January 31, 2018

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A 1S6

PaintBot Inc.

Re: ENSC 405W/440 Project Proposal for an Automated Painting Robot

Dear Dr. Rawicz,

The attached document outlines a proposal for the design and implementation of an automated room-painting robot which my group and I have put together. This product aims to drastically reduce the manual labor involved in painting the interiors of apartments, condos and other residences by partially automating the process - requiring only that the human operators mask the room appropriately and fully enclose the robot within it (i.e. close any entrances).

The aim of this proposal is to provide a high-level overview of our product. This will include: an early-stage prototype design; projected risks and benefits associated with the product; a preliminary analysis of the market with a focus on where we see our product positioned; a list of tentative component and material costs required to produce our initial prototype; and, lastly, a project schedule to illustrate the expected work-flow.

PaintBot Inc., the company we will henceforth be operating under, consists of 5 hardworking and talented senior engineering students: Bradley Barber, Lior Bragilevsky, Hyun Gyu (Billy) Choi, Ben Korpan, and Peter Kvac. Coming from various engineering concentrations, our team has extensive hardware and software experience to aid us in realizing this proposition. Detailed profile biographies are provided at the end of this proposal.

Thank you for taking the time to review our proposal. If you have any inquiries regarding the proposal, please contact our Chief Communications Officer, Lior Bragilevsky, by phone (778-991-1051) or by email (lbragile@sfu.ca).

Sincerely,

Bradley Barber
Chief Executive Officer
PaintBot Inc.

Enclosed: Project Proposal for an Automated Painting Robot

PROJECT PROPOSAL

Automated Painting Robot

Make life simpler, one stroke at a time

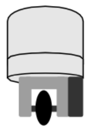
Project Members: Bradley Barber
Lior Bragilevsky
Hyun Gyu (Billy) Choi
Ben Korpan
Peter Kvac

Contact Person: Lior Bragilevsky
lbragile@sfu.ca
778-991-1051

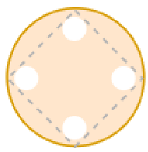
Submitted to: Steve Whitmore (ENSC 405W)
Dr. Andrew Rawicz (ENSC 440)
School of Engineering Science
Simon Fraser University

Issue Date: January 31, 2018

Executive Summary

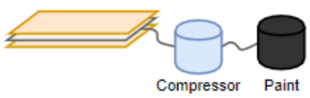


(a) Wheels

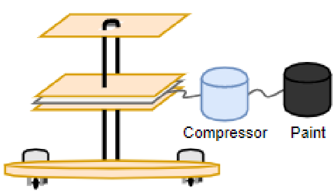


(b) Base

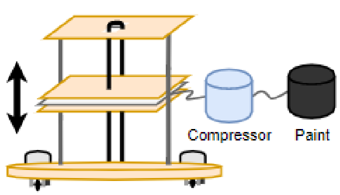
(c) Base & Wheels



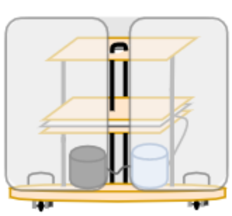
(d) Spray Gun Setup



(e) Base & Tower



(f) Support Rails



(g) Prototype

Figure 1: Prototype Stages

Painting a room is a repetitive, time consuming, and messy task for homeowners and contractors alike. Even in ideal conditions, applying the necessary coats of paint to a large wall can be a long and monotonous task that is ill suited to a human being - but perfect for a machine.

Our prototype, PaintBot, aims to automate the procedure in order to reduce costs for homeowners and increase the productivity of contractors. Figure 1 illustrates the different components associated with our prototype.

The 4 wheels (Figure 1a) will contain 2 motors each. The upper motor will rotate the wheel $\pm 45°$ in the lateral direction, while the lower motor will turn the wheel itself to provide motion. The chosen wheel setup (Figures 1b & 1c) allows the prototype to turn and move in any direction while minimizing the motion of the base for better sensor readings.

The spray gun (Figure 1d) used for painting the room will be held in place with metal sheets and pins to prevent any movement. A pulley system (Figure 1e) will be used to raise and lower the spray gun. Guide rails (Figure 1f) will be installed to ensure that the spray gun "platform" does not rotate in the lateral direction.

The final prototype (Figure 1g) will be housed in a cylindrical casing containing a slot for the spray gun nozzle. Additionally, easy to access locations inside the prototype will store the compressor and paint, to allow for quick cleaning/refilling between consecutive tasks.

PaintBot Inc. is made up of 5 highly motivated and knowledgeable Engineering students that have extensive hardware, software, and hands-on work experience. We plan to continuously work on the prototype for the next 7 months. With all the planning and designs out of the way, nothing can stop us from revolutionizing the world of painting.

