“G-Potential”
Business Plan

Submitted by

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1 Executive Summary

Those of us who drive cars usually prefer to have all four wheels on the ground, but there are those individuals who derive great joy and excitement from performing vertical leaps in the air. Currently there are over 20 million skateboarders flying over trash cans, ramps, and half-pipes every day in the United States. We propose a new device, the “G-Potential,” that will give these skateboarders a way to measure the height and time duration of their jumps. Over the last five weeks, we have developed a working prototype of the G-Potential with complete functionality. We conducted surveys and assessed our competitors, determining the G-Potential to be of high interest and value. The G-Potential measures flight time by monitoring gravitational loading of the skateboard, and outputs time of flight, height in feet and seconds, and best height over many successive jumps. There are no significant legal or failure issues to consider. The G-Potential can be manufactured at a standard cost of $16, and if sold at a retail price of $50, offers a return on investment of 27%. With an interested and growing consumer market and no present competitors, the G-Potential is a product that may easily soar to great heights in manufacture and sale.
1. Introduction

1.1 Problem Statement

In the beginning of this project, we were presented with the following problem statement:

“Design and construct a platform that allows calculating the height that a person jumps. In operation, a person will stand on the platform. Then the person will jump vertically. Your device must calculate the vertical distance jumped and present the results in either feet or meters. The platform must be able to sell for less than $50.”

1.2 Planned Approach

The problem statement above requires that we design a device that measures the vertical height of a person’s jump. The statement specifies certain jump criteria:

- the jump must be on a platform
- a person must perform the jump
- the jump height must be accessible in both feet and meters

All of these criteria limit the possible approaches to the problem at hand. While our approach addresses the basic problem of measuring a jump, our solution does not adhere closely to the above criteria. We feel that the above criteria reflect a limited view of the potential of a jump meter; in solving the general problem at hand, we do not want to put any initial constraints on implementation.

Before considering ways to measure a jump, we thought about who would benefit most from such a product. Our market research, which will be explained in section 3 of this report, revealed that there is great interest among skateboarders for a device to measure the height and time duration of skateboard jumps. We see this market as having enormous potential, and for this reason, our planned solution to the jump problem targets the particular needs of skateboarders. Our initial plan was to design a device that would mount non-obtrusively on a skateboard so that a skateboarder could measure both the height and time of jump. Pursuing this plan means that our design does not involve building a platform for the jump, although we are still implementing the design on a platform (the skateboard). Also, from our market research we discovered that while there is interest in conversion between feet and inches, there is little interest in feet / meters conversion, so we altered that criteria accordingly. While our planned approach does not adhere exactly to the problem statement, it does adhere to the specific concerns and problems related to a skateboard jump. When consulted, our manager agreed that our changes to the initial problem statement are reasonable given our planned approach.
2 Product Specification Generation

2.1 Market Research

We propose to design a device to measure the hang time and the height of jump for skateboard jumping. Skateboarding is rapidly becoming one of the most popular activities in the world. Currently, skateboarding is the sixth largest participant sport in the U.S., and the third largest among people age six to eighteen (skatepark.org). As skateboarding has gained popularity, its recognition as a sport has increased, and it has migrated from sidewalks and parking lots to advanced skate parks and competitions. Trick and competition skateboarding has exploded in the past few years, and technology has not kept up with the amazing abilities of these athletes on new ramps and skate pools.

There are over 20 million skateboarders in the United States today, most of whom are teenage boys, who are primary consumers of inexpensive, interest-oriented, enhancement technology (skateboarding.com). These skateboarders represent a huge potential market for skateboard accessories. Currently, people spend 500 million dollars on skateboards and 750 million dollars on skateboard accessories each year (skatepark.org). These accessories include protective gear and enhancement equipment; however, there is little to no equipment available to skateboarders to measure their own accomplishments.

Over 60,000 skateboarders frequent skate parks each day (skateboarding.com). At these parks they can perform impressive jumps, but there is no accurate way to measure the height or time duration of these jumps. Current technology uses time-lapse photography and tape measures to measure these jumps at competitions, but this is not the most precise solution. Additionally, there is great interest among the larger skateboarding population in a simple and accurate way to measure their own jumps, in practice or at competition.

To determine the customer requirements for a skateboard jump height indicator, we surveyed 34 skateboarders across the United States. We spoke to skate shop employees, who are particularly knowledgeable about the specific possibilities and constraints of skateboards. We spoke to competition and recreational skateboarders. Our survey findings represent a cross-section of primarily bicoastal, male, teenage skateboarders, who represent the majority of skateboarders in the United States today.

75% of the people surveyed expressed interest in a product that measures height and hang time of skateboard jumps. All surveyed indicated that they would want to know both the height of jump and the time duration of jump. In general, skateboarders who skate primarily in skate parks expressed the most interest in the product; they are performing high-skill tricks in a controlled environment on a regular basis. Skateboarders who skate mostly in urban settings, focusing on tricks like sliding down rails or grinding their skateboards, expressed less interest in the apparatus. Their preferred tricks are more destructive to the skateboard, and many expressed concern that such a device would break. However, many of these skateboarders became more interested when we explained that such a device may be removable.
Customers put primary focus on portability; all surveyed desire a removable device. Skateboarders frequently, grind, slam, and slide their boards, all of which puts great stress on the entire board. For these kind of activities, a device mounted almost anywhere on the board is in danger of destruction. However, when skateboarders are jumping their boards, or skating at skate parks, such a device could be used without fear of damage. Therefore, all expressed the need for the device to be removable. A removable device would allow skateboarders to continue to skate in different environments and at differing levels of stress, mounting the device when they see fit. While a skateboarder who only focuses on jumps, or uses one particular skateboard only for jumps may find use for a permanent device, our findings suggest that such skateboarders are in the minority. Most skateboarders want a device that they can mount on their board for jump practice or competition, but not for general urban use.

The customer requirement of a removable device leads to implied requirements of simplicity, durability, and size. If skateboarders plan to mount and remove the device frequently, it must be easy to remove. It must be small enough to fit in skateboarders’ pockets or backpacks so that they can carry it with them while the device is not in use. Additionally, this requirement suggests that the device must, when mounted, be very durable and stable. Skateboarders require a removable device because some of their tricks put stress on the board that might damage the device. However, all skateboarding tricks, including jumps, put stress on most parts of the board. Therefore, when the device is mounted to the board, it must be able to sustain some high level of stress, and it must stay firmly in place so that it will not suffer damage.

The second important customer concern was for the size and placement of the device. As stated above, skateboarders stress the entire board in use. For this reason, it is essential to carefully choose the device location so as to minimize stress and potential damage. According to our survey findings, the only viable location for the device is under the board, directly under or behind the front and or back wheels. These spaces are protected by the wheel axles from direct contact with the ground or other skateboarding surface, even during jumps and stressful tricks. However, the device must be less than two inches by one inch by one inch in size in order to fit in this space. Additionally, within this space the device must be highly insulated, since it will still suffer stress in skateboard use.

Size and placement of the display is also a major customer concern. All customers surveyed want a small, watch-size display. 69% want the display to appear on the skateboard, though 31% would prefer a display on a removable wrist strap. The strap option would require a transmission line in a leash to the device mounted on the skateboard, or a transmitter / receiver system setup. The leash option is potentially dangerous to the skateboarders’ safety; if a wrist strap were installed, it would have to use a transmitter / receiver system so that it would not impede the motion of the skateboarder. Skateboarders prefer the display to be on the skateboard because that allows them to have their arms free while performing tricks. Additionally, keeping the sensor device and display together on the board allows the entire apparatus to be smaller, which is desirable.
Keeping the display on the board has bearing on another customer requirement: low cost. Customers surveyed indicated that they would pay twenty to forty dollars for a hang time – height jump meter. The mean cost acceptable is $31.89, and the mode cost range is $30 - $40. A transmitter / receiver system may increase the total production cost of the device so that such a cost requirement would be impossible to meet.

