OddBotics: Technology Development Plan

Team D

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1. Executive Summary

The current problem with robotics education is that too much time is spent focuses on building the robot. Not enough time is spent programming the robot and learning about robotics control.

OddBotics is a company focused on STEM education for students. We aim to help teachers teach programming and advanced mathematics to the next generation of leaders. We will use the multidisciplinary nature of robotics to bring the world-class education that we received at Carnegie Mellon University to high schools in the United States.

OddBotics was founded by robotics students at Carnegie Mellon University. We have a diverse set of skills and backgrounds that will enable us to create robots and curricula to help teach programming. We are being advised by top engineers and designers at CMU and in Pittsburgh.

The OddBot value package is a platform of modular robot components and the curricula to teach advanced programming and mathematics. This curricula is going to be built from the ground up to aid schools in teaching critical skills for the age of automation. The curricula will include a breadth of material such as path planning, sensor integration, and manipulation to give an accessible physical platform to explore these advanced robotic topics.

The OddBot is currently being marketed to FIRST Robotics to be used in a new competition focused on programming to target the 120,000 students currently competing at the highest levels in FIRST Robotics. The current robotics education market is $1.7 billion per year. We are also working with high schools that already teach basic robotics to develop a more advanced curricula for students that are ready to go beyond remote-control toys. This small beginning will enable us to focus on quality and ensure that our subsequent expansion can bring the greatest impact across education.

LEGO, VEX, Clearpath, and iRobot have been identified as the strongest competitors to the OddBot platform and curricula. However none of these competitors offer a truly capable robot that is also expandable in combination with a software-focused engineering curricula targeted to high school and undergraduate students.

We will develop our prototype and curricula while conducting outreach and securing our partnership with FIRST. We will stay in Pittsburgh to take advantage of connections we have made as well as the intellectual capital of CMU. Once we are ready to manufacture, we will use Dragon Innovation to help us design for manufacturing and successfully manufacture in China. We will keep innovating and will hire new people as we grow to keep marketing our product and design new robots and curricula.

The OddBot starter modular robotics kit with included curricula will be prices at $5,000. After beginning sales in 2016 we project a break-even point in 2018. By the end of 2019 we expect to have annual revenue of $5.25 million, annual expenses of $4.24 million, with an annual net profit of $1.01 million.

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2. The Company's Mission

The goal of OddBotics is to be the leading provider of painless-to-integrate robot platforms for education to help teach programming and advanced mathematics and increase student interest in STEM fields. Initially working through organizations like FIRST and local high schools, OddBotics is working to expand the number of students served throughout Pennsylvania and the United States. FIRST robotics alone reaches thousands of schools in the United States.

Our emphasis is on providing the hardware to bring programming and mathematics to life. We will package curricula with the hardware to maximize the teaching potential of our toolset. Market research indicates that many schools are interested in teaching computer science and robotics, but don't know how to start [1]. Often the teachers tasked with figuring these topics out have little to no familiarity with the field and have to go through extensive training. We want to help schools add this important aspect to their roster with as little pain as possible.

Robots are used in classrooms across the United States to get children interested and excited about STEM and to motivate them to study these fields as they get older. However, in this field robots are either low quality and cheap or difficult to build and expensive.

By capitalizing on our experience in robotics and our work with schools like Central Catholic High School in Pittsburgh we will be able to provide a highest quality and cost-effective path to teaching robotics.

The Pennsylvania state government and U.S. federal governments have identified STEM education, the training of new teachers for this education, and the graduation of students from high school with STEM skills into STEM programs as a priority. They have allocated money and attention to this and we plan to be an integral part of the expansion of STEM in the United States [2] [3].

Here at OddBotics we are going to foster a community of education. Our belief is that you never stop learning. We want to make sure our employees reflect that ethos and that we can continue to push the OddBot platform and the curricula that we are developing.

We believe that every child has something great to add to the future of the United States and every teacher is the light to guide them down this path. We want to make sure teachers get as much help and support from us as possible to help transform the minds of today's youth to create the engineers and scientists of tomorrow.

We will not be afraid to take risks trying new things, but our products will reflect time tested teaching methods and skills that will be useful in the real world. Our goal is not sales, it is converting students into knowledge workers prepared for the modern automated world.

3. Company Background

3.1 Eric Feuvrier Danziger, President and CEO

He founded OddBotics as a Master's student at Carnegie Mellon University studying Robotics Systems Development. He graduated from the University of Virginia with a degree in systems engineering. He is responsible for overall management of the corporation and is charged with maximizing the value of OddBotics. In addition he manages outreach with schools, STEM organizations such as FIRST, and public relations.

3.2 Chris Dunkers, CTO

Chris has an undergraduate degree in robotics from Worcester Polytechnic Institute. He has minors in mechanical engineering and computer science. As CTO, he will oversee the technical operations of the company and be responsible for the development and delivery of new products technology within the company.

3.3 Drew Marschner, COO

Drew has an undergraduate degree in mechanical engineering from Vanderbilt University. He worked for 3 years at Qualcomm as a mechanical engineer. He has experience in CAD modeling, fabrication, and software development. As COO he runs the day-to-day operations of the company such as manufacturing, operations management, and product design.

3.4 Mitch Kosowski, CFO and Sales Manager

Mitch has undergraduate degrees in biomedical engineering and materials science & engineering from Carnegie Mellon University. He worked for 4 years as an option trader. As CFO, he is responsible for financial planning and record-keeping and directly assists the COO with securing new funding, budget management, forecasting, and cost benefit analysis for the company. As Sales Manager, he manages OddBot's sales operations.

3.5 Gary Kiliany, Engineering Advisor

Gary has been working as an entrepreneur with technology and design for decades, and brings a common sense approach grounded in his training as an ECE. He has mentored the group in product development and engineering design.

3.6 Tim Cunningham, Design Advisor

Tim founded a design company in Pittsburgh before returning to CMU as a professor of design. He still teaches at Carnegie Mellon University and advises top-notch startup companies like OddBotics.

4. Value Package Description

4.1 Robot Description

Every person involved with robotics that our team has spoken with has complained about hardware integration with their robotics platforms. Adding functionality to an existing platform often takes an unacceptable amount of time and effort. We interviewed several professors in CMU's Robotics Institute [4] [5]. While professors initially discounted the pain of hardware integration they went on to complain about ROS, reliability of the hardware, and the lack of documentation. Our team aims to develop a standardized, multi-functional robotics platform that would remove the difficulties of hardware integration. With easy hardware integration, our users will immediately be able to have different robotic configurations that will allow them to have a wide range of functionality. Those professors spent weeks trying to add simple additional functionality to their robot platforms. Once they were integrated, they were done and would not change anything for years out of fear of the pain of integration.

The programming tool we will be using is ROS. ROS is currently widely used in research and at universities. It is a message subscribe system that allows inter-changeability between nodes in a system. It also allows users to run nodes on different processing units such as ARM processors and a laptop. Our system will give the students the ability to use ROS and understand some more complex robot architectures. To achieve this the students will be able to use predefined ROS packages with dependencies and executables already established. They will also be given skeleton nodes to reduce some of the barriers to entry in ROS. Each package and node will allow the student to easily interface their code with the ROS system.

The current OddBot prototype, shown in Figure 1, has an external controller, a locomotion base, a sensor module and actuation modules. Each module is programmed using ROS and has specific ROS node templates that can be used as starters for developing code to use within each module. Each module and the locomotion base contains an ARM processing unit so that ROS can be run and information processing can be completed within the module. This allows for the distribution of computing between modules keeping the cost down but the capability high.

