Design Review 1.1 Documentation

Engineering Senior Design

Engineering and Computer Science Department

Seattle Pacific University

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Design Team: Robo-Medics

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Executive Summary

The Problem

Across the globe, medical facilities are operating to treat people in need everyday. Within each of these medical facilities, there is the possibility of life-threatening human errors. Among these errors are those that involve medication distribution inaccuracies, leading to more than 1,730,000 deaths per year (Institute of Medicine). These medication delivery mistakes are often caused by medical professionals being overworked or distracted by other tasks. While the health care community has made tremendous strides in the function of medical facilities over the last few decades, there is still room for improvement in order to increase efficiency and reduce avoidable mistakes. By addressing the issue of medication delivery errors, nurses and other registered medical professionals will be able to focus their efforts on more critical tasks. Knowing this, the Robo-Medics' primary goal is to reduce dangerous medication distribution errors in medical facilities.

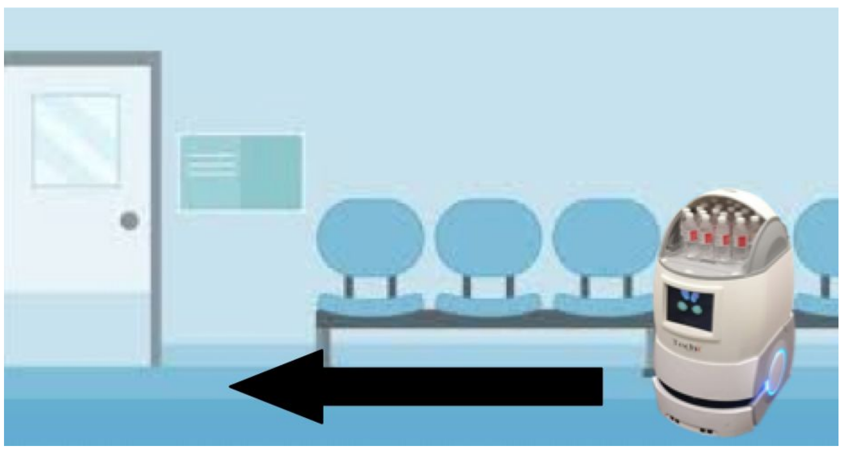
The Solution

To address these recurring issues and project goals, the Robo-Medics are proposing to create a medication delivery robot, which will be able to be employed in various medical facilities, including hospitals, nursing homes, etc. The bot will autonomously navigate to specific room locations and securely deliver various medications to nurses, who will then administer the doses to patients. A basic outline of this approach can be seen in Figure 1.

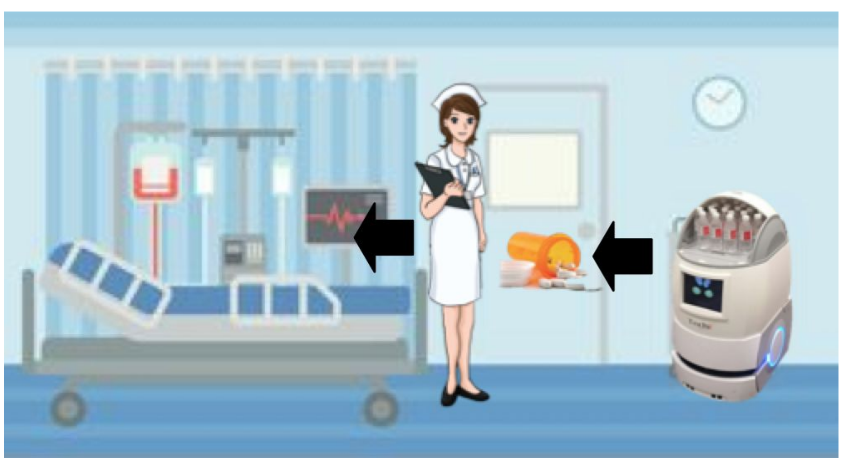
The Process

In designing this delivery bot, the Robo-Medics have determined several high-risk paths that will require significant technical research. Mechanically, the mobilization component of the robot provides the challenge of supporting and stabilizing a given load, while allowing the bot to travel and turn around corners. Electrically, the navigation component of the system will be difficult to design, since it requires wireless communication between a microcontroller and various sensors, both on the body of the robot and along it's designated path. To address these critical paths, the Robo-Medics will design and fabricate two risk reduction prototypes, which will be integrated together in order to test the success of the designs. One of these prototypes is the wheel/base-frame assembly, which houses the motors and controls the bot's mobility. The other prototype involves sensor communication and will demonstrate how the robot will autonomously direct itself into designated rooms on a user-defined schedule.