With regards to the display features, customers want a display that shows time duration of jump, height of jump in feet and or inches, and possibly some storage of best jumps. The time duration requirement implies that the device must be capable of measuring the time of jump accurately in seconds. No customers indicated any interest in height of jump in meters or centimeters; the device should, however, be able to transfer between feet and inches. The average skateboard jump is between one and twelve feet; for this reason, it is acceptable to compute height accuracy to half an inch, which corresponds to 5% error for the smallest jumps. In regards to memory storage, 62.5% of those surveyed expressed interest in a best jump storage feature. This feature may be necessary to easily retain the best jumps after multiple jumps have been attempted, so that the skateboarder could check the display after a series of jumps. This requirement implies a need for data storage, comparison, and retrieval capabilities.

Finally, with regards to device operation, 75% of skateboarders prefer automatic streaming jump detection to on / off switching. This division probably corresponds to the diversity of skateboarders; street skateboarders may want to turn the devices on and off when they are specifically focusing on jumps, whereas ramp skaters need streaming detection, and best jump storage, so that they can jump multiple times without stopping to toggle a switch. As ramp and skate park skateboarding gain popularity, the desire for streaming jump detection may increase; therefore, this may become an important feature for markets in the future.

### 2.2 Customer Requirements

The results of the customer surveys yield the following product requirements:

- The G-Potential should be portable and removable
- The G-Potential should have a street cost of $30 - $40
- The G-Potential should be small enough to fit underneath the wheel axles
- The G-Potential should be easy to mount and remove
- The G-Potential should be able to withstand shock and stress
  - The G-Potential should have a durable, strong casing
- The G-Potential should have a watch-size LCD display mounted on the top of the board
- The display should show jump time in seconds
- The display should show jump height in feet or inches
- The G-Potential should be accurate to 0.5 inch
- The G-Potential should have streaming jump detection
- The G-Potential should store the best jump for retrieval
The G-Potential should have user interface that allows the user to choose
- Turn the G-Potential on or off
- Best jump retrieval of duration of time G-Potential is on
- Jump time or height display
- Inch or feet display

2.3 Initial Product Specifications

After establishing the customer requirements for the G-Potential, we used these requirements to create a set of product specifications.

Originally, we planned to case the G-Potential in a wooden box 2 inches long by 1 inch wide by 0.75 inch deep. The casing would have a rubber insulating strip to protect from rain and other environmental factors. This casing would hold a 5V microprocessor which will calculate jump time, jump height, do mathematical conversions, and perform memory functions. The casing would also include the sensor which indicates the beginning and end of jump. The casing would hold two AAA batteries to power the G-Potential. The casing would also hold circuitry required to interface the power, sensor, microprocessor, and the LCD. A wire would leave the casing to connect to the LCD mounted on the top of the board.

Originally, we decided to power the G-Potential with two AAA batteries that would perform the following functions:
1. They will provide 1.5 V and 0.5 mA each to power the G-Potential. This corresponds to 3 mW of power.
2. The batteries will power the sensor, the microprocessor, the LCD, and all circuitry.
3. They will respond appropriately to the on / off switch.

The sensor will perform the following functions:
1. It will record the time that the jump begins and ends by measuring force or vibration differentials.
2. It will send a signal to the microprocessor at these times to begin and end a clock function.
3. The sensor will perform these functions continuously as long as the G-Potential is on.

The 5V microprocessor will perform the following functions:
1. It will receive signals from the sensor indicating when to start and stop a timer.
2. It will measure the total jump time.
3. It will transform this jump time into a height in feet using the following expression: \[ H = \frac{1}{2} g t^2 \]
4. It will be able to transform this height in feet to inches using the expression \[ I = \frac{F}{12} \]
5. It will be able to store one jump, against which it will compare the time length of each new jump, retaining the longest jump as the “best jump”.
6. The microprocessor will do these functions continuously as long as the sensor is sending information to it.

The circuitry in the casing will perform the following functions:
1. It will connect the batteries to the microprocessor and sensor.
2. It will use op-amps or transformers to provide required power to each component.
3. It will connect the microprocessor to the sensor.
4. It will insulate the microprocessor with filtering capacitors and diodes.
5. It will connect the microprocessor to the user interface buttons and LCD display.

The buttons on the top of the board will perform the following functions:
1. They will allow the user to switch the G-Potential on and off.
2. They will allow the user to retrieve best jump.
3. They will allow the user to toggle between jump time and jump height.
4. They will allow the user to toggle between jump height in feet and jump height in inches.
5. They will interface with the microprocessor to send requested information to LCD display.

The LCD display on the top of the board will do the following:
1. It will display the jump time or height of the jump.
2. It will interface with the microprocessor to show requested information.

We will attempt to manufacture the G-Potential for $30 - $40.

2.4 Final Product Specifications

While our final product specifications still meet all of the original product requirements, some of our specifications changed during the design process. We decided that the prototype need not be fully mounted on the board as long as we could show that it could be mounted on the skateboard successfully. The only part of the design that must be mounted on the skateboard is the sensor circuit that measures jumps. Therefore, we attached this part of the G-Potential to the skateboard while leaving the rest of the prototype on a breadboard.

Section 3 of this report will explain our design in detail; however, here we will quickly address the general parts used in the final product design. We changed our power source to two 9V batteries, necessary as positive and negative rails for the amplification circuitry. Our sensor circuit is a wheatstone bridge configuration of strain gages, which measure loading on the skateboard. This bridge is powered by positive and negative 5V
coming from the batteries through +5V and -5V regulators. The output of the bridge is an analog voltage signal of 117 to 123 mV, which changes with respect to whether a person is loading the skateboard or not. This output is then amplified and shifted by an instrumentation amplifier. The amplifier circuit output is 0 to 5V. This analog signal is then sent to a comparator, which changes it into a digital signal. The digital signal drives the PIC to start and stop jump measurement.

To determine the height reached in flight, we originally used the equation $H = \frac{1}{2} g * t^2$. We found this equation to be incorrect for our purposes. Since we were only interested in the time that it reaches its maximum height which would correspond to half the time he is in the air, we determined the correct equation for height to be $H = \frac{1}{2} \left( \frac{t}{2} \right)^2$, where only half the time is of importance.

Also, to protect our circuitry from noise interference, we added 0.1 micro Farad capacitors across all power supplies (-9v-0v, 9v-0v,5v-0v) to block AC and therefore prevent oscillation.

Our final product specifications are as follows:

Two 9 V batteries power the G-Potential. They perform the following functions:
1. They provide 9 V each to power the G-Potential.
2. They power the strain gages, the amplification circuit, the microprocessor, the LCD, and all circuitry.
3. They respond appropriately to the on / off switch.

The strain gage wheatstone bridge performs the following functions:
4. It records the time that the jump begins and ends by measuring force differentials.
5. It sends a signal to the amplification circuit to the microprocessor at these times to begin and end a clock function.
6. It performs these functions continuously as long as the G-Potential is on.