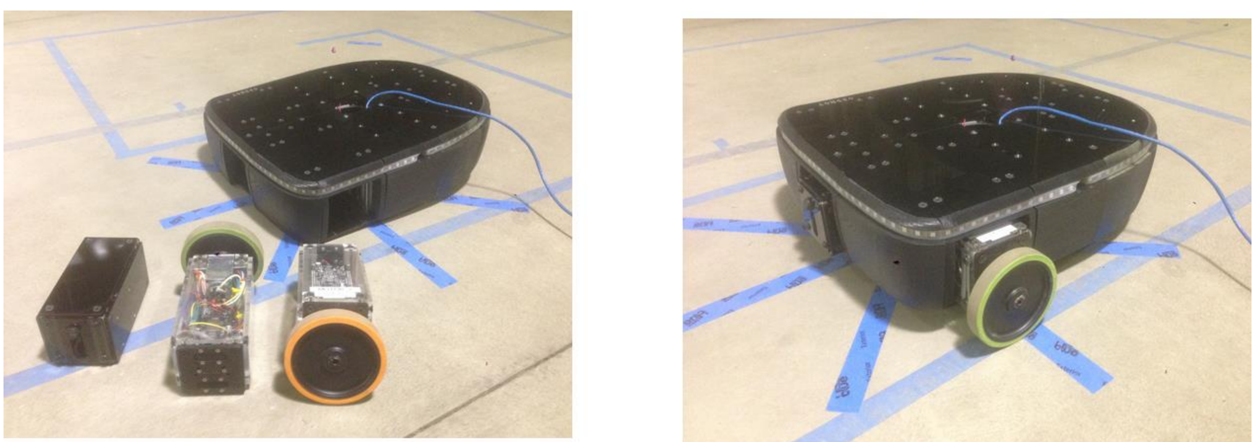

Figure 1: Current OddBot System (left back, locomotion base, left front, left, sensor module, middle and right are actuation modules)

The external controller would be a personal laptop or desktop provided by the end user. It will be used to send commands to the robot. It can be controlled by the user or an external sensor system. Using the ROS node templates provided, students can program trajectory controllers and other systems to move the robot.

The actuation modules, seen in Figure 2, will come with a DC motor which can be controlled using position or velocity. Each module will be provided to use PID control to velocity and position. The actuation modules only need to be given a desired velocity in order to move. They also will have built in safety feature such that if a desired velocity is not given after one second the wheels will stop moving.

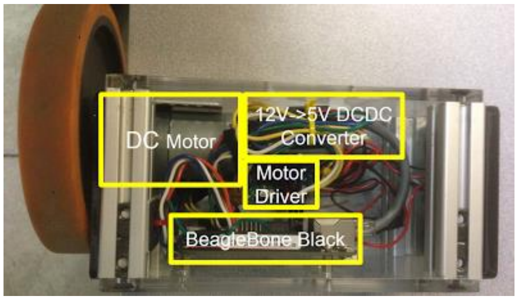

Figure 2: Annotated Actuation Module

The sensor module, seen in Figure 3, will be by default only providing data. With the ARM processor in the module, the sensor module is also capable of performing operations on the data before it is sent out to the rest of the system.

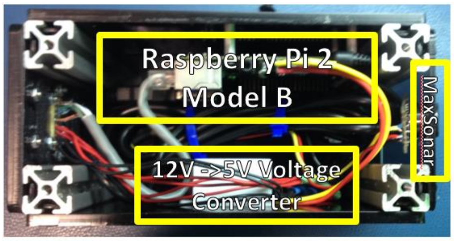

Figure 3: Annotated Sensor Module

For each of the modules, upstart scripts were written to launch the desired nodes in each module. As soon as power is applied the module will start up. This makes sure that each module launches the necessary nodes so that the system could interface with the sensor or actuator without having to deal with the wiring or driver installation associated with the sensor.

The connector that we developed used 12V to deliver power to the module as well as provides Ethernet connection to the locomotion base. A CAD model of the connector can be seen in Figure 4.

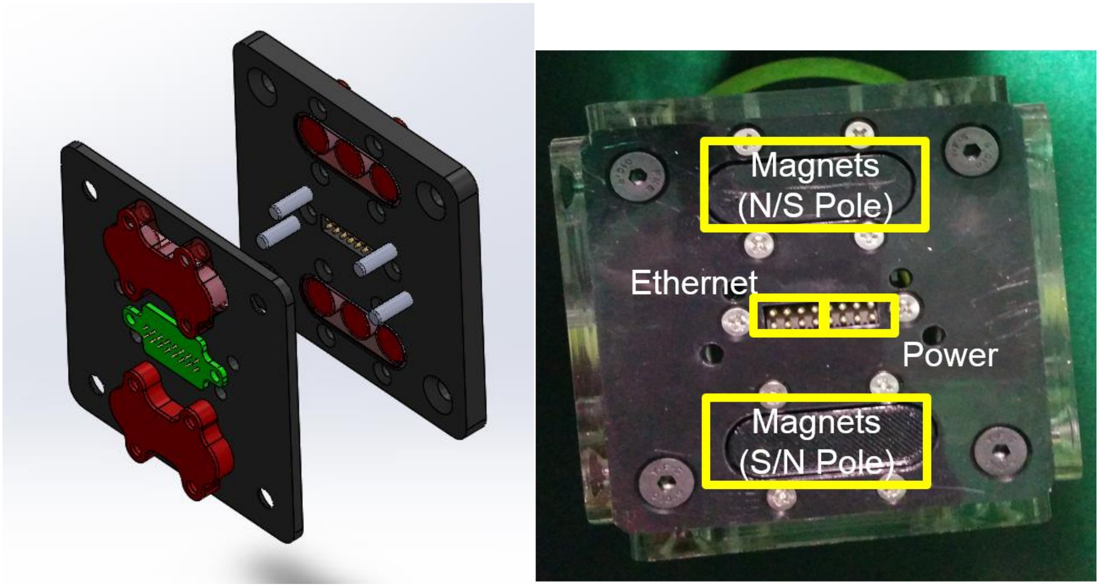

Figure 4: Connector Design, left, CAD model, right, is an annotated male connector

This connector uses Ethernet because the locomotion base can assign each seperate module to a different subnet. Using this information each module knows where it is in the robot and can publish the correct transformation for that module. It also provides sufficient bandwidth between modules to reduce delays and increase data rates.

The locomotion base, seen in Figure 5, uses its internal transformation seen in Figure 6. Currently the locomotion base can house four modules and a connection to an external controller.

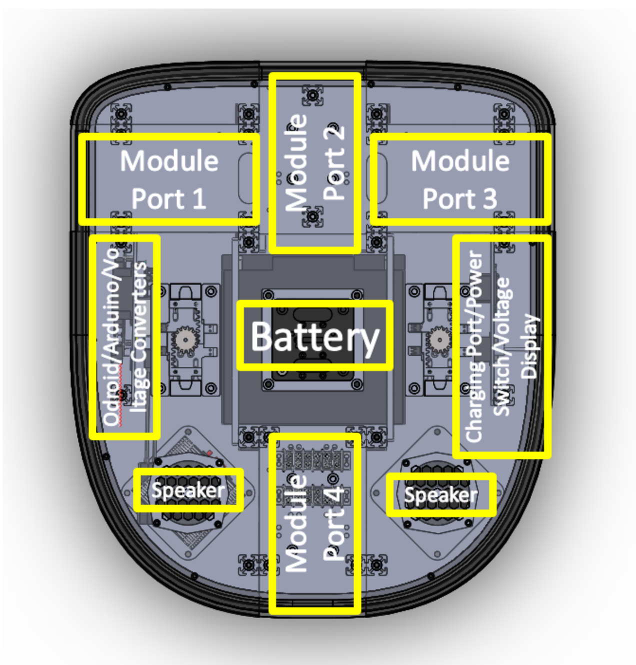

Figure 5: Annotated Locomotion Base

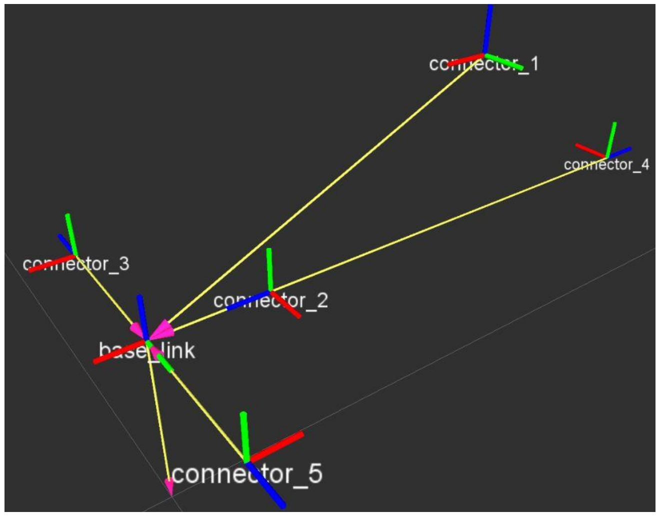

Figure 6: Transformation frames used by the robot to understand its current configuration

With the transformations within the locomotion base and the transforms from the modules the system can understand its configuration. It can understand which directions it can travel and understand what each wheel velocity means for how the robot will travel.