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Glossary

counterweight An added weight used to balance a vertical movement pulley system. If it is well matched to the load the drive system will only apply force to overcome friction, rather than the force of gravity on the entire load. 3

mask Masking in the industrial painting context is the process of applying tape, or some other form of covering, to edges and/or other features of the room to which paint is not to be applied. 1

photodiode A semiconductor device capable of converting light to electric current. Photodiodes can be equipped with lenses, optical filter, or other secondary devices to alter or process the optical input. 5

profit The difference between the incoming business revenue and the expenses associated with operation and the supplying of goods and services. Also known as financial gain, return(s), or surplus. 5

revenue The income that a business receives from regular operation, typically from the sale of goods and services - but may also be from collected interest, royalties, and other fees. This does not include income from investors or personal cash-flow into the business. 7

Servomotor A rotary actuator designed for precise control of angular position (translatable to linear position), velocity, and acceleration. Typically consists of a multi-polar electromagnet motor and internal sensors for position feedback. 12

Timing Belt A toothed mechanical drive belt designed for non-slipping. In our application, this refers to a flexible belt with teeth molded into it's inner surface. 12

Ultrasonic sensors A device that uses sound waves to calculate its distance from a given object. To achieve this with precision, it sends the sound waves at a specific frequency and measures the amount of time the sound waves take to bounce back. 3

1 Introduction

With today's continuous advancements in robotics and machine learning technology, many more laborious processes are able to be automated than in the prior century. This automation is key to ensuring companies thrive and living standards improve. Consequently, the team at PaintBot Inc. have a keen interest in providing an efficient, effortless, and cost effective means for painting areas of interest.

Currently, all walls - there are many of them - need to be painted manually using either a roller or spray gun. In the spirit of eliminating this avoidable laborious process, we introduce PaintBot 1.0, a scaled up version of the prototype described in this proposal. PaintBot 1.0 will automate the painting of residential and commercial interiors at a speed and efficiency level that is on par with current industry standards.

At the push of a button, PaintBot will autonomously navigate the perimeter of a room and spray the walls with a professional quality coat while avoiding surfaces that should not be painted. This revolutionary innovation will provide contractors with the option of a time, cost, and labor efficient method of painting spaces using a spray gun - leaving only "detailing" work. With a continuous strive for improvement, we believe that it is only a matter time before PaintBot can be transformed to automate the painting of full scale commercial building exteriors.

The purpose of this proposal is to provide a high level overview of our product and prototype, as seen in Section 2. In Section 3, the risks and benefits associated with our product are outlined. Additionally, a comprehensive analysis of the market and possible competition is provided. In Section 4, we list the costs for each component in the prototype to provide a rough estimate of the required funding. Lastly, Section 5 provides a schedule at which each stage of the project will be completed.

2 Project Overview

2.1 Background

Automation of manual labor is becoming increasingly prevalent in society as the technological field grows each day. Our team is seizing this opportunity to automate something that is necessary and simple, yet time consuming and often messy - wall painting.

At the beginning, our team discussed an automatic painting robot that would paint the exterior walls of commercial buildings. This would have required a large scale robot to be constructed, which is both expensive and impractical for a prototype. Due to these reasons, our team decided to create a scaled down version of the original idea and focus on painting the interior walls of newly built apartments and condos.

Additionally, to stay with the current trends in the industry, a paint roller was replaced with a spray gun - yielding more effective coverage on each pass. Although our prototype aims to automate the laborious task of painting a wall, its core principles can also be adopted to automate other time consuming tasks. This property makes PaintBot appealing to many sectors in the market.

2.2 Scope

The scope of the Capstone project encompasses the design, assembly, and testing of a prototype for PaintBot. The prototype will be able to maneuver and paint a variety of common wall configurations in an fast, yet accurate manner as a result of its ability to:

1. Paint wall sections efficiently and accurately;
2. Detect approaching corners at a range of angles;
3. Turn precisely, ensuring correct distance from the target wall is maintained;
4. Avoid painting large and small marked objects such as windows and outlets.

As outlined in Figure 1, our product will be able to achieve such efficiency and functionality due to the following features:

1. Round footprint for efficient maneuvering in corners;
2. Four independent wheels capable of rotating;

3. An on-board spray gun with a fast and reliable trigger mechanism;
4. A tower containing the spray gun, allowing for smooth and accurate vertical movement through the utilization of a counterweight pulley mechanism;
5. Ultrasonic sensors for maintaining distance from the target wall section and detection of corners in a room;
6. Color sensors to detect regions marked as “Do not paint”.

The prototype will be ~2 feet tall, while the final version will be ~9 feet tall (~4.5 times larger than the prototype). This increase in height will ensure that the final product is also applicable to apartment buildings and condos. The small scale version is capable of proving our concept while reducing material costs and required resources (including manufacturing needs), allowing it to fit within the scope of a Capstone project.

Figure 2.1 provides a high level overview PaintBot’s hardware and software design. All of the subsystems shown in the figure will be present in the prototype.

