ADAPTABLE BOCCE BALL LAUNCHER

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ABSTRACT  
The New York Special Olympics (N.Y.S.O.) organization wanted to add bocce ball as a sport for their athletes to participate in, but many of the athletes were unable to produce the desired force required to roll a bocce ball 60 feet. A simple non intrusive assistive device was needed to enable more athletes to fully participate in the sport. This need led to the development of the adaptable bocce ball launcher that strategically rolls the balls down a ramp without taking the need for skill development out of the game. This device is essentially a portable ramp on top of a locking swivel base, resulting in providing a means for a greater range of NYSO athletes to participate.

INTRODUCTION  
Bocce is a precision sport closely related to ancient games dating back to the Roman Empire. Developed into its present form in Italy, it is played around Europe and has spread to other continents, including Australia, North America and South America. The game is also well-known in Croatia as bočanje, bućanje, or balote. [1]

Bocce was introduced at the Special Olympics World Games for the first time in 1995. During the 2003 Summer Games, 180 bocce athletes from 39 Special Olympics Programs competed. [2] As of the 2005 Special Olympics Athlete Participation Report, 90,884 Special Olympics athletes compete in bocce.

In Unified Sports bocce, a team would consist of two Special Olympics athletes and two partners. As in all Special Olympics sports, athletes are grouped in competition divisions according to ability level, age and gender.

The game’s objective is for one team to get as many of their balls closer to the pallina (the small target ball) than the opposing team's closest ball. The teams are given points for the balls rolled closest to the pallina. Each player is given two bocce balls and the pallina ball is thrown onto the field. Players then take turns rolling their balls toward the pallina. Balls, including the pallina, may also be displaced by the balls of other players in order to prevent them from scoring. [2]

Figure 1 depicts an example of possible ball placements at the end of a round.

(Figure 1)

There are several different types of court surfaces that the sport can be played on. Everything from a gym floor, outdoor park with no boundaries, all the way to regulation sized crushed stone dust.

Official courts consist of a level 3-5 inch top layer of crushed stone (pea gravel); middle layer of 3 inch crushed lime stone, insuring proper water drainage, and finally 1-3 inches of tennis clay or crushed oyster shells. The dimensions of the court can be seen in Figure 2, below.

(Figure 2)
The pallina must pass this point at the start of the frame. Ten feet from backboard equals inbounds for pallina at start of frame and foul line for pointing and shooting. [2]

In order to compete, athletes have to be able to throw out the pallina, and roll the bocce balls strategically anywhere onto a court. The barrier to participation was that many athletes lack the physical strength and/or mobility to toss or roll either of the two balls to desired distances.

The customer envisioned a product that would be adaptable for athletes with varying levels of ability and physical sizes, which would normally not be able to compete. This device would be usable on several different types of bocce courts. The ideal device would provide assistance without removing the elements of skill that come with selective ball placement games. Athletes still would be required to train for aiming and proper launch speed/force.

The object of the project was to design a safe device that would make the game of bocce accessible to a greater variety of athletes participating in the Special Olympics, as well as casual participants. Ideally this device would not slow down the play of the game, being easily transferred between players and transported to different courts with relative ease.

The end product would result in allowing athletes to benefit from the physical competition as well as their new ability to participate in a social sport.

**CUSTOMER NEEDS**

During the initial consultation with the director of the Genesee Region of Special Olympics New York, several needs were discussed of what, as a customer, they would need from a device and under what constraints the system would have to operate. The following is a list of the derived needs in descending order of importance.

Need 1: The device will assist N.Y.S.O. athletes in rolling both the pallina and bocce balls.
- Assist athletes in rolling the pallina
- Assist athletes in rolling the bocce balls
- Function within the official rules of Special Olympics bocce
- Very basic design, not too much involved in the mechanical design, no force assistive mechanisms

Need 2: The device will provide assistance to the athlete without removing strategic aspects of bocce from the competition.
- Retain the need for the athlete to aim
- Retain the need for the athlete to determine force or speed of throw or roll
- Require a level of control over velocity / ball speed and aiming of the device
- Free moving system no "muscle memory"

Need 3: The device will work for individuals with a wide range of different needs.
- Accommodate users of varying height
- Accommodate users with different wheelchairs
- Accommodate users with different levels of strength
- Accommodate users with different levels of mobility
- Accommodate both left- and right-handed users