The true value of the OddBot platform is that it allows teachers to immediately begin a diverse robotics programming curricula. The core of the curricula is advanced programming and mathematics topics based on the basic OddBot platform.

4.2 Curricula Description

These curricula will focus on more advanced programming and mathematics topics as the lower end are well covered by our competitors VEX and LEGO MINDSTORMS.

Our current curricula includes the following topics [6]:

4.2.1 Basic Programming

Get up to speed on basic robotic programming. This will cover programming languages such as Python and C++, frameworks such as ROS, and robot assembly. This will include loops, objects, variable types, and other basic programming topics. The lab for this class would include writing a basic ROS node to get familiar with the system.

4.2.2 Linear Algebra and Matrix math

This will cover the essentials necessary for many operations in frame transformations, and data manipulation. The lab would include frame transformations in ROS and understanding how they could be used

4.2.3 Advanced Odometry

This course will cover receiving encoder data, translating it to distance and arcs incorporating robot turns. It will also cover some basics of correction in localization, working with data that may not be perfect, understand things like wheel slippage and maximum inclines traversable by a robot. The lab would include dead reckoning tests, to get the robot to follow a path and measure the error in the position the robot thinks it is and the position the robot actually is

4.2.4 Path Planning
This will cover the basics of searching through a grid map to find a path to a given goal. The lab would include programming a node to search a map using search algorithms such as Dijkstra's algorithm or a wave-front algorithm.

4.2.5 Sensor Integration/Mapping
This would include understanding the information that sensors such as a laser scanner or a Kinect return and learning how these can be used to understand your environment. The lab would include using a Kinect to update a map dynamically

4.2.6 SLAM
This would teach the basic ideas of SLAM and the methods currently used to determine a robot's location such as a particle filter and feature mapping. The lab would include mapping and environment while moving around a room. This lab would build upon the previous lab as the previous code could be used alongside the dead reckoning developed earlier.

4.2.7 Manipulation
This would include understanding the basics of D-H parameters and learning how to assign frames and develop position control of the robot. The lab would work with a prebuilt manipulator to control location. Based on found waypoints the students would then use the predefined positions to pick up and move obstacles

4.2.8 Mobile Manipulator
This would introduce the students to the current mobile manipulator and their uses in industry. Students would then attempt to complete a final project where they would use a mobile manipulator to retrieve obstacles in a room and bring them to a predefined location.

4.2.9 Computer Vision
This would introduce the students to basic computer vision concepts such as template matching to perform recognition. It would allow the students a chance to work with vision libraries and get them to understand the difficulties associated with computer vision.

4.3 Value Package Pricing
The price of the OddBot value package which consists of our robot platform and one year's worth of curricula will be $5,000. The team arrived at this figure by performing comparison analysis on our competitors' pricing, calculating our curricula development cost, pricing the components for our robot, and estimating our labor costs in manufacturing the robot. Finally, the team factored in warranties and returns to obtain the final value package price.

To find an appropriate value package price we first performed comparison analysis on our competitors' products. Over 30,000 teams are expected to compete in the FIRST LEGO League and the Junior FIRST LEGO League in the 2014-2015 school year [7]. The standard kit for these competitions is close to $3,000 as seen in Table 4: FIRST LEGO League Price List [7]. As our robotic platform is much more capable than these LEGO kits, we use this $3,000 price as a baseline for our value package.

Next we looked at the FIRST Robotics Competition, the highest level of competition in FIRST. The registration for the FIRST Robotics Competition is $6,000 for a rookie team and $5,000 for a veteran team [8]. Included in this registration fee is a kit of parts, but we learned by talking to local teams that the average team needs at least $20,000 more in parts to have a truly functional robot that can compete [9]. This combined price of $26,000 serves as the extreme upper bound for our value package.

The team plans to partner with Carnegie Mellon Robotics Academy to develop a curricula appropriate for use with the OddBot. Based on discussions with Erin Cawley, Library Coordinator for the Pittsburgh Robotics Library, developing a curricula tailored for use with the OddBot platform will cost approximately $25,000 [10]. Over the first two years of OddBot sales, the team estimates that we will sell 75 robots. Therefore this $25,000 figure adds $333 to the price of each robot.

Next the team priced the parts of each robot, shown in Table 1. It is important to note that this is a partial list. Modules beyond the standard brain, locomotion, perception, and manipulation modules would require additional parts not included in this list and would increase the total price of the robotic platform. However as these are parts for a prototype OddBot there would be cost savings associated with bringing OddBot to manufacturing. Therefore we think the total cost of $1,168 serves as a good baseline for the actual cost of producing an OddBot system.

Refined Parts List					
Module	**Part**	**Description**	**Cost**	**Quantity**	**Total Cost**
Locomotion	Powerizer Battery	10Ah Battery	$348	1	$348
	Voltage Converter	24V to 12V	$20	1	$20
	Case	80/20 + Acrylic	$100	1	$100
	Voltage Converter	12V to 5V	$20	1	$20
	Odroid	Module Processor	$35	1	$35
	Arduino Mega	Debugging Processor	$55	1	$55
Actuation	BeagleBone Black	Module Processor	$55	2	$110
	Motor	Robot Drive System	$100	2	$200
	Voltage Converter	12V to 5V	$20	2	$40
	Case	80/20 + Acrylic	$50	2	$100
Sensor	Raspberry Pi	Module Processor	$35	1	$35
	Voltage Converter	12V to 5V	$20	1	$20
	Case	80/20 + Acrylic	$50	1	$50
	MaxSonar	Ultrasonic sensor	$35	1	$35
				TOTAL	**$1,168**

Table 1: Parts List

We plan on using Dragon Innovation to help us design for manufacturing and find a manufacturer in China. The cost of their services are estimated at $30,000 [11], which with our expected sales of 75 robots in the first two years will add $400 per robot. Once these costs are defrayed, however, we will be able to reduce our reliance on them and work directly with our Chinese partner if we desire.

With four team members earning $30,000 per year salary, we would expect the per robot cost of labor to be $1,600. This assumes that we sell 75 robots in the first two years.

Finally the team incorporated warranties and rate of returns into our price. Recent studies have shown that the top 500 merchants' median rate of return is actually only 3%, well below some broader industry studies. However, as we are delivering a high tech product and because we also want to factor in the cost of a 1 year warranty on our value package, the team will err on the side of caution and use a combined warranty and rate of return percentage of 10%.

Adding up all the costs so far yields $3,851, as shown in Table 2.

	Cost
Curricula Development	$333
Parts	$1,168
Manufacturing	$400
Labor	$1,600
Subtotal	$3,501
Warranty and Rate of Return	$350
Total	$3,851

Table 2: Cost of the OddBot value package

From the price of our hardware and this comparative analysis we will sell our value package at the $5,000 price point, which yields a healthy profit margin of approximately 25%. This $5,000 price point is positioned in the middle of our competitors' prices, which is appropriate as we will offer functionality in-between that of our competitors.

5. Marketing Plan

The team used the funnel approach to help identify the most viable market for our value package. Rather than using the horizontal market approach of attempting to enter a large, crowded market with the goal of capturing small market share, we used the vertical market approach to drill down and find a smaller, less crowded market (but still big enough to be interesting) that we could enter, grow, dominate, and become the gold standard.

To start the funnel, we first wanted to get an understanding of the overall robotics market. In 2013, the worldwide market value for robot system, including the cost of software, peripherals, and systems engineering was estimated to be $29 billion [12]. As mentioned previously we do not want to attempt to simply enter this large and broad market. Using the vertical market approach, we then look at a segment of the total robotics market. In 2012, the mobile robotics market including unmanned ground vehicles, unmanned aerial vehicles, unmanned marine surface vehicles, and autonomous underwater vehicles was estimated to be $6.2 billion [13].

We first investigated the military market for this product. This market is crowded in the robotics space, and the companies that are providing products are much more mature than OddBotics. In addition, the military budget is expected to continue contracting, making this an overall unattractive market for our company.

We also investigated the hobbyist market. This is a poor market littered with companies that tried to help them make things. Hobbyists don’t spend much and enjoying building from scratch themselves. Sales in this sector are focused on single board computers and atomic units like motors and motor drivers. We decided this market was also not a good fit.