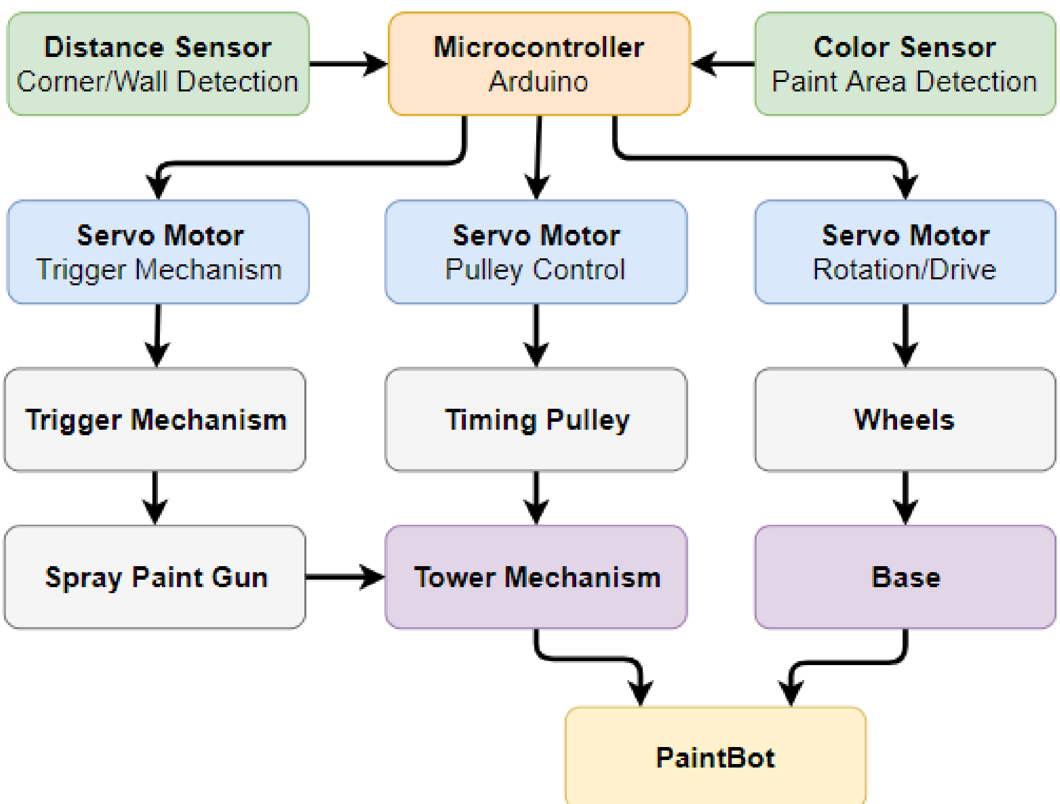

Figure 2.1: PaintBot’s System Overview

3 Product Justification

3.1 Risks

We do not foresee significant safety hazards being posed to us as designers, or to the end user. While some potentially dangerous work will be required during assembly, such as cutting aluminum, we have received training on the proper operation of shop equipment and will proceed carefully with these tasks. Therefore the primary risks associated with our proposed product, as detailed below, largely pertain to its adoption and use in the market.

Generality of Use-Case

We expect the product to be deployed primarily inside newly constructed apartment buildings; very regular and minimally obstacle-laden structures. However, there are still many complex cases which the robot may be required to handle, such as small outsets and curved wall segments. The chassis and movement system of our proposed design is highly robust and adaptable to a wide range of room layouts. Consequently, the primary challenges lie in the positioning of sensors for range-finding and color-detection, and the design of control algorithms which make use of their data.

Required Human Setup and Intervention

Ultimately, some human intervention will be required when utilizing our product. Regions to avoid painting will need to be marked with tape, and the robot will need to be manually moved between successive areas within a building. Additionally, rooms to be painted will require some vetting for obstacles outside the scope of the product's use case. These factors introduce undesirable labor overhead and provide a vector for the introduction of human error.

Mechanical Issues

The robot will have a total of nine independent servo motors, broken down into the four wheel-drivers, four wheel-rotators, and the tower platform elevator. This abundance of motors and moving parts introduces many possible points of failure.

Effect of Paint Fumes

The fumes from the spray gun may result in an accumulation of paint on the robot. The majority of this would fall on the outer cylindrical casing. However, accumulation over the filtered photodiode or camera used for color detection could be problematic.

Assembly of Full-Scale Variant

In order for the final variant to be usable in apartments and condos, we will need to increase its height to ~9 feet without significantly increasing its footprint. Such a tall and narrow structure could have stability problems.

3.2 Benefits

The proposed product aims to provide several benefits to its stakeholders and end users which outweigh the mentioned risks, thereby justifying its production and use. As stakeholders, we and our prospective investors require the development costs of our prototype to be very small in comparison to the potential future profits. Additionally, we require assurance that the target market has potential to adopt our product. For adoption to occur, the end user must be able to see concrete, significant improvements in productivity resulting from the adoption of our product.

