THE ADAPTIVE PADDLEBOARD

Stephen Eldridge, Claire Francis, Curtis Hodgson, Haley Rentfro, and Spencer Shotts
Collaborative Senior Project: Mechanical Engineering and Kinesiology – 2015/2016

PROJECT DESCRIPTION

The purpose of this project was to help Damien, a fire fighter and San Luis Obispo resident, who was injured after a tree fell on him in July of 2015. The incident left Damien with an incomplete spinal chord injury, meaning some motor and sensory function below his waist was preserved, while still maintaining full function of his hands and arms.

Damien with his family

Problem Statement

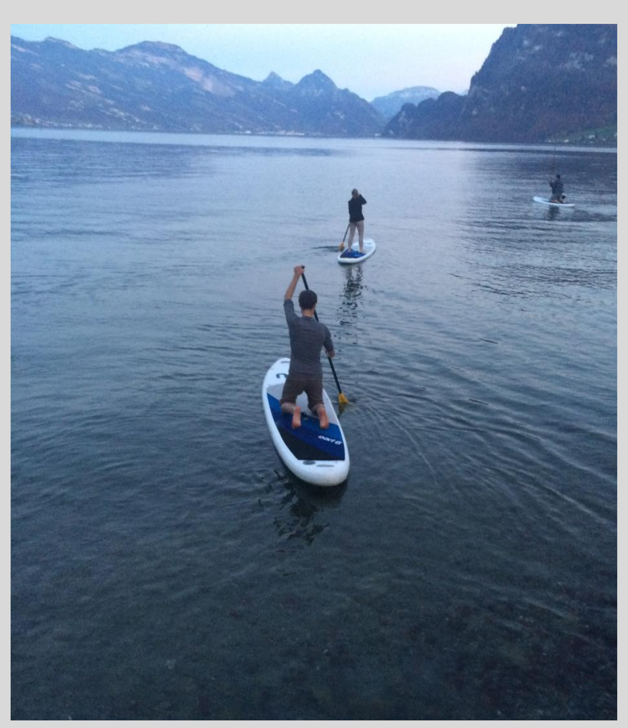
The client desires a paddleboard design that will enable him to participate in traditional paddleboarding activities throughout the duration of his recovery. Such a design will allow him to enjoy the water sport from beyond the seat of his wheelchair.

Primary Engineering Design Requirements

Requirement	Value	Unit
Overall Length	< 13	ft
Attachment Weight	< 35	lb
Weight Capacity	> 250	lb
Board Thickness	< 6	in
Structural Strength	> 200	lb
Board Must Not Incorporate a Wheelchair	-	-
User Must Not Be Attached to Board	-	-
Must Assist User Stability	-	-

DESIGN PROCESS

- Idea generation was crucial in the early phases of this project due to the unique challenges presented
- Preliminary testing of initial concepts were tested on Lake Luzern, Switzerland
- The team focused the concept development process on three critical features:
  - Standing Position
  - Kneeling Position
  - Increasing Stability



The team on their first paddleboard ride on Lake Luzern, Switzerland

Initial Concept

- Folding support to accommodate both standing and kneeling positions. Folded flat against the board, the support would have a low profile appearance when not in use
- Increased board width and volume for improved stability

CAD model of initial concept

Client Feedback

- Feedback from Damien, such as the addition of dip bars and a sitting position, became instrumental in the progress of the team's design
- Ergonomic features were added such as a kneeling support and a slight angle to the structure
- The design process was constantly evolving; as Damien's physical ability developed in therapy, the design had to be adjusted to reflect his progress