The team then explored the field of educational robotics. These days robotics are becoming more and more integrated into the classroom as educators want to get their students started and comfortable with the technology, programming, and other general concepts of the robotics field in order to prepare them for a global economy. This market was estimated to be $1.7 billion in 2014 [14].

This finally leads to our market entry point of elite high schools involved in FIRST Robotics. As mentioned previously, FIRST Robotics runs some of the biggest robotics competitions in the United States. The two highest levels of competition FIRST Robotics Competition and FIRST Tech challenge, are projected to have approximately 119,500 students spread across approximately 7,750 teams for the 2014-2015 school year [15]. These students and those that help run their teams are the innovators in the innovation adoption lifecycle. These are people who are not afraid to try new technologies. We think by directly targeting these innovators we have the highest chance of success. A summary of this strategy is depicted in Figure 7: Our Funnel Strategy.

5.1 Funnel Strategy

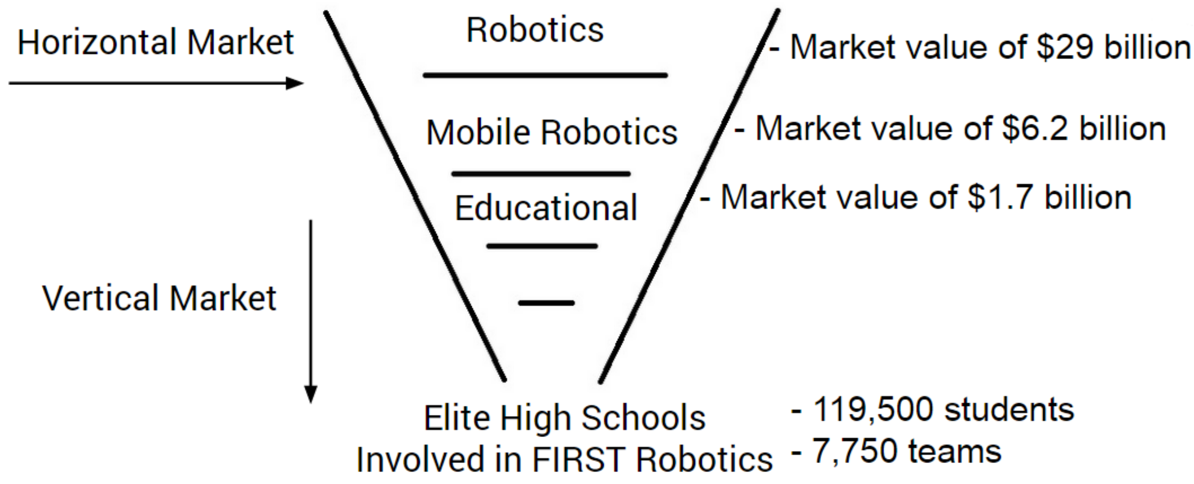

Figure 7: Our Funnel Strategy

That leads to our sales strategy. We plan on working with FIRST Robotics to sell the OddBot platform. We will be pitching to FIRST representatives in the coming weeks. The premier FIRST Robotics Competition is almost all hardware-oriented with very little programming. We plan to pitch the concept of a FIRST Robotics Programming Competition, wherein each team uses the same standard hardware platform (the OddBot system). In this event, teams will compete on the strength of their programming and algorithms instead of how well they can build their robot. We do not want this event to replace the FIRST Robotics Competition, but instead complement. Therefore, the FIRST Robotics Programming Competition will occur during the FIRST Robotics Competition offseason.

This idea is analogous to one used by the DARPA Robotics Challenge (DRC) [16]. In this event, teams competed using robots to complete tasks related to assisting humans in responding to natural and man-made disasters. While many teams built their own robots for the competition, several also competed as software teams who all programmed a common robotic platform. Our idea for the FIRST Robotics Programming stemmed from this concept.

Therefore, we plan on primarily selling OddBot using FIRST Robotics as a distributor to be used in the FIRST Robotics Programming Competition. If we are able to secure this relationship, we will have immediate access to almost 8,000 teams who we think can be turned into customers relatively easily. It is important to note that these teams include not only school teams but also neighborhood teams that would be difficult to contact without using FIRST as a middleman.

Additionally, we plan to use own salesforce to go after schools ourselves. This would be merely to supplement our revenue, as the team believes that if we cannot secure a relationship with FIRST robotics this business plan is not feasible.

Finally, the team will pursue governmental grants for educational robotics. Once again, this will simply be a supplement to our revenue as it will not be sustainable to have a business running entirely on government grants in this space.

6. Competitor Analysis

There are many potential competitors to the OddBot. STEM education is a growing market and is increasingly attractive to a wide range of companies. Robotics education programs in high schools and undergraduate colleges do not have a standard and use many different hardware and software vendors. LEGO, VEX, Clearpath and iRobot have been identified as the prime competitors to OddBot.

6.1 LEGO

LEGO is one of our primary competitors. They have a multi-faceted approach to the education market focused around their MINDSTORMS platform. LEGO MINDSTORMS was spawned from work with the MIT Media Lab on a “smart brick” and was commercialized in 1998 [17]. LEGO has gone through several iterations of the product, beginning with the Lego MINDSTORMS Invention System kit, then the NXT 1.0, next the NXT 2.0, and now the EV3. The EV3, seen in Figure 8, is sold as a standalone consumer product for $350 as well as in curricula kits designed for educators [7]. These curricula kits are sold at multiple price ranges. The largest EV3 kit is priced at $6800 and designed for 30 high school students at 2 students per robot.

Figure 8: LEGO's EV3 Kit

LEGO’s products are significantly cheaper than the OddBot platform, but are also significantly less capable. The core of any MINDSTORMS system is the “programmable brick”, which is a self-contained system holding a 300MHz microcontroller, 4 inputs and 4 outputs, a battery to power all other components, 16GB of flash memory, Bluetooth 2.1, a speaker, SD card reader, and speaker. The “smart brick” is programmed through a custom language, ROBOTC.

Compatible components include “large” (240 - 250 RPM) and “medium” (160 - 170 RPM) servomotors with encoder accuracy of 1 degree, touch sensor, gyroscope, IR sensor, ultrasound sensor, and color sensor. The entire kit is well-designed and easy to integrate together into all kinds of robotics projects. However, it is very difficult to use MINDSTORMS for more advanced robotics projects and typically the entire system must be abandoned in favor of a system with more powerful and accurate components [18].

LEGO also has its own FIRST competitions called the FLL (FIRST LEGO League). This is a competition aimed at students aged 9-14. In the competition, challenges are released that teams aim to complete. These challenges include building and programming robots out of LEGO components that pull levers, collect foam balls, and move rocks. There are several different kits available for the FLL through LEGO, with a single full robot kit typically costing $500 [19].

In addition to the hardware kits available online, LEGO sells curricula packages focused on K-12 education. These kits are priced from $70 - $350. These curricula emphasize robot construction rather than programming or integration tasks which the OddBot curricula will exclusively feature [7].

6.2 VEX

VEX Robotics is a subsidiary of Innovation First International Inc., a producer of consumer robotics toys and kits for STEM education. VEX has multiple kits, as seen in Figure 9, for middle school, high school, and undergraduate students. Individual starter kits range from $400 - $500 [20]. Classroom kits range from $800 - $1000. These kits are designed for use by 2 - 6 students. VEX licenses a programming environment using ROBOTC for programming of its microcontrollers. These licenses range in price from $80 for an individual seat, $300 for a 6 seats, and $800 for a 30 seats [21]. VEX also sells individual hardware components such as gears, pulleys, motors, sensors, and other equipment.

Figure 9: Multiple VEX Kits

VEX’s products vary in quality, but are in general are one step above LEGO in terms of ruggedness and capability. The framing of most of their kits is made from extruded aluminum fastened together using screws. The standard VEX microcontroller has 10 motor outputs, 1 I2C port, 2 UART ports, 8 analog inputs, 12 digital I/O ports, 2 Rx ports, and 1 speaker output. VEX has several different motors, many of which are significantly more powerful and accurate than LEGO's motors. However, VEX's products are all designed to operate within the VEX ecosystem and are not designed for use with other systems, although it is possible to do so [22].

Since 2007, VEX has had its own STEM robotics competition in which middle school and high school students build and program robot. Similar to the LEGO FIRST challenges, VEX competitions typically focus on moving and collecting objects. VEX also has a kits it sells that conform to the standards of the FIRST Robotics Challenge (FRC) [23]. In addition to these kits, VEX has a free online curricula available. This curricula is very basic and based primarily on robot construction. There is extremely little content based around programming the robot, sensor integration, and more complex tasks such as manipulation and path planning [24].