Need 4: The device will work in a variety of the environments physical settings.
- Work with different bocce court surfaces
- Work indoors and outdoors

Need 5: The device will be easy to set up, use, and maintain.
- Minimal setup time
- Lightweight and covered for transportation and storage
- High transferability between several players during play
- Initial use will be inferred with little to no instruction
- Requires little maintenance

**CONSTRAINTS**

The customer requested that the delivered device be similar in functionality to the bowling ramp that the Special Olympics already uses nationwide. The main reason for this is that the bowling ramp has already gone through all the stages of approval by the governing body of Special Olympics and it was felt that a design similar in nature would have a greater chance of actually being used and accepted into the greater organization.

**ISSUES & RISKS**

- Outdoor court surfaces not available for testing due to time of year.
- Skill aspect of the game will be lost with over design
- Devices will be too complicated for athletes to use/learn.
- Not all of the Athletes’ disabilities will be covered with one set of devices
- Devices may not be accepted or used
- Device may not have reproducibility/repeatability

**SPECIFICATIONS**

Quantifiable metrics were developed from the customer’s needs and set with technical targets, which can be seen in the table below. These specifications would be the guidelines for the concept generation phase of the project, steering the brainstorming to focus on ways of accomplishing the technical values while operating under the customer’s constraints.

(Specifications Chart with Technical Targets)
In order to spark innovation, benchmarking was done to find previous solutions to similar problems or techniques that would help in the development of a final concept that would produce a device that would meet all the specifications.

The main benchmark discovered was the bowling ramp, referred to directly by our customer and an already a widely accepted assistive device within the Special Olympics. This device served as the base line for comparison throughout this project.

(Figure 3)

The bowling ramp, shown in figure 3 above, is a simple design consisting of hollow metal rods bent to a spline, using gravity to produce the required energy needed to allow a bowling ball to travel the full distance of a lane and still knock down pins.

Bowlers unable to throw a bowling ball may use a bowling ramp. This is a two-piece unit which assists wheelchair users and/or those with limited strength or mobility. A light push by the bowler pushes the ball down the ramp and onto the lanes. [5]

**CALCULATIONS**

The velocities of the pallina and bocce balls were required to travel the maximum length of court needed to be determined. The following equations (1), (2), and (3) were used to find the final velocity required to go 60 feet:

\[
\text{(1)} \\
\text{(2)} \\
\text{(3)}
\]

The height required to produce the needed velocity to go 60 feet was determined using equations (4) and (5):

\[
\text{(4)} \\
\text{(5)}
\]

The calculated height required fell under the NIOSH 95 percentile of the population’s upper reach limit from the base of an individual’s torso to the end of an extended arm.

Slipping of the balls as they traveled down the ramp was a concern. A ball will roll without slipping if the tangential force \( f_t \) is less than the force due to static friction \( f_s \). In order to calculate whether or not slippage would occur as the balls traveled down the ramp, equations (6), (7), (8), and (9) were used:

\[
\text{(6)} \\
\text{(7)} \\
\text{(8)}
\]
Solving for the tangential force shows that some slipping in theory may occur. The only way to mitigate this sliding motion is by utilizing a ramp profile with a maximum angle of 30°. Unfortunately this shallow an angle would not allow for sufficient momentum for the ball to go the required 60 feet. Therefore some amount of slippage would have to be tolerated.

Sometimes in the game of bocce a player must break up a group of balls. Equations (10) and (11) were used to determine if the bocce balls had enough velocity to disperse a tight cluster of balls.

The ballistics analyzed in our project consisted of three principles:

- Conservation of Energy
- Conservation of Angular Momentum
- Equations of Motion

These principles were used to determine the required velocity in order to make the ball travel 60 feet. They were also used to determine the required velocity needed to break up a cluster of balls 59 feet from the point at which the ball was launched. The minimum distance required for the balls in the cluster to move after the collision was 1 foot. Another key point in our analysis was to determine if the ball was going to be rolling down the ramp or slipping. This was a concern since if the balls were slipping down the ramp they were losing energy to frictional forces. Due to the environmental conditions during the time frame of the analysis the indoor surface of carpeting was selected.

