Senior Design 2018/2019

Maroon Five

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Design Review 1.1 Documentation - Revised

11/19/18

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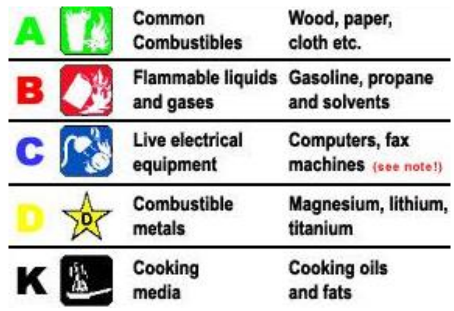
Executive Summary

Research shows that employees and machinery in an industrial environment may not be sufficiently protected from machine fires. In industrial and manufacturing environments an average of 37,000 fires occur each year. This amounts to $1 billion in property damage and hundreds of injuries [1]. Even though machines are designed with the highest safety standards, the materials they work with may be susceptible to fires. Fires can also start due to tool failures, programming mistakes for CNC machines and more [2]. These types of fires wouldn't be a problem if there was a person assigned to watch running machines, but this is not always possible, and also a large cost. For this project, type A, B, and C fires will be considered. Class D fires - combustible metals, are not currently a concern. Magnesium, Lithium, and Titanium are not used often enough in small machine shops to be considered a fire safety concern. Through professional consultation it was also determined that Class D fires are not an issue in small machine shop areas.

One such possible solution to increase fire safety is an X-Y ceiling gantry system with an integrated fire extinguisher. This system would automatically detect fires using sensors integrated with a microprocessor. The system would move the extinguisher to the location of the fire and suppress the fire automatically, eliminating the need for a designated fire-watcher, and decreasing damage that would normally be caused by sprinkler systems. This system would be mounted to the existing ceiling infrastructure and use sensors on the system and placed around the shop area to detect fires (Fig. 2).

The highest risks in this solution are the accurate detection of the fire, and the successful movement of the extinguishing housing to the area of the fire. The analyses that will be done to mitigate the overall risks of the sensors and the sensing system will include safety and sensitivity of the sensors analyses. There need to be sensors not only to detect and locate a fire, but also to detect if there are obstacles or people in the area of the fire. Research will be conducted on sensors to determine which sensors will most accurately and precisely detect the presence and location of a fire. For successful movement in x and y directions there must be analyses conducted to determine translational to rotational movement, and structural rigidity of the gantry system.

To demonstrate the feasibility of this solution, two risk reduction prototypes will be built, one for sensing and one for moving. A four foot by four foot stable two axis rail system mounted on ceiling supports will be constructed to successfully move in both X and Y directions. A combination of infrared, ultraviolet, thermal, and smoke sensors will be integrated with a microcontroller and programmed to successfully detect a fire. These prototypes will show that it is possible to build the full system to detect, locate, and extinguish a fire.



A	Common Combustibles	Wood, paper, cloth etc.
B	Flammable liquids and gases	Gasoline, propane and solvents
C	Live electrical equipment	Computers, fax machines (see note!)
D	Combustible metals	Magnesium, lithium, titanium
K	Cooking media	Cooking oils and fats

Figure 1: Classes of Fires[1]

Figure 2: Prototype Model[8]

Quad Chart

Autonomous Fire Extinguisher: Drop it Like its Hot

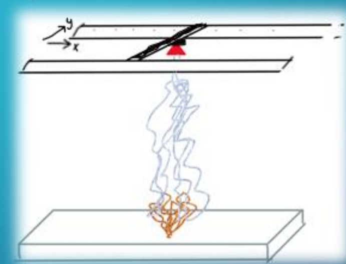
Team: Maroon Five   Anas Alhamad (EE), Arik Espineli (ME), Jasmine Gill (EE), Jeff Smith (ME), Miranda Sweigert (ME)

Objective

- Increase fire safety and decrease production downtime in an industrial/shop environment
- Our goal is to improve on current fire sensing/sprinkling systems
- Current research shows undetected machine fires can spread quickly, even compromising building structures and endangering lives
- The average manufacturer has up to 800 hours of total downtime per year, which can cost an automotive manufacturer up to $22,000 per minute

