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Maroon Five

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Design Goals for Autonomous Gantry Extinguishing System (A.G.E.S.)

Project Definition:

The A.G.E.S is a customizable autonomous fire extinguishing system designed for use in small machine shops and industrial spaces. The system will detect a fire and send the extinguishing system into action to extinguish the fire. The system will be able to extinguish small to medium size fires. In cases of larger fires, the system will act to contain the fire until emergency responders arrive.

- A. The sensor box will be able to detect fires that may start in a machine shop
- B. The gantry system will be able to move around a specified area
- C. The extinguishing actuator will reliably extinguish small fires
- D. The AGES will be easily attached to existing ceiling infrastructure without causing damage to the environment around it
- E. Sensor box packages will be attached to machines that are more prone to catching fire in order to provide more custom coverage for a wider range of machines.
- F. The AGES will be a viable replacement for existing fire safety solutions and help in reducing machine downtime due to fires

Safety (S)

A.G.E.S is first and foremost a safety system and it should be safe. It is Maroon Five's goal to provide a system that is safe for usage in small machine shops and industrial spaces. The following specifications ensure the safety of the environment and people that will be working in the same space of the gantry system.

1. **S001: Interfering Object Detection** - **The gantry system shall come to a complete stop if an unexpected obstacle is detected within 0.5 foot of the system. The gantry system should come to a complete if an unexpected obstacle is sensed within a foot of the system.** This range should allow the system to come to a complete stop to avoid a collision.
2. **S002: Stop Speed** - **From maximum speed (M003) the gantry shall come to complete stop in 0.2 second. From maximum speed (M003) the gantry should come to complete stop in 0.1 second.** Stopping the gantry system as soon as the stop signals are sent ensures that there is no collision if there is an obstruction and that the motors don't stall when the rails run out.
3. **S003: Structure** - **The support structure shall be able to support 30 kilograms (66 pounds). The support structure should be able to support 40 kilograms (88 pounds).** This requirement will ensure that our system will be supported and be safe to install in a busy workplace.
4. **S004: Range Limitation** - **The gantry system shall come to a complete stop within 4 inches of the end of the gear rack. The gantry system should come to a complete stop within 2 inches of the end of the gear rack.** The triggering of the limit switch will stop the gantry system from reaching the end of the end of the gear rack and falling off the rail.
5. **S005: Emergency Stop** - **The gantry system will cut off the current to all of the components once the stop button has been pressed.** This will allow for the safe shutdown of the entire system in case of an emergency.
6. **S006: Bluetooth Compliance** – **The sensor box and microcontroller will be compliant with IEEE 802.15.1: WPAN / Bluetooth.** The system is a commercial product so it is important that it meets the industry standards.
7. **S007: Electronics Fire Resistance** – **The electronics will be compliant with ULC-S139.** The system is a commercial product so it is important that it meets the industry standards. The nature in which the system is designed to be used in will require safety standards in regards to operation in the same vicinity as fire.
8. **S008: Power** – **The main unit will operate on a wall outlet, 120VAC, and the drawn current will not exceed 13 Amps.** This will ensure the safety of the unit wires and to prevent triggering the panel breaker.

Durability (D)

A.G.E.S will need to be able to operate in a machine shop environment. The individual sensor boxes should be able to survive being moved around to different machines. The sensor boxes will also need to be durable enough to be in close proximity to heavy duty machinery.

