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EML 4551-2

Team 35: Aftermarket Child Detection for Car Seats

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Abstract

An average of 37 child deaths occur each year because of heatstroke in parked cars. What's worse, the number of deaths a year shows no sign of decreasing. This means that even with safer cars and smarter devices, this issue isn't going away.

The infant heatstroke issue results from two scenarios. First, parents intentionally leave their child in the car, believing they have enough time to "run into the store and come back." Second, the parents unintentionally leave their child in the car, altogether forgetting to remove their child from the car seat after they exit. Our team is solving both of these by designing a smart baby monitor. This monitor will be aftermarket and attachable to any car seat. It senses the presence of a child in order to "Activate." Once on, the monitor observes temperature changes within the vehicle, and uses that data to predict future temperature. If this predicted temperature is a danger to the infant, the monitor will alert the parent/guardian through a key fob alarm.

As an entrepreneurial project, our main objective, besides creating a functioning product, is to either market or license the monitor. After conducting market research, we believe we have included most, if not all, desired qualities from our target audience. This includes affordability, adaptability, and ease of installation. Finally, the monitor offers more capabilities than any other competing product on the market, meaning loss of business to competitors is minimal.

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Disclaimer

Acknowledgement

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Notation

Chapter One: EML 4551C

1.1 Project Scope

To get a better baseline understanding on the customer needs, a project scope needed to be created. Establishing a project scope allows for the entire project to be broken down into small portions that add up to the entirety of the project. This will help to establish a scheduled, budgeted, and more organized design process. Additionally, having a scope of work is important to limit the focus of the project to the specific needs that the customer initially presented. Without a scope, the project could lose focus and develop a product completely unrelated to the original problem. This common problem is often referred to as project creep, a situation that should be avoided.

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Taking the customer needs into consideration, the following project description, goals, primary and secondary markets, assumptions, and stake holders were developed.

Project Description:

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In the United States, an average of 37 child fatalities occur each year due to heat stroke after being left unattended in parked vehicles. When a vehicle's air conditioning is shut off, interior air temperature rapidly rises to dangerous levels. As of December 2017, 42 cases were reported, suggesting that this is a growing problem. A need has developed for a device to aid in preventing this tragedy. The objective of this project is to design a system that detects when an infant is in a vehicle subject to dangerous temperatures and alerts the designated parties.

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Goals:

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The seven major goals to complete the objective of this project are as follows:

- Detect child in car seat
- Detect the temperatures within the vehicle that would cause harm to the child
- Develop working prototype
- Universal adaptability
- Tap into undiscovered market
- Device must be able to withstand its environment (temperature fluctuations, humidity, etc.)
- Incorporate with OEM technology

Each of these goals represent the combination of functions which the system will perform to protect infants.

Primary Market:

The primary market for this product are families/caregivers with children who still utilize car seats. Preliminary market research has been performed and three user profiles have been developed. These profiles will help put ourselves in the shoes of the customer and develop key desired features.

Secondary Market:

The secondary markets that would be interested in this product include baby product manufacturers, vehicle manufactures, and child care service that transport car seat aged children.

Key Information

Currently, there is not an existing product in this market that utilizes innovative features such as cellular notifications for child car seat detection. Current products use audible alarms that

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alert the user after exiting the vehicle. Our mission is to engineer a cost-effective product with innovative features such as cellular/wireless notifications and OEM integration.

Assumptions:

Technology can be integrated into an existing car seat without compromising the integrity of the crash protection. User has correctly installed child car seat.

Stake holders:

Dr. McConomy, Dr. Devine, Legal

1.2 Customer Needs

Preface

There is currently not an established market for an aftermarket child detection device for car seats. We conducted research to explore the potential customer needs by examining three personas: i-Mom, involved dad, and soccer mom. We considered these personas when developing the customer needs.

Research

After researching top selling SIDS detection devices and baby monitors we determined that the potential customer favors peace of mind with the convenience of wireless alerts or alarms. We noticed recurring themes in the features of various top selling baby health monitoring devices that included: simple user interface, reliability, and adaptability to other baby items (such as diapers.)

Interpreted Customer Needs

The eight interpreted customer needs are as follows:

- Detect an infant in the automobile

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- Determine if conditions in the automobile are dangerous
- Notify outside parties to respond to the situation
- Needs to be aftermarket
- Needs to be able to attach to every car seat
- User friendly
- Compatible with mobile device
- Incorporate with OEM technology

1.3 Functional Decomposition

To get a better understanding of this project, we performed a functional decomposition. A functional decomposition aids in breaking down a complex system into smaller parts. We determined that our product needs to be able to sense the conditions of the vehicle and presence of a child. It also needs to be able to determine when the conditions of the vehicle are dangerous and take appropriate actions to mitigate the risk of death. We concluded that we could break down our product into the following five functions:

- Sense vehicle interior air temperature
- Identify presence of a child
- Calculate when temperatures are dangerous
- Indicate threatening conditions
- Initiate appropriate response

1.4 Target Summary

To establish targets, we broke down the process and reviewed our functional decomposition, and created targets that directly relate to the functions for our device. After creating these targets, we looked at our customer needs and matched those that seemed fulfilled by a certain target.

