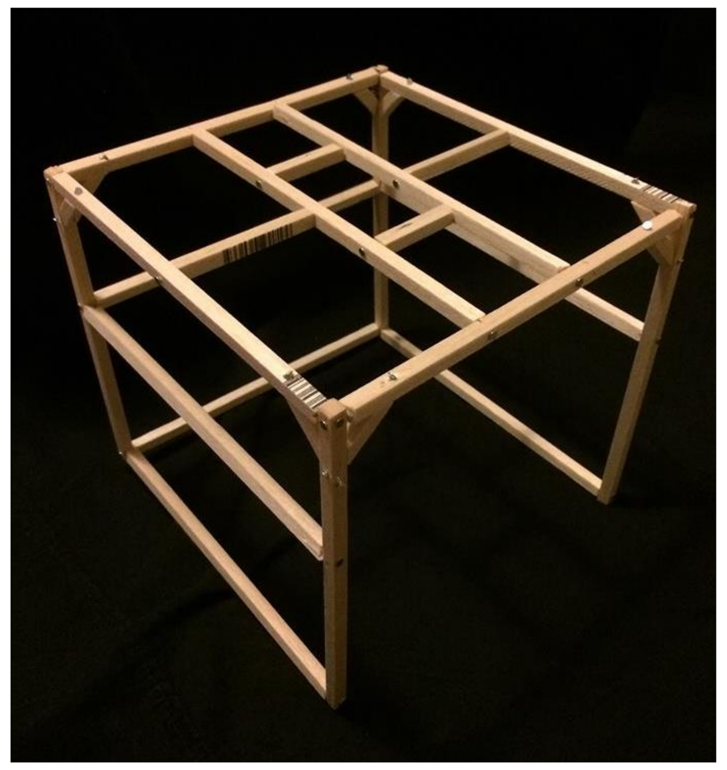

Figure 7: 1:12 scale balsa wood model of cage prototype

Balsa Wood Results

- Two 1:12 balsa wood models were created to observe how structural changes altered prototype stability
- The model on the left features the addition of cross braces and supplemental overhead members compared to a model with only 2 overhead beams and no cross braces (not featured)
- "Hands on" analysis was used to infer how changes to structure altered stability
- Conclusion: additional overhead members reduced deflection at 1 lb (4.4 N) load, cross bracing reduced open face shear from lateral loads significantly

ANSYS Results

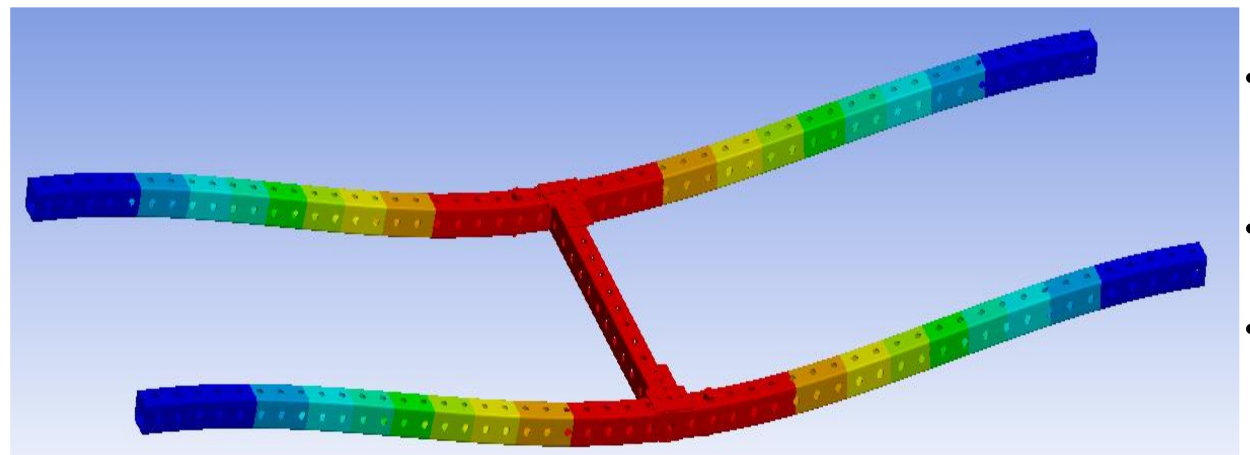

Figure 9: ANSYS Simulation utilized for bracketry analysis. Deflection measured 3.972 mm at a 1500 N load. Red represents high deflections whereas blue represents low deflections

- Utilized to model design upper truss systems to minimize deflection
- Added four connecting beams to top of cage
- Significantly lowered deflection compared to unsupported beams shown in Figure 9

MTS Results

- Simulated 3pt bending test in ANSYS and SAP2000
- Compared with data from MTS Testing
- Added 30% to SAP Simulation Forces (maintain FOS)

Deflection at 320 lb (1423N)		
MTS Testing	SAP 2000	ANSYS
.09788 mm	0.072mm	.0118mm
% Difference from MTS	-30.47%	-157%

Table 2: Comparison of 3pt Bending simulations with MTS data.