The amplification circuit performs the following functions:
1. It amplifies the wheatstone bridge output signal into a signal that goes from 0 to 5 V.
2. It uses a comparator to change the 0 to 5 V analog signal into a 0 to 5 V digital signal to send to the PIC.

The 5V microprocessor performs the following functions:
7. It receives signals from the comparator indicating when to start and stop a timer.
8. It measures the total jump time in seconds.
9. It transforms this jump time into a height in feet using the following expression: $H = \frac{1}{2} g * \left( \frac{t}{2} \right)^2$.
10. It transforms this height in feet to inches using the expression $I = F/12$ plus a remainder function.
11. It stores one jump, against which it will compare the time length of each new jump, retaining the longest jump as the “best jump”.
12. The microprocessor performs these functions continuously as long as the wheatstone bridge is sending information to it.

The circuitry in the casing performs the following functions:
   6. It connects the batteries to the microprocessor and wheatstone bridge via 5.1 V voltage regulators.
   7. It insulates the power sources and microprocessor with filtering capacitors and diodes.
   8. It connects the microprocessor to the user interface buttons and LED display.

The buttons on the top of the board perform the following functions:
   6. They allow the user to switch the G-Potential on and off.
   7. They allow the user to retrieve best jump.
   8. They allow the user to toggle between jump time and jump height.
   9. They allow the user to toggle between jump height in feet and jump height in inches.
   10. They interface with the microprocessor to send requested information to LED display.

The LED display on the top of the board performs the following functions:
   3. It displays the jump time or height of the jump.
   4. It interfaces with the microprocessor to show requested information.

We will manufacture the G-Potential for $40 to $50 street cost. Please see cost analysis in section 3 for further details.
3 Product Plan

3.1 Timeline

We completed our project within the six weeks available for market research, design, testing, and presentation. Because we had little time to accomplish all goals, we had to follow a very strict itemized schedule. Our team schedule assigned different tasks to each teammate; however, we continually worked together to solve different challenges that came up throughout the design and implementation phases.

![Figure 4.1. Final Schedule.](image)

3.2 Budget
4 Design Approach

4.1 Design Options

After outlining our product specifications, we turn to analyzing possible methods of implementation. Our product specifications involve the following problems:

- design of a device that will measure the height and time duration of a skateboard jump
- design of such a device that is small, removable, and able to sustain shock

We decided that the best way to measure the height and time duration of a skateboard jump would be to design a device that in some way indicates the beginning and end of a jump by sensing when the skateboard leaves and recontacts the ground. The sensor will set off a timer that will measure the time duration of the jump; the microprocessor will use simple physical laws \( h = \frac{1}{2} g t^2 \) to translate this time into jump height. Using these laws is a reasonable way to record height accurately because the force of gravity on the board in the air is far greater than any extraneous forces (friction, air resistance, etc.).

This design plan was chosen for its simplicity and flexibility of implementation. Using a sensor to measure the time of the jump means that the sensor need only recognize the commencement and end of jump; it need not record any information about the jump itself. The only sensor requirements are that the sensor accurately indicates the start and stop of jump and communicate that information to the microprocessor. Therefore, the sensor can be simplistic in design, which allows us flexibility in choosing the type of sensor that most satisfies our criteria of small size, durability, and low cost.

4.1.1 Sensor Options

There are many options for types of sensors that will perform the necessary functions. These sensors fall into three main categories: sensors that measure force on the skateboard, sensors that measure friction and velocity of the skateboard wheels, and sensors that measure distance to the ground using optics or sound. Our criteria for evaluating specific options in each area are: cost, size, availability, utility, durability, and ease of use.

Force sensors include sensors that measure vibration, force of weight, pressure, and strain on the skateboard. Vibration sensors, such as accelerometers, could be placed underneath the board to measure the vertical acceleration of the skateboard. When the skateboard reaches some calibrated cut-off acceleration, the accelerometer reading at that level would send a “start jump” to the microprocessor. Similarly, when the skateboard jump ends, the accelerometer would measure a large acceleration in the negative direction. The same cutoff acceleration value could be applied (in the negative direction) as the “stop jump” level to send to the microprocessor.
We were able to find accelerometers fairly cheaply (approx. $13 per unit for 1000). These accelerometers are very small, and very rugged. In these ways the accelerometer option satisfies our requirements with regard to size, weight, and durability. However, using an accelerometer may result in inaccuracies in measurement due to the orientation of the skateboard during a jump. If the skateboard flips, the accelerometer may register accelerations during flight beyond the cutoff acceleration, thus falsely signaling the end of the jump. This can only happen if the skateboard turns over very rapidly in the air; such motion is not standard in normal skateboard jumping. However, the accelerometer also may send false signals due to the orientation of the board. In this application, the accelerometer’s readings are only important on a vertical axis normal to the ground. This axis may not be normal to the skateboard as well. If the skateboard jumps from an angle (as on ramps or in skate pools), a single accelerometer would not accurately measure the start and stop of jump. There are two possible solutions to this problem. One is to mount two accelerometers on the board, one normal to the plane of the board, and one normal to the truck of the front wheels, to allow for both flat ground and ramp skating. This may be too expensive an option to pursue. Another option is to hang the accelerometer from the truck so that it will always be normal to the earth. However, this will significantly decrease the force on the accelerometer, which may lead to less accuracy in measurement of jump start and stop.

The other viable option in force sensors is use of a strain gage. The strain gage determines the displacement of a compression or tension force on a piece of metal, i.e. the truck of the skateboard. Strain gages are available very cheaply ($3 per unit for 1000), small and flat, and have fairly high durability. When the compression of the truck reaches some cutoff force, the strain gages would send “jump start” signals to the microprocessors. When the skateboarder lands, a high force will again be applied and a “jump stop” signal will be sent to the microprocessor. Because they are cheap, we can mount one on the front wheel truck and one the back wheel truck. This increases the accuracy of the sensor by only measuring jumps in which both the front and back wheels leave the ground. The only problem with the strain gage option is that the strain gauges themselves must be epoxied onto the truck. The strain gages would not be removable; however, their impact on the skateboard is minimal.

Sensors that measure friction and velocity rely on some contact with the ground. Whether the sensor is measuring the friction of the wheels, the induced voltage on the wheels, or their velocity, some component of the device must be in contact with either the wheels or the ground. Many of the options in this area are very cheap and simple to implement; however, these would sustain the most shock and may impede skateboard usage. One option in this field is to drag a lug on the ground behind the wheels and measure the drop in voltage when the lug loses contact with the ground. Alternatively, a wire may be draped around a wheel to measure induced voltage or frictional force on the wheel. All of these options have the same problem; they rely too heavily on hardware that will hamper the skateboard’s general use. While physically sensing the skateboard’s flight may be cheap initially, the components used to do so are subject to extreme stress during use. Components would be high-maintenance as well as cumbersome to the skateboarder.
The third area of sensors is sensors that use reflective optical or sound methods to measure the jump start and stop time. These sensors are calibrated to send and receive a signal at a specific distance; if they do not receive the signal sent, then the distance is identified as out of range. These sensors may use optics, lasers, sonar, or microphones to send and receive signals. The laser, sonar, and microphone options are not viable for this project. The laser sensors available for the range and accuracy required are too large and far too expensive ($2000 - $5000) for the project. Sonar is only useful for effective displacements of at least one meter. Microphones are not a viable option because there is too great a variability of skateboarding surfaces and environments to effectively calibrate the “average” dB sound on the skateboard.