Step 1: Nurse inputs medications and delivery information into Pill Bot



Step 2: Pill Bot autonomously delivers medications at set times



Step 3: Nurse administers medication to patient

Figure 1: Pill Bot Process

Quad Chart

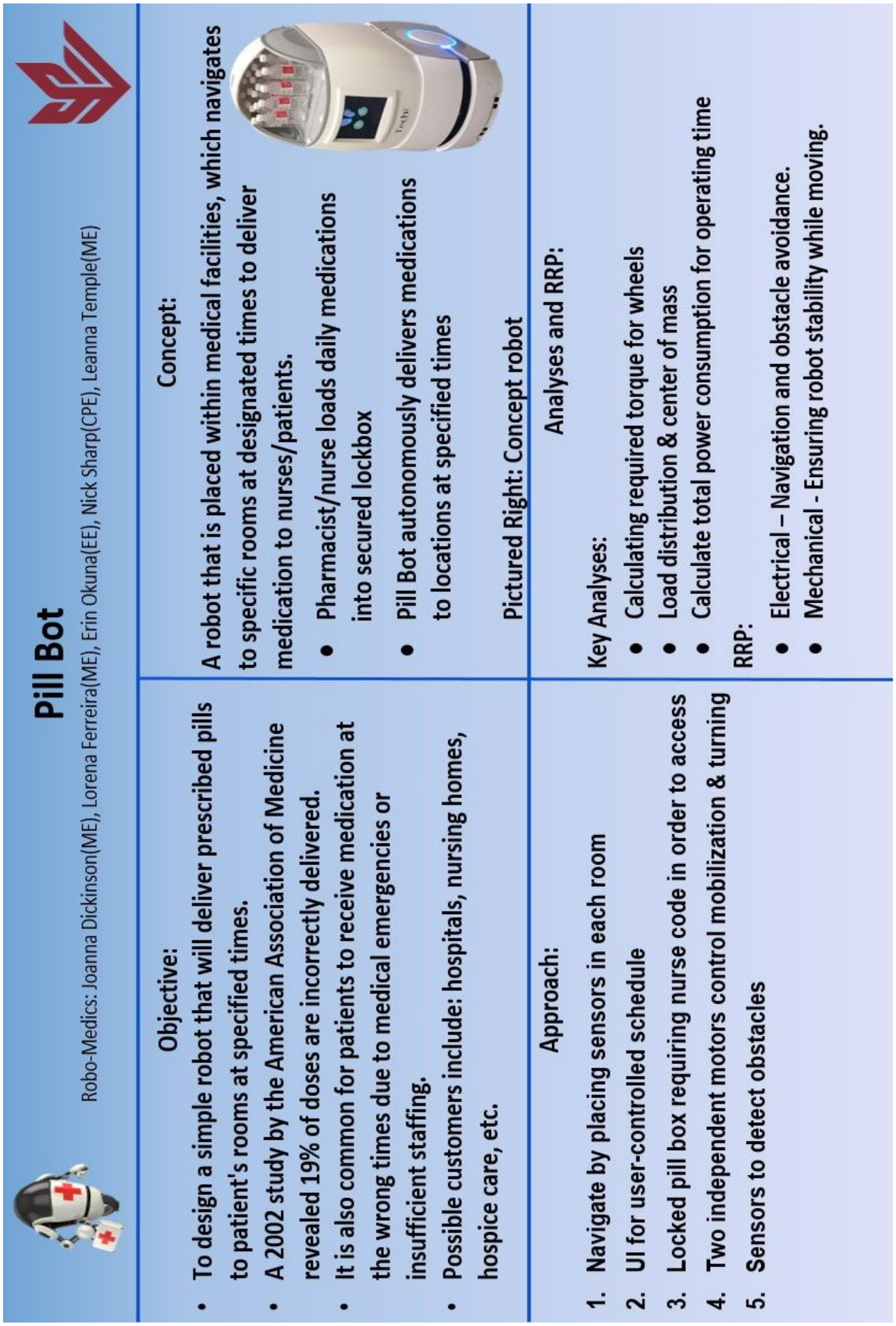


Figure 2: Pill Bot Quad Chart

Introduction and Overview

The **problem space** that the Robo-Medic's have chosen to focus on is the lack of efficiency and accuracy of medication distribution within medical facilities. As detailed in the Research Summary on page 6, a significant number of patients across the US are injured each year due to errors in the medication distribution process. While every workplace is susceptible to human error, the consequences of these errors in medical facilities can be extremely dangerous and/or fatal. Pill Bot aims to reduce the amount of mandatory human interaction in the medication distribution process, ensuring the safety and satisfaction of patients while alleviating medical facility employees of their already strenuous workload.

In creating the Pill Bot, the Robo-Medics have several **goals and objectives** to aim for, which will eventually determine the success of the project. These objectives are summarized in the project Quad Chart (Figure 2). First, the design should aid nurses and medical professionals by reducing the time they spend on counting/sorting/verifying dosages. Secondly, the project should reduce the number of medication distribution errors in a given medical facility by running on a timed schedule and independently.

Research Summary

The health care community was awakened to the issue of preventable medication distribution errors in 1999 when the Institute of Medicine (IOM) released its influential patient safety report, *To Err is Human*. The report provided several heinous statistics, including that as many as 98,000 people die each year in hospitals due to medical errors that are avoidable. Specifically, a more recent 2006 IOM report points out that a shocking number of these errors are drug-related injuries: “400,000 (per year) in hospitals—averaging more than one per day — 800,000 (per year) in long-term care facilities and another 530,000 (per year) among Medicare patients in outpatient clinics” (Institute of Medicine).

The US National Library of Medicine describes several medication administration errors (MAE), such as omissions, deliberate dosage violations, or skill-based errors such as “slips” and “lapses” (Keers). These MAEs include errors involving over-the-counter products, prescription drugs, vitamins, and dietary supplements. A 2002 study of 36 accredited US hospitals, performed by the American Association of Medicine, revealed that the most frequent medication delivery errors by category were wrong time (43%), omission (30%), wrong dose (17%), and unauthorized drugs (4%). The results of this study revealed 19%, or about 1 in every 5 doses, is incorrectly delivered (Barker).

Aside from the obvious medical issues that arise from improper medication delivery, there is also a massive price tag on the loss/misuse of the drugs. They account for at least $3.5 billion in extra medical costs in the hospital setting alone (Orlovsky). The Institute of Medicine has voiced their concern about this issue and continues to advocate for the use of computerized prescribing and delivery systems to reduce the risk of errors relating to handwriting, misinterpretation of dosage, and medication differentiation.