**CONCEPT**

Several theoretical concepts were discussed but the final concept that the customer choose was a one piece, platform based, collapsible v channel ramp. This device is broken into several subsystems by functionality as follows: ramp, handles, braking system, supports, platform base, and protective cover. Sketches of which can be seen in the following to figures, 4 and 5.

The general operation of the ramp should be as follows:

1) The device would be removed from the transport vehicle and placed on the ground.
2) An individual would pick the device up using the rear handle engaging the wheels.
3) The device would be rolled to the desired position on the court, (the exact middle of the court’s width and the wheels lining up with the boundary line of the launching line).
4) The device would be lowered off the wheels and onto the feet and situated level.
5) The latches holding the cover would be opened and the cover set aside.
6) The holding straps and pins removed.
7) The ramp is lifted up by the aiming handles until the legs swing free and are placed in their associated locating holes.
8) The users would then be ready to play.

The use during play would consist of:

1) A user choosing which side to approach, left or right.
2) Aiming the device at any angle within the 30 degree arc.
3) Locking it in place using the brake lever.
4) Placing the ball on the ramp at a desire location and releasing it.
5) The brake may then be released from the locked position and the next roll may proceed.

The ramp design chosen was a straight v-channel section with a curvature at the end. Several different profiles were explored using simulation, this was found to be the optimum option based on manufacturing and velocity attained.

The user would determine the exit velocity, and consequently the rolling distance, by choosing the placement of the ball on the ramp. Releasing the ball at the very top of the ramp would give the ball the greatest amount of velocity and force to go the maximum distance or have the most power to strike other balls. The curvature at the end of the ramp allows for a minimal loss of energy upon the balls impact with the court surface. The V-channel allows for both the pallina and bocce to use the same ramp with only two contact points for each ball.
The best material for the ramp was determined to be that of a composite e-glass material. This is based mainly on the coefficient of friction and weight characteristics compared to wood or various metals. The low cost of the e-glass compared to carbon fiber led us to use this particular type of composite material.

The ramp would be supported when extended at two locations; the front pivot hinge and the back legs. The pivot hinge mounts permanently in place on the curvature of the ramp and the legs are mounted farther back on the straight section of the ramp to achieve the desired height for maximum force without slippage, while still being able to be reached by 95% of users. The ramp has two positions: collapsed for storage or transportation or extended for use in play. When collapsed the legs are pivoted underneath the ramp and the ramp rest on the base. When the ramp is inclined the legs naturally swing down into place and the user inserts them into their locating holes.

The pivot hinge and legs are mounted onto a platform made of polyvinyl chloride (PVC) that rest on top of a swivel. This piece allows the ramp to rotate 15 degrees in either direction until it hits a stop, enabling a user to aim at any position on the court from either side of the ramp.

The swivel is in-turn mounted onto the top of the base with a brake system. The base is the footprint of the ramps length and the width of the PVC platform. These dimensions will safely keep the users far enough away from the rotation of the swivel. A piece of Alumilite is mounted on top of a frame consisting of 1”x 1” extruded aluminum referred to as 80/20. This frame is supported and kept level on the court’s surface by 6 “feet” located on the four corners and middle of the base. These feet also allow for ease of transportation of the device by providing a gap between the base and the court surface and, with the extruded aluminum, provide a nice gripping surface for picking up the device.

The base also has two wheels located on the front at an angle which allows them to only be engaged when the user picks the ramp up from the back with a mounted center handle. These wheels allow the user to easily position or reposition the device in a desired location. While the ramp is ready for game play the wheels are disengaged and will not interfere with the path of the pallina or the bocce balls.

The handlebar system consists of an angled piece of steel plate, contoured to the underside of the ramp and held in place with structural adhesive. This plate has two aluminum rods welded to it creating easily gripped handles. These handles are covered with a grip to provide a safe interface with the user. The handles are the main points of contact for users aiming the ramp from either the left or right side, accommodating users that are either left or right handed. The height of the handles is conveniently located to allow comfort for users that may be seated. Each handle has a lever connected to the braking system.

The brake is what allows the user to lock the device in place during their turn. This prevents accidental movement of the ramps position when the athlete rolls the balls. Also if a volunteer is holding the brake in place until the athletes turn is finished, shifting the ramp after each turn, may prevent “memory” of aiming the ramp in the same location automatically. When a user squeezes the handle the brake is engaged against the swivel, locking it firmly in place. Once the user has finished their turn the brake lever is released and the swivel is free for movement.