Design Challenge: Mounting Interface Inserts

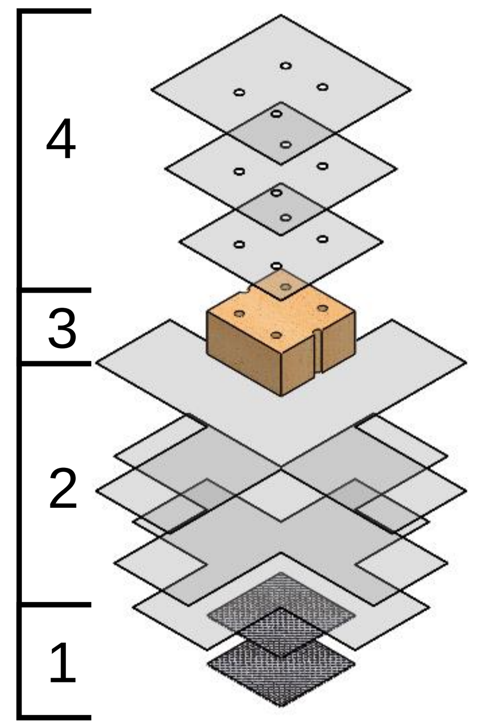
The design of the mounting interface inserts allows for a structurally sound bolt pattern on the surface a foam core board that does not compromise the board's buoyancy or performance.

Layer 4: Three layers of fiberglass to cap the insert and integrate into the board surface.

Layer 3: Wooden insert with threaded bolt pattern. Wood is porous enough to form a strong bond with epoxy. Female tapped inserts were driven into the wood.

Layer 2: Three fiberglass "tophat" layers for maximum surface area and shear strength.

Layer 1: Two carbon fiber layers for thermal resistance during epoxy curing.