The first function we have listed is sensing the interior temperature of the vehicle. The target we have created based on this function is that certain tiers of temperature should be detectable. These various ranges would then correlate to different responses by the communication system. For instance, a higher temperature would indicate increased risk, meaning less time allowable for the parent/guardian to react before Emergency Services are contacted. This target helps to meet the listed customer needs of “Determining if conditions in the automobile are dangerous” as well as “Notifying outside parties to respond to the situation.”

The next target is that the device should be able to detect temperatures between 70°F and 104°F. The device should also be able to operate at temperature range of 0°F to 200°F. The device should be able to operate within this range because the temperature inside a parked car has been measured to reach 172°F when the outside ambient air temperature ranges from 80°F to 100°F (Sutz, 2017). This target will contribute to the product’s robustness, repeatability, and usability.

The first customer need listed is to “Detect an infant in the automobile,” which is one of the functions we created for the functional decomposition. The target created for this function is to detect the presence of a child in the car seat, allowing false positives, but zero tolerance on false negatives.

The next function we have is to calculate dangerous conditions, which corresponds with the customer need to "Determine if conditions in the automobile are dangerous." Although this customer need is partly fulfilled by the first target we discussed, we decided it was necessary to determine exactly what 'dangerous conditions' are, as well as how those conditions might be met based on different ambient temperatures. As a result, we created a target that states that temperature change data should be extrapolated from the data we currently know about the temperature in the vehicle. For instance, a cooler car will take longer to reach dangerously high temperatures levels than a car whose interior temperature started higher.

Next, we created a target that states that if it has been determined that conditions in the vehicle pose a danger to the infant inside, the user should be alerted within 20 seconds. This satisfies the "Compatible with mobile device" customer need, as well as the "Notifying outside parties to the situation."

Our final target was that the device must be attachable to the top five selling child car seat brands and their product lines. We created this target to ensure the device's ease of use by many different customers, not just those with one specific car seat brand. This target satisfies both the "User friendly" and "Needs to be able to attach to every car seat" customer needs.

1.5 Concept Generation

From the functional decomposition, the design was broken down into 5 main systems. For each of these systems, concepts were generated. The concepts were determined using ideation. For each concept, there is a description on how the concept would apply to the design. Below is a table which displays this process.

Table 1

Systems and Generated Concepts of the Project.

System	Concept	Description
1. Vehicle Interior Temperature Sensing	1	Negative Temperature Coefficient Thermistor
	2	Resistance Temperature Detector
	3	Thermocouple
	4	Semiconductor Based Sensor
2. Child Detection	1	Chest Restraint Harness Clip
	2	Pressure Activated Switch
	3	Pressure Sensor
	4	Coupled Motion and IR Sensor
	5	Heartbeat Sensor
3. Dangerous Temperature Calculation	1	Temperature Rate Extrapolation
	2	Temperature Threshold Switch
4. Threatening Condition Indicated	1	Verification of Dangerous Conditions
5. Response Initiation	1	Key Fob Alarm
	2	Cellular

System 1. Vehicle Interior Temperature Sensing

This system will handle the sensing of the temperatures within the vehicle. This system must be able to obtain the necessary data to be processed in System 3 Dangerous Temperature Calculation.

Concept 1. Negative Temperature Coefficient(NCT) Thermistor

This thermistor experiences large and predictable changes in resistance which correlate with changes in temperature. As temperature increases, resistance decreases. Since it experiences very large and noticeable changes in resistance per degree, the NTC has a high level of accuracy (0.05 to 1°C). Range for standard is -50°C to 150°C (4 Most Common).

Figure 1. Image of different types of NTC thermistors (Arduino: Using NTC Thermistors).

Pros: high accuracy, inexpensive, available on Amazon, standard range fits our purposes

Cons: requires linearization, does cheap indicate poor robustness?, testing required to determine accuracy after multiple cycles

Concept 3. Resistance Temperature Detector (RTD)

RTDs measure temperature by creating a relationship between temperature and resistance, and then being able to indicate temperature once a resistance is hit. Consists of fine wire (copper, nickel, or platinum) wrapped around a glass/ceramic core. Replacing thermocouples in industrial applications, when used below 600°C (Resistance Thermometer).