Reflective optical sensors that measure accurately within 2 mm are available cheaply ($6.32 per unit for 1000). These sensors measure reflective light at a maximum of 18 mm (~3/4 inch), with 2 mm deviation. This type of sensor would solve our problem by consistently measuring the distance from the bottom of the board to the ground. When the sensor, and the skateboard, move out of the sensor range, the sensor would send a “jump start” signal to the microprocessor. When the sensor and skateboard return to the ground, the sensor will once again reflect light and the “jump stop” signal will be sent. In this way, the optical sensor can be used regardless of skate environment (flat, ramp, skate pool) to accurately measure the beginning and end of the jump. However, for optical sensors at reasonable cost, the effective reflection distance is about ½ to ¾ inch. The bottom of the skateboard is about 3 inches from the ground, and the lowest point on the truck is still 1 inch from the ground. This means that using an optical sensor would require some way to mount the sensor very close to the ground, which may be dangerous in regard to durability and maintenance issues, as well as security of mounting. Also, the optical sensor can only be used for 10 to 90% light reflectivity, which would limit the skate environments and times of day available to the skateboarder.

4.1.2 Recommendations for Device Sensor

After considering all of the options for sensors that will measure the beginning and end of a skateboard jump without impeding motion, the best option is to use two strain gages mounted on the trucks of the skateboard. These strain gages are cheap, small, and highly accurate. While using strain gages means that the G-Potential will not be entirely removable, the strain gauges will take up very little space on the skateboard, and will not impede skateboard use.

If possible, combining the strain gages with an accelerometer would insure that the G-Potential measures actual skateboard jumps. The accelerometer constantly monitors whether or not there is a person on the board, so that if a person falls off the board or jumps off of the board, the strain gage does not prompt the “jump start” signal. If adding an accelerometer proves to be too expensive, it is possible to approximate this solution with a timeout feature on the interface between the strain gauges and microprocessor. If the strain gage measures no strain for some specified excessive amount of time, the
microprocessor would recognize that the skateboard was no longer in use and would not record the strain change as indicative of a jump.

4.2 Value Analysis

Appendix A displays the Value Analysis Spreadsheet used to determine competitive analysis in this section.

4.2.1 Value Criteria

We chose our criteria for our value analysis based on customer requirements of the skateboard jump height / time meter. Our quality criteria involve issues of utility, accuracy, user-interface, and durability. The most important quality criteria follow our customer requirements of a device that measures height and time without impeding skateboard use. Specifically, these essential criteria are strength of mounting, ability to display height and time duration of jump, and reliability. The least important quality criteria are materials (though these have bearing on strength and reliability) and power consumption.

The convenience criteria we chose involve issues of environment, size and placement, and ease of operation of the G-Potential. Specifically, the most important convenience criteria are that the G-Potential be removable, of small size, lightweight, and requires no external operator for use. The least important criteria are the speed of results and the necessity of technical knowledge for use.

The cost criteria we chose include initial price to customer, maintenance, and design costs. It is most important to keep the G-Potential low maintenance and fairly low cost. It is also important that the G-Potential not require the services of an external operator.

4.2.2 Our Competitors

We identified both present and potential competitors for this value analysis. There are no present competitors for a removable product specifically designed to measure the height and time duration of a small vehicle jump. However, there are present competitors in the jump displacement and or time duration industry. Currently, time-lapse photography systems are used to measure the height of jumps at skateboarding competitions. Also, laser optical flight displacement sensors are available which measure both displacement and time duration of flight. Potential competitors include stopwatch companies, who could easily adapt their timing technology to make height sensors that are small, durable, and cheap. Our final competitor manufactures an alternative training tool for skateboarders to work on their jumps. While this product does not measure height or time of jump, it competes for our market of skateboarders interested in performance-oriented technology.
Presently, time-lapse photography dominates the competition skateboarding jump height recording market. Time-lapse photography uses a video camera that records still frames and sends these frames to a computer, which can display the frames individually for analysis. Time-lapse photography provides very high quality documentation of jumps. While the actual height measurement may be somewhat imprecise, the photography offers extensive information about the motion of the jump itself. Time-lapse photography uses high quality materials, has high memory capabilities, is very reliable, and can be used in a wide variety of environments.

Despite its excellent quality, time-lapse photography is highly inconvenient and costly as a viable option for skateboarders to measure and document their jumps. The equipment required for time-lapse photography is both unwieldy and extremely expensive (upwards of $5000). This equipment is too delicate to sustain the shocks suffered by a skateboard; also, there is no way to make the equipment effectively small enough to be portable, let alone mountable on the skateboard. Time-lapse photography is limited to environments where a skateboarder is jumping in one area successively, and is not suitable for the average skateboarder moving through a city or skate park. Furthermore, time-lapse photography requires an external operator with technical knowledge of the camera and support equipment. In this way, time-lapse photography is not convenient for the average teenage skateboarders, who do not have extensive knowledge about photography.

In summary, time-lapse photography is an excellent method for jump documentation at skateboarding competitions. However, it is very expensive and highly inconvenient for the average skateboarder, and does not satisfy his primary requirements of small size, durability, and low cost. This is reflected in time-lapse photography’s low total value in our analysis (see attached).

Our other present competitor for displacement measurement are optical laser sensors. These sensors provide highly accurate documentation of jumps. They have an average range of 0 to 50 ft, and precision to 0.1 inch. In some systems, variable signal strength is recorded as a gray scale graph. They have a very fast response time and can operate in a wide range of environments. The laser sensors mount tightly, with 6-32 screws, and interface easily with microprocessor equipments. The sensors offer multiple user interface and calibration capabilities.

Despite the high quality of the laser displacement sensors, they too are highly inconvenient and costly for the problem at hand. These sensors cost about $2500 on average, which is far outside the viable price range for our demographic. While the sensors mount strongly, they are too long (9 inches minimum) to mount to the bottom of a skateboard without impeding skateboard motion. Also, the laser sensors are fairly heavy (22 oz. average), which impedes normal skateboard use, as well as making jumps more difficult. The laser sensors require extensive technical knowledge to operate, well outside the capabilities of our average customer. While the laser sensors are highly accurate, they are too large, too expensive, and too complicated to be useful to skateboarders.
Stopwatch manufacturers may be powerful potential competitors with our G-Potential. Stopwatches and timers satisfy a large market for cheap, durable, small timing devices. These devices already perform many of the functions desired by our customers. They are accurate timers with a wide range of measurement; they are easy to operate and to maintain; they can be used in a wide variety of environments; they are very cheap. Companies like Omega and Timex already have access to resources and distribution lines that could be easily adjusted to accommodate a new height and jump meter if the market proves viable.

Designers of stopwatches and timers have some obstacles to overcome before they will compete with our G-Potential. They must integrate mathematical functions into their products to measure height as well as time. They need some kind of sensor to automatically start the timer, unless they choose to have the user activate and deactivate the meter themselves, as in standard timers. They may or may not try to mount their device on the board; they may choose to capitalize on the portability of their current product instead of turning to mounting technologies. If the timers stayed off of the boards, they would be highly portable, but the devices would still have to “know” when the jump started and stopped. They might integrate some transmitter – receiver system between the sensor on the board and the display to facilitate a completely portable device. However, like our G-Potential, this would still require the sensor to be mounted in some way. Additionally, a transmitter – receiver system may incur large cost increases.