Limited Competition

The automation of manual labor is both a long-standing and rapidly-progressing field. However, established commercial solutions for automated painting do not exist outside of assembly lines. We aim to bring automation to the realm of interior painting - a new and unexplored market. This gives our product the advantage of novelty, and the lack of well-known competitors against which a direct comparison may be drawn.

Cost Reduction

The product will represent a moderate up-front cost, which will then provide significant savings over its operational lifetime. While some supervision will be required as mentioned above, it represents far less labor than fully manual painting.

Health and Safety

One consequence of the automation of manual labour over the past century has been the gradual elimination of high-risk jobs. Our product will contribute to this trend: no longer will painters inhale paint fumes as they utilize spray guns in confined spaces for long durations.

Reliability and Quality of Service

A level of inconsistency is inherent in human labor. Our product aims to provide a consistent, high-quality paint application. Additionally, it will reduce the probability that absent workers incur delays in a project.

Research and Innovation

Since the design space we are targeting is relatively unexplored, the solutions we find may be of research value. In particular, the sensor setup and control algorithms developed could provide some value to the field of indoor robot navigation.

3.3 Market Analysis

US Market

While the most-recent industry numbers from the interior painting industry are costly to obtain, we can analyze some freely available statistics from 2013. As reported by the Bureau of Labor Statistics and the Institute of Business in Society, compiled by CorkCRM, we present the 2013 statistics for the US market in Table 3.1.

Table 3.1: US Market Statistics [1]

Category	Statistic
Painting businesses	260, 350
Approximate employment	192, 890
Average hourly wage	$18.89
Average annual wage	$39, 290

State	Number of Painters
California	27,220
Texas	18,000
Florida	14,750
New York	12,090
Washington	7,240

These statistics are quite limited, giving only a high-level view of the US painting industry. Furthermore, observations such as the approximate employment in the industry reporting a value below the number of operating businesses (approximate employment/number of painting businesses = 192,890/260,350 = 0.74 average employees/business) in the industry casts doubt on their accuracy, or at least how comprehensively they capture the market. However, as a preliminary market analysis, the statics do suggest that there is a large painting industry in the US. This is a positive sign for our proposed product since it suggests that, if we can offer a product of value to these companies, there is a large market to be targeted.

The relatively low reported average hourly wage of \$18.89 is not as promising. Since our product proposes to save these businesses money by replacing human labour with a more cost-efficient alternative capable of achieving results of at least equal quality, our product's unit cost would need to be scaled to ensure financial viability. This could limit the technologies we can utilize to produce our solution, potentially to the point of nullifying any benefits we could offer. However, more analysis is needed to determine the range of wages this represents, as well as the accuracy of these statics. At the moment, very few solid insights can be extracted from these numbers. They merely provide an outline of the industry and suggest areas for further research.

Canadian Market

The Canadian painting market statistics are much easier to obtain. The government of Canada provides the 2015 statistics for the industry, which we have reproduced in Table 3.2.

Table 3.2: Canadian Market Statistics [2, 3]

Category	Statistic
Painting businesses	$17,824$
Businesses with $0-99$ employees	90.9%
Range of annual revenues	$\$30,000-\$5,000,000$
Average annual revenue	$\$218,700$

As reported by the Government of Canada, the number of operating painting businesses in Canada is predictably lower than the numbers reported in the US. A large fraction (90.9%) of these businesses are rather small, having under 100 employees [3]. However, while these businesses are relatively small, the same percentage of businesses reported being financially profitable. This shows a very healthy painting industry in Canada, where only a small fraction (9.1%) of companies are failing to turn a profit [3].

Further analysis can be performed on the more detailed data set collected in Table 3.3 on the next page. These statistics reveal some promising characteristics of the painting market in Canada.

The first statistic of note is revenue. The top quartile of the industry reported a revenue range of $\$184,000-\$5,000,000$. While the high end of $\$5,000,000$ is likely an outlier - it

Table 3.3: Canadian Market Revenue Breakdown [2]