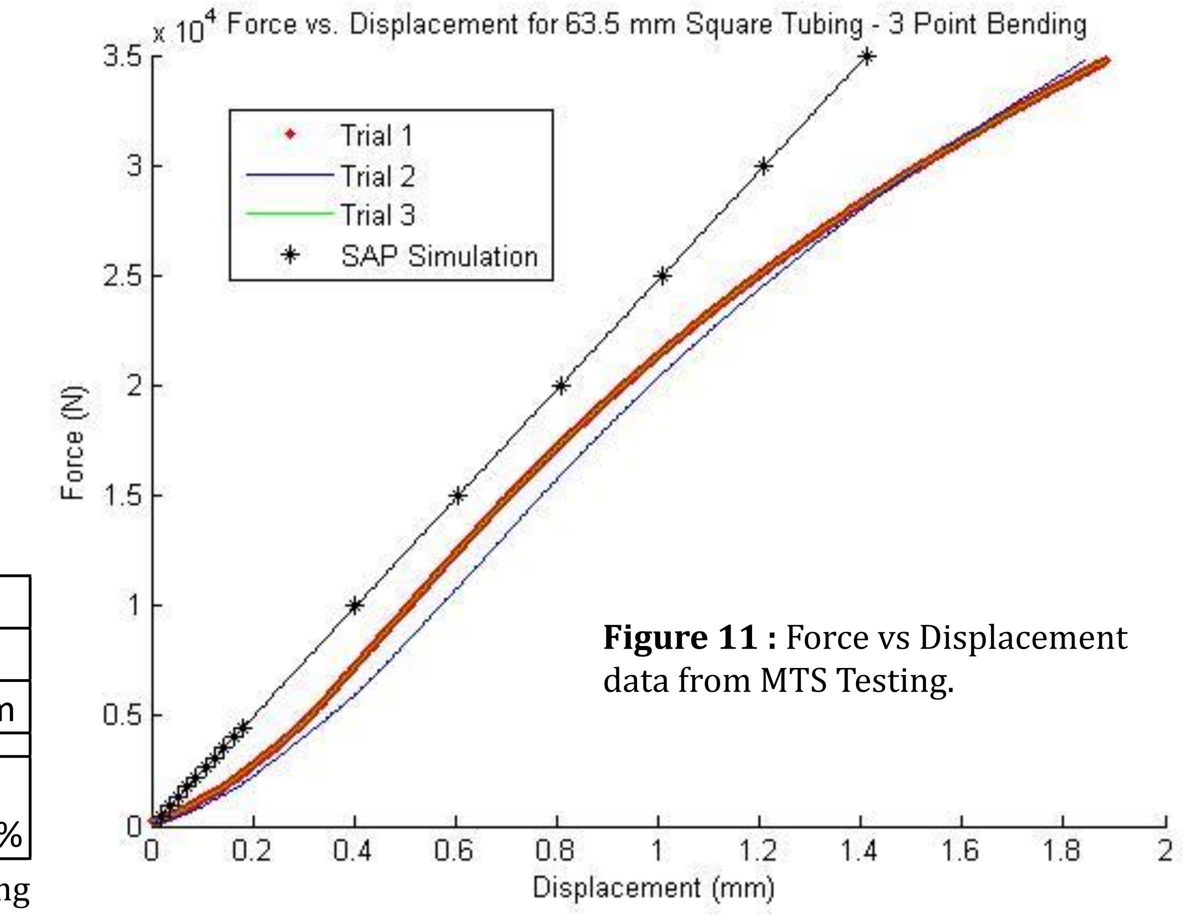

Figure 11 : Force vs Displacement data from MTS Testing.

SAP2000 Results

- .37" (9.4 mm) deflection observed at a 400 lb (1780 N) vertical load
- Differs only 3% from Telespar cited perceptible deflection amount of .36" (9.1 mm) for a 7' (2.13 m) beam
- Additional 150 lb (667 N) Lateral load applied on top left member
- .17" (4.34 mm) shear deflection observed on axial open face beam
- Conclusion: Prototype is stable under simultaneous axial and lateral loads

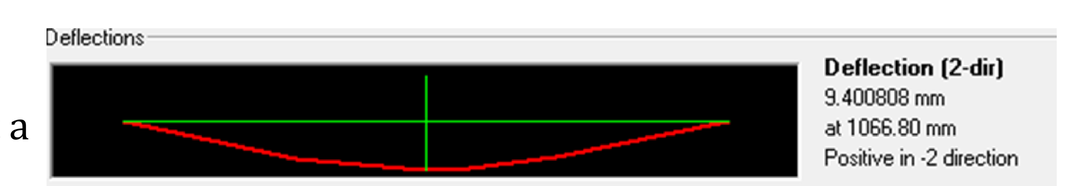

Figure 10a: SAP figure detailing deflection of a 2.13 m beam under 1780N beam centered load on an overhead beam

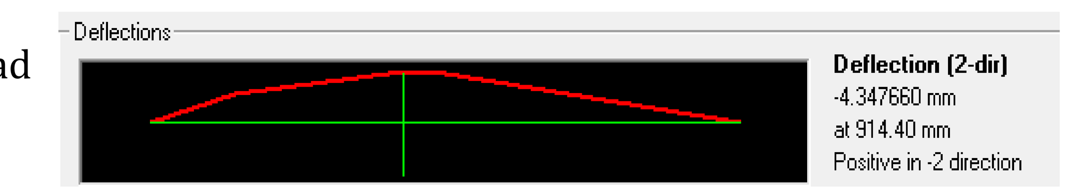

Figure 10b: SAP figure detailing deflection of an axial 2.13 m beam under a laterally applied force of 667 N on the top left beam