Our final competitor is a skateboard jump training device called the “Revolution,” manufactured by Balance Boards, Inc. This device consists of a skateboard with a special truck strip along the middle of the underside of the board, and a set of two wheels that are independent of the board. The skateboarder can use this special board to practice jumps by jumping the board off of the ground AND wheels and trying to land on the wheels while staying balanced. While this device does not measure time duration or height of jump, these functions could be integrated into the device if such functions proved of interest to their demographic. It would be easy for the Revolution to measure height and time of jump because all related equipment could be integrated into the board itself. Because the Revolution is a separate unit, it can be redesigned to perform new functions while maximizing durability and reliability and minimizing hindrance to the skateboard’s use.

Despite the fact that the Revolution may be easily adapted to perform the functions our device will perform, it is unlikely that the Revolution will become a serious competitor with our G-Potential. The Revolution is not designed for high jumps; it is designed to train for balance. Customers of the Revolution are less interested in the height of their jumps than in their overall quality and balance. The Revolution is not an evaluative tool; it is a training tool.

The Revolution is our competitor not in function but in market. The Revolution targets the same demographic as our G-Potential; skateboarders with expendable income to spend on performance technology. Even in this respect, however, the Revolution is not a
serious threat to the success of our G-Potential. According to our customer research, there is very little interest in such a device as the Revolution, a device that is separate from the skateboard, expensive ($84.95 retail), and not of real utility to the average skateboarder. Skateboarders are interested in technology that enhances, not replaces, their present equipment.

4.2.3 Our Capabilities

In many respects, our capabilities exceed those of our competitors simply because we are targeting a market for which there are no products presently. Our G-Potential will be specifically designed to the customer requirements indicated, which means that our G-Potential will provide features that are not present in our competitors. We will be stronger than our competitors in regards to providing the exact functions our consumers want. Specifically, our product will be accurate for the typical range of skateboard jump heights. The user interface and display will align exactly to customer requirements, although the memory capabilities of our G-Potential may be somewhat limited. Our materials are limited by cost, but we will be selecting materials that align as best as possible to the constraints and issues of a skateboard. With regards to quality, our capabilities may be limited with respect to competitors that document jumps more extensively, but we will be providing the measurements specifically requested by our customers.

We also have the advantage over our competitors in designing for the convenience requirements specific to skateboard use. We will try to maximize mounting strength while focusing on removability and small size. These criteria are related, and one may have to yield somewhat to others in our final product, especially with regard to the possible permanent attachment of the sensor. We will design for great shock insulation and use in a variety of skateboarding environments. Our G-Potential will not require an external operator, nor extensive technical knowledge for operation. It will be easy to maintain, although some parts may require frequent maintenance due to the high stress suffered by the G-Potential.

In regard to cost, our G-Potential will be highly advantageous with regard to the high-quality time-lapse photography and laser sensor options. Initial price and design costs may be high, due to the fact that we are just entering this new industry, but these costs should level off once our product is established. Because skateboarding is a very spread-out activity in the U.S., we will have to spend a large amount of money initially on advertising in order to reach a significant portion of our market. Our main competitor in regard to cost are stopwatch manufacturers, who have the advantage of a well-established industry and lines of distribution.

In summary, our G-Potential will have a high value compared to the competition, largely due to the fact that we are introducing a new product into the market. This may be risky; there is no second source for this device, and the market may not respond favorably to the
new product. However, our market research indicates that there is wide market appeal for our product. The risk may be well worth it.

4.3 Module Definition

In overview, the skateboard jump time / height indicator works in the following way. Sensors on the skateboard create a small voltage differential corresponding to whether a person is inflicting gravitational force on the skateboard or not. That differential is amplified and converted into a digital signal. Loading on the skateboard translates to a logical low, and no loading (jumping) corresponds to a logical high. The microprocessor reads that signal and when the signal changes state from low to high, it starts a timer to measure the duration of the jump. This timer stops at the next state change in the signal. The microprocessor then translates this time into a height using an algorithm to calculate $\frac{1}{2}gt^2$. The microprocessor then outputs the time and height to an LED display.

The skateboard jump time / height indicator can be split into five basic modules: the sensor module, the amplification module, the analog-to-digital module, the microprocessor module, and the display module. These modules are connected as follows (Fig. 5.1):

[Diagram of system design]

Figure 5.1. Total System Design.
4.3.1 Sensor Module

The sensor module consists of four strain gages connected in a wheatstone bridge configuration to measure the loading status on the skateboard at any time. Strain gages are variable resistors whose resistance increases under compression and decreases under tension. For this project, we are using strain gages with a base resistance (under no strain) of 350 Ohms. These CEA strain gages have a strain factor of +-3% under 1/8 inch strain, and +-5% under greater than 1/8 inch strain. This means that the resistance of each strain gage will change by 3-5% under loading, depending on the strength of loading. When mounted on a thin aluminum plate using MicroMeasurements standard strain gage mounting procedure, these strain gages readily change +-0.5 ohms under strain. Because this change is minimal, four strain gages are combined in the wheatstone bridge configuration is used to maximize strain gage output.

We constructed the wheatstone bridge as follows (Fig. 5.2):

![Wheatstone Bridge Diagram]

Figure 5.2. Wheatstone bridge design.

In this diagram, strain gages 1 and 3 are under compression, and strain gages 2 and 4 are under tension, mounted on opposite sides of the aluminum plate. The wheatstone bridge is powered by two 9 V batteries, each connected to a voltage regulator. The positive 9V is connected to a 78L05 regulator which provides a 5.1 V output to the positive terminal of the wheatstone bridge. The negative 9V is connected to a 79L05 regulator which provides a −5.1 V output to the negative terminal of the wheatstone bridge. While connecting the bridge directly to the 9V batteries would result in a higher voltage output, using the regulators ensures that the voltage input to the bridge will be constant over a long time in use.

Under no compression, the wheatstone bridge has a voltage output of 117 mV. This voltage is due to slight imbalances in the base resistances of the strain gages; in an ideal
situation, the output under no strain would be 0 V. When I flex the aluminum plate, strain gages 1 and 3 increase in resistance by 0.5 ohm each, and strain gages 2 and 4 decrease in resistance by 0.5 ohm each. These changes unbalance the output voltage and boost it from 117 mV to 123 mV. While this may seem to be a very small change, it represents a measurable response to loading.

Once it was established that the wheatstone bridge behaved properly under loading on the aluminum plate, we had to mount the plate on the skateboard in such a way that it would measure loading on the skateboard itself. To do so, we cut the aluminum plate into a thin rectangle and attached velcro to the ends of the rectangle. Then, we mounted the plate with velcro to the underside of the board as shown below (Fig. 5.3). We used a rubber pad to stretch the plate so that the velcro would not absorb all of the weight of a person loading or jumping the skateboard.

![Figure 5.3. Aluminum Plate Mounting](image)

When mounted on the skateboard, the wheatstone bridge was again tested. Now, due to the strain induced by the rubber stopper, the base output voltage of the bridge is 9 mV. When a person stands on the board, this voltage increases to 10 mV. While this may seem like a very small difference, it is consistent and can be amplified into a signal on the range of 0 to 5 V.