LEGO and VEX are both used as the standard robot platforms by Carnegie Mellon's Robotics Academy education program. The Robotics Academy is an online resource for educators ranging from elementary to undergraduate education. It has multiple curriculas available with focuses on software, electronics, and hardware development [25]. There are multiple paid and free options for the Robotics Academy curricula, however they all focus on rudimentary robot construction and programming and do not address more complex robotics programming tasks that the OddBot curricula includes.

6.3 Clearpath

Clearpath is a robotics company selling multiple different robotic hardware systems, as seen in Figure 10. It began in 2009 with the goal of building mine-clearing robots. In 2010 Clearpath began producing robotic systems designed for prototyping in research and industrial settings [26]. Currently Clearpath offers 11 different robotic systems divided into 4 sub-types: "Land", "Air", "Water", and "Lab". The prices of these products range from $2000 - $20,000 [27]. Clearpath also offers services in the form of systems design, perception and mapping, navigation and control, and simulation.

Figure 10: Examples of Clearpath Robots

Clearpath's products are well-engineered and of high quality. This is reflected in the price, which limits Clearpath's customers to higher education, research, and industrial prototyping. Clearpath also does not offer any kind of curricula, as its products are primarily used by researchers and engineers already well-versed in programming robotic systems. Because of the price of their hardware platform and lack of accessible teaching materials, Clearpath has no clear path into the high school education market. OddBot is cheaper and easier to integrate with other hardware systems.

6.4 iRobot

iRobot is an old robotics company, originating in 1990 developing EOD robots for the military. In 2002 iRobot released the Roomba floor cleaning robot, entering the consumer robotics space. Since then iRobot has been selling both consumer and military robots. In 2007 iRobot released the Create version of the Roomba [28, 29]. The Create was essentially a robotic base very similar to a cheap Roomba used for STEM education.

Figure 11: iRobot's Create 2 Mobile Base

iRobot has recently released the Create 2, as seen in Figure 11, a significantly upgraded version of the Create, for $200. The Create 2 has integrated drop sensors, IR sensors, and bump sensors on top of a differential drive system. It is functionally equivalent to a Roomba. iRobot has released documentation and projects for programming and modifying the Create 2 for various education challenges such as light painting (using an LED with a long exposure photography), taking pictures, and tethered driving [28].

While the Create 2 is both affordable and capable of many tasks right out of the box, it is not as extensible as OddBot and does not come with curricula designed for a classroom. iRobot is primarily a military and consumer robotics company. STEM education is lower in the company’s priority.

Company	Hardware	Curricula?	Hardware Price (USD)	Curricula Price (USD)
Lego	MINDSTORMS EV3	Yes	$350.00	$70-$350
VEX	VEXIQ	Yes	$250/$300 (classroom bundle $3500)	$250-$3500
VEX	VEX	Yes	$400/$500 ($800/$1000 classroom)	$250-$3500
VEX	VEXPro	Yes	Sells individual parts	$250-$3500
Clearpath	Turtlebot	No	$2,000	N/A
iRobot	Create 2	No	$200	N/A
OddBot	Starter Kit	Yes	$5000/kit	N/A (comes w/hardware)

Table 3: Competition Matrix

In conclusion, while there are many potential competitors to the OddBot platform/curricula, there are no strong contenders offering the level of capability, affordability, and expandability of the OddBot combined with a strong curricula focused on robotic software development topics such as path planning, SLAM, computer vision, and manipulation, among others. The market for skilled software developers has been consistently growing and is projected to grow 22% from 2012 to 2020 [30]. The existing educational platforms such as VEX and LEGO do not provide the kind of software development training that is necessary for the next generation of programmers, and systems such as Clearpath and iRobot offer too little assistance for use in a high school or undergraduate learning environment. As can be seen by Table 3, the OddBot robot and curricula are priced slightly higher than entry level VEX and LEGO kits. However the increased capability of the OddBot robot and the focus on programming put it in a different tier. The OddBot robotic platform and curricula fills the void left by companies such as the competitors listed to offer a compelling product to educators looking to teach skills beyond simply constructing a robot.

7. SWOT Analysis

7.1 Strengths

The strengths of the OddBot platform are its level of hardware abstraction, programming curricula, and expandability.

The OddBot has been designed with modularity and ease-of-use as its main design goals, so getting up and running with the system is very straightforward. Putting together different modules is a no-screws-removed process that involves simply attaching the modules using our electro-mechanical connector. Once connected, the user simply needs to flip the power switch and the OddBot will activate, identifying all connected components using an inter-module network communication protocol. Our competitors do not provide the kind of plug-n-play capability that OddBot offers, which allows for a focus on programming rather than robot construction.

We will provide a curricula along with the robot to help educators teach STEM concepts with a focus on programming. Currently LEGO provides a similar package, but the OddBot will be significantly more capable than any MINDSTORMS system and will give students a taste of programming tools and environments used in industry and research (ROS, OpenCV, OpenNI, etc.).

The OddBot's connector interface and information architecture will be open source and freely available for use by anyone. This will allow educators to focus on building hardware if they really need to, as well as develop their own specialty modules that they can in turn open source, growing the available number of modules and functions of the OddBot.

7.2 Weaknesses

We have been asked why this level of modularity. We are attempting to answer this question with customer discovery. We have been asking about use cases for smart motors (the 1 actuator level) and fully packaged robots (no modules at all), trying to find the optimal value package for our customers. So far it is not obvious what the best level of modularity is, and it will take some more time and experimentation to determine what will best serve customer needs.

Another weakness is the expense in building out a hardware system on a shoestring budget. Component and material costs are a significant portion of our costs, particularly in the first years of building the OddBot. This is an unavoidable weakness with a hardware company however, and will hopefully be mitigated by customer adoption and continued sales to FIRST and other early adopters.

7.3 Opportunity

Federal and state governments are focused on STEM education as a key part of America's future. STEM education is receiving more funding than before and there is a major push to increase the number of teachers that educate students about science technology engineering and math. We aim to be a key method for schools to increase their rosters of STEM-capable teachers and courses. This will be an important part of our marketing plan as we attempt to increase the number of schools we sell to and courses we teach in each school.

STEM education is a growing source of spending nationwide, and will likely continue to do so. In 2009 the Obama administration announced a $260 million initiative in STEM education [14]. In 2012 the Obama administration and several private companies unveiled a $100 million proposal to improve STEM education. In November 2014 a federal partnership with multiple private partners agreed to invest a further $28 million [31]. STEM spending has grown consistently even through the Great Recession, showing itself to be a robust market and an excellent opportunity for the OddBot [32].

7.4 Threats

There are currently a large number of providers of robots for education, and the number only keeps increasing. LEGO MINDSTORMS and VEX are the biggest in the space, but there are many others, including Atom, Finch, Little Bits, MOSS from Modrobotics, as well as many kits sold by Robotshop, DFRobot, Sparkfun, Pololu, and others. Educators and FIRST components buyers have a huge array of parts and kits to choose from and differentiating the OddBot is going to be a challenge.

However these competitors cannot provide the high level control that leads to our advanced programming and mathematics curricula, but they provide an alternative for schools who only want to give their students a small taste of STEM before shipping them off to college. With the paucity of STEM educators out there, these competitors are a real threat to OddBotics.

8. Operations Planning

Currently, we have a prototype of the OddBot, shown in Figure 12. It is built with 80/20 aluminum T slots and acrylic and is not consumer ready. We also have a draft of a curricula and lab which could be taught to high school students. In both cases, the OddBot needs to be redesigned to be easy to use and aesthetically pleasing, while the curricula needs to be updated to ensure the level of detail and difficulty of the labs are appropriate.