Delivery robots are being produced and employed in big cities across the world including London and Japan, and several thought the US including Dallas, San Francisco, and Washington D.C. Existing bots are being used to roam the streets carrying food orders, groceries, and other online purchases for frontrunner delivery bot companies such as Marble and Starship Technologies (Hunt). However, this technology has yet to be successfully introduced to the medical field in a way that is compact, efficient, and secure. The Pill Bot is intended to address the issues raised by the Institute of Medicine 20 years ago by providing a solution to alleviate medication distribution errors.

Project Summary

Pill Bot will be an autonomous robot that will carry medication to patients' rooms and then be dispensed by a nurse. People die every year because patients receive the wrong medication or the wrong dosage while staying in a medical facility. Some of these problems are caused by insufficient staffing, keeping track of multiple patients, or medical emergencies that nurses have to handle before medication can be distributed. In order to deliver medication both safely and correctly, Pill Bot must be secure, move autonomously, be user friendly, and have object/obstruction detection.

Security will be a high priority since all of the patients' pills for the day will be stored within Pill Bot. With this in mind, Pill Bot needs to be secure enough so that people cannot break into it easily and steal medications. Pill Bot will also need to move autonomously to the patients' rooms on a specified schedule so that the patients never miss their arranged medications. While navigating between locations, object detection will be essential as the robot moves through a busy medical facility. It will need to detect when an object is in its path, then move around it to avoid collisions, and then arrive at the specified room in a timely manner. Lastly, the robot will need to provide a user friendly programming experience, as the nurse will input data once a day. This will include loading the appropriate pills into the robot daily and then loading all important information such as patients' room numbers, time they take the pills, and where their coordinating pills are stored in Pill Bot.

Overall, Pill Bot will be a user-friendly robot that medical professionals can rely on to deliver pills to their patients. If the system is not simple and easy to operate, then programming and set up will consume too much time, negating the time saving aspect of the system. The bot will need medical facility faculty to unlock it with a code, so that the pills and dosage may be verified and administered correctly to the patients. Medical facility faculty also must be in the patient's room to make sure that the medication is delivered accurately, which is why Pill Bot will not administer the medication directly to the patients. The Pill Bot will be successful if it alleviates the workload of medical professionals and reduces the likelihood of medication distribution errors.

System Design/System Block Diagram

The Pill Bot block diagram (Figure 3), shows each component of the autonomous robot, including mechanical and electrical connection paths. Identified in green, the critical paths in the Pill Bot system are those which are expected to require the highest level of research and skill to successfully design and fabricate. The mechanical critical path involves the base frame, drive motors and wheels of the robot, which combined, provide the system with mobility and stability. This base will support the load of all of the Pill Bot's components and will allow the system to physically move around medical facilities. The electrical critical path focuses on navigation and communication between the Pill Bot's sensors and the PSoC 6 microcontrollers. Wireless navigation is an essential part of Pill Bot system, allowing for autonomous delivery.