Concept

Autonomous fire extinguisher that moves on an X-Y ceiling track and successfully detects fires and actuates an extinguisher



Approach

- Integrate UV, IR, and smoke sensors with a microcontroller to cohesively detect and locate fires
- Design and test a ceiling gantry system that can be adapted to existing ceiling infrastructure
- Design a housing for a fire extinguisher to be the trolley of the gantry system that is programmed to move to the detected fire location when fire is detected
- Design and test an actuation system for the extinguisher when it reaches the fire location

Analysis and RRP

Analyses:

Power Consumption, Navigation Accuracy, Structural Strength, Motor Power

RRP:

~ ¼ scale model

- 2 foot by 2 foot range of motion in X and Y directions (plan to reach 10ft by 3ft range)
- Fire sensors at 90% recognition accuracy (with plan to reach 99%)

Introduction and Overview

In industrial and manufacturing environments, there are often machines that require long hours of operation, often manned with a designated fire watcher. Sometimes, these types of machines are not monitored, which can lead to fires that not only damage equipment, but can also quickly spread through an entire building and endanger the lives of people. In industrial and manufacturing environments an average of 37,000 fires occur each year [1]. This amounts to $1 billion in property damage and hundreds of injuries [1].

In order to create a safer environment, and save money in an industrial setting, the proposed project plan is to create an autonomous overhead fire extinguisher. This system will be a great improvement to current sprinkler/fire monitoring systems, and it would increase safety by reducing human responsibility and increasing fire sensing capacity. There are many similar fire extinguishing systems on the market for various environments [4], but none of them are made to protect more than one industrial machine at a time [5]. This fire extinguisher system will also eliminate the need for a human to stand on fire watch, saving more money in the long-term. This system will be a ceiling gantry system with a fire extinguisher carried on the trolley of the gantry. The autonomous fire extinguisher will move on an X-Y ceiling track and successfully detect fires and actuate an extinguisher.

To create this system, a variety of sensors will be utilized to successfully detect and locate a fire. A ceiling gantry system that can be adapted to an existing ceiling infrastructure will also be designed. On the gantry system there will be housing for a fire extinguisher to be carried on the trolley of the gantry system. The sensors will be integrated into the final gantry system and be programmed to move to the detected fire location when a fire is successfully detected. A system to actuate the fire extinguisher when in the appropriate location will also be designed.

Research Summary

Research shows that employees and machinery in an industrial environment may not be sufficiently protected from machine fires. In industrial and manufacturing environments an average of 37,000 fires occur each year [1]. This amounts to $1 billion in property damage and hundreds of injuries [1]. Even though machines are designed with the highest safety standards, the materials they work with may be susceptible to fires. Fires can also start due to tool failures, programming mistakes for CNC machines and more [2]. These types of fires wouldn't be a problem if there were someone attending to each machine while they are running, but this is not always possible. Class D fires - combustible metals, are not currently a concern as A, B, and C fires are. Magnesium, Lithium, and Titanium are not used often enough in small machine shops to be considered a fire safety concern. Through professional consultation it was also determined that Class D fires are not an issue in machine shop areas.

Shop employees or managers may feel that the overhead sprinkler systems recommended by the National Fire Protection Association (NFPA) are enough to protect the workers and the environment and thus elect to leave active machines unattended. In the event of a fire the sprinkler system will suppress the fire, but in doing so it will cause damage to the surrounding machinery [2]. The damage caused by the sprinkler system may end up exceeding the damage that the fire would have caused depending on the numbers of sprinklers that were triggered.

To combat this problem shop owners have started to utilize supplementary fire suppression systems. These systems are designed as one-time fire suppressants for the specific machine that they are mounted near or above each machine. One such system is the OPW automatic fire extinguisher system [3]. It is made to suppress fuel fires if the temperature reaches 175°F and must be replaced after it has been triggered. There are many similar fire extinguishing systems on the market for various environments [4], but none of them are made to protect more than one industrial machine at a time [5].

Upon further research it was found that there aren't any autonomous fire suppression systems similar to our proposal on the market. There are student designs for robotic solutions that detect a fire and move a robot on the ground towards it [7]. Maroon Five's proposed design will be able to fulfill the need for a secondary fire suppression system that will help prevent employee injury and reduce monetary damage.