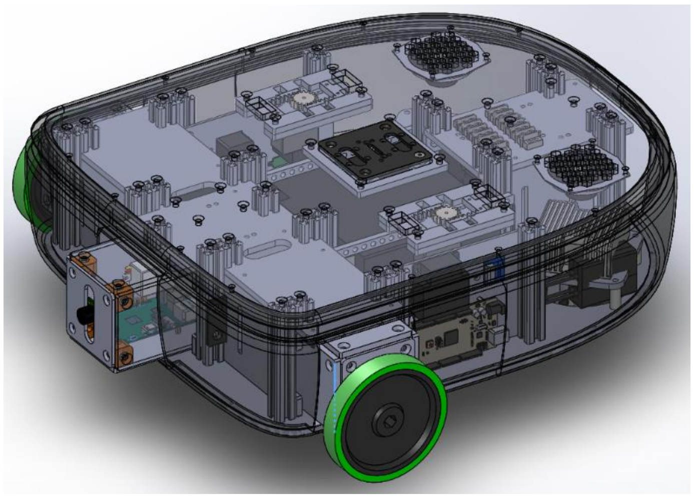

Figure 12: Assembled OddBot CAD Drawing

We would like to continue development of the OddBot alongside the contacts we have made at Girls of Steel, Central Catholic High School, and additional local schools and teams. The first step is to allow the users to interact and program the current prototype. With their feedback we would look to redesign the OddBot for a second iteration, making it easier to use, easier to build, and more aesthetically pleasing. This second iteration would allow us to also start conversations with Dragon Innovation to ensure that the product is manufacturable. Dragon Innovation will help us design for manufacturing and find a partner in China to manufacture it. Using them will help minimize the cultural barrier [33]. Since we anticipate a large number of parts we expect that manufacturing in China will be cheaper.

We would look to a few suppliers such as Pololu, UDOO, and Newegg to supply the prebuilt electrical equipment necessary to build each module. We would also look to McMaster-Carr for the mechanical and raw materials supply for the frame and casing of the robot. Once the parts are built we would assemble the initial batch of robots ourselves. Once we reach critical mass of robot production where it is no longer feasible to build the robots ourselves, we will look to switching our manufacturing to a United States batch manufacturer. Using our sales projections from the Financial Planning section, this will most likely occur in 2017.

Once the robots are assembled we would load ROS onto the robots. We would then test for basic functionality, such as making sure all the connections work, that ROS communicates between all modules, and that the robot generally operates as expected. This will be done through a remote tele-operation test. The modules would then be delivered through FedEx. Once delivered, the robots will be supported online via an online forum.

To develop the curricula we will work with schools, teachers, and students to develop challenging and engaging labs and projects. Fortunately we have the resources of CMU and CMU's Robot Academy in determining a curricula for high school and undergraduate students. We will also look at research papers in the field and new products to gain an understanding of what technology is currently being used in industry and researched in schools. With this information we will build lecture materials as well as supporting labs and projects that will give students experience with real-world robotics problems. With this information a website will be built which will allow teachers to purchase a subscription to the material. Both students and teachers will have access to the online material. The students will then have access to the material as well as a place to find and submit the labs and projects.

To test the curricula we will work with students from partner schools to ensure the difficulty of the material is appropriate and the topics covered are relevant and interesting. We will then incorporate feedback, revise the curricula, and release the material to our customers. In both cases the tests of the robot and the curricula will be executed in classrooms of our partner schools.

The technology development will happen collaboratively over the next few years. This can be seen in the Gantt chart in Table 4.

	2015				**2016**				**2017**			
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Prototype Development												
Software Refinement												
Design for Manufacturing												
Connector Reliability												
Curricula Development												
FIRST Curricula Development												
HS Curricula Development												
Manufacturing												
V2 Prototype Development												

Table 4: Technology Development Gantt Chart

We plan to have the headquarters in Pittsburgh as we have cultivated some connections with accelerators, schools, and mentors on which we can rely on for advice. We also want to make sure that we are near new robotics technology so Pittsburgh is great fit as Carnegie Mellon is a leader in the field. This decision was also based off of a cost of living comparison with other technology cities such as San Francisco/Silicon Valley and Boston. This comparison can be seen in Table 5: Cost of Living Comparison [34].

City	Comparable Salary ($)
San Francisco	85,058
Boston	72,439
Austin	49,788

Table 5: Cost of Living Comparison

Since we will be assembling and testing in-house we will require a significant amount of space to be able to conduct experiments. As a quick space estimate we would estimate a 1500 sq. ft. workspace to account for desk area as well as testing area. We would need an additional space for storage of the robots. We would also need equipment such as oscilloscopes, power supplies, electrical tools, wires, connectors, etc. to establish a good and useable location to test and debug our system. We will have standard 9-5 operating hours during which we would have 4-5 employees operate.

The current members of the team cover the C level employees, as well as the electrical, mechanical, and software engineering fields. However, we have no experience designing for manufacturing or for ease of use. In order to facilitate this change from a prototype to a manufacturable, easy to use, aesthetically pleasing product we would hire a designer. The business process is summarized in the Gantt chart in Table 6.

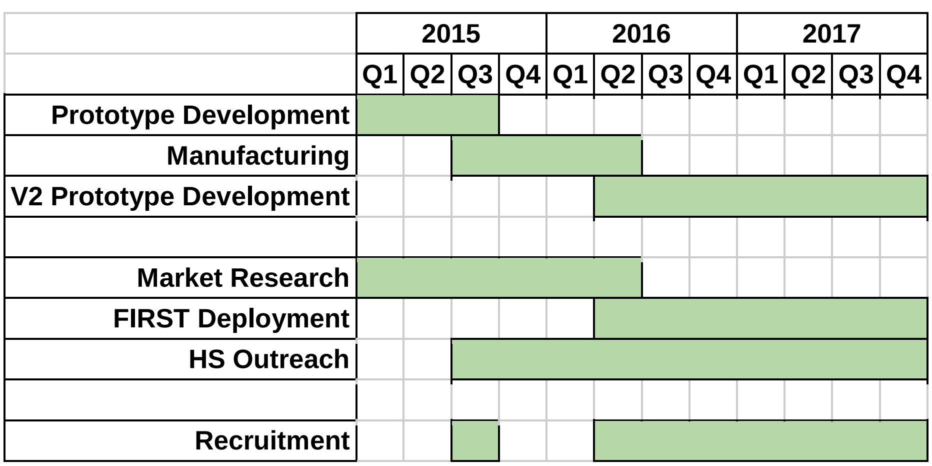

Table 6: Business Development Gantt Chart

9. Financial Planning

For our financial planning we are primarily concerned with revenue and expenses. Sales drive revenue, so first let us discuss a projection of our sales figures is shown in Table 1: 2015 - 2018 Sales.

Year	2016	2017	2018	2019
Robot Sales	2	10	25	50
Robot Sales Via FIRST	10	50	250	1000

Table 7: 2016 - 2019 Sales Projections

The sales figures for 2016 are based on discussions we have had with local schools and the idea that we would have advance orders for a FIRST trial competition for the end of the school year in 2017. From 2016 we make conservative assumptions on the growth of sales of the platform, primarily through our relationship with FIRST and the expectation that we can successfully launch the FIRST Robotics Programming Competition. The projected sales lead to projected revenues, detailed in Table 2: 2015 - 2018 Revenue.

Year	2016	2017	2018	2019
Revenue From Robot Sales	$10,000	$50,000	$125,000	$250,000
Revenue From Robot Sales Via FIRST	$50,000	$250,000	$1,250,000	$5,000,000
Total	$60,000	$300,000	$1,375,000	$5,250,000

Table 8: 2016 - 2019 Revenue Projections

The projected revenues come directly from the projected sales using the assumptions that each robot and curricula sale will be $5,000, whether sold through FIRST or not. To determine the viability of the business, we now must examine our projections for expenses, shown in Table 3: 2015 - 2018 Expenses Projections.

Year	2016	2017	2018	2019
Manufacturing	$30,000	$150,000	$687,500	$2,625,000
Shipping	$900	$4,500	$20,625	$78,750
Payroll	$325,000	$500,000	$750,000	$1,200,000
Technology Expenses (development integration, website design, web hosting, etc.)	$50,000	$75,000	$100,000	$125,000
Advertising	$25,000	$50,000	$100,000	$150,000
Testing Equipment	$50,000	$10,000	$10,000	$10,000
Office Furniture	$15,000	$10,000	$15,000	$30,000
Rent and Utilities	$9,000	$12,000	$15,000	$20,000
Total	$504,900	$811,500	$1,698,125	$4,238,750

Table 9: 2016 - 2019 Expenses Projections

For manufacturing expenses we used the $2,500 per robot charge justified in the Value Package section and the sales figures shown previously. Although we plan on selling more capable systems in later years, this charge per robot remains the same as we expect to offset these price increases with decreases in price as hardware prices inevitably decrease over time.

