Annual Project Report June 2008
Award Number: 0756210

Access by Design:
Capstone Projects to Promote Adapted Physical Activity

Brian Self, Ph.D., J. Kevin Taylor, Ph.D., Jim Widmann, Ph.D., Lynne Slivovsky, Ph.D.
Cal Poly, San Luis Obispo

This is an interim project report for award number 0756210, for the reporting period 3/15/08 through 6/30/08. The project award date was March 15th, 2008 which fell between the winter and spring quarters of the Cal Poly academic calendar. In anticipation of receiving the grant, the design phase of several proposed projects was initiated in January of 2008. Materials to complete the manufacturing and test phases of these projects were purchased with the grant funds in April and May of 2008. This allowed for significant progress to be made on work proposed in the grant by June of 2008. This partial year cycle has provided a solid foundation for a full year of funded projects beginning in the Fall quarter of 2008.

There were five proposed projects in the design phase when the award was made and funds were used to purchase materials for each, the projects were:

1. Adjustable Sit Ski
2. SoloQuad Kayak Conversion Project
3. The Universal Play Frame (UPF) Mk.V
4. Universal Play Frame Attachment: The Frisbee Launcher Mk.II
5. Universal Play Frame Attachment: Rock n’ Bowler
Adjustable Sit Ski
Student Team: Niklas Barreto, Kevin Gibbs, Evan Melgares & Jerry Schneizer

Project Description and Impact
The Adjustable Sit Ski project was initiated after Jon Kreamelmeyer, Coach of the US Paralympic Ski Team, contacted Dr. Brian Self (P.I.) about the possibility of developing a modular sit ski. A modular design would improve upon existing sit skis by helping athletes adjust the ski to their optimal body position for maximum power output as well as potentially increasing access to the sport by recreational skiers. The modular design could help ensure that rental shops have appropriate equipment on hand for those who need a sit ski wanting to try Nordic (cross country) sit skiing.

Cross Country skiing is a relatively new addition to the Winter Paralympic Games and not widely available as a recreational activity. People with paraplegia or partial quadriplegia are able to participate in the sport through the use of a sit ski that was initially developed for use in downhill skiing. It has been hypothesized that for cross-country sit skiing a kneeling position, as opposed to the usual sitting position, would improve the power output of some participants during poling.

The project team set out to design a sit ski that would be used for the Paralympic team to determine the optimal seating position for each athlete. Because many sit skis are individually assembled for one specific athlete there is widespread variation in existing designs. The positioning of the rider is a critical consideration in cross-country sit skiing and there is great potential for optimization of both comfort but also power through the ability to vary the position of the rider in the sit ski. With the goal of making cross-country skiing more accessible the project team also aimed to develop a sit ski that could be used globally at ski resorts, something that could be ridden by any person with paraplegia, partial quadriplegia or double leg amputation wanting to try cross-country skiing.

The sit ski project was a resounding success in that we learned a great deal and produced a prototype that has the ability to adjust seat angle, seat height, seat width, and foot rest positions thereby providing a broad range of positions for the skier. No current sit ski on the market has a comparable range of adjustment; hence the current design has significantly increased accessibility in the area of cross-country skiing. The existing prototype is being given to the US Paralympic Team to facilitate testing variation in seating positions to determine the optimal riding position for the individual athletes on the US Paralympic Team where it is hoped to provide a competitive edge.

Side View of the Adjustable Sit Ski showing possible seating positions.
**Technical Description & Cost**

The main goal was to design a light, strong, durable, comfortable, functional sit ski that can fit the 95th percentile of male bodies (and 5th percentile of females) and have the seat height, angle, and leg positions all be adjusted to an optimum position for the rider. The complete set of design specifications are given below.