1. D001: System Lifetime – **The system shall remain operational for 2 years with annual maintenance. The system should remain operational for 5 years with annual maintenance.** The system should work for an extended time period in order for the product to be a viable option for consumers. The system should be visually inspected monthly and maintained once a year to ensure all parts are functioning.
2. D002: Sensor Box Durability - **The housing for the sensor box shall withstand multiple falls from 6 foot above ground and should withstand multiple falls from 10 feet above the ground.** Sensors will be placed directly above the machinery and this will allow for the sensor box to maintain full functionality when dropped, as occurs by human error. These heights have been determined sufficient as this is approximately where someone may be storing or holding the sensor box.
3. D003: Sensor Box Operating Temperature - **The sensor box housing shall be able to operate at a temperature of 440 F and should operate at a temperature of 980 F.** This has been determined a small fire can reach temperatures exceeding 1000 F. These temperatures have been determined to be sufficient because the sensors should detect and trigger the system before reaching maximum temperature.
4. D004: Sensor Box IP Liquid Rating – **The sensor box shall have an IP liquid rating of 3 (Water falling as a spray at any angle up to 60° from the vertical shall have no harmful effect). The sensor box should have an IP liquid rating of 4 (Water splashing against the enclosure from any direction shall have no harmful effect).** The sensor box will be located closer to the ground and in the presence of heavy machinery. It is important that liquids such as water or oil do not affect the packages.
5. D005: Sensor Box IP Solid Rating – **The sensor box shall have an IP solids rating of 5 (Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact). The sensor box should have an IP solid rating of 6 (No ingress of dust; complete protection against contact).** The sensor box will be located closer to the ground and in the presence of heavy machinery. It is important that solids such as metal shavings, metal dust, saw dust, and larger particle do not affect the packages. The sensor boxes should also be protected from tampering and small objects.
6. D006: Gantry System Operating Temperature - **The gantry system shall be able to operate in a temperature of 440 F and should operate at a temperature of 980 F.** The gantry system should be able to briefly operate directly above a fire until it is extinguished by the system.
7. D007: Electronics Housing Water Resistance IP Rating – **The electronics housing shall have an IP liquid rating of 1 (Dripping water (vertically falling drops) shall have no harmful effect). The electronics housing should have an IP liquid rating**

of 2 (Vertically dripping water shall have no harmful effect when the enclosure is tilted at an angle up to 15° from its normal position). The electronics housing will be located on the ceiling with the gantry system. The electronics should be protected from small amounts of water that may come from splashing or drips from the ceiling.

8. D008: Electronics Housing Dust Resistance IP Rating - **The electronics housing shall have an IP solids rating of 5 (Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact). The electronics housing should have an IP solid rating of 6 (No ingress of dust; complete protection against contact).** The electronics will be in the presence of heavy machinery. It is important that solids such as metal shavings, metal dust, saw dust, and larger particle do not affect the packages. The sensor boxes should also be protected from tampering and small objects.

Detecting (DE)

The A.G.E.S requires a sensing system that can detect fires in order to locate the fire and trigger the extinguishing system. The sensors will be designed to detect a fire quickly and accurately to ensure the most efficient use of A.G.E.S.

1. DE001: Bluetooth Data Rate - **The data to trigger the fire suppression system shall be transmitted at a rate of 1Mbps. The signal should be transmitted at a rate of 2Mbps.** Transmission at a rate of 1-2Mbps leads to a transmission time of 8-16 microseconds. Optimizing time here leaves more time for the rest of the A.G.E.S. system to process the data and extinguish the fire in 10 seconds.
2. DE002: Timing of detection - **The sensor box shall detect a fire within 2 seconds or less. The sensor box should detect a fire in 1 second or less.** In order to be an efficient and successful system, fire should be detected within 2 seconds. This provides for timing optimization and allows the full gantry system to extinguish the fire within 10 seconds.
3. DE003: Field of view – **The sensor box will have a field of view of 9.8ft x 9.8ft x 9.8ft where it will detect the fire.** This ensures that the sensor box is able to cover the largest machine in the Seattle Pacific University machine shop which is 4.58 ft x 3.75ft x 6.5ft.
4. DE004: Accuracy of detection- **The sensor box shall detect a fire 99% of the time in its field of view. The sensor box should detect a fire in its field of view 99.99% of the time.** This is to comply with SFPE (Society of Fire Protection Engineers) recommendations for reliability of fire alarms, as they recommend 99.9% accuracy.
5. DE005: False Alarm – **The system shall have no more than 1 false alarm out of 100 times that it is deployed. The system should have no more than 1 false alarm out of 500 times that it deployed.** In 2017, when the fire size was large enough, 7.6% of the fire alarms were false. Therefore, our system to beat this rate of reliability must have at maximum 8 false alarms per 100. Our system will be more reliable, and therefore shall have no more than 1 false alarm out of 100.