### 4.3.2 Amplification Module

The amplification module is a two-step amplification change that transforms the 1 mV output change in the strain gages into a signal that goes from −5V to 0V. The chain consists of an instrumentation operational amplifier (op-amp) and an inverting op-amp connected in series as follows (Fig. 5.4):
All op-amps in this module were built using the LM348 Quad pack, which has four op-amps packaged together on a single integrated circuit (IC). Before building the amplification circuit particular to the skateboard jump time / height indicator, we tested the LM348 with simple inverting amp designs to make sure that all four op-amps are fully functional. The LM348 requires rails of at least –4V to 4V. Since we wanted an output on the range of 0 to 5V, and the output swing of the LM348 is about half the input voltage differential for low voltage rails, we chose to use the positive and negative 9V batteries directly as rails for the LM348. While the voltages of the batteries will decrease over use, the exact values of the rails is not as important to the circuit as the voltage swing they represent. For supply voltage of +-9V, the LM348 can handle about 2 mA of input current. For this reason, all inputs to the op-amps have at least 10 Kohm resistance, which means that the maximum supply current will be 0.9 mA, which is within tolerance. Also, since the input voltage will always be less that 1V (at both stages of amplification), there is no danger of exceeding the source current limit of 15 mA.

The first stage of amplification is the instrumentation amplifier. This amplifier is composed of three smaller amplifiers. The first two provide high impedance gain to the two input voltages that are being compared. The third is a differential op-amp that subtracts the middle-stage outputs of each voltage input. The instrumentation schematic for this circuit is as follows (Fig. 5.5):
The inputs to the first two op-amps are the positive and negative output terminals of the wheatstone bridge. There is a gain factor of 20 on each op-amp, due to the gain resistor of 510 Ohms. The amplified outputs of each of these op-amps is then sent to the differential op-amp, which subtracts one input from the other, with unity gain. The final output of this instrumentation op-amp is $-0.3V$ to $-1.13V$, with the more negative voltage corresponding to the wheatstone bridge under no loading.

Now that the change in voltage measured by the wheatstone bridge is amplified from 1 mV to about 0.8 V, the output of the instrumentation op-amp must be amplified so that this change can be read from 0 to 5 V. To do so, the second op-amp must have some DC offset to offset to $-1.13V$ base voltage output of the instrumentation amplifier. This DC offset is accomplished by connecting a 10K trimmer potentiometer to a voltage source to “dial in” to the offset voltage necessary. This offset will change depending on the exact stress of the rubber stopper on the bridge, and therefore, the trim pot should be readily accessible for adjusting. This offset will always be negative; for this reason, the trim pot circuit is attached to the $-5.1V$ output of the 79L05 regulator. The $-5.1V$ goes to a 10 Kohm resistor, which consumes at least $-2.5V$, and then the trim pot can be adjusted to assume whatever negative voltage is necessary for offset. This will work for offsets from 0 to $-2.5V$. It is impossible to need an offset lower than that due to the constraints on the output of the instrumentation amplifier. There is a large non-electrolytic capacitance (2 uF) attached to the trim pot to reduce any low frequency noise that may affect the circuit. The total amplification circuit is shown below in figure 6.

![Instrumentation Amplifier Diagram](image)
Once the offset is set, that voltage is the input to the positive terminal of the inverting amplifier. This amplifier has a gain factor of 50, which boosts the output voltage swing to a change of 0 to –5V under loading. It may seem that this gain is too high to accomplish the needed result; however, due to the damping of the skateboard, the output of the instrumentation amplifier is much lower in real application than in testing, and the second stage gain must be higher to compensate. Also, higher gain increases sensitivity to skateboarders of lower weight without losing the basic characteristic change. Finally, since the op-amp will clip off at about –7V, it doesn’t matter what the actual output is, since we are only interested in a threshold change. Over many tests, this amplification change consistently creates a 0 to –5V change from a person loading or unloading the skateboard.

### 4.3.3 Comparator Module

After the amplification process the output from the amplifier must be converted from an analog to a digital signal so that it can be processed by the PIC. This is accomplished by the use of a comparator, which converts an analog signal to a digital signal by comparing the input to some set threshold voltage. We decided to use the LM311 single comparator because it is optimized for high switching.

The first stage of the comparator module is a simple inverting amplifier used to convert the analog signal to 0 – 5V. This is necessary because the comparator requires a positive voltage input to function properly. The rails of the comparator are equivalent to the switching outputs (0V and 5V), and for this reason all negative voltage inputs are clipped.
Therefore, we inverted the analog signal to become positive so that it would be an acceptable input to the comparator. The comparator has a threshold voltage of 2 V, created with a voltage divider circuit coming from the 5.1 V regulator output. Using this threshold, all inputs below 2 V will output 0 V, and all inputs above 2 V will output 5 V. These outputs correspond to “no loading” and “loading,” respectively.

The comparator has a 0.01 uF capacitor across the output to cut out high-frequency noise and improve the comparator response to the input. The circuit also uses a 100 Kohm resistor as positive feedback to improve consistency of the comparator. The comparator module is shown below (Fig. 5.7).

![Comparator Module](image)

**Figure 5.7. Comparator Module.**

### 4.3.4 Software Algorithms

Appendix B displays the source code for all PIC assembly code.

#### 4.3.4.1 Timer 2

The PIC microprocessor will be used to determine the height and time of the skateboard jump. The comparator described in the above section will be used to send a high or low signal to the PIC. The PIC will then determine the state of the skateboard.
When a “no load” signal is sent to the PIC, an internal timer will start within the PIC. This timer is called timer2. Timer2 is used to keep time every 10ms. This time was calculated to give us the best resolution with the least amount of calculations. The maximum height we can display on the LED display is 999.9 inches. From the start we wanted the G-Potential to be accurate to one inch. To find our accuracy we first convert 999.9 inches to feet. This comes out to 83.25 feet. With this complete we then do the following equation \( 83.75 = \frac{1}{2} \times 32 \times t^2 = 2.281 \text{ sec} \). If you round of the last decimal place to get 2.28 seconds and plug it back into the equation we get 998.09 inches. So a 10ms counter will give us the desired resolution.

4.3.4.2 Division Function

After the skateboard has done a jump we need to divide the time by two. Simple physics tell us that an object in flight takes the same amount of time to go up in the air as it takes to come down. Since the time in the air is both the up time and the down time we have to divide by two to see how long the skateboard was going up or coming down. This will give us the desired height.

The division function algorithm is just like doing long division see figure below.

![Figure 5.8. Long division](image)

The basis of this algorithm is a division function that uses subtraction to find the answer and the remainder. In the example above we first divide 4 by 2. If there is a remainder then we have to multiply this by ten using booth’s algorithm and then add the next digit to this and divide again. When reaching the end of the division if there is a carry on the last digit we drop it and only keep 2 decimal places. We do this because we only need two decimal places in the time to get the desired resolution, which is one inch.

4.3.4.3 Multiplication Function

The base of the multiplication function is Booth’s Algorithm. Booth’s Algorithm allows us to multiply two eight bit numbers together. With this powerful algorithm we can
devise a algorithm to do floating point multiplication. Before writing any code I did a few multiplications out by hand. See figure below.

\[
\begin{array}{c}
\phantom{0}2.44 \\
\times \phantom{0}2.44 \\
\hline
\phantom{0}976 \\
9760 \\
48800 \\
\hline
59536 \\
\end{array}
\]

Figure 5.9. Long Multiplication

By doing out this multiplication I was able to come up with an algorithm to do multiplication.

First, 5 separate variables were made c1, c2, c3, c4, and c5. C1 will hold the most significant integer and c5 will hold the most significant integer (before function is called c1-5 is cleared). When we multiply the 4*4 the 6 will be added into c5. The carry will be sent to c2. Then the value of c2 (one) will be added to the multiplication of the second 4. The carry of the second 4*4 will be placed into c3. Then c3 is added to the result of 2*4 = 8 +1 =9. The same goes for every line seen in the figure above. When the function is complete the answer is broken down into integer form is c1-c5.