<table>
<thead>
<tr>
<th>Spec #</th>
<th>Parameter Description</th>
<th>Requirements or Target</th>
<th>Tolerance</th>
<th>Risk</th>
<th>Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sit Ski Mass</td>
<td>6.8 kg</td>
<td>Max</td>
<td>M</td>
<td>S, T, A</td>
</tr>
<tr>
<td>2</td>
<td>Seat Height Range</td>
<td>20 to 40 cm (target 50 cm)</td>
<td>Range</td>
<td>A, T, S</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Seat Pan Angle Adjustment</td>
<td>-40° to 40° (from horizontal)</td>
<td>± 5 °</td>
<td>A</td>
<td>S</td>
</tr>
<tr>
<td>4</td>
<td>Angle Adjustment Increment</td>
<td>10°</td>
<td>± 5 °</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>5</td>
<td>Height Adjustment Increment</td>
<td>6 cm</td>
<td>± 2 cm</td>
<td>A</td>
<td>I</td>
</tr>
<tr>
<td>6</td>
<td>Collapsed Length of Assembly</td>
<td>100 cm</td>
<td>Max</td>
<td>A, S, T</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Collapsed Height of Assembly</td>
<td>100 cm</td>
<td>Max</td>
<td>A, S, T</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Total Cost</td>
<td>$2,000 (target: $1000)</td>
<td>Max</td>
<td>M</td>
<td>S</td>
</tr>
<tr>
<td>9</td>
<td>Max Rider Mass Supported</td>
<td>100 kg (86% for std. male)</td>
<td>Max</td>
<td>M, S, A</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Track width</td>
<td>24.1 cm (9.5 inches)</td>
<td>± 2 cm</td>
<td>A, S, I</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Leg Positions</td>
<td>2 (out in front, and front)</td>
<td>N/A</td>
<td>L, A, S, I</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Number of people needed to adjust</td>
<td>2 (athlete and 1 able bodied individual)</td>
<td>N/A</td>
<td>M T I</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Padded Contact Regions</td>
<td>Must not induce sores or pain</td>
<td>N/A</td>
<td>L TUS</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Allowable Sharp edges</td>
<td>0</td>
<td>N/A</td>
<td>L</td>
<td>I</td>
</tr>
<tr>
<td>15</td>
<td>Binding Compatibility</td>
<td>Must be compatible with Salomon</td>
<td>N/A</td>
<td>M A TI</td>
<td></td>
</tr>
</tbody>
</table>

There are three main components to the design: a four pillar telescoping tubular aluminum 6063 frame, split carbon fiber seat, and four bar tubular aluminum 6063 detachable front foot rest. Each component was structurally analyzed and all components met conservative assessment calculations in the areas of stress, fatigue, and deflection. The cost to produce the prototype was $1114.43 in materials.
SoloQuad Kayak Conversion Project

Student Team:
**Engineers:** Jed Rivero, Jeromy Santos (Fall & Winter); Brian Smith & Frank Sanchez (Fall, Winter & Spring).
**Kinesiology:** Zachery Thurow & Erin Morrison

**Project Description and Impact**

The SoloQuad Conversion Project was an ongoing project that has been significantly enhanced through inclusion in the RAPD grant. The SoloQuad Conversion Project started in 2003 with the award of a “Quality of Life Grant” from the Christopher and Dana Reeve Foundation and was the first collaboration between Kinesiology and Engineering to focus on student design projects to facilitate participation in recreation.

The project goal is to give independent control over a kayak to someone with high-level quadriplegia. The project began by adding an electric motor to the kayak and seeking to gain control over the motor using a joystick to pilot the craft. After a promising start, initial progress was slow as students and faculty from both departments actively cultivated the relationship and generated numerous prototypes. With a promising initial prototype of a joystick control, more attention was focused on the need for special seating and increased stability.

A fundamental principle of adaptation for people with disabilities is to adapt for congruence, meaning the adaptation should blend in as far as possible with the original equipment. In deference to the principle of congruence initial efforts to increase stability focused on inflatable sponsons that closely contoured the hull, we also prototyped a removable keel weighted with lead bricks. Ultimately the increased visibility of two outriggers was deemed necessary to achieve the required stability, the existing design makes it practically impossible for the kayak to capsize.