	Whole industry	1st quartile (25%)	2nd quartile (25%)	3rd quartile (25%)	4th quartile (25%)
Revenue Range:					
Low($000)	30	30	48	81	184
High($000)	5000	48	81	184	5000
Revenues and Expenses ($000):					
Total Revenue	218.7	38.4	62.1	121.4	652.9
Cost of sales (direct expenses)	100.4	5.1	11.9	37.8	347.0
Wages and benefits	31.3	0.5	1.4	6.6	116.5
Purchases, materials and sub-contracts	69.4	4.6	10.5	31.2	231.2
Opening inventory	3.4	0.8	0.3	0.9	11.5
Closing inventory	3.6	0.7	0.3	0.9	12.3
Operating expenses (indirect sales)	71.9	14.3	23.3	46.4	203.4
Labour and commissions	29.8	1.5	4.4	16.3	97.1
Amortization and depletion	3.8	1.2	1.7	2.6	9.5
Repairs and maintenance	1.3	0.2	0.3	0.7	4.1
Utilities and telecommunications	2.9	1.1	1.4	2.2	6.8
Rent	3.4	0.5	0.7	1.7	10.9
Interest and bank charges	0.7	0.2	0.3	0.5	2.0
Professional and business fees	3.4	0.6	1.0	2.1	10.1
Advertising and promotion	2.4	0.3	0.6	1.3	7.4
Delivery, shipping and warehouse	0.1	0.0	0.0	0.0	0.2
Insurance	2.1	0.4	0.7	1.4	5.8
Other expenses	21.9	8.4	12.2	17.6	49.5
Total expenses	172.3	19.4	35.2	84.2	550.3
Net profit/loss	46.4	19.0	26.8	37.2	102.6
Financial ratios (averages):					
Interest coverage ratio	63.1	115.6	92.4	73.8	51.8
Gross margin (%)	54.1	86.8	80.8	68.9	46.9
Profitable vs non-profitable ($000):					
Profitable:					
Percentage of businesses (%)	90.9				
Total revenue	210.5	38.4	62.0	121.1	653.5
Total expenses	156.8	17.5	32.5	78.0	526.6
Net profit	53.7	20.9	29.5	43.1	126.9
Non-Profitable:					
Percentage of businesses (%)	9.1				
Total revenue	300.2	38.3	62.9	124.0	649.5
Total expenses	326.4	54.2	71.2	138.0	697.5
Net profit	-26.1	-15.9	-8.4	-13.9	-48.0

is more than four times the value of the low end - the average total revenue of this quartile is $\$652,900$, suggesting that a statistically significant fraction of these top earners fall in the middle of this range. The next lower quartile, the upper middle, reported a revenue range of $\$81,000 - \$184,00$ with an average revenue of $\$121,400$. Combined, these quartile represent the top 50% of the industry by revenue, with a reported average total revenue range of $\$121,400 - \$652,900$. Businesses within this range of revenue represent the most likely viable targets for our product.

The bottom 50% of the industry, on the other hand, reported an average total revenue range of only $\$38.4-\$62.1$. This range is below the average Canadian family income reported by Stats Canada, making this segment of the industry likely not viable for our product [4]. As such, we will not be targeting this segment.

Of course, total revenue does not necessarily reflect high profit. After subtracting the overall costs from these total revenues, the top 50% of the industry reported a net profit range of $\$37,200 - \$102,600$. Meanwhile, the average net profit across the whole industry was $\$46,000$. This provides us with some reasonable values to consider when targeting a final unit cost of our product, as well as the achievable unit lifespan. It's too early in development to be able to provide an accurate target for these characteristics of the final product, however, these stats suggest that a target range for the final unit cost could achieve viability even at high values approaching $\$100,000$, especially with a lifespan approaching a decade or more to reduce the annualized worth of the product.

The largest direct expense that reduced the net profits of the businesses reported here was, not surprisingly, "Purchases, material, and sub-contracts" [2]. Our product does not offer a solution to reduce this; in fact, it would inflate it since it would represent an up-front purchase cost or, alternatively, a periodic lease cost. Which purchase or lease options we provide will have to be informed by this stat, among others, in order to achieve viability.

The second highest direct expense, across all percentiles, that reduced the net profits was "Wages and benefits" [2] - this is the expense that our product is aimed to help reduce. If we can reduce this expense enough to justify the extra cost of the product by ensuring that the resultant is an increase in annual profit, we can achieve viability for this segment of the industry. Our product is also aimed to produce savings on the "Labour and commissions" expense, the highest reported operating expense across the industry, providing more opportunity for balancing the cost/benefit equation in favour of our product so as to maximize the flexibility we have when calculating the maximum viable unit cost [2].

Combined, these expenses represent $\$2,000 - \$5,800$ annually on the lowest end and $\$22,900 - \$213,600$ annually on the highest end, with an average of $\$61,600$ annually. This further informs us that the low end of the market will not be viable for our product. Even if we can save these businesses 50% of their labour costs, likely an unreasonably high estimate, this would only represent a $\$1,000 - \$2,900$ savings.

Our product would likely not be able to offer a significant enough savings for these companies to justify the upfront unit cost, even over a 10+ year operating life. This would require a maximum unit cost of $\$10,000 - \$29,000$ if we assume interest to be 0% and annual maintenance costs to \$0 - which is highly unrealistic. While this may be just on the edge of achievable, with non-zero interest and annual maintenance costs this maximum viable unit cost reduces and becomes highly unreasonable. This will have to be revisited once the design specs approach their final state, but, at the moment, we will consider this segment of the industry a non-viable target for our product.

On the high end, however, again using the over-estimate of 50% savings, our product could offer a $\$11,450 - \$106,800$ annual savings. These are inflated projections that assume our product would reduce labour and wage expenses by 50%, but even at a low estimate of 25% this represents an annual reduction in operating and sales costs of $\$5,725 - \$53,400$ for the companies in the top 50% of the industry.