Movement (M)

The A.G.E.S will be designed to cover a specified area in a machine shop. The gantry system will be able to move the extinguishing system anywhere within the specified area. The system will also operate at speeds that ensure both safety and quick response times.

1. M001: X Movement Range- The gantry system **shall move a total of 3 feet in the X-axis, 1.5 feet in both positive and negative. The gantry should move a total of 4 feet, 2 feet in both positive and negative.** This is to allow for sufficient range to reach a fire and was determined based on the Seattle Pacific University Machine Shop. This will be tested by measuring the full range of motion of the axis.
2. M002: Y Movement Range - The middle bar of the 'H', or gantry, shall successfully move in the Y-axis between the other two beams. **The beam shall move 9 total feet in the Y-axis, 4.5 feet in positive and negative directions. The beam should move 10 total feet, 5 feet in positive and negative y directions.** This size has been determined to be sufficient by examining machines and their relative locations in the Seattle Pacific University Machine Shop, and will allow for a sufficient range to reach a fire. This will be tested by measuring the full range of motion of the axis.
3. M003: Movement Speed - **The system shall move at a speed of 4 feet per second, and should move at a speed of 8 feet per second.** Based on tests conducted in a machine shop setting and average human running speed (22 ft per second), our system will be able to move to the furthest location in the range (M001, M002) in roughly the same time it would take someone to run from the fire to the fire extinguisher and back. This was determined by testing how long it took one of our team members to safely disengage from use of a machine and obtain a fire extinguisher and return to the machine location. While there is not a large difference in timing, the system will allow for people to leave the dangerous situation.
4. M004: Extinguisher Location Accuracy - **The housing shall move within a 3-inch radius of the location and should move within a 1-inch radius of the location.** The extinguisher housing will be sent a signal to move to a specified location with X and Y coordinates. The fire extinguisher will be most effective when closest to the location of the fire and this accuracy will allow for coverage of the fire size (E002).
5. M005: Gantry System Scalability – **The system will be designed to able to be adapted to a variety of spaces, such that the size and range can be modified to fit different sized rooms.** The gantry system will be customizable to fit in different spaces.

Extinguishing (E)

The A.G.E.S will be able to deploy a fire extinguisher in order to douse a fire. The extinguisher housing will be able to hold various sizes of extinguishers. The design of the actuation allows for easy replacement of the canisters.

1. **E001: Fire Type** – **The system shall be able to extinguish type A, B, and C fires. The system should be able to extinguish type A, B, C, and D fires.** The application for this prototype is for Seattle Pacific University's machine shop. After talking to the shop manager, Professor Lee, he stated the types of fire that are mostly likely to occur in the shop would be type A, B, and C.
2. **E002: Fire Size** - **The system shall extinguish fires that cover an area of 0.44² feet (8" x 8"). The system should extinguish fires that cover 16² feet (4, x 4').** The system is designed to detect and extinguish fires quickly. By the time our system arrives (M003) and extinguishes the fire (E006), it will still be in its early stages and be relatively small (16² feet).
3. **E003: Actuation Reliability** - **The extinguisher actuator system shall successfully trigger an extinguisher 95% of the time. The extinguisher actuator system should successfully trigger the extinguisher 99% of the time.** In 2017, when the fire size was large enough, 92% of fire sprinkler systems were successful in actuating. Our system must be more reliable than the average sprinkler system.
4. **E004: Actuation Time** – **The extinguisher actuator system shall be triggered within 3 seconds of arriving at the fire. The extinguisher actuator system should be triggered within 2 seconds of arriving at the fire.** A lower actuation time makes it so that the fire is extinguished as fast as possible. It also makes it so that the response time is lower for the overall system. This timing was chosen because it is an equivalent time to someone to pulling the safety pin, aiming the extinguisher, and squeezing the trigger.
5. **E005: Extinguisher Access** – **When the extinguisher is at its home position the extinguisher will be accessible.** In accordance with NFPA standards, fire extinguishers must be visually inspected by employees once a month and must have maintenance inspections conducted by a fire protection professional. In order to comply with these standards, the extinguisher must be accessible when the system is in place. The extinguisher must also be accessible to replace the extinguisher after it is used.
6. **E006: Time to Extinguish** – **The total time for the system to detect a fire (DE002), move to the fire (M003), and trigger the extinguisher (E004) shall be no more than 20 seconds. The total time for the system to detect a fire (DE002), move to the fire (M003), and trigger the extinguisher (E004) should be no more than 10 seconds.** The quick response time of the system will help reduce the damage done by a fire. Quick response time will also ensure a fire does not grow to a size (E002) that will be too large for our system to suppress.