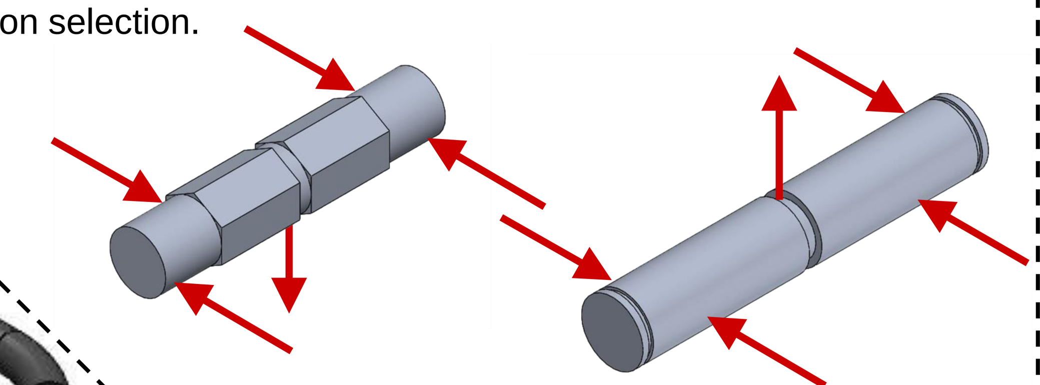


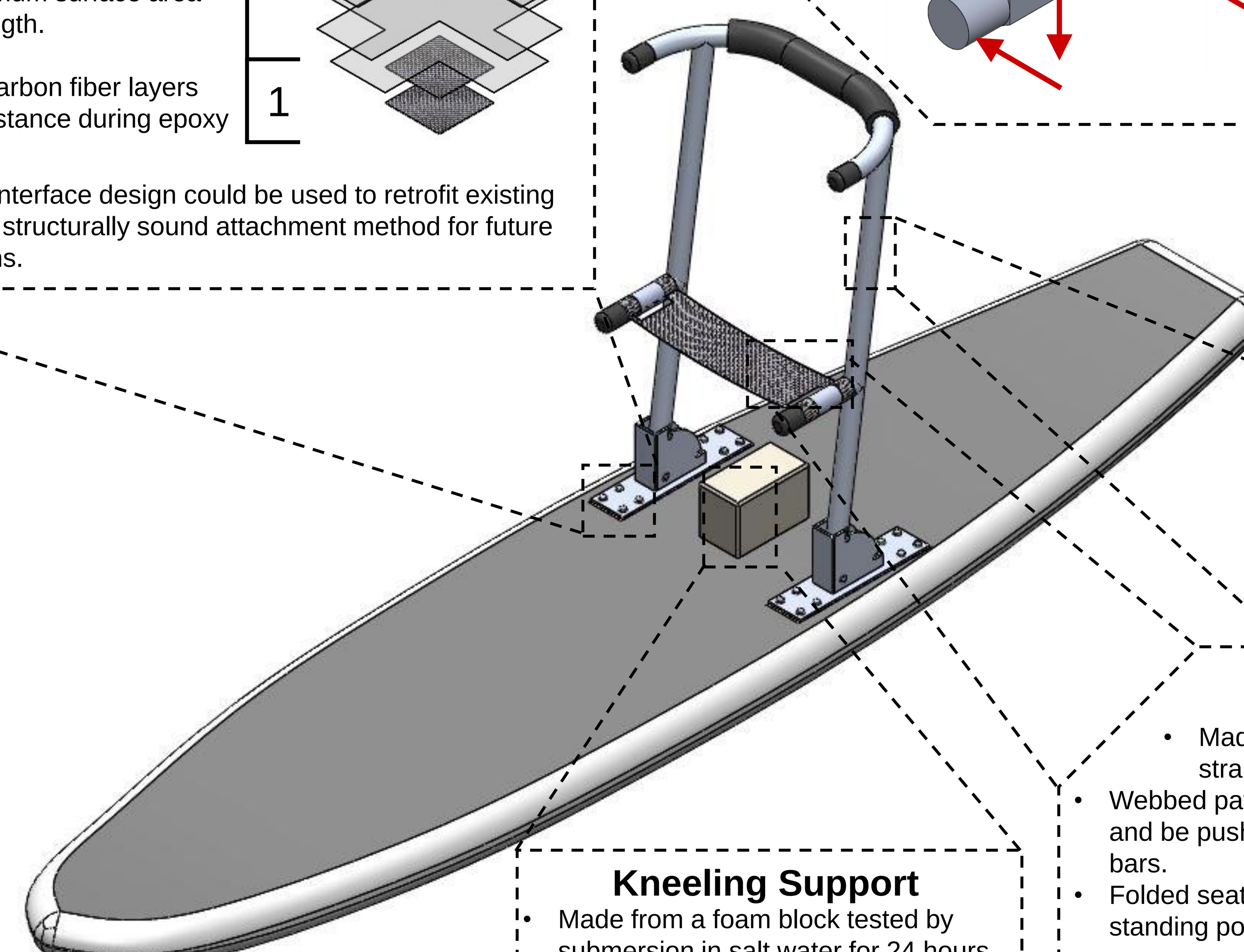
This mounting interface design could be used to retrofit existing products with a structurally sound attachment method for future adaptive designs.

Stress Analysis

Critical Feature	Method of Analysis	Maximum Value	FOS
Hexagonal Pin	Principle Stress	7,900 psi	3.8
Bottom Pin	Principle Stress	12,400 psi	2.4
Vertical Beams	Bending	16,000 psi	2.17
Cap Screws	Tensile Loading	27,400 psi	2.73

- Among the most critical components of the design were the pins of the folding joint that transfer loads on the structure to the baseplates. The geometry of the pins created areas of stress concentration that influenced final dimension selection.