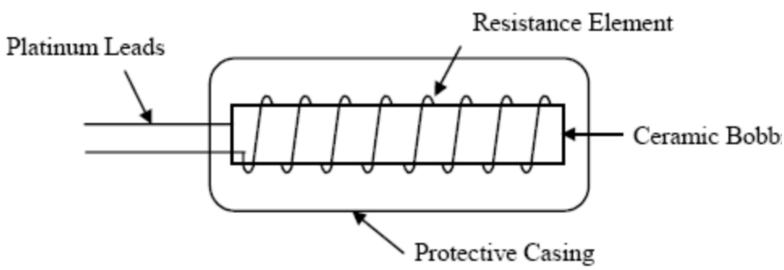

Figure 2. Illustration of RTD (Resistance Thermometer).

Pros: highest accuracy, available on Amazon, standard range fits our purposes

Cons: most expensive, fragile; Requires protection, need to use platinum to achieve repeatability

Concept 3. Thermocouple

Thermocouples are the most commonly used temperature sensors, and consist of two wires of different metals which are connected. The differing voltage indicate proportional changes in temperature. They are nonlinear and require conversion when used for temperature control (Thermocouples).

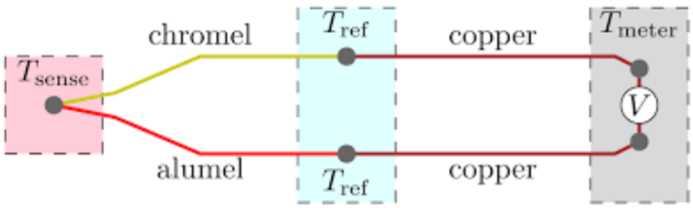

Figure 3. Schematic illustrating how a thermocouple works (Thermocouples).

Pros: most used, reliable, widest temperature range, -200°C to 1750°C, widely available and inexpensive

Cons: Least accurate (up to +/- 5°C)

Concept 4. Semiconductor Based Sensors

Effectively made up if two diodes that have temperature sensitive voltage versus current aspects, and can indicate changes in temperature. They must be placed on an integrated circuit.

Pros: Linear response

Cons: Least accurate (up to +/- 5°C), slowest response time (up to 60 seconds), doesn't seem to be as easily available

System 2. Child Detection

This system will detect and determine the presence of a child within the car seat. This system must be reliable to achieve our target of no false negatives.

Concept 1. Chest Restraint Harness Clip

This concept utilizes the chest restraint harness on existing car seats to determine the presence of a child. The device can attach to the existing clipping system or be attached to the straps themselves. This device can house all necessary sensors and determine if there is a child present. The device determines the presence of a child by using an open or closed circuit. If the two ends of the clip are pressed together, as shown in Figure 4, then the circuit is closed. By closing the circuit, the device is activated and it can be concluded that a child is in the car seat. By separating the clips, the circuit is opened and the device is turned off, which can be seen in Figure 5.

Pros: Ease of use and installation, seamless integration for user, reliable, low cost

Cons: Requires Child to be buckled in to be detected, Difficult to design to be universally adaptable

Figure 4: Device schematic to illustrate the closed circuit for activation of the device and verification that a child is in the seat (Graco Baby buckle used for illustration purposes).

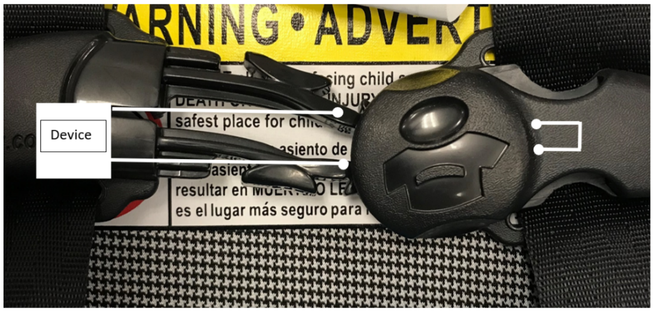

Figure 5: Device schematic to illustrate the opened circuit for deactivation of the device and verification that a child is not in the seat (Graco Baby buckle used for illustration purposes).

Concept 2. Pressure Activated Switch

This concept utilizes a pressure pad to detect when a child is in the car seat and activate the system. The pressure pad will be placed underneath the child in the car seat. A separate module will house all electronics and attach to a convenient location on the car seat with hook and loop fasteners. The pressure pad will be linked to the module via a wire and locking electrical connector. The pressure pad will be encased in a soft, washable cover with hook and loop retaining straps to maintain proper positioning.

Pros: Will work with any style car seat, simple installation, low cost

Con: Pad must be positioned correctly to ensure reliability

Figure 6: Pressure activated switch to be placed under car seat.