Project Summary

The goal of this project is to create an overhead autonomous fire extinguishing system that can be used in a wide variety of applications from small machine shops to industrial factories. The critical features are sensing the fire, moving to the fire, and extinguishing the fire. The sensors will successfully detect the fire, then locate the fire. Then the trolley of the gantry, which carries the extinguisher, will be moved to the location of the fire, and then the extinguishing system will be triggered to put out the fire. The device will also be able to be attached to existing ceiling infrastructure without causing damage to the surrounding environment. The design will be completely autonomous as well as safe to have installed in places around people and heavy machinery.

System Design / System Block Diagram

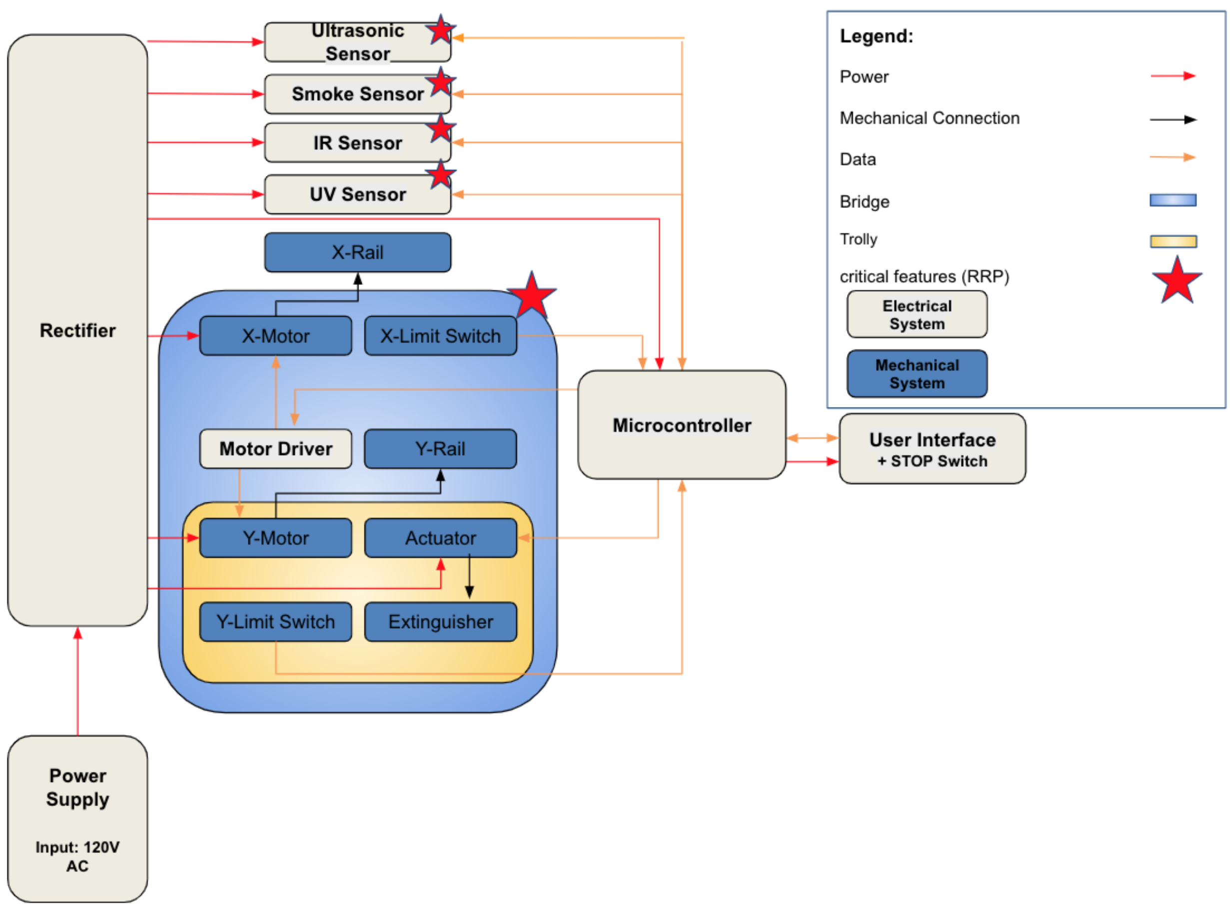


Figure 3

<u>Engineering Analysis List</u>

Engineering Analysis List & Descriptions: Electrical

- **Power Consumption -** Compute max power supply for each component and find the sum.
- **Movement Speed -** Find the required movement speed for the equipment to get to the fire on time but not fast enough so that when the motor is turned off the system moves past the fire.
- **Fire Detection -** Research the type and size of fire that we'll be trying to suppress and the sensors that will be used to detect that fire.
- **Sensitivity of Sensors -** Determine the range that the sensors will be able to detect the fire from.
- **Safety -** How to detect if there are obstacles or people in the area where the fire suppression system will be deployed.

Engineering Analysis List & Descriptions: Mechanical

- **Structural Strength -** Analyze the strength and rigidity of the rail system and extinguisher housing to ensure that it will be safe to have this system hanging above machinery.
- **Extinguisher Actuation -** Analyze most efficient and safe method for squeezing the fire extinguisher autonomously and determine what this system will look like. We will do this by creating candidate solutions and utilizing design matrices to compare solutions.
- **Motor Distance -** Determine how many steps in stepper motor are required for how much x or y movement
- **Motor Power -** Calculate the amount of power for the motors controlling the movement and select motors.
- **System Dynamics -** Evaluate the equation of motion of the trolley
- **Fire Safety -** Calculate the heat transfer within the electronics housing to ensure system does not overheat

Risk Reduction Prototype Specifications

D001: Fire Recognition - Timing: **The system shall be able to recognize when a fire occurs within 90 seconds. The system should be able to recognize when a fire occurs within 60 seconds.** The sensors will be able to detect when a fire occurs in the room. Ninety seconds has been determined to be sufficient for our RRP response time. This will be validated by using a timer that will record how long it took for the system to detect the fire within ignition.