For the shipping expense we used a $75 per robot charge and the sales figure shown previously. We found this $75 amount by comparing shipping values for FedEx and UPS across the United States for a robot of our size and then adding 50%. An important note is that we must use ground shipping as the batteries we intend to ship cannot be flown in an airplane due to safety regulations.

To determine payroll expenses we used the personnel numbers from the Operations section and numbers from the Department of Labor as a baseline. We modified the Department of Labor numbers down as this is a start-up so employees should expect less salary in return for equity. We made this assumption based on research we performed on current trends in start-up salaries [34] [35].

We intend to outsource general technology such as a website, information systems, accounting software, payroll, software, web hosting, etc. The 2016 figure come from averaging different estimates for these expenses. Later figures assume growth in the company that would lead to further expense in this segment [36].

We primarily intend to advertise via the Internet as this is the medium that our target market uses the most. Specifically, we intend to use Google AdWords and Reddit advertising as these provide good advertising value per click and will allow us to directly target our intended market [37].

For testing equipment expense projections we used MRSD Lab and equipment contained within as a baseline. From there we added 100% to this cost to account for unforeseen equipment needs to get the 2016 figure. After 2016 we expect this expense to drop dramatically as we will only need to maintain current equipment while procuring a few additional pieces of equipment here and there.

To get the office furniture expense we used an initial amount of $3,000 per employee and personnel numbers from the Operations section. In addition we included some cost for maintenance and replacement of furniture in this expense [35].

Finally, we come to the rent and utility expense. The initial figure for this in 2015 was calculated by comparing real estate costs using online tools such Craigslist and then averaging them. Then, using growth in personnel covered in the Operations section to project the increase in real estate required for the company and therefore the rent and utility expense. We found an average of around $10 per square foot per year for cheaper office and warehouse space in Pittsburgh. Assuming we can use a 1000 square foot space for our starting company, we can assume $10,000 per year in rent [38]. This will be compounded with another $500 a month in utilities, assuming gas, electricity and internet as our bills.

Combining the figures we have for revenue and expenses yields the break-even plot, shown in Table 10: Break Even Plot.

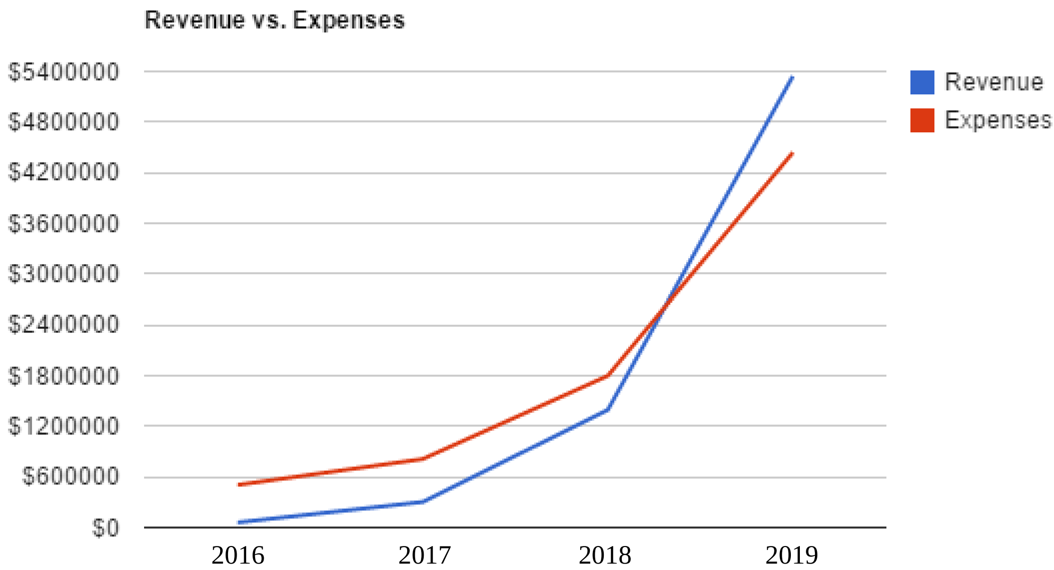

Table 10: Break Even Plot

From our calculations, OddBotics will break-even in 2018. To reach this point, OddBotics will need to raise $1,500,000 over the course of the next three years to stay afloat, with starting capital of $500,000 required in the first year to pursue the project.

10. Appendix

10.1 FIRST LEGO Prices

FLL Program Items	United States	Canada
2014 FLL Team Registration (required. Non-refundable)	$225.00	$225.00
2014 FLL Field Setup Kit (required but can be shared across teams. Non-refundable)	$75.00	$88.00
FLL EV3 Robots		
FLL EV3 Robot Set with DC battery (required but robots from previous seasons can be used)	$499.00	$570.00
EV3 Robot Options		
EV3 Intelligent Brick	$159.95	$183.95
EV3 Ultrasonic Sensor	$31.95	$36.95
EV3 Gyro Sensor	$29.95	$34.95
EV3 Color Sensor	$34.95	$40.95
EV3 Touch Sensor	$19.95	$22.95
EV3 Medium Servo Motor	$19.95	$22.95
EV3 Large Servo Motor	$21.95	$25.95
EV3 Rechargeable DC Battery	$59.95	$68.95
DC Battery Charger (for NXT or EV3)	$24.95	$26.95
FLL NXT Robots		
FLL NXT Robot Set with DC Battery	$435.00	$499.00
FLL Green City Challenge Combo	$299.00	$325.00
FLL NXT Robot Set & Green City Challenge Combo Pack	$715.00	$760.00

NXT Robot Options		
NXT Rechargeable DC Battery	$59.95	$64.95
NXT Interactive Servo Motor	$19.95	$23.95
NXT Color Sensor	$39.95	$45.95
NXT Touch Sensor	$19.95	$22.95
NXT Light Sensor	$19.95	$22.95
TOTAL	$2,811.30	$3,112.30

Table 11: FIRST LEGO League Price List

10.2 History of LEGO MINDSTORMS

While the first computer controlled LEGO product was released in 1986, it wasn't until 1998 that MINDSTORMS was broadly released. Almost immediately following its release, Dean Kamen partnered with Lego to start the FIRST LEGO League. There was an update in 2000, but then nothing for 9 years as LEGO was unsure of what to do with the product. In 2009 the NXT was released, and 2013 the EV3 version was released. LEGO is now taking MINDSTORMS seriously, and there are many examples of rather complicated mechatronic devices, remote control vehicles, and semi-autonomous robots built using the MINDSTORMS set. They are arguably the best of the low level robotics kits for schools, but a classroom set still costs around 6500 dollars.

10.3 CMU's LEGO MINDSTORMS curricula

CMU's Robot Academy has a large set of curricula that go with the LEGO MINDSTORMS platform [39]. Their 'Introduction to Programming' block uses LEGO MINDSTORMS EV3 to bring these concepts to life. There are three main parts, the Basics Unit, the Behaviors Unit, and the Final Challenge Unit.

The Basics Unit covers set up of the robot, the big ideas that will be covered throughout the course, and how to use the software for EV3 programming.

The Behaviors Unit will cover the main three parts of robotics - sense plan act. They cover acting in the Movement section, sensing in the Sensors section, and planning in the Decisions section. Each part builds on the previous parts, and the result is a comprehensive Final Challenge section that uses all that was learned to get the children involved with a competitive capstone build.

This curricula is a great introduction to programming (hence the title), but it is only a beginning.

The Robot Academy also covers VEX Cortex materials for the more in depth course. It teaches meta concepts like Program Management as well as hardware and programming. These are valuable, and the Robot Academy has valuable curricula. It describes the challenges teachers face in starting new programs, and promises to help teachers that have no background in programming get started instantly. They also go into the virtual world version of the VEX platform so that programming could be the focus. This is a good model for what we are looking to do. The goal would be to exist at a level slightly above these guys in complexity and difficulty.

10.4 Clearpath History

Started in 2009 by robotics students, Clearpath has been providing top-notch robot platforms for research and education. The Husky alone, which costs about $15,000, is used throughout robotics, but often as a mobile base for sensor platforms that will never go out of doors.

10.5 STEM Education Market:

The federal government wants to recruit and train 100,000 new STEM teachers over the next decade. We will be positioned to help train those teachers and give them the curricula to help their students.