Anodized Aluminum Structure

Lightweight and stiff support structure that is corrosion resistant even in harsh marine conditions

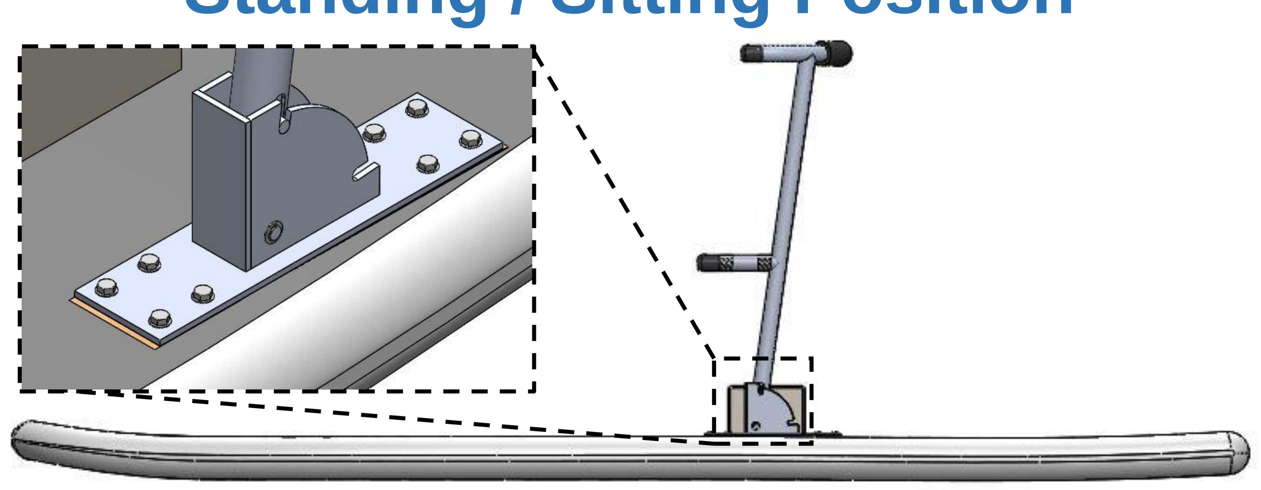
Seat Design

- Made from military grade nylon straps.
- Webbed pattern allows seat to collapse and be pushed out of the way for use of dip bars.
- Folded seat allows for an unimpeded standing position.

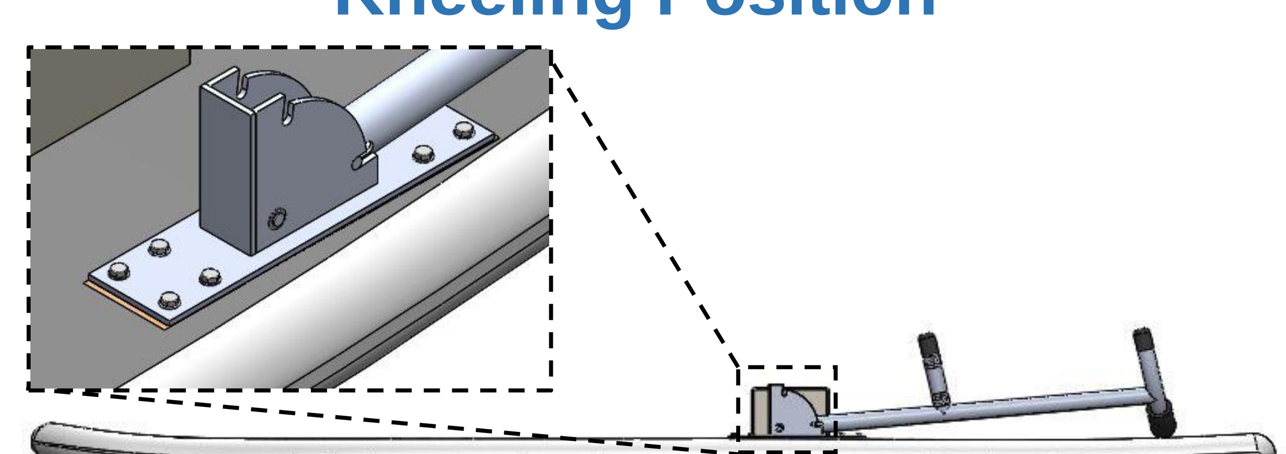
Kneeling Support

- Made from a foam block tested by submersion in salt water for 24 hours.
- Allows for comfortable kneeling for an extended period of time.
- Attached to the board using marine grade hook and loop closures for possible removal.