The protective cover was designed to provide basic protection for the device while it is being transported or stored. The composition of the cover consists of the same 80/20 extruded aluminum as the base giving it an aesthetically pleasing look. When placed over the ramp and locked in place with latches the device is plain shaped and can be easily stacked.

**MANUFACTURING OF PROTOTYPE**

The manufacture of the prototype was broken into the functional systems in efforts to complete them in an efficient manner, as well as to allow their testing to be done independently of each other and then as a completed system.

The ramp system itself was determined to be the most critical subsystem since it provided the velocity of the ball going the length of the court and that the team had little to no experience with the method of manufacturing with composite materials. Predicted times and materials were a rough estimate, so in order to allow maximum time for build the ramp system was the primary concentration of the group.

Manufacturing the ramp required the build of a reusable mold. This mold was made of Styrofoam shaped to mirror the inverse of the profile of the finished product. The build of the mold took four weeks of shaping, sanding and sealing to give the correct coefficient of friction on the final surface of the ramp.

With the completion of the mold, the ramp itself only took a period of 16 hours to build; including drying time of the chemicals required. The ramp is made up of gel coat, 3 layers of e-glass running the entire length of the ramp, a quarter inch thick foam, 3 more layers of e-glass running the entire length, 3 layers of e-glass supporting just the handle and pivot pin locations, black paint and rubber trim.

The base up to the swivel being primarily made of extruded aluminum from 80/20 was very easily assembled in as little as a 2 hour period, once the parts were all available.

The swivel and brake system were made up of a mixture of custom machined and off the shelf parts, effectively providing the aiming with self return aspect of the device. The swivel holds the PVC platform of the legs and pivot hinge to the base through a series of bolts and spacers. This allows half of a bicycle brake to be pressed against it, engaged by the brake levers. The brake levers reside on the handle bars mounted to the ramp itself, with a cable on both the left and right side running down the length of the ramp crossing and connecting to the brake under the PVC platform.
MEETING OF SPECIFICATIONS

The concept developed was designed to meet the technical targets of the metrics derived from the customer needs. The following describes how each specification was met by the final design.

Accuracy & Precision
Experimentation was performed for determination of the ramp accuracy and precision feasibility. Stability of the device and the manner at which the ball exited the ramp must remain constant so that only the angle of aiming and position of ball release provide variation in the overall outcome. Releasing the same ball from the same position produces the same results.

Appearance
The overall aesthetics of the finished product compares positively to that of the bowling ramp currently used in the Special Olympics. Overall aesthetics the finished product appears to be professionally made.

Dimensions
The size of the device is restricted to its mode of transportation as well as the physical dimensions of the court. The device is easily transported in a standard passenger van and is within the physical restrictions of the player’s area of a bocce ball court.

Durability
The ramp itself is built of material design and supported to withstand the force of the ball dropping from a height of five feet from the ground. A layer with supportive material, such as a metal sheet may be incorporated along the length of the ramp portion later on as additive support.

Portability
Two wheels located on the front of the ramp and an angled handle located in the back allow for easy maneuvering. The six feet on the bottom raise the base up providing a nice one inch by one inch bar to grab on all sides. A clip-in-place cover provides protection during transportation and storage with a standard box shape.

Life Cycle
The overall life of the product will be limited by its weakest part, which appears to be the wear on the ramp profile with an estimated 200,000 lifecycles. Although with a provided reusable mold it is possible to extend the lifecycle of the device considerably.

Range
The ramp profile is set to give the best exit velocity which will, in turn, give the best range.

Safety
Ergonomic handles and recommendations for lifting were designed into the system, along with removal of all sharp edges. Safe handing maintenance and user’s operation instructions come with the completed device.

Sensitivity
The sensitivity needed within the device for a user to distinguish what an inch of movement either up or down the ramp for ball release would equate to in distance achieved needed be detectable. The design allowed for the angle of slope that would provide a user with a coarse adjustment to easily see how ball placement would affect the results.

Setup time
The device is a single piece product, no assembly required for activity. Taking the cover off and unfolding the ramp, is done easily within a minute after ramp is placed into the court.