Using the average combined expenses for the industry with the estimated savings range of $25\% - 50\%$, we can estimate an average annual savings of $\$15,400 - \$30,800$. This average savings is certainly a low estimate however, since we have already determined above that we will not be targeting the lower 50% (by revenue) of the businesses in the industry due to poor financial viability. Therefore, this average estimated annual savings is likely a modest estimate. This is good since this estimated savings range, even at the low end, provides a very reasonable target for our final unit cost to achieve a financially viable proposition - at least for the top half of the revenue earners in the industry. Based on the numbers reported, this would represent around 8,912 businesses operating in Canada.

3.4 Competition

There are currently a number of projects which share a similar concept as ours, offering solutions for autonomously painting walls. However, most of these products are not created with the intention of offering a profitable solution for residential painting companies to reduce labour costs. This is of significant advantage when attempting to introduce PaintBot into the market. PaintBot will be superior to these competitors due to its abilities to detect and avoid objects and maneuver in any direction autonomously, allowing unsupervised, full room painting capabilities - something which none of our competitors offer. The following discusses some of these potential competitors that our product needs to outperform in order to appeal to the market.

Walt

Walt, shown in Figure 3.1, will be PaintBot's main rival in the market. Using the same core principles and mechanisms as described above, its creators, Endless Robotics, claim that "While assisting humans in painting, Walt can enable a three-member team to accomplish 10 times the work they would have otherwise done in a day" [5]. One key difference between Walt and PaintBot, is that Walt is not fully automated and thus needs crew members to assist it with navigation through a built in mobile application. Nevertheless, it is important to mention that Endless Robotics was able to raise over $100,000 in funding from investors [5], highlighting the fact that there is interest in the concept which we plan to improve upon.

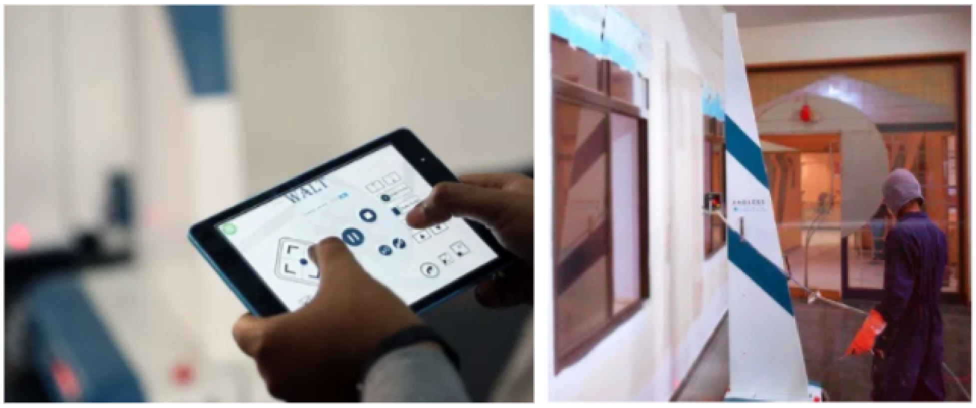

Figure 3.1: Walt - Endless Robotics [5]

PictoBot

PictoBot, shown in Figure 3.2, is an automated painting robot that has been developed by Nanyang Technological University in Singapore which targets large industrial spaces such as factories. The robot itself has dimensions of $2 \times 2 \times 3.5$ meters with an arm that can reach up to 10 meters. This makes it suitable for open environments, but impractical for use in residential buildings, which is why this robot has yet to become accessible to a wider audience. However, just like Walt, an operator uses a remote control to bring PictoBot to the correct position. Once at the required position 3 mechanically controlled supports disassemble into a “tripod” configuration to lock PictoBot in place and the painting begins. Moving to a new location requires that these supports first retract to expose the wheels, drastically reducing PictoBot’s moving speed and overall painting efficiency.

Figure 3.2: PictoBot - Nanyang Technological University’s Robotic Research Centre [6]

4 Finances

4.1 Cost Analysis

The breakdown of each component for PaintBot's prototype is summarized in Table 4.1.