Seating is a critical component of any adaptation for people with quadriplegia but the SoloQuad project also had to produce a seat that was lightweight and highly durable, given the harsh marine environment that it will inevitably have to endure. Student teams of mechanical engineers developed a total of five different prototype seats before the goal was accomplished.

This year’s team, supported during spring quarter through RAPD funding, engaged a group of four Computer Engineering students to redesign the control mechanism. The initial control solutions no longer worked so the new team had a great deal to accomplish. Working throughout the school year, the engineers successfully established the option of either joystick or “sip and puff” control over the kayak. On May 16th, 2008, the SoloQuad Conversion Project completed its maiden voyage. Pilot Bryan Gingg, a Cal Poly alumnus with high-level quadriplegia was able to navigate the waters of his hometown for the first time in 25 years. Bryan, pictured next to his wife Beverly, described the experience as breathtaking.

Throughout the year students collaborated with the Central Coast Assistive Technology center for advice and technical suggestions. CCATC also assisted with testing.
Technical Description & Cost

This structure was part of the original grant proposal and allows pilots with quadriplegia to independently pilot the kayak. Initial funding was low so RAPD funding was applied Spring Quarter. This RAPD project was to establish interchangeable controls of either a joystick or sip and puff control.

Engineering Requirements: The requirements given to the project team were as follows:

1. The system must be durable.
2. The system must be able to be used by people with various capabilities.
3. The system must be able to operate for long periods of time.
4. The system must be intuitive and designed with for an operator that is not technically inclined.
5. The system must be self inclusive and not require any external dependencies.
6. The system must minimally take away from the original kayaking experience.
7. The user must be able to have four directions of control (forwards, backwards, left, and right).
8. The user must be able to determine when the power supply is nearly empty.
9. The system must be safe for the user.

Although the launch was a success and the project worked, during the official launch one of the position sensors on the motor failed and the kayak had to be towed back. The failure of the control sensors was mechanical in nature as one of the sensors fell off and clearly needs to be secured in a more durable and reliable fashion. The SoloQuad conversion project will be extended through next academic year to provide mechatronic students the opportunity to make the control system more durable. Ultimately the SoloQuad Conversion Project will be utilized by the Cal Poly Adapted Paddling Program to provide opportunities to kayak for local community members with quadriplegia.

Cost: Total funds expended from RAPD grant $425.
The Universal Play Frame (UPF) Mk. V
Student Team:
Engineers: Tim Paulsen, Trevor Shepherd and Dan Levi
Kinesiology: Kellie Radosovich

Project Description and Impact
The Universal Play Frame (UPF) has been an ongoing project for four years with this frame being the fifth prototype (Mk. V). The UPF Mk. V is designed to be a fully adjustable, sturdy frame that can easily and quickly attach to any wheelchair. The UPF concept is that the basic frame will connect to a participant’s wheelchair and provide a foundation to which a variety of attachments could be fixed allowing users to participate in activities such as disc golf, bowling, tee-ball, soccer and golf.

Perhaps the most important design feature of the UPF Mk. V was its attempt to achieve universal wheelchair compatibility. Many of the latest motorized wheelchairs are taking on sleek designs that conceal the frame, this makes a universal attachment mechanism difficult to achieve. The UPF Mk. V uses a ratcheting ladder strap mechanism that can swivel to facilitate attachment to vertical or horizontal poles. While this appears to be a good strategy for most chairs, it is unlikely to be a truly “universal” attachment mechanism with so much diversity in new wheelchair designs.