Transfer time
The time allowed between rolls is limited by the damper switch setting, which is adjustable. More time will be spent actually rotating users than adjusting the ramp itself.

Velocity
The minimum required exit velocity needed to project a pallina and bocce balls 60 feet within the system was calculated and set as the ramps minimum distance achieved if released from the maximum position. A V-channel ramp was found to give the best reduction of elastic collisions while the ball travels down the profile.

Weight
The weight of the finished product has been estimated by adding the total weight of all parts in the design. A composite ramp was used to lower weight.

TESTING
A test plan was developed for the device as subsystems were completed and for the final assembly. The device would be fully functional if each engineering specifications was met through testing. Some test were setup for an in-depth analysis, where as others just required a check inspection.

Testing surfaces included an outdoor and an indoor test, both including the same plan. The testing on outdoor surface (crushed stone) consisted of transporting the final prototype to a local crushed stone bocce court and setting it up in the designated area for the athletes to roll the balls. Testing on the indoor surfaces consisted of setting the device up on similar carpeting that the NYSO currently uses for practice. In both locations the range, sensitivity, setup time, transfer time and velocity were all evaluated.

Portability of the device was tested by transporting it by a maximum of two people a hundred feet fully lifted, as well as only one person was needed when moving it around on the wheels. Also, the device was to be measured and compared to dimensions for fitting into an eight passenger van, for this was to be its standard mode of transportation.
Determining if the device was easy to use consisted of an ergonomic analysis. There is easy access around the ramp to be on either side, depending on the dominant hand of the athlete. The handles have rubber grips and are in a fairly comfortable position. Easy rotation of the ramp allows for smooth aiming for desired positioning.

RESULTS

The testing on the outdoor surface (crushed stone) did not result in the ramp providing enough velocity to travel the full 60 feet but instead only allowed for a distance of 45 feet.

The testing on the indoor surface resulted in the balls traveling the full distance needed of 60 feet or over with an actual velocity close to the predicted value of about 2 m/s. The following charts provide the collected data for the ramp as a subsystem and the final device.

(Ramp Subsystem Test Results Chart)

<table>
<thead>
<tr>
<th>Pallina</th>
<th>Bocce balls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop point (from the top of the ramp down)</td>
<td>Distance traveled</td>
</tr>
<tr>
<td>top</td>
<td>60'-2&quot;</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>58'</td>
</tr>
<tr>
<td>3&quot;</td>
<td>56'-6&quot;</td>
</tr>
<tr>
<td>4 1/2&quot;</td>
<td>53'-4&quot;</td>
</tr>
<tr>
<td>6&quot;</td>
<td>48'-8&quot;</td>
</tr>
<tr>
<td>7 1/2&quot;</td>
<td>44'-3&quot;</td>
</tr>
<tr>
<td>9&quot;</td>
<td>40'-4&quot;</td>
</tr>
<tr>
<td>10 1/2&quot;</td>
<td>35'-4&quot;</td>
</tr>
<tr>
<td>12&quot;</td>
<td>33'-7&quot;</td>
</tr>
<tr>
<td>13 1/2&quot;</td>
<td>30'-8&quot;</td>
</tr>
<tr>
<td>15&quot;</td>
<td>27'-10&quot;</td>
</tr>
</tbody>
</table>

(Final Test Results Compared To Engineering Specs Chart)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Importance</th>
<th>Unit of Measure</th>
<th>Technical targets</th>
<th>Spec. Met?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>Medium</td>
<td>&quot;Person lift&quot;</td>
<td>≤= 2</td>
<td>Yes</td>
</tr>
<tr>
<td>Dimensions</td>
<td>Medium</td>
<td>feet</td>
<td>&lt; 3 X 10 X 8; fit in a cargo van</td>
<td>Yes</td>
</tr>
<tr>
<td>Setup Time</td>
<td>Medium</td>
<td>mins</td>
<td>&lt; 3</td>
<td>Yes</td>
</tr>
<tr>
<td>Transfer Time</td>
<td>Medium</td>
<td>mins</td>
<td>&lt; 2</td>
<td>Yes</td>
</tr>
<tr>
<td>Portability</td>
<td>Medium</td>
<td>n/a</td>
<td>Fit in van, 1 person to wheel</td>
<td>Yes</td>
</tr>
<tr>
<td>Accuracy</td>
<td>High</td>
<td>rate</td>
<td>80%</td>
<td>Yes</td>
</tr>
<tr>
<td>Range</td>
<td>High</td>
<td>feet</td>
<td>&gt; 60</td>
<td>Yes</td>
</tr>
<tr>
<td>Safety</td>
<td>Medium</td>
<td>n/a</td>
<td>Safe as bowling ramp</td>
<td>Yes</td>
</tr>
</tbody>
</table>