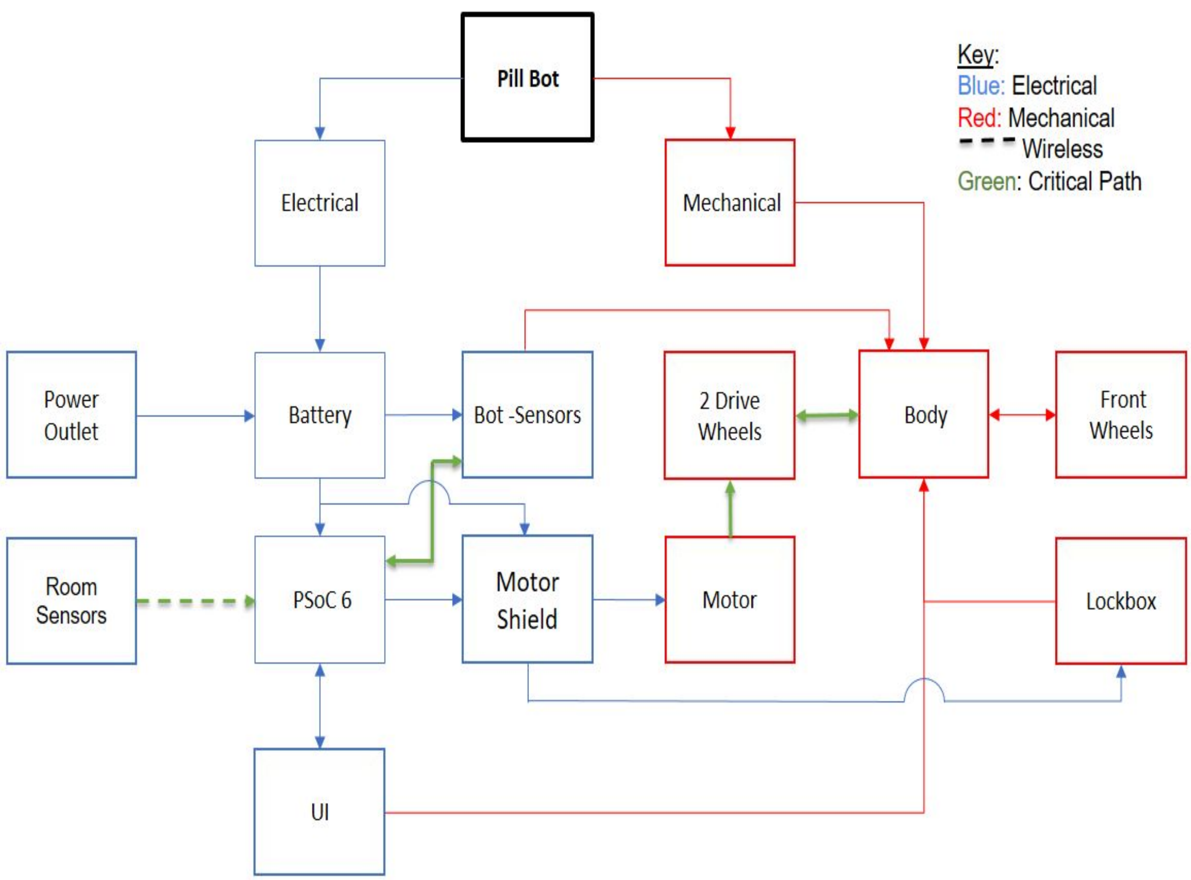


Figure 3: Pill Bot Block Diagram

Engineering Analysis List

Engineering analysis is an essential part in predicting if a project can succeed, and for reducing risk. Below is the dependency-ordered list of electrical and mechanical analyses which the Robo-Medics have determined to be fundamental in designing an effective Pill Bot system.

- Structural – Build a rough CAD model with estimated loads and apply Finite Element Analysis to determine what kind of stresses can be applied to the bot before failure.
- Center of Mass – Determine the system's center of mass to determine the stability when turning around 90 degree corners.
- Stability – Use the center of mass to determine the stability of the bot as it turns around corners.
- Torque – Compute the torque required to turn the wheels under the given mechanical load.
- Motor Power – Find out how much power will be required to move the robot at a speed of approximately 1 ft/s with at least 45 lbs.
- Current Drawn – Determine the amperages to be provided by the power source so that components work at their desired performance.
- Power Consumption – Compute how much power each component will draw over a twelve-hour time span in delivery mode and over a nine-hour time span in sleep mode to determine minimum reasonable wattage to be provided by the power source.
- Heat Transfer – Determine how much heat all of the electrical components will output in the confined space and calculate heat loss out of the box to the environment to ensure that the medication is properly insulated and not harmed during travel.

Risk Reduction Prototype Specs

To evaluate the Risk Reduction Prototypes (RRPs) the Robo-Medics will assess a set of specifications which have been defined below and in Table 1.

Mechanical Specifications

M001: Translational Movement: **The system shall be able to move forward and backward in a straight line for at least 30 feet. The system should be able to move forward and backward in a straight line for at least 100 feet.** In order not to run into obstacles or veer away from a designated path, the robot must be able to travel on a direct path once it is oriented in the desired direction. This can be verified using a physical test by measuring how far the robot strays from a straight-line path of a given length.

M002: Speed**: The system shall be able to travel at a velocity of at least 1 ft/s. The system should be able to travel at a velocity of at least 2 ft/s.** To prevent running into obstacles, heighten stability of the system, and deliver medications in a timely manner, the robot must be able to travel at a reasonable speed. The reasonable speed of 1 ft/s was determined by experimentally timing travel over a distance of 20 ft. The system's speed can be verified by measuring the time the robot takes to travel a determined distance once the robot has reached a constant speed.

M003: Turning Radius**: The system shall have a minimum turning radius of 3.5 ft while traveling at approximately 1 ft/s. The system should have a have a minimum turning radius of 1 ft while traveling at approximately 1 ft/s.** The robot will need to turn around corners and into rooms in order to deliver the medications properly. Assuming that an average hallway is 3.5 ft wide, that dimension is the minimum turning radius the robot must be able to satisfy. Ideally, the robot would be able to function with a near zero turning radius, pivoting around a central point. This can be verified by programming the robot to turn as sharply as possible and measuring the radius of the circle it follows.

M004: Stability: **The system, moving and turning at 1 ft/s, shall support a load of at least 45 lbs without tipping. The system, moving and turning at 1 ft/s, should support a load of at least 65 lbs without tipping.** The system will need to hold up and still have the ability to move from room to room to deliver medications. The robot will consist of at least one battery, which is estimated to weigh 10 lbs, and other metal components for security and durability. With the durable materials, the estimated weight of the empty robot is to be 35 lbs. This leaves 10 lbs of space for medications and UI. Before being built, stability can be calculated by finding the center of mass. After construction, weights will be added to the finished system and observed to see whether or not the system can still move.

Electrical Specifications

E001: Navigation Efficiency: **The system shall reach its destination within a maximum of five minutes off of its programmed schedule. They system should only ever be a maximum of two minutes off of its programmed schedule.** The system will need to be able to navigate itself to a room at a specific time. This means that it needs to move efficiently.

E002: Object Detection: **The system shall have a minimum obstruction detection radius of six inches. The system should have a minimum obstruction detection radius of twenty-four inches.** The system will need to detect if an object is in its path, to ensure both that the robot will be able to continue following its path according to its given schedule and that the robot does not injure anyone in the event that the object happens to be a person. Six inches would allow enough room for the robot to decelerate to a stop before colliding with any blockage. An ideal two feet would allow distance and time for an alarm-equipped system both to decelerate and to alarm bystanders of any blockage. Detection radius will be measured by ensuring that the sonar sensor be held up with nothing in front of it and then moving a hand from far away, closing in towards the sensor and documenting at what distance the object had been detected.