To be compatible with as many wheelchairs as possible, the frame adjusts vertically and horizontally for different sized chairs. The speed and ease of adjustment is significantly greater with the Mk. V because of the circular tubing and quick release clamps, similar to those seen on bike seats. Quick release collars have the added advantage of being easy to replace in the event that they fail or are lost or damaged, a common problem with earlier prototypes. The Mk. V set out to achieve off-road capability through the use of more durable five-inch caster wheels that were sold as being compatible with hard gym floors, grass, and asphalt. The frame has six crossbar mounts for various attachments, making it compatible with the new Frisbee II and bowling devices, currently also under development at Cal Poly, it also allows flexibility in the design of future attachments.

The Mk. V frame has yet to be fully tested as construction fell behind schedule and the frame was not ready for testing. Four frames were constructed and are being completed by students taking independent study over summer 2008. Issues with the quick release clamps are currently being resolved, as the telescoping frame members tend to twist if the user makes quick turns. On the plus side, the Mk V. has no loose parts, required no tools for assembly, and has increased maneuverability on a range of surfaces.
Technical Description & Cost

Many aspects of past UPF designs needed improvement in this design (Mk. V). It is critical for practicality the UPF break down for storage, but to ensure that pieces are not lost or damaged it is important that the frame not break down into a large number of pieces. To accomplish the ease of storage without creating large numbers of removable components, past frames featured hinged folding supports that proved problematic, as they were unstable and prone to break.

Early prototypes adjusted by “click stop” buttons that quickly deteriorated and proved difficult to operate without pinching the operator’s fingers during adjustment. The chair attachment mechanism worked well with standard wheelchairs, but was limited in its use with newer power wheelchairs on which the frames are often covered by aesthetic paneling.

Initial tests show that the Mk. V has resolved the tendency of previous frames to lock up when changing directions. We are working to resolve the issue that quick turns now sometimes cause the telescoping round tubes to slip and twist.

The design and construction of the frame conform to the following parameters that were derived in order to ensure the frame had the potential at least to be attached to the maximal number of wheelchairs possible:

- Height range of 34 – 42 in.
- Lateral range of 18 – 24 in.
- Vertical cross-bar load of 100 lbs.
- Width range of 24 – 36 in.
- Max point load of 50 lbs.

Cost: Production of four prototypes to facilitate more extensive testing is $1,759.59. Approximate pricing per frame will be as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Total Length (in.)</th>
<th>Price</th>
<th>Cost</th>
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<tr>
<td>1.75” Diam 0.065” Wall Tubing</td>
<td>108</td>
<td>$5.00/ft</td>
<td>$45.00</td>
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<tr>
<td>1.625” Diam 0.065” Wall Tubing</td>
<td>134</td>
<td>$6.52/8ft</td>
<td>$78.89</td>
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<tr>
<td>0.25” x 1” Flat Bar</td>
<td>8</td>
<td>$6.46/ft</td>
<td>$4.31</td>
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<tr>
<td>Wheels</td>
<td>N/A</td>
<td>$28.95</td>
<td>$51.90</td>
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<tr>
<td>Clamp Skewers</td>
<td>N/A</td>
<td>$12.00</td>
<td>$168.00</td>
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<tr>
<td>Ladder Straps</td>
<td>N/A</td>
<td>$10.00/strap</td>
<td>$20.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>$368.10</td>
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</table>
Universal Play Frame Attachment: The Frisbee Launcher Mk. II

Student Team:
Engineers: Lauren Nelson, Lawrence Fong & Colin Corey
Kinesiology: Kellie Radosovich

Project Description and Impact
The Frisbee Mk. II is a specialty sports attachment designed for the Universal Play Frame (UPF), it represents a significant refinement of the first prototype (Mk. I). By attaching to the UPF, the Frisbee Launcher Mk. II is designed to allow people with partial quadriplegia to throw frisbees and play disc golf. The Mk. II affords the user greater control over the frisbee as it is launched and provides much higher levels of safety for both the user and their assistants.