Table 4.1: PaintBot Component Cost Breakdown

Function	Component	Quantity	Price ($/Unit)	Subtotal ($)
Painting Mechanism	MXL 60 Tooth Timing Pulley	2	3.04	6.08
	MakeBlock 3m Open End Timing Belt	1	16.99	23.07
	Servomotor HS-422	1	14.74	37.81
	800mm x 8mm Linear Rail Shaft Rod	4	19.01	113.85
Driving Mechanism	Lynxmotion Base Rotate Kit (HS-422 Servo)	4	38.40	267.45
	HSR-1425CR Continuous Rotation Servo	4	20.37	348.93
	RW2 - Large Rubber Wheel	4	4.99	368.89
	Actobotics Gearmotor Pinion Gear (6mm) 16T	4	10.24	409.85
	Actobotics Gearmotor Pinion Gear (6mm) 32T	4	10.24	450.81
Extras	Arduino	3	25.99	528.78
	Paint Spray Gun	1	69.99	598.77
	Tower/Spray Gun Platform	2	17.04	632.85
	Cylindrical Wheel-Case	4	9.03	668.97
	Base Board	1	48.23	717.20
		Tax (12%)	86.06	803.26
			Total	803.26

4.2 Funding

When deciding which components to use for PaintBot, our team quickly realized that we need funding in order to make the prototype successful. As mentioned above, our prime competitor (Walt) has received financial support from various investors. This demonstrates that PaintBot is appealing to the market which drastically increases our chances for external funding.

In addition, several sources of funding are available for Engineering students who are currently in the process of completing their Capstone project:

1. Wighton Engineering Development Fund, administered by Andrew Rawicz, is typically awarded to projects benefiting society. As mentioned previously, our product aims to automate laborious tasks and increase the productivity of workers, which is of great benefit to the society. We will apply for this fund during this semester.

2. The Engineering Science Student Endowment Fund is provided by SFU's Engineering Science Student Society (ESSS). Our prototype falls under Category B (Entrepreneurial), and we can apply in the Summer 2018 semester as the application period for this semester has already passed.

Lastly, if all funding opportunities become unavailable, each member of our team has agreed to contribute at most $160 to the material costs. This will provide us with exactly $800, which should be just enough to successfully construct our prototype.

5 Project Scheduling

5.1 Gantt Chart

Figure 5.1 shows the Gantt chart which encapsulates the team's scheduling for the duration of ENSC 405W including milestones (green diamonds and orange rectangles) for key tasks throughout the term.