Table 1: Mechanical and Electrical RRP Specifications

Spec ID	Requirement	Threshold (Shall)	Objective (Should)	Validation Method	Notes
M001	Movement	Move in a straight Line for at least 30 ft	Move in a straight Line for at least 100 ft	Deviation distance measured from known straight line	
M002	Speed	Travel at least 1 ft/s	Travel at least 2 ft/s	Measure speed of robot and verify it meets required speed	
M003	Turning Radius	$R < 3.5$ ft	$R < 1$ ft	Measure R of tightest possible circle that the bot can make	
M004	Stability	Support at least 45 lbs without tipping	Support at least 65 lbs without tipping	Load with specific weight and observe movement	
E001	Schedule	Enter a room within five minutes of the schedule	Enter a room within two minutes of the schedule	Time when it gets to a specified room and compare that to when it is supposed to be there	
E002	Object Detection	$D \geq 6$ in.	$D \geq 24$ in.	Minimum distance at which the bot will detect an object in front of it	

Risk Reduction Prototype Description

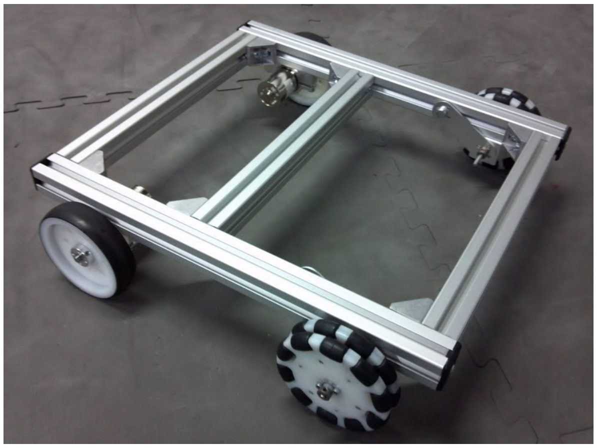


Figure 4: Mechanical RRP - Wheel/Base Frame

Figure 5: Electrical RRP - RFID Tag

Mechanical

The Robo-Medics intend on designing, manufacturing, and testing an autonomous wheel/base-frame system by the end of Fall Quarter. The prototype should be able to move at a speed of 1 ft/s and turn around tight corners without tipping or colliding with nearby objects. The prototype will be controlled by a PSoC microcontroller. Figure 4 is an example of the intended design for the finished mechanical Risk Reduction Prototype. The materials listed in Table 2 will be used to manufacture and construct the designed prototype as detailed in the mechanical block diagram (Figure 6).

Electrical

At the end of Fall Quarter, the Robo-Medics also plan on designing, creating, and testing the sensor based autonomous system. This means the robot prototype will be able to take input from the sensors both in the robot's environment and on the robot, process it, and use it to get to the robot's destination on time. This means that a floor plan that the Pill Bot will follow will need to be designed and programmed into the robot. This will be done using an array of sensors including sonar, RFID as in Figure 5, and an RPM sensor to measure distance. Once all of this data is taken, the PSoC will need firmware to guide the robot to its intended location on time without running into obstructions. The list of materials in Table 2 details the components that will be incorporated into this autonomous part of the system, which will then later be integrated into the mechanical housing as pictured in Figure 7.