The launch mechanism is powered by a spring attached to a rotating arm similar to commercially available skeet launchers. An assistant stretches the spring and loads a frisbee on the throwing arm. The distance the Frisbee launches is based on its placement on the rotating arm. A spring loaded pin attachment holds the arm in place until the user presses the trigger, which cannot be depressed until the safety cage is moved from the “load” position to the “launch” position. The user is able to change the flight trajectory of the frisbee by using hand wheels to adjust a screw mechanism controlling the pitch and roll angles, the hand wheels are designed to require less than five pounds of turning force. The direction in which a frisbee is launched can be controlled easily by the user by simply turning their wheelchair. The trigger mechanism is a large push lever that launches the Frisbee. These controls promote inclusion by giving the user a sufficient level of control to participate in a game of disc golf.

Safety was major concern with the Mk. I hence the Frisbee Launcher Mk. II includes a number of safety improvements. A ratcheting mechanism incorporated into the throwing arm prevents it from springing back as it is being loaded. The Mk. II includes a shatterproof polycarbonate shell that rotates between a “launch” position and a “load” position. With the shell in “load” position a ratchet mechanism is constantly engaged, preventing release of the Frisbee arm. A frisbee can only be launched from the Mk. II once the shell is put in “launch” mode at which point the protective shell prevents the frisbee from exiting in any direction other than that intended by the user.

The user controls and safety features of the Mk. II are major improvements over the previous prototype. Initial impact has been extremely positive; this device has been used with clients of the Central Coast Assistive Technology Center and participants in a local Special Olympics program. Greater impact will be realized once final modifications are made to the Mk. V Universal Play Frame.
Technical Description & Cost

The Frisbee II set out to improve upon the Frisbee I in the areas of safety, user controls and durability. Although there was success in all of these fields, the one with the greatest success was safety. The ratcheted Frisbee arm and nearly complete enclosure provide a level of safety for both the user and helper that was not attained by the Frisbee I. The durability of the system was also greatly improved by increasing component sizes although this unfortunately also increased the weight. User controls were significantly improved, the hand wheel and large trigger user interfaces made the Mk. II much easier to use, hence making it useable by a greater number of potential participants.

The manufacturing phase, which encompassed the second half of the project, included over two hundred hours of manufacturing and over eighty custom machined parts. Although the testing phase was cut short due to behind schedule manufacturing, it did show that the Mk. II met most specifications.

Several possible improvement areas were identified for future iterations. These areas include: weight reduction, flexible transmission shaft resizing, and pitch control pin resizing. Although there are numerous areas where small improvements could be made, our team feels that the fundamental design of the Frisbee II is one of the best possible. The power screw mechanism with slight modifications will work flawlessly. The safety features engineered into the shell provide more than sufficient protection for both the user and the helper. The launch mechanism as designed by the Frisbee I team works perfectly.

Cost: The original budget for this project was $500 although an extra $500 dollars was added to the project budget during the design phase as it was deemed necessary to maintain the necessary complexity of the system.

After finishing the final design and compiling a bill of materials, the total cost of raw materials for the frisbee Mk. II was projected to be $885 with an uncertainty of approximately 20 percent. Because this value was so much higher than the previous group, an in depth summary of costs was prepared to help identify what subsystems or types of components were inflating costs.

The projected cost was $885, the final total cost amounted to $952.
Universal Play Frame Attachment: Rock n’ Bowler

Student Team:
Engineers: Daniel Lyons, Matt Winter, & Lionel Young
Kinesiology: Kellie Radosovich

Project Description and Impact
The Rock n’ Bowler is a specialty sports attachment designed for the Universal Play Frame (UPF). The purpose of the Rock n’ Bowler is to allow people with partial quadriplegia to bowl, designed primarily for someone who uses a motorized wheelchair. This device is a “high-end” attachment for the Universal Play Frame, giving the user a great deal of control over the spin and placement of the ball. The Rock n’ Bowler is designed to give the user a feeling of inclusiveness when participating in the sport of bowling.