Standing / Sitting Position



Kneeling Position



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PROOF OF CONCEPT TESTING

- The strength of the mounting interface inserts could not be predicted via traditional analysis.
- Strength testing of potential insert design was conducted using surfboard blanks subjected to bending and vertical tensile loading
- Failure in the foam occurred with the application of a 100 lb tensile load, but the wood – fiberglass interface did not fail.

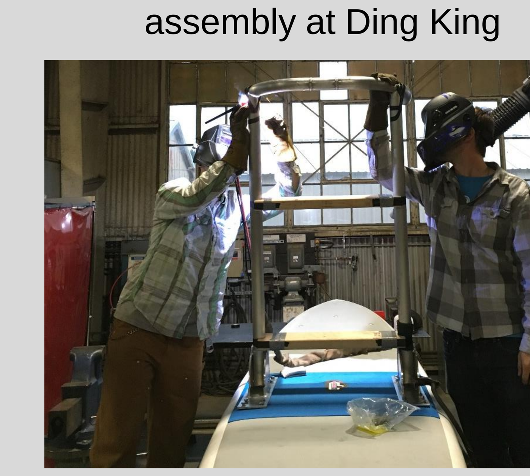
Failure in foam structure of surfboard blank test specimen

FABRICATION

- Fabrication of the support structure and joint components took place the Cal Poly Hangar and Mustang 60 Machine Shops
- Installation of the tapped inserts was completed at Ding King surfboard repair shop in Encinitas, CA

Applying epoxy for the insert assembly at Ding King

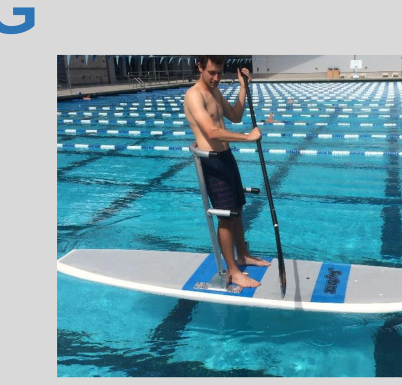
Spencer using the lathe to face the joint pins



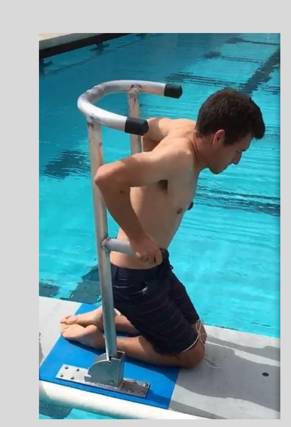
Tack welding the support structure in the Cal Poly Hangar

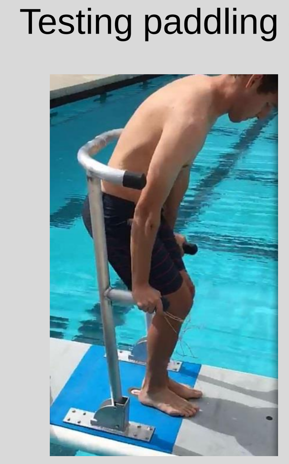
TESTING

- All items of the design verification test were passed
- Testing included transitioning from kneeling to standing, paddling clearance, maneuverability, stability, and ergonomics
- Testing and verification was completed at the Recreation Center Pool at Cal Poly



Testing paddling clearance





Curtis successfully transitioning from kneeling to standing using only his arms

CONCLUSIONS

- The design of the mounting interface inserts could be used in numerous applications beyond this project to retrofit existing foam core structures like surfboards and paddleboards
- The developed design may have additional applications beyond assisting mobility impaired individuals
- The team was successfully able to improve the quality of life for a recovering spinal chord injury patient with the development of an adaptive product