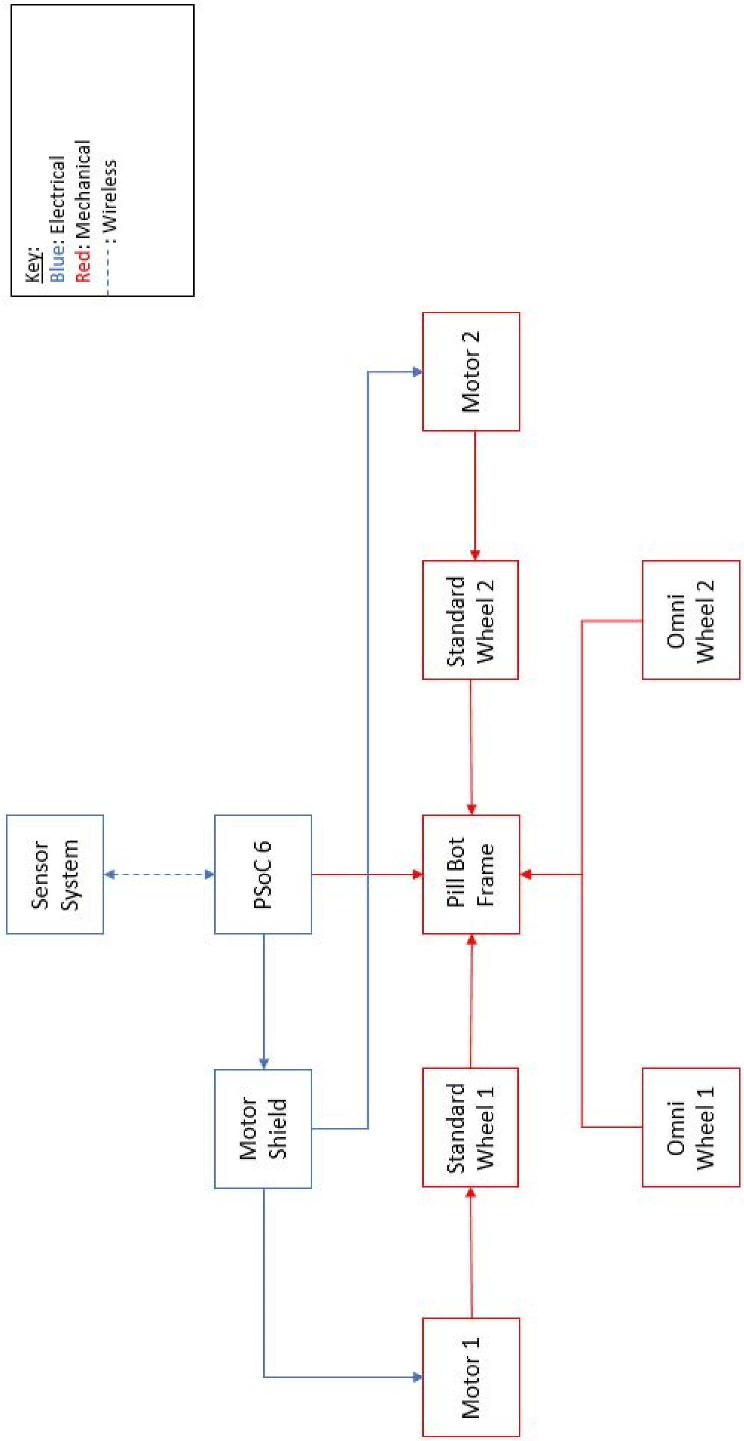


Figure 6: Mechanical RRP Block Diagram

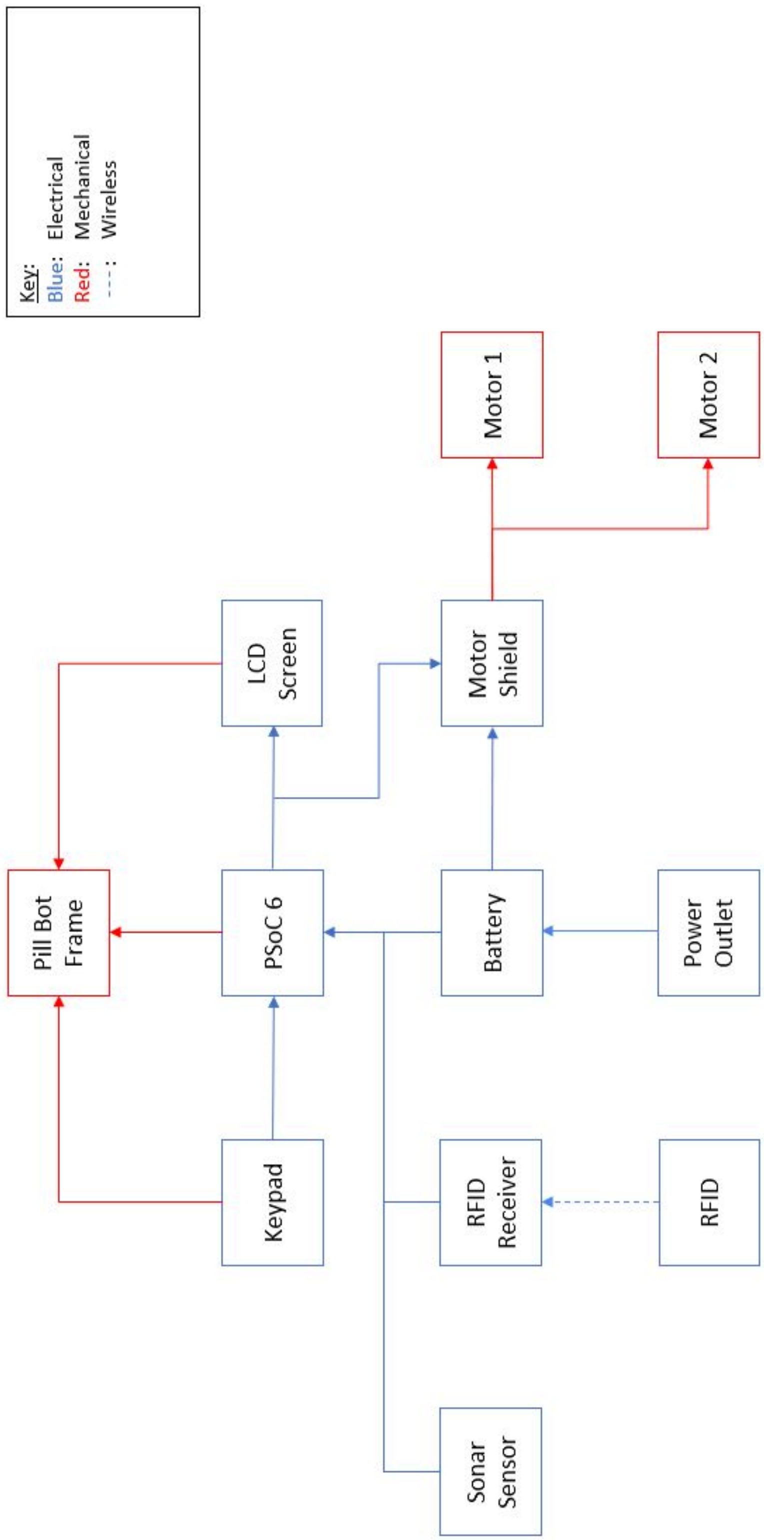


Figure 7: Electrical RRP Block Diagram

Bill of Materials

Table 2: Bill of Materials

Item	Description	Quantity	Price ($US)	Vendor
Omni Wheels	4" Omni-Directional Wheel	2	$47.60	VEXROBOTICS
Aluminum Plate	1' x 1'x 0.25" Aluminum Plate	4	$15.70	Buymetal
Traction Wheels	4" Traction Wheels & Tread	2	$15.12	VEXROBOTICS
DC Motors	Brushless Gear Motors	2	$46.98	RobotShop
Lock Motor	Stepper motor with cable	1	$28.85	Karlsso robotics
Microcontroller	PSoC 6 Stamp Board	1	$10	Cypress
MOSFET	MOSFET	3	$1.54	Mouser
User Interface	3.5" LCD Screen	1	$12.99	Newegg
Circuit board	3x5 PCB	1	$5.99	Amazon
Motor sensor	Low RPM sensor	2	$13.75	Hobbyking
Reciever	RFID Reciever	1	$3.89	GearBest
Obstruction Detection	Sonar Sensor	1	$4.49	Vetco
Connecting Wired	28ga Wire	1 meter	$0.50	Amazon
User Interface	Ten Digit Keypad	1	$4.59	Newegg
Power	Eight Amp hour Battery	1	$20.99	Amazon
Charger	Charger	1	$9.87	Amazon
Resistors	Various Resistors	Assorted	$12.99	Amazon
Circuit protection	Diodes	4	$0.80	Amazon
Total Cost			$256.64	