D002: Fire Recognition - Size: **The system shall be able to recognize a fire that is 8 inches in diameter. The system should be able to recognize a fire that is 6 inches in diameter.** The system should be able to detect a wide range of fire sizes, the smallest of which is a six-inch fire. This size was chosen because the size of a welding & plasma cutter flames can range from one to six inches. The size of the flame for testing will be validated by building the fire on a measured piece of equipment.

D003: Fire Recognition - Accuracy: **The system shall accurately detect a fire 7 out of 10 times. The system should accurately detect a fire 9 out of 10 time.** The accuracy of detection makes the system more reliable. This will be validated by testing the system repeatedly and recording results.

M001: Middle Bar Movement - the middle bar of the 'H', or gantry, shall successfully move in the y axis between the other two beams. **The beam shall cover 3 total feet in the y direction, 1.5 feet in positive and negative directions**. **The beam should cover 4 total feet, 2 feet in positive and negative y directions.** Current plans are that 2 feet is expected to be sufficient to show movement is possible to reach the location of the fire, this means a 16 square foot area. This size has been determined based on equipment located in the Seattle Pacific University Machine Shop. This will be tested by measuring the full range of motion of the axis and compare it to the actual size.

M002: Extinguisher Movement - the extinguisher housing will move along the rail system successfully in the x direction. **The housing shall cover 3 total feet in the x direction, 1.5 feet in positive and negative directions**. **The housing should cover 4 total feet, 2 feet in positive and negative x directions.** Current plans are that 2 feet is expected to be sufficient to prove movement and reach the location of the fire. This will be sufficient within the given area, see M001. This will be verified by measuring the full range of motion of the axis and compare it to the actual size.

M003: System Movement - the extinguisher housing will move to a specified position in the room. **The housing shall move within a 1-foot radius of specified location and should move within a 0.5-foot radius of specified location.** The fire extinguisher will be most effective with a sweeping motion. If the trolley is located within this range the extinguisher will be able to suppress our target fire size, see D002. This will be verified by inputting a desired location and physically measuring the actual position and compare it to the desired location.