Cost (C)

In order to remain a viable solution for fire safety, the A.G.E.S must be reasonably priced. The system should be affordable for a wide range of customers, from hobby garage machinist to industrial manufacturing shops.

1. C001: Total Cost - **The total cost to the customer shall cost less than \$1,500. The system should cost less than \$1,000.** The system may cost more than a simple fire extinguisher or existing automatic fire suppression system; however the system will provide more accurate detection, customization, and versatility. In the event of a larger fire the system will also help contain the fire until first responders arrive and will help provide additional time for people to evacuate a room. In addition, the system will help protect expensive machinery from water damage caused by traditional sprinkler systems.

Specification Summary Table

Spec ID	Requirement	Threshold (Shall)	Objective (Should)	Validation	Notes
S001	Interfering Object Detection	0.5 Foot	1 Foot	Tape Measure	
S002	Stop Speed	0.2 Second	0.1 Second	Stopwatch	
S003	Structure	30 Kilograms	40 Kilograms	Weights and FEA	
S004	Range Limitation	4 Inches	2 Inches	Repeated Movement Tests	
S005	Emergency Stop	N/A	Complete Stop	Repeated Tests	
S006	Bluetooth Compliance	N/A	IEEE 802.15.1	Tests	
S007	Electronics Fire Resistance	N/A	ULC-S139	Tests	
S008	Power	N/A	<13 Amps	Multimeter	
D001	System Lifetime	2 Years	5 Years	Repeated Tests	
D002	Sensor Box Durability	8-foot drop	10-foot drop	Tape Measure and Data Analysis	
D003	Sensor Box Operating Temp.	440 F	980 F	Temperature Gun	
D004	Sensor Box IP Liquid Rating	3 IP	4 IP	Splash Tests	
D005	Sensor Box IP Solid Rating	5 IP	6 IP	Tests	
D006	Gantry System Operating Temp.	300 Kelvin	350 Kelvin	Thermometer	
D007	Electronics Housing IP Liquid Rating	1 IP	2 IP	Drip Tests	
D008	Electronics Housing IP solid Rating	5 IP	6 IP	Tests	
DE001	Bluetooth Data Rate	1 Mbps	2 Mbps	Data analysis	
DE002	Timing of Detection	2 Seconds	1 Second	Stopwatch and data analysis	
DE003	Field of View		9.8ft ²		
DE004	Accuracy of Detection	99% Detection	99.99% Detection	Repeated Testing	
DE005	False Alarm	1/100	1/500	Repeated testing	
M001	X Movement Range	3 Feet	4 Feet	Tape Measure	
M002	Y Movement Range	9 Feet	10 Feet	Tape Measure	
M003	Movement Speed	4 Feet/Sec.	8 Feet/Sec.	Stopwatch and Tape Measure	
M004	Movement Accuracy	3 Inch Radius	1 Inch Radius	Tape Measure	
M005	Gantry System Scalability	N/A	Yes		
E001	Fire Type	Type A, B, C	Type A, B, C,	Extinguisher	

			D	rating	
E002	Fire Size	0.44 ² Feet	16 ² feet	Tape Measure	
E003	Actuation Reliability	99%	99.99%	Repeated tests	
E004	Actuation Time	3 Seconds	2 Seconds	Stopwatch	
E005	Extinguisher Maintenance	10 Minutes	5 Minutes	Stopwatch	
E006	Extinguisher Access	5 Minutes	2 Minutes	Stopwatch	
E007	Time to Extinguish	20 Seconds	10 Seconds	Stopwatch	
C001	Total Cost	\$1,500	\$1,000	Compare Final Selling Cost	