Code Summary

Firmware for the PSoC will need to be developed to control the system. The firmware will include an internal map of the medical facility along which the robot will travel by default, a calculator that will process data gathered from the bot's location to orient itself on the map, and a set of instructions of how to reposition itself from its current location back on to its default path: The firmware will receive information from RFID sensors installed into the environment, which will indicate reference points where the bot will be able to relocate itself onto its internal map in case of deviation. Equipped with a frontal sonar sensor, the system will be able to detect obstructions in its path. Once a blockade has been recognized, the firmware will process the need to maneuver around it. The firmware instructions will then drive the robot around the obstruction and back onto its default route.

Detailed Schedule

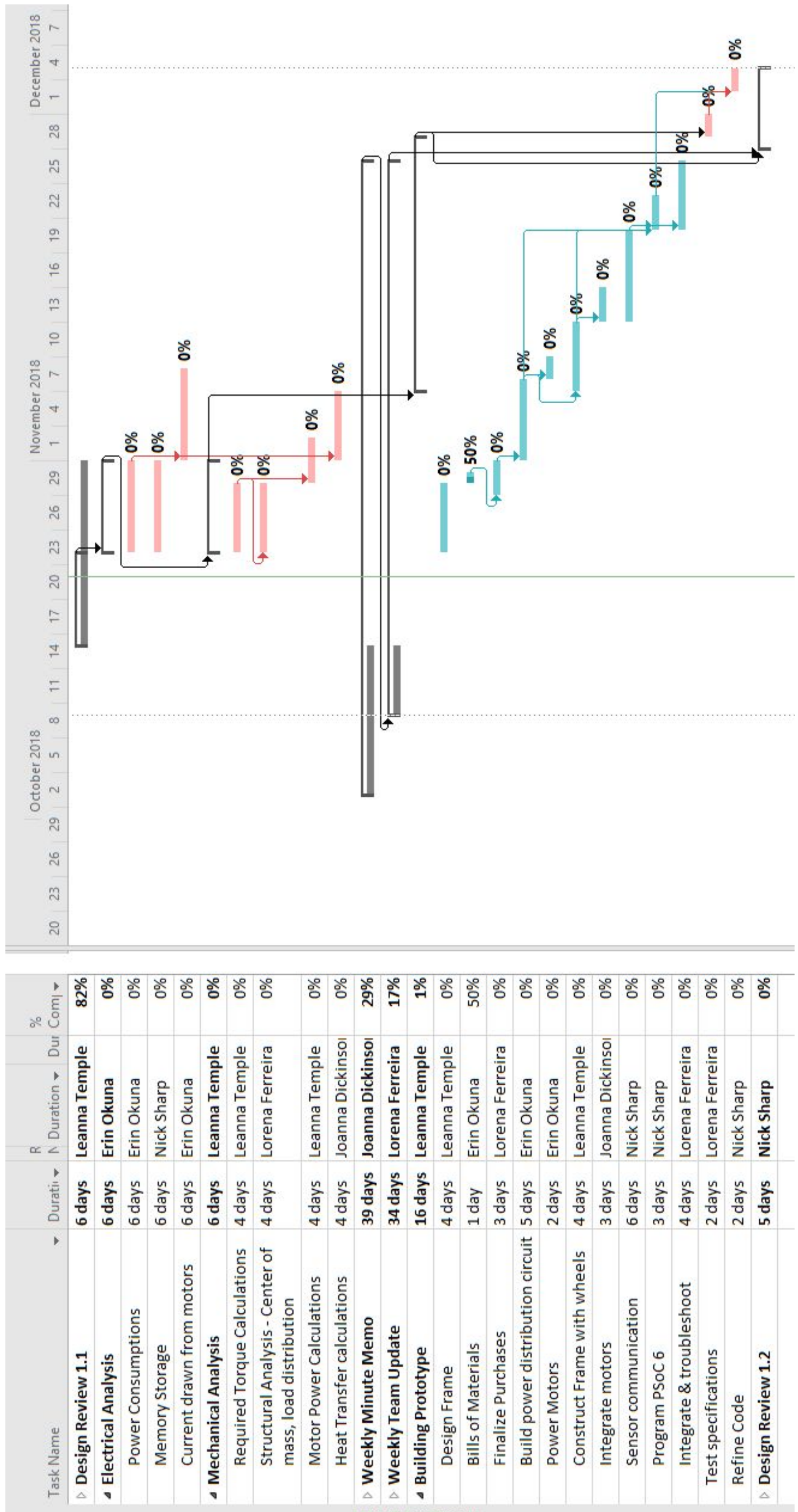


Figure 8: Robo-Medics' Autumn 2018 Schedule

Schedule Discussion

In regards to the above planned schedule for the design and construction of the Pill Bot (Figure 8), the Robo-Medics have identified several major concerns. Firstly, the design team recognizes that researching all of the required information and coding skills in order to program the robot may be time consuming and is necessary in order to begin the electrical RRP. The second major concern is finding, ordering, and receiving the correct materials with enough time to fabricate the prototypes. Lastly, because the mechanical and electrical RRPs are dependent on one another, the Robo-Medics are concerned about how they will integrate and troubleshoot the independent designs.

To cut down on how much time the research and coding will take, different tasks will be split up between the EE and CPE team members in order efficiently divide the amount of research and programming between the two. If parts do not arrive as planned, the schedule could be significantly impacted. To counter this, the Robo-Medics plan to purchase materials and necessary supplies as early as possible.