The typical adaptation for some unable to bowl through disability is a simple ramp down which the user rolls the ball. There are slightly more complex bowling adaptations that help the user increase the power of their bowl but the Rock n’ Bowler takes bowling adaptations a step further by giving the user control over spin on the ball.

Perhaps the most unique feature of the Rock n’ Bowler is the powered spinning rail system that can be used to add spin to the ball. As the ball rolls down the ramp, it comes in contact with two rails spinning in the same direction that “hook” the ball. An electric motor from a cordless power drill was used to drive the rails because it allows the user to easily control the speed and direction of the rails in order to change the “hook” on the ball. Either hand can be used to operate the controls. The user also has a spring assisted trigger mechanism that releases the ball, reducing the force required when the user chooses to release the ball. A safety mechanism prevents the ball from rolling down the ramp prematurely and a rail at the top prevents the ball from falling onto the user. Safety rails near the spinning rails also prevent the ball from jumping off the track.

The Rock n’ Bowler was designed to be practical and easy to transport. The base detaches from the main ramp and the two pieces fold together and interlock, making it compact and maneuverable similar to a dolly.

Although the impact of this device has not been fully tested, the degree of control afforded the user is far beyond any other device currently available. The Rock n’ Bowler should be ready for full testing by fall 2008, potential clients for this adaptation are extremely excited by the demonstrated potential of this device. The Rock n’ Bowler is unique and ingenious, controlling the many aspects requires skill and does not afford the user an inappropriate level of consistency, thus facilitating realistic recreational competition with non-disabled bowlers.
Technical Description & Cost

The table below contains the performance specifications for the bowling device. The design uses a ramp to give the ball speed. Hook is achieve by imparting a spin on the ball transverse to the main rolling direction. This transverse spin is obtained by having the roll roll along a rotating rail after it travels down the ramp and prior to entering the lane. The rotation of the rail is achieved through the use of battery powered electric motor. The control of the speed is set by the user.

<table>
<thead>
<tr>
<th>Spec. #</th>
<th>Parameter Description</th>
<th>Requirement or Target</th>
<th>Tolerance</th>
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<tbody>
<tr>
<td>1</td>
<td>Ball Velocity</td>
<td>15 ft/s</td>
<td>Min</td>
</tr>
<tr>
<td>2</td>
<td>Ball Hook</td>
<td>1.5 ft</td>
<td>Min</td>
</tr>
<tr>
<td>3</td>
<td>Frame Deflection</td>
<td>1 in</td>
<td>Max</td>
</tr>
<tr>
<td>4</td>
<td>Positioning Freedom</td>
<td>3.4 ft</td>
<td>Min</td>
</tr>
<tr>
<td>5</td>
<td>Approach Freedom</td>
<td>15 ft</td>
<td>Min</td>
</tr>
<tr>
<td>6</td>
<td>Range of motion Req’d for Operation</td>
<td>12 in</td>
<td>Max</td>
</tr>
</tbody>
</table>

The three main components of the Rock n’ Bowler are the upper and lower ramp assemblies, the base, and the powered spinning rail system. The upper and lower ramp assemblies are easily adjustable to change the height of the ramp (anywhere from 3 feet to 4 feet) and fasten with clamps. The height may be adjusted based wheelchair height, user preference, or desired speed of the ball.

The user has multiple levels of control over the direction and spin of the ball. First, the user can determine how to approach the lane, or can choose to launch the ball from a stationary position. The user can determine the angle that he launches the ball from relative to the lane. The user can decide on the height of the ramp which will affect speed of the ball, ranging from 12 ft/s to 13.8 ft/s. The direction of the spinning rails can also be controlled based on which way the user wants to “hook” the ball. Lastly, he or she can determine the speed of the spinning rails. All of these possibilities make the Rock n’ Bowler stimulating and challenging, giving the user ultimate control over the device and allowing him to become a skilled bowler.

**Cost:** The total cost to produce the prototype was **$865.33**