4.3.4.4 Program Flow

When the system is turned on the program will call an initialization function to set up variables and input and output ports. The program will then check to see if the skateboard has left the ground. If it is still on the ground then it will wait until it leaves the ground. Once the board leaves the ground the program will calculate the time while the board is in the air, the timer stops when the board hits the ground again. When the board is done with its flight the program then divides the time by 2, and does the equation \( \frac{1}{2} g t^2 \). The program will then check to see if it will be displaying a time or a height. If it is a height, the program has to check to see if it is going to be in inches or feet. The program then calls a procedure to light the LED display. The program will then repeat until the G-Potential is shut off.

The G-Potential will be able to detect irregular jumps. The PIC will have a procedure that will timeout after a maximum jump time is achieved. When the time is greater than the cutoff time of 5 seconds, the PIC will disable the jump.
4.3.4.5 Buttons

We have three buttons to operate the different options on the G-Potential. We need one button to control height/time, a button to control best jump and a button to control inches/feet.

4.3.4.6 LED Display

The LED display used in this prototype has four seven segment numbers. Each digit has its own enable pin. This allows us to drive one digit at a time. The LED display works like a computer monitor, constantly being refreshed. See PIC and LED schematic below for a detailed pin out.

Figure 5-10.

4.4 Manufacturability

The G-Potential prototype works using standard parts; all parts of the device are readily available. The G-Potential requires minimal assembly, with the exception of the strain gage wheatstone bridge, which must be epoxied to the aluminum sensing plate on the bottom of the skateboard. This is probably the only major module of the G-Potential that cannot be manufactured by machine.

While our prototype’s functionality is excellent, the prototype form must be significantly adapted for manufacture. In the prototype, the strain gage circuit is mounted with velcro on the skateboard, and connects via ribbon cables to the amplification circuit, comparator, PIC, and LED display. The final product must have all of the circuitry mounted on the skateboard for convenient use. For this reason, we recommend that all of the amplification circuitry be combined into a single integrated circuit (IC) chip for manufacture. Also, considering that we are not using all of the ports on the PIC, in manufacture we may use a smaller PIC.

The G-Potential final product has two possible placements on the skateboard. Either the circuitry will be connected to the wheel truck of the skateboard, or the circuitry will be mounted to the sensing plate along the middle of the skateboard with the strain gages. Both configurations have advantages and disadvantages. If the circuitry is mounted to a wheel truck, it will be well-protected during all skateboard use. However, then the G-Potential would need connection wires between the sensing plate and the circuitry which could impede safe use of the skateboard. Additionally, mounting the circuitry to the wheel truck requires a second set of mounting materials, which makes the product less portable and drives up cost to manufacture.
If the circuitry is mounted directly to the sensing plate, there are no concerns about
connective wires or mounting ease, as the entire G-Potential will be localized to the plate.
However, in this configuration the circuitry will be more prone to stress and damage.

With regards to casing, the G-Potential requires a durable and protective casing that does
not impede skateboard use. Regardless of the placement of the G-Potential on the
skateboard, it will undergo stress in use, and the casing must help to insulate the
electronics from the full impact of this stress. If the wheel truck configuration is chosen,
the casing may mold around the truck, securing the G-Potential at some expense. If the
sensing plate configuration is chosen, the casing may simply cover the G-Potential, which
will be cheap but not as secure as the wheel truck option.

4.5 Cost Analysis

Appendix C contains the Cost Analysis Spreadsheet used to determine values explained
in this section.

4.5.1 Standard Cost

The standard cost to produce the “G-Potential” is $16. The $16 includes the parts to
make the G-Potential, the labor, overhead and accounts for less than 100% yield when
manufactured. Eight dollars of the standard cost will be used to buy parts for each G-
Potential, the other $8 will cover other associated costs mentioned above. The chart
below shows the cost for each part needed for the design.

<table>
<thead>
<tr>
<th>Part</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strain Gages</td>
<td>$1</td>
</tr>
<tr>
<td>Op-amps</td>
<td>$0.25</td>
</tr>
<tr>
<td>Power Converters</td>
<td>$0.50</td>
</tr>
<tr>
<td>Resistors/Capacitors</td>
<td>$0.25</td>
</tr>
<tr>
<td>PIC Microprocessor</td>
<td>$3.00</td>
</tr>
<tr>
<td>LED Display</td>
<td>$3.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$8.00</strong></td>
</tr>
</tbody>
</table>

In order to make the G-Potential successful we have to have an engineering team
to work on the product to finalize it. To complete the project we will need two electrical
engineers, a mechanical engineer and a manufacturing engineer. The four engineers will
not be working full time on the G-Potential because most of the design was done for the
prototype. The electrical engineers need to work out any bugs that appear in the code or
the circuits. The electrical engineers will also have to figure out how to reduce the size of
the device by combining the analog circuitry into an integrated circuit. The mechanical
engineer will have to design a casing that will be able to absorb the normal abuse caused
by skateboarders. The manufacturing engineer will have to figure out how this can be
manufactured in an efficient way. The projected cost for research and development is
$300,000. This is the first year RDE spending; during the second year of production
RDE is dropped to $100,000. We have this in our budget because we feel some further development is necessary to provide more quality to the product.

The amount of money budgeted to manufacturing and development is $250,000. This cost will be used to buy a mold used to produce the housing for our product. This money will also be used to purchase any machinery needed to manufacture the product.

Our marketing cost for the first year will be one million dollars. First year marketing costs are high to ensure a successful entry into the skateboarding accessories market. The faster we can get our product name out there the faster and higher volume sales we are going to make. In this marketing strategy we would like to have a big name sponsor or professional skateboarder to promote the G-Potential. Teenagers are most likely to buy the G-Potential if their favorite celebrity skateboarder sponsors it.

4.5.2 Retail Pricing

Now that we have our standard cost defined, we turn to the retail price of the G-Potential. The standard cost is $16; in order to have a margin of 50% we multiply the standard cost by 2 to give is $32. The dealer will get 30% of the price; this drives the cost up to $41. Since we would like to have a margin higher than 50%, we will raise the price up to $50. This will give us a margin of about 55%.

Along with selling the total product we will have a consumable available to the customer. This consumable will be a replacement detection system which includes the circuitry located in the high stress area of the skateboard. In this way, if the skateboarder forgets to take the G-Potential off of his/her board while performing destructive tricks, he/she can replace only the part that is broken at low cost. This piece will have a retail price of $10. The cost to make the product will be $2. Our margin on this product is very high.

4.6 Failure and Hazard Analysis

We performed a general failure and hazard analysis to identify and avoid any possible failures and hazards of the G-Potential. These failures and hazards can be separated into two main categories:

- Failures and hazards internal to the G-Potential
- Failures and hazards due to interaction between the G-Potential and the environment and user

4.6.1 Internal Failures and Hazards

There are no significant internal hazards of the G-Potential. All circuitry in the G-Potential operates within specified requirements for current and voltage. No circuitry is
volatile or prone to failure. However, the most likely internal failures are due to the delicacy of the strain gages and power consumption.

Strain gages are very delicate devices. While they are robust with regard to withstanding stress and strain, their connection ports are weak and easy to break. If any strain gage connection ports break, the G-Potential will stop measuring jumps. To avoid failures caused by snapped strain gage connections, we did the following:

- Sealed the strain gages and their connectors with a polymer sealant to protect the connection ports themselves from damage
- Connected the wheatstone bridge with connection wires that are under no stress or strain
  - These connection wires fed into a ribbon cable that connects to the rest of the G-Potential. This ribbon cable absorbs any stress of the circuitry on the wheatstone bridge. This is only an issue if the final product uses the wheel truck configuration.