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Appendix

Our Vision

A world where today's best healthcare is inspired by tomorrow's best technology.

Our Mission

To create an environment where nurses can focus on caring for patients without worrying about timely and tedious medication delivery details.

Our Team

Joanna Dickinson

Robo-Medics' Recorder
Seattle Pacific University, Seattle, WA
BS Mechanical Engineering, 2019

Joanna previously worked at Rockwell Collins in Everett, Washington as a Program Management Intern during the Summer of 2018, and as a Mechanical Engineering Intern during the Summer of 2017. Prior to this, she also worked at B/E Aerospace as a Technical Aide during the Summer of 2016 where she gained material testing knowledge. With prior work experience, she is interested in continuing expanding her knowledge and research in the aerospace field.

Ms. Dickinson is a member of ASME and Women in Science and Engineering Club at SPU.

Lorena Ferreira

Robo-Medics' Coordinator
Seattle Pacific University , Seattle, WA
BS Mechanical Engineering, 2019

Lorena previously worked at Kenworth Truck Company in Kirkland, Washington as a Mechanical Design Engineering Intern during the summer of 2018. Lorena currently works as a learning assistant for experimental methods (PHY3311) at Seattle Pacific University. After graduation she is interested in further her career in the transportation industry, and later research the use of nanotechnology in the medical field.

Ms. Ferreira is a member of ASME, Woman in Science and Engineering Club at SPU, and was previously a member of the rear team for SPU Falcon Racing Baja SAE.

Erin Okuna

Robo-Medics' Financial Bookkeeper
Seattle Pacific University, Seattle, WA
BS Electrical Engineering, 2019

Erin previously worked at Aviation Technical Services in Everett, Washington in repairs as an Electrical Engineering Intern during the summer of 2018. The previous summer, she also interned at InSynergy Engineering, Inc. in Honolulu, Hawaii and, from 2015-2016, held the position of Summer Hire at Consulting Structural Hawaii in Wahiawa, Hawaii. After working in the industry, she is interested in pursuing a career in electrical consulting and sustainable engineering.

Ms. Okuna is a member of ECS, SPU's Women in Science and Engineering Club, and previously a member of SPU's Falcon Racing Baja SAE.

Nick Sharp
Robo-Medics' Requisitioner
Seattle Pacific University, Seattle, WA
BS Computer Engineering, 2019

Nick is an employee at Cypress Semiconductors in the applications department as an intern in Lynnwood, Washington. Before working at Cypress he did data entry at Portfolio Strategies in Tacoma, Washington. He has been interested in engineering since a young age, building his first computer at age seven, and then building his first of many go-karts at age twelve. After graduating he plans on pursuing a full time job at Cypress and continuing his education with embedded systems.

Mr. Sharp is a member of ECS.

Leanna Temple
Robo-Medics' Facilitator
Seattle Pacific University, Seattle, WA
BS Mechanical Engineering, 2019

Leanna is currently employed at the City of Bellevue in the Utilities Department as a Planning Engineer Intern in Bellevue, Washington. Prior to working in Bellevue, she worked as a Robotics Specialist at Chestnut Lake Camp as well as a Physics Learning Assistant at Seattle Pacific University. She is interested in continuing her research in robotics and hopes to soon extend her knowledge to the fields of aerospace and aeronautics.

Ms. Temple is a member of ASME, National Collegiate Honors Society, and the Women in Science and Engineering Club at SPU.

Team Contract

Robo-Medics

A. **Commitments**:

As a project team we will:

1. See the project through to completion.
2. Complete assignments on time.
3. Communicate effectively.
4. Give 100%.
5. Respect all team members.

B. **Team Meeting Ground Rules: Participation**

We will:

1. Be open to new approaches and listen to new ideas.
2. Avoid placing blame when things go wrong. Instead, we will discuss the process and explore how it can be improved.
3. Adhere to meeting agenda.
4. Come prepared to meeting.
5. Show up on time.

C. Team Meeting Ground Rules: Communication

We will:

1. Seek first to understand, and then to be understood.
2. Not interrupt. Instead, we will listen to our teammates, all the way through.
3. Inform team prior to meeting/deadlines on schedule and attendance.

D. Team Meeting Ground Rules: Problem Solving

We will:

1. Encourage everyone to participate.
2. Promote each other's skills.
3. Utilize appropriate confrontation.

E. Team Meeting Ground Rules: Decision Making

We will:

1. Get input from the entire team before a decision is made.
2. Discuss concerns with team members during team meetings or privately, rather than with non-team members in inappropriate ways.
3. Pass a decision if 4/5 members agree.

F. Team Meeting Ground Rules: Handling Conflict

We will:

1. Choose an appropriate time and place to discuss and explore the conflict.
2. Listen openly to other points of view.
3. State our opinions/perspectives in a non-judgmental and non-offensive manner.
4. Utilize appropriate confrontation.

G. Meeting Guidelines:

1. Regular meetings will be held at least once a week
2. Meetings can be called by anyone on the team.
3. Any schedule will be rescheduled if less than 4/5 members can attend.

H. Meeting Procedures:

1. Meetings will begin and end on time.
2. Meetings will be recorded using the memorandum format provided
3. Team members will come to meetings prepared.
4. Team members will open meetings with individual updates.
5. Team members will conclude meetings with defined expectations/action items.

AGREED TO: The above contract

NAME: Joanna Dickinson
DATE: 10/3/18

NAME: Lorena Ferreira
Date: 10/3/18

NAME: Erin Okuna
Date: 10/3/18

NAME: Nick Sharp
Date: 10/3/18

NAME: Leanna Temple
Date: 10/3/18