CONCLUSION

The adaptable bocce ball launcher device that was built allows more Special Olympic athletes to participate in the sport of bocce. This in itself satisfied the main need of our customer. From the results provided it can be seen that the technical targets have been met. Several uses of the ramp to play a full game of bocce indoors have been done and the device makes for a complimenting addition to the sport.

Where the device fell short was in allowing play on any surface, as well as providing a self correcting damper system. The risks involved with these two aspects had been identified early on in the project and when they came to be, the preset alternatives were put into effect.

The customer did not want an impact device for producing velocity of the pallina and bocce balls, this coupled with NIOSH’s 95 percentile reach envelope restricting the possible heights of the ramp, made the velocity needed to send the balls the full sixty feet in a crushed stone court unattainable. [6] The unavailability of an actual court to test prevented having the exact coefficient of friction that would be present during play. This was discovered during testing and the issue addressed to the customer that maximum roll distance needed on this type of surface was not possible with this device. The customer agreed that continuation of the project and the particular device was still valid because it would allow athletes to participate in events where the surface was more appropriate.

A major critical subsystem was the damping brake with auto-correction; this was designed to satisfy a need identified later on in the project, for the device to return to a neutral position after each turn, in efforts to counter the possibility of an athlete rolling a ball twice from the same exact position without having to line up the shot. The damper system was planned out and worked as a separate subsystem, but when added to the device itself the appropriate amount of force that need to be applied was not able to be reached. This being so, the plan to have a locking brake that required a release was put
into place and proven. With this need not being met there will be more need for involvement of the volunteers to ensure that proper use between turns is followed.

Manufacturing

The prototype was developed to prove systems and to provide one working device for the user, methods used were not the best available for producing duplicates in number of thousands. If more devices are to be made different methods of manufacturing should be applied, such as cast and injection molding.

With future production in mind most of the parts used were off the shelf items that may be purchased at various locations. The brackets that were machined may be easily reproduced by using a cast or CNC machinery.

The ramps profile itself may already be easily reproduced in maximum period of 8 hours with the materials and method used for the prototype since the mold was created to be reusable. An alternative method would be an injection molding approach to cut time down as long as the material type is comparable to the fiber glass used.

RECOMMENDATIONS

This device being the first of its kind was built to meet the engineering specs based on the customer’s needs. The device that has been built meets the requirements but may be improved upon to exceed its current performance and features. Some recommendations for improvement include: discrete positioning, ramp extension, solenoid for damper and an impact device.

In order to incorporate more of the Special Olympics’ athlete population, particular those with more severe disabilities, setting up discrete positions along the length of the ramp for holding the balls would allow athletes to coordinate with a volunteer to place the balls where the want the along the profile of the ramp, and then be able to release the balls themselves using a cord and pin attachment. The current prototype may be modified to accommodate this.

To resolve the issue of playing on a crushed stone surface, one possible solution may be to make an extension ramp profile that would mount onto the existing prototype. This piece move would be removable to allow the current dimensions to remain the same. A downfall with this extension is that those athletes in wheelchairs would not be able to reach unassisted to the top of the profile.

The damper system did not react as well as initially thought when it was installed into the system. Instead of using a mechanical system an electrical solenoid setup would be easily implemented if the customer would allow it. This would provide a precise amount of time between turns satisfying the customer’s want of auto-correction.

The allowing of an impact device would have definitely change the complete design of the device and allowed for enough force to project the balls the distance needed for the various court surfaces. Going away from an impact device greatly restricted the project and eventually limited the resulting prototypes functionality.

The overall cost associated with the build of the prototype was $1423.98. This cost may be greatly reduced if the product is to be mass manufactured using the recommended techniques.

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REFERENCES