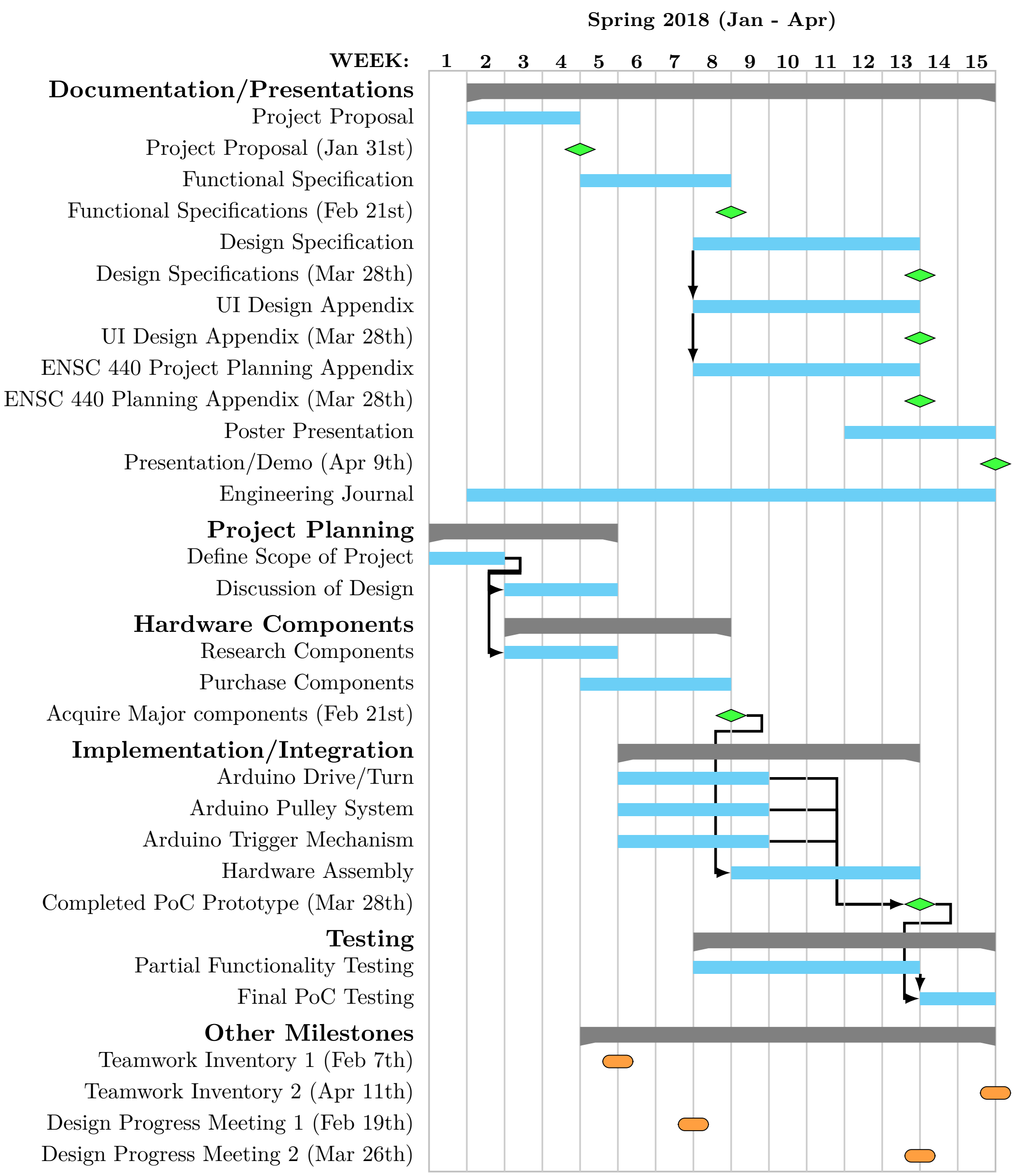

Figure 5.1: Gantt Chart for Project Scheduling With Milestones

6 Company Overview

Formed on Jan. 3^{rd}, 2018, PaintBot Inc. aims to revolutionize the painting industry with its fully automatic prototype, PaintBot. With PaintBot, workers will only prepare the room as usual and with the push of a button the rest of the laborious and repetitive task (painting) will be completed in a fast and efficient manner.

6.1 Meet the Team

Bradley Barber
bradleyb@sfu.ca
Chief Executive Officer

Currently in his 4^{th} year as a Systems Engineering student, Bradley has a passion for developing and contributing to useful and sustainable solutions to everyday problems - whether they be small, quality of life problems or large issues that affect our shared future. Currently, Bradley works as a Software Developer at PHEMI Health Systems, helping develop tools for securing and analyzing big data. Outside of engineering, Bradley also pursues many diverse interests such as film-making, traditional and digital art, and physical wellness.

Lior Bragilevsky
lbragile@sfu.ca
Chief Communications Officer

As a 4^{th} year Electronics Engineering student, Lior is a machine learning enthusiast with interests in mechanical design. For the past 8 months, Lior worked as a research assistant (USRA) at SFU's Multimedia Laboratory, analyzing satellite images using deep learning. In the process, Lior published an article and presented it at the 2017 IEEE Pacific Rim Conference. Additionally, Lior compiled his Undergraduate Thesis document and successfully defended it in the Fall 2017 Semester. Having extensive writing experience, Lior will keep the format & structure of our documents at a high standard.

Hyun Gyu (Billy) Choi
hgchoi@sfu.ca
Chief Product Officer

Billy is a 4^{th} year Systems Engineering student with interests in Android application development. He has completed a full year of co-op in the mobile team of PNI Digital Media as a Quality Assurance Analyst where he took part in testing the photo center applications for Costco and developed a partial test automation script for mobile apps using the JUnit 4 framework and Appium. From the co-op term, he also gained a solid understanding of the agile software development life cycle and knowledge of teamwork.

Ben Korpan
bkorpan@sfu.ca
Chief Technology Officer

Ben is a 4^{th} year Electronics Engineering student whose primary interests are in Processor Architecture and VLSI. He has completed industrial internships at Microsemi and Kardium Inc. Additionally he has worked as an undergraduate researcher in SFU's Reconfigurable Computing Lab, where he designed a Floating-Point Unit for a RISC-V processor. Ben will apply his knowledge of computation and hardware design to ensure that key subsystems of the product function as intended.

Peter Kvac
pkvac@sfu.ca
Chief Operating Officer

Peter is a 4^{th} year Electronics Engineering student coming off an 8 month work term as a Linux Developer at Tantalus Systems Corp. Peter has interests in wrestling, ending world hunger, saving the world's oceans, and Engineering Physics applications.

7 Conclusion

Numerous simple, yet time consuming tasks that were completed manually in the past - such as mass production on assembly lines - are now largely performed by automated technologies. This is of great benefit to companies as it allows increased productivity, reduction of human error, and increased allocation of time for employees to focus on intellectual problems in place of manual labor [7]. The goal of PaintBot Inc. is to extend these advantages to the painting industry by providing a product that would automate the labourious process of painting the interior walls of residential buildings.

To accomplish this task, PaintBot will utilize four 360 degree rotating wheels for smooth and consistent turning upon detection of a nearby wall, a pulley system with an on-board paint gun that will travel vertically for coverage of the wall, and a triggering mechanism for the paint gun that will be in charge of activation/deactivation of the gun itself.

The members of PaintBot Inc. are excited to propose and build an ambitious but practical product for our Capstone project. With limited competition in the current market, we believe our project represents not only a real innovation in how painting companies and contractors can operate, but has the potential to achieve market viability as a product.

We would like to thank Steve Whitmore and Dr. Andrew Rawicz for organizing, running, and overseeing ENSC 405W and, next semester, ENSC 440 - as well as for their support and encouragement in guiding us through this import chapter in our undergraduate careers. We look forward to working with you and learning all we can from your insights and experiences.

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