STEM innovation networks - $110 million in 2015 for schools that increase the number of student that seek out and are well-prepared for STEM. STEM Teacher pathways - $40 million in 2015 and will provide competitive rewards for high quality programs that recruit and train talented STEM educators.

10.6 Bruno Sinopoli Meeting Notes

We met with Bruno twice during the past 3 months. Our first meeting covered using the UDOO and his relationship with the manufacturer. He claimed that he could get us slightly modified boards in quantity if we needed them. We also talked about education and schools in Pittsburgh.

Our second meeting covered specifics on school presentations, as well as possibly working on SBIRs for the National Science Foundation. We would need a principle investigator, and he offered to headline our SBIR and help write it.

10.7 Patti Rote Meeting Notes

We met with Patti Rote several times over the course of the semester to discuss our project. Although Patti does not have a technical background, she is very passionate about robotics and co-founded Girls of Steel, a local FIRST Robotics team. We discussed the various levels of FIRST competitions and where the OddBot could fit into the ecosystem. With Patti, we first fleshed out the idea that OddBot could be sold through FIRST in a competition that stressed programming a robot, not just building it. Patti also filled the team in on various financial aspects of the FIRST Robotics Competition, including Girls of Steel yearly operational budget.

Patti arranged for times for the team to shadow Girls of Steel during their meetings. There, the team confirmed that almost all of the FIRST Robotics Competition was building the robot with very little time spent programming the robot to behave autonomously. The team was very impressed with the Girls of Steel as they are run as a business, including a functional business plan. In addition, Patti made several introductions for us to meet people involved with STEM education in Pittsburgh.

10.8 Central Catholic High School Meeting Notes

Patti arranged with us to meet the brothers at Central Catholic High School on 11/9/2014. There, we discussed educational robotics and education in general. Central Catholic also has a FIRST team. We confirmed with them that the FIRST team spent almost all the time building the robot and not programming it. They also showed a desire for their students to be able to spend more time programming with robots.

When we told them about our system, they seemed cautiously optimistic but wanted to know how our physical robot was better than a purely software solution. We told them that although we think software modeling has its place in education, there is something quite real and visceral about programming and working with a physical robot that pure software cannot replace. They seemed to be persuaded and instructed us to keep them informed of our work. We attempted to arrange additional meetings with their robotics teams but were unable to get our schedules to match up during this semester.

10.9 Cost of Living Comparison

Given a $50,000 salary in Pittsburgh we used CNN Money to calculate a comparable salary in other start-up centered areas in the United States. To make the comparisons, it used groceries, housing, utilities, transportation and health care.

10.10 AlphaLab Gear Manufacturing Meetup

We attended a meetup in Techshop focused on manufacturing on China and the United States. The meetup focused on the difficulties of manufacturing overseas and the responsiveness of local manufacturers. From this meetup we learned of resources for manufacturing overseas safely and ways to choose manufacturers. The main take away was to aggressively search for a manufacturer that makes goods similar to your product, and then make sure to in person inspect their location and talk with the staff.

They also talked about the issues associated with manufacturing in China and the cultural differences that exist. They confirmed the allegation that the Chinese will say yes even if they cannot do it. This means they will tell you they can manufacture a part to the specified tolerance. They will not tell you they can’t and you will only find out about the miscommunication when they give you the parts.

10.11 RBR Market Details

Robotics Business Review sent out a survey about household/consumer robotics. It provides price points, and tries to establish an emotional trend toward robotics as well as understand any resistance toward consumer robotics. In the summary it stated that robotics kits for complex robots should be less than $200 to hit the majority of the consumers surveyed while hobby robots should be less than $500. If we identified our current prototype as a kit or hobby robot, it would be considered too expensive. Given each module individually the $500 price point is a reasonable one to hit. However, we are not targeting consumers but instead educational and after school programs aimed at STEM education.

Some of the key features to consumer robotics are: works as advertised, solves a problem, robust, ease of use, good customer support, cost. Rated at a 3.78, with 1 being not important and 5 being very important, is extensibility via programming. This is where our system can remain competitive as we will have all of these things, except cost. Cost is the one area at which we are higher than the desired price point.

The information that we are not given, or was not collected, is the background of the people taking the survey. We have no idea about whether people have technology expertise or are aware of the component costs of robotics systems. Although this survey establishes a price point for consumer robotics and establishes features and systems which people are interested in and care about it does not compare that to the current capabilities of robotics systems. Although there are features and price points established are they reasonable. For example, the people want high quality manufacturing, high quality components, with expandability for accommodating new components and online resources for under $500. Depending on the robot this may not be feasible.

In any case the information about which aspects of the robot people care about and the price points are all good number to consider when developing a robotic system.

10.12 IBISWorld Market Details

We also could work on selling parts of the robot through hobby and toy stores as educational toys.

This is a market with over 16 billion dollars in sales, and is a place that parents and teachers use to find educational aids for children.

This is a highly seasonal field but also informed by household disposable income. A full OddBot might be too expensive for this market but single modules (like a locomotion module changed to a remote control vehicle for play)

However this industry is highly concentrated. The key success factors IBIS identifies for this market segment are:

- Having exclusive sales contracts
- Stocking seasonal products
- Access to sales staff that are highly knowledgeable
- Development of new products
- Attractive Product Presentation

This market is something we would look into in addition to our focus on FIRST and high schools, as an alternative way to raise our profile in the minds of parents and teachers.

10.13 IRF Market Details

According to the published statistics from the International Federation of Robotics for 2014, the sales of service robotics is expected to increase in the 2014-2017 time period. They also estimate 3 million robots for education and research to be sold in the same time period. Although these number look promising this number are for the entire world and not just the United States. This means that these numbers may not be representative of the marketplace in which we plan to operate in.

The report lists service robot projections, but only a small section. This section does not have a lot of information or sources for the information and there is no way to check these as the part of the report for which we have access is merely the executive summary. The entire report is more than 1000 Euros. For this reason it becomes difficult to judge whether the promising outlook of the robotics future and sales estimates in the industry are conservative or over estimations. However, given that four other reports published by the robot report all have similar projection for the future of the robotics industry, it would be difficult to discard the data. However, we still don’t have access to those reports either.

10.14 Detailed Competition Matrix

Company	**Hardware**	**Curricula?**	**Description**
Lego	MINDSTORMS EV3	Yes	New version of NXT
VEX	VEXIQ	Yes	Similiar to MINDSTORMS
VEX	VEX	Yes	Metal frame more robust robots
VEX	VEXPro	Yes	FIRST supporter
Clearpath	Turtlebot	No	Expensive Robotic Platforms
iRobot	Create 2	No	Locomotion Base
MOSS	Zombonitron 1600	No	Modular cubes
MOSS	Exofabulatronixx 5200	No	Modular cubes
Anki	Anki Drive	No	Toy racecars
Aldebaran	Nao	No	Humanoid Robot
Robotis	Darwin-OP	No	Humand Robot
Robotics	Darwin Mini	No	Humand Robot
Makeblock	Kit	No	Parts, Kits, Etc.
AndyMark	Kit	No	Parts, Kits, Etc.
RobotShop	Kit	No	Parts, Kits, Etc.
OddBot	Starter Kit	Yes	Expandable Modular Platform

Assembly type	Target Customer	Sold By	Curricula Price (USD)	Hardware Price (USD)
Parts	Education	Lego, ToysRUs	$70-$350	$350.00
Parts	Education/Hobbyist	Online	$250-$3500	$250/$300 (classroom bundle $3500)
Parts	Education/Hobbyist	Online	$250-$3500	$400/$500 ($800/$1000 classroom)
Parts	Education/Hobbyist	Online	$250-$3500	Sells individual parts
No assembly	Research/Industry	Online	N/A	$2,000
No assembly	Education	Online	N/A	$200
Modules	Education	Online	N/A	$150.00
Modules	Education	Online	N/A	$150.00
No assembly	Education/Hobbyist	Online, ToysRUs	N/A	$200
Kit assembly	Education	Online	N/A	$8,000
Kit assembly	Education	Online	N/A	12,000
Kit assembly	Education	Online	N/A	$500
Parts	Education/Hobbyist	Online	N/A	Sells individual parts
Kit assembly	Education	Online	N/A	$560.00
Kit assembly	Education/Hobbyist		N/A	Sells individual parts
Modules	Education	Online	N/A (comes w/hardware)	$5000/kit

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