M004: Bridge Speed of Movement - **The motor required for the movement of the bridge in the x-direction shall supply a torque that provides a speed of 4 feet per second, and should supply a torque that provides a speed of 8 feet per second**. This was determined by measuring the average speed of human response to a fire and how long it would take to obtain an extinguisher and extinguish a fire. This took an average of 20 seconds to move 20 foot, which is a speed of 1 foot per second. Our system must be faster than human response. This will be validated by making the motor move the bridge a specified distance and recording the time.

P001: **The power needed for all components shall not be greater than 15 Amps and should not be greater than 12 Amps**. The device needs to adhere to code standards and easily be utilized in a standard outlet. At 110 volts in a standard outlet, the power supply should not be higher than 15 Amps.

<u>Table 1: Specifications</u> - Overview of Specifications, Thresholds and Objectives, and Validation Methods

Spec ID	Requirement	Threshold (Shall)	Objective (Should)	Validation Method	Notes
D001	Fire Recognition - Timing	Recognize fire within 90 seconds	Recognize fire within 60 seconds	Testing with different fire scenarios and sensors in a controlled area.	
D002	Fire Recognition - Size	Recognize a fire that is 8 inches in diameter	Recognize a fire that is 6 inches in diameter	Testing with small fires that are built and see if small or larger fires are detected.	
D003	Fire Recognition - Accuracy	Recognize a fire accurately 7/10 times	Recognize a fire accurately 9/10 times	Test the system repeatedly in the scenarios described in the other specs.	
M001	Middle Bar (y) Movement	Move 1 foot in positive and negative y	Move 2 feet in positive and negative y.	Measure the total distance between the beams and compare the total range of the extinguishing housing.	
M002	Extinguisher (x) Movement	Move 1 foot in positive and negative x	Move 2 feet in positive and negative x	Measure the total distance between the beams and compare the total range of the extinguishing housing.	
M003	Housing Movement	Move to within a 1-foot radius of fire location	Move to within 0.5-foot radius of fire location	Prescribe a desired location and measure how close to the nozzle of the extinguisher is to the point	Sweeping motion will cover fires of specified size (D002) if within that range

M004	Bridge Motor Speed	Shall move the bridge at 4 feet per second	Should move the bridge at 8 feet per second	Recording the time it takes to move to specified distances	
P001	Power Supply	≤15A	≤12A	Measuring supplied current with Ammeter	

Risk Reduction Prototype Description

Electrical: Detect Type A, B & C Fires

For this project to work the sensors used need to detect type A, B & C fires.
For the RRP Maroon Five Engineering will be researching the best sensors to use to accurately detect a fire. Maroon Five will be testing IR, UV, thermal, and smoke sensors. The selected sensors will be integrated with a microcontroller, where in future quarters their outputs will be used in a feedback control system. The sensors will be able to successfully detect a fire of 512 cubic inches (an 8x8x8 inch 'cube').

Mechanical: Build a Gantry and Trolley system with 16 ft2 range of motion

For this project to work there must be a two-axis system that can successfully move a fire extinguisher to a specified location. For the RRP Maroon Five Engineering will design and construct a stable two axis rail system that can be mounted to existing ceiling infrastructure that will not cause damage to the environment around it. The system should be able to move the extinguisher housing (trolley) at least 16 square feet. The rail system should be able to be controlled to move to specific locations and programmable to be autonomous and move further distances in future quarters. See figure 4.