Power consumption is the other most likely cause of failure. If the batteries do not supply at least 6 V to the circuit, the rails of the op-amps will be too low to properly amplify the wheatstone bridge signal, and the G-Potential will not output correct height and time. To avoid power consumption related failures, we did the following:

- Integrated a power switch into the G-Potential to prevent battery drain when the device is not in use

Before final manufacture, the G-Potential will be optimized for long battery use.

### 4.6.2 External and Interface Failures and Hazards

Most potential G-Potential failures and hazards have to do with the G-Potential’s interaction with the skateboard, skateboarder, and skateboarding environment. The most likely hazard of the G-Potential is that it will in some way impede or endanger the skateboarder. Some potential hazards include:

- Connection wires dragging or tripping the skateboard during use
- G-Potential detaching from the skateboard during use

The first hazard will be minimized in the final G-Potential design by eradicating all unnecessary connection wires. There is no reason that the G-Potential need use any connection wires long enough to drag on the ground if detached in some way from the device.

The second hazard will be minimized in the final G-Potential design by mounting the device tightly to the skateboard. If velcro is used, the design may wrap the velcro strip around the skateboard or sensing plate to avoid slippage. If the G-Potential is mounted to the wheel truck, it will be mounted tightly enough to withstand significant shock without moving.
The most likely G-Potential failures are due to user misuse. These may include:

- Keeping the G-Potential on the skateboard when performing tricks that are particularly damaging to the skateboard
  - Using G-Potential outside of prescribed environment conditions
- Keeping the G-Potential “on” when not in use

The first failure is most likely. Even if the G-Potential is easily removable, some skateboarders will still forget to remove the device when they stop jumping and move on to grinding or riding rails, two potentially destructive skateboard activities. This mistake may cause significant damage to the G-Potential, and may render it unusable. The second failure would cause battery drainage, but no damage to the G-Potential. One way to avoid both failures is to integrate a simple sound alarm into the G-Potential that would make a sound when the timeout was activated. In this way, the skateboarder would remember, after he has stopped jumping, to both turn off the device and to take it off the board.

We will also address the first failure by offering to users a replacement pack that includes only the wheatstone bridge and connectors. The wheatstone bridge is most vulnerable to the stress of skateboarding, and therefore is most likely to malfunction. For this reason, we will offer a replacement sensor pack cheaply to replace the most vulnerable part of our G-Potential.

4.7 Legal Considerations

All the circuit design is original and proprietary so there are no concerns about getting sued for copyright infringement of code or circuit diagrams. With regard to patent infringement, we could not find any product that was comparable to the G-Potential in form or function.

Our company may have to worry about suits against our product due to people misusing the G-Potential. Some may argue that the G-Potential encourages users to try more risky jumps and tricks, and may therefore cause injuries. However, we believe that the G-Potential is an enhancement product satisfying the needs of skateboarders already performing high risk tricks. The G-Potential is not a safety product; while our design maximizes safe use and minimizes potential hazards or failures, we are not liable for the actions of skateboarders. We will insure the G-Potential for its own operation but not for its psychological effect on users.
5 Product Results

5.1 Product Functionality

In section 5.4, two choices were presented on how to mount the G-Potential on a skateboard. The best place to mount the skateboard would be near the truck or wheel area. This portion of the skateboard suffers the least amount of damage. Placing all of the electronics in this area would allow us to give the device the most protection. This area would also give us more space to use for a protective shell around the electronics. The casing will have to contain all of the electronics, batteries and LED display. The batteries are going to be the biggest part that has to be contained in the casing.

The product functionality is 100%. We did not have to cut out anything from our original specification sheet. The product will be removable, display best height, hang time, and height in both inches and feet. The only thing the prototype does not meet is the size constraints for fitting on the board, but this can be easily accomplished by making an integrated circuit.

5.2 Product Form

The casing size would have to accommodate all skateboards. All skateboards do not have the same amount of space under the truck. However, with careful research the casing can be designed to accommodate all skateboards with the maximum mount of protection possible. A conservative analysis of general-use skateboards yields a 2 inch by 2 inch by 1 inch space on each side of a wheel truck. By wrapping the casing around a truck, we can make use of all of this space while providing extra shock protection to the circuitry. Therefore, we have 8 square inches of space for the casing, which is more than adequate for the circuitry that will be held within.

Our final design will appear as follows (Figure 6.1):
5.3 Expected ROI

Using the cost analysis in section 5.5, we calculated our return on investment to be approximately 27%. The initial capital needed to produce this figure is $250,000.

From our market research we determined that we could sell this product to about 25% of the United States skateboarders. During our market research, we found out that 75% percent of the people interviewed would be interested in this product. From that, 50% said they would like to have something on their skateboard to measure height. From that remaining 50%, 75% said they would buy the product. In the United States there are 20 million skateboarders. By extrapolating the results of our survey, we determined that we could sell 5 million of these devices within a 5 year span. With these figures, we will be able to produce a 27% return on investment. The figure below shows the G-Potential’s profits after taxes.

Profit After Taxes

![Profit After Taxes Graph](image-url)
6 Next Steps and Recommendations

In order to make this product successful its size needs to be reduced so it will be able to fit onto the bottom of the skateboard. The electrical engineers working on the project will have to put all of the circuits onto one integrated circuit. Once this is done the mechanical engineers will have to design a case that looks good, provides enough protection, fits in the allowable space and is easily removable. The manufacturing engineers will then have to figure out a way to produce the G-Potential. While the engineering team finalizes design, the company will file for patents and copyright to protect the company from imitation.

The G-Potential is a product that will open an entirely new market with our company as the front-runner. Since our company will be the first ones to offer such a product we will have the entire market share before any competition enters the market. During this time we will be able to build our brand name and by the time competitors hit the market we will already have our foot in the door. The G-Potential team highly recommends future development of this product because it will offer a quality return on investment.
Appendix A – Value Analysis
<table>
<thead>
<tr>
<th>Market</th>
<th>Time Lapse Photo</th>
<th>Stop Watch</th>
<th>Laser Displacement Sensor</th>
<th>Revolution</th>
<th>WPI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quality</strong></td>
<td>Value point</td>
<td>Total</td>
<td>Value point</td>
<td>Total</td>
<td>Value point</td>
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<tr>
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<td>4</td>
<td>12</td>
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<td>6</td>
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<tr>
<td>3 Accuracy</td>
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<tr>
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<td>20</td>
<td>2</td>
<td>8</td>
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<tr>
<td>5 Strength of Mounting</td>
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<td>5</td>
<td>1</td>
<td>5</td>
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<tr>
<td>6 User Interface</td>
<td>4</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>7 Reliability</td>
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<td>5</td>
<td>25</td>
<td>3</td>
<td>15</td>
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<tr>
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<td>4</td>
<td>20</td>
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<td>5</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>10 Memory Capabilities</td>
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<td>Total</td>
<td>Value point</td>
<td>Total</td>
<td>Value point</td>
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<tr>
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<td>78</td>
<td>133</td>
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<td>Value point</td>
<td>Total</td>
<td>Value point</td>
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<td>289.9</td>
<td>150.7</td>
<td>153.2</td>
<td>336.3</td>
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Appendix B – PIC Assembly Source Code
Appendix C – Cost Analysis