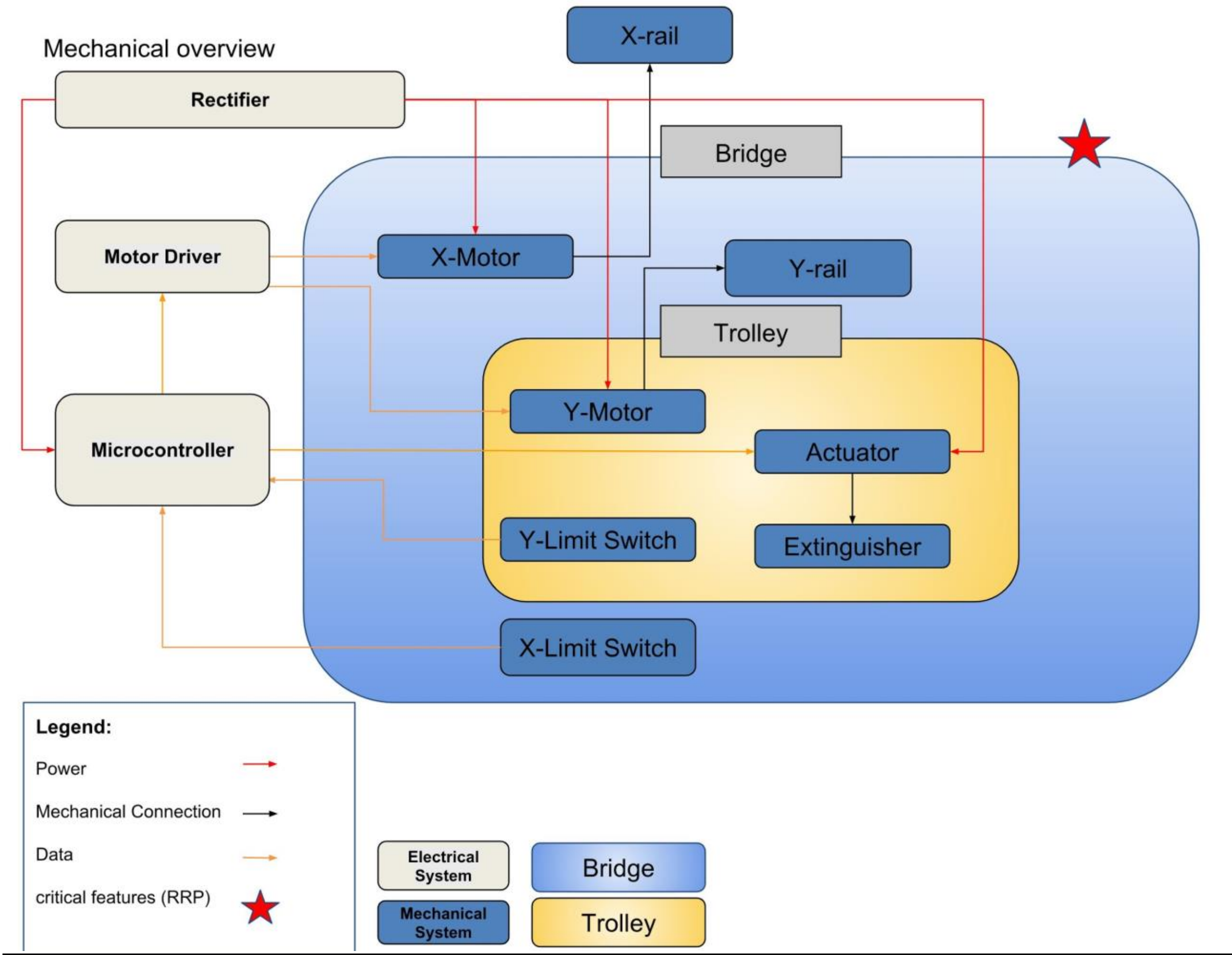


Figure 4: Mechanical Overview Block Diagram

<u>Table 2: Bill of Materials</u> - Description of items purchased and their values

Part	Description	Value	Manufacturer	Quantity Used	Source
UV Sensor	Sensor for fire	$11.99	Waveshare-Module	1	Amazon
IR Sensor	Sensor for fire	$6.99	Atomic Market	1	Amazon
Smoke Detector	Sensor for fire	$6.99	SUKRAGRAHA	1	Amazon
Raspberry Pi	Microcontroller	$			
Rails	Materials for rails	$21.98	PZRT	2	Amazon
Bridge	Materials for bridge	$14.98	PZRT	2	
Extinguisher	Fire extinguisher	$19.99	Kidde	1	Amazon
Ext. Housing (Trolley)	Materials for trolley, Aluminum sheet	$25.20	Online Metals	1	Online Metals
Trolley wheels	Caster Wheels for ext. Housing	$22.99	Houseables	4	Amazon

Detailed Scheduled:

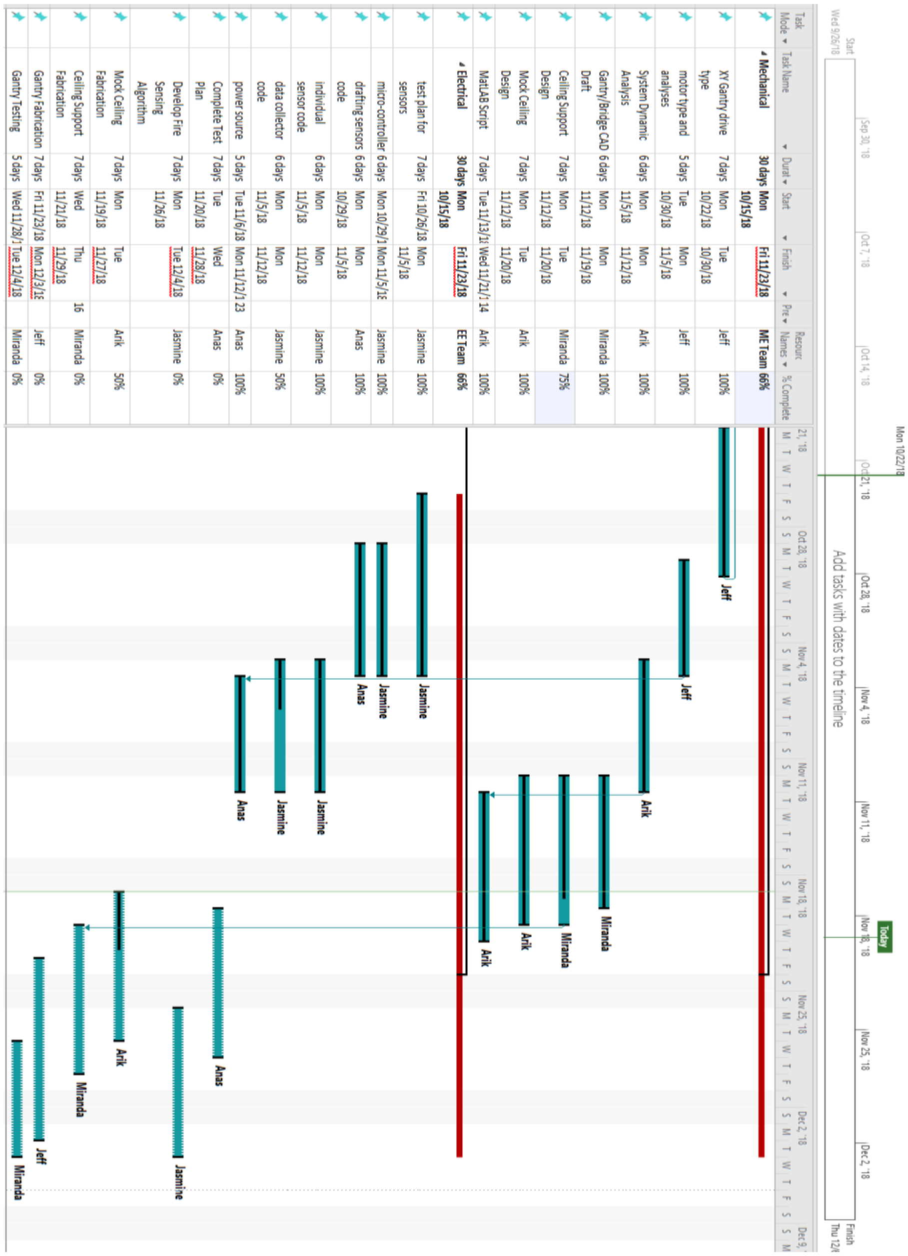


Figure 5: Gantt Chart

As seen in Figure 5, the items that present the greatest risk to our success by December are obtaining materials and testing our product. We need to make sure that what we design and fabricate functions as it should, and allow ourselves time to make minor iterations to get our RRP to complete functionality.

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Appendix
Team biographies

Anas Alhamad

Electrical and Mechanical Integration Lead

BSEE, electrical engineering, Seattle Pacific University, Seattle WA, USA 2019.

He was an Electrical Engineering Intern at Saudi Aramco, the main oil company in Saudi Arabia, Abqaiq, Saudi Arabia, Summer 2018.

Arik Espineli

Project Manager

BSME, general and mechanical engineering, Seattle Pacific University, Seattle WA, USA 2019.

He was a Mechanical Engineering Intern at RevelHMI in Seattle, WA, Summer 2018. He was the Tech Coordinator at iD Tech Camps at UC San Diego, Summer 2018.

Mr. Espineli is a member of the American Society of Mechanical Engineers, and is currently the president of the ASME club at Seattle Pacific University. He also is a member of the Engineering and Computer Science Student Council at Seattle Pacific University.

Jasmine Gill

Electronics Lead

BSEE & BSCE, electrical and computer engineering

Seattle Pacific University, Seattle WA, USA 2019

She is currently the Technical Director of the Baja SAE Falcon racing team at SPU in Seattle, WA and an Advanced Solutions Group intern with United Rentals in Bellevue, WA. Previously she worked as a technical intern at an aerospace manufacturing company, Skills Inc during the summer of 2017.

Ms. Gill is a member of the Society for Automotive Engineers (SAE International) and the Society of Women Engineers (SWE).

Jeff Smith

Design Lead

BSME, mechanical engineering, Seattle Pacific University, Seattle WA, USA, 2019

He has internship experience in automotive and production assembly engineering at MetalCloak industries, Sacramento CA in 2017 and at Kenworth Trucks, Renton WA in 2018.

Mr. Smith currently serves as the Operational Director of the SAE Baja team at Seattle Pacific University.

Miranda Sweigert

Mechanical Lead

BSME, general and mechanical engineering, Seattle Pacific University, Seattle WA, USA 2019.

She was an Energy Research Engineering Intern with the Alaska Center for Energy and Power in Fairbanks AK, summer 2017. She was the Technical Marine Operations Intern at Holland America Line in Seattle WA, summer 2018.

Ms. Sweigert is a member of the American Society of Mechanical Engineers, and serves as the President of the Engineering and Computer Science Student Council at Seattle Pacific University. Her third year undergraduate design project was recommended for NCEES award submission by faculty.

Vision

A safe work environment for the good of the employees as well as long term monetary benefits for the employer.

Mission

Our mission is to create an autonomous fire suppressing device that moves on the ceiling in an industrial environment. We will only use the most innovative and creative research, technology, and solutions.

<u>Team Contract</u>

Name: Maroon Five

A. Commitments:

As a project team we will:

1. See the project through to completion.
2. Be honest about our progress with the project.
3. Adhere to the timeline set as closely as possible.

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. Allow and seek participation from all members by listening attentively and asking for opinions

C. Team Meeting Ground Rules: Communication

We will:

1. Seek first to understand, and then to be understood.
2. Ask for help when we're stuck.
3. Be honest with our progress and struggles.

D. Team Meeting Ground Rules: Problem Solving

We will:

1. Encourage everyone to participate.
2. Clearly Identify the issue.
3. Resolve issue in a timely manner and to the satisfaction of the team.

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 other team members during the team meetings or privately rather than with non-team members in inappropriate ways.
3. The decision should be made in only the best interest of both team members and project success
4. Decisions should reflect our team's mission statement.

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 points of view and our interests in a non-judgmental and non-attacking manner.
4. Provide a safe place for people to discuss team issues
5. Demonstrate respect for the team members.

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. If a team member can not attend a meeting they need to provide notification to the rest of the team

H. Meeting Procedures:

1. Meetings will begin and end on a predetermined time.
2. Meetings will be recorded using the memorandum format provided
3. Team members will come to meetings prepared.
4. Note taker will be in charge of minutes and position will be changed for each meeting

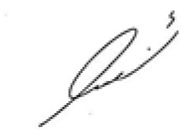
AGREED TO:

NAME (Signed and printed): **Jasmine Gill**

DATE: **10/3/18**

NAME (Signed and printed): **Anas Alhamad**

DATE: **10/3/18**



NAME (Signed and printed): **Jeff Smith**

DATE: **10/4/18**

NAME (Signed and printed): **Arik Espineli**

DATE:**10/4/2018**

NAME (Signed and printed): **Miranda Sweigert**

DATE: **10/4/18**