Concept 3. Pressure Sensor

This device would use pressure sensors to detect if I child is left unattended in a car seat. A pressure sensor, attached to a microcontroller would be placed underneath where the child would be sitting. The pressure sensor would be inside of a matt or cushion. The cushion would easily conform to the child's car seat. Another pressure sensor would be placed underneath the driver's seat, also inside of a cushion or seat mat. If the driver gets out of the seat, an audio producing device would immediately make a distinguishable noise, alerting the driver to acquire their child. If the child is acquired, then the device will stop.

Pros: The pros of this is that it is a simple design that does not require a lot of complex equipment. It is also easy to install.

Cons: The cons of this design are that there are times when the driver is not in the car, but someone else is left in the car to watch the child. This could cause a lot of false alarms. To correct this a pressure sensor would need to be placed on each seat of the car. This would drive up the price and inconvenience the parent. Items could also be placed in the seat that trick the pressure sensor. To solve this problem, expensive pressure sensors that map the shape of the individual could use in the design. The problem with this is that it would also drive the price up.

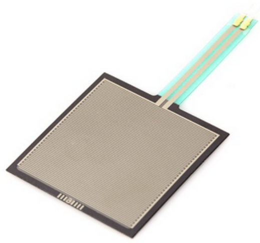

Figure 7. A pressure sensor to be placed under driver seat and car seat.

Concept 4. Coupled Motion and IR Sensor

This concept would utilize a coupled motion and IR sensor to detect if a child is in the car seat. There exists sensor and technology already that uses this method to detect human presence. It uses both a motion sensor and an IR sensor so that it can have two references if one is not being activated. For example, if the baby were to fall asleep or pass out the motion detection would not be sensed but it would still have IR data to determine the presence. This sensor would mount onto a clamp and bendable shaft and the whole system would clamp to the back of the car seat and angle the sensor at the top of the child's head.

Pros: Technology is already developed, allows for a greater certainty in detection

Cons: Required complex filtering and programming, high cost, must have an extremely reliable securing method because of mounting position above the child's head

Concept 5. Heartbeat Sensor

There are already technology/patents out for seatbelt-mounted heartbeat sensing technology. This concept simply employs the use of these devices on the car seat straps. Whenever a child is strapped into the seat, the sensor will identify its heartbeat and therefore know of the child's presence. Additionally, the heartbeat could provide vital information concerning the child's health and comfort, and whether drastic measures (contact EMS) need to be taken at that moment. Less expensive and simpler options of heartbeat sensing do, however, require skin contact (usually on the finger or wrist). This is possibly intrusive and time consuming to attach each time the child is placed in the car seat

System 3. Dangerous Temperature Calculation

This system will process the data from System 1 and utilize an algorithm to determine the danger of the temperatures given by the sensor.

Concept 1. Temperature Rate Extrapolation

Once the vehicle has been shut off and a child is determined to be inside the vehicle, an accurate method is needed to determine when the interior air temperature of the vehicle is dangerous. The challenge is determining this critical value prior to the air temperatures reaching the critical temperature. One method discussed is to extrapolate the temperature based on the amount of time it would take for the vehicle interior air temperature to reach the critical value. This would be achieved using average vehicular interior air temperature change. Using the rate of vehicular air temperature change gathered from this average, a curve can be generated with a series of measurements within the first few minutes that the vehicle is off. If the extrapolation deems that the vehicle interior temperature will reach the critical temperature, the device will proceed with the next phase.

Concept 2. Temperature Threshold Switch

This concept analyzes the temperature data from System 1. The algorithm will determine varying levels of danger based on the current temperature. These levels would have a range of temperatures that if the conditions are met will trigger the corresponding level. For example, the algorithm may have a safe range of temperatures. The response may be a simple green light on the device. If the temperature reaches a dangerous range, the response may be a loud alarm. The responses and the temperature ranges would have to be determined with research and development.

Pros: low programming complexity, low strain on microcontroller, does not need large amounts of data

Cons: must have extensive research to ensure temperature thresholds will ensure safety of child

System 4. Threatening Condition Indicated

System 4 will take the results of all the previous systems to determine if there truly is threatening condition.

Concept 1. Verification of Threatening Condition

This concept will reduce the likelihood of a false negative occurring. This will be achieved by using a system of checks and balances. The system will likely need a certain percentage of the sensors to signal a threatening condition for the device to alert. For example, the temperature sensor, calculations, and child detection will all have to be indicated as positive for the system to proceed to system 5.

System 5. Response Initiation

This system will utilize the output given by System 3 to initiate a response if it is determined that one is needed.

Concept 1. Key Fob Alarm

This concept utilizes two XBee wireless communication antennas. These antennas can have a range of 300ft to 15 miles. One antenna will be placed in the vehicle and the other would be placed in a key fob. The key fob would have some type of alarm such as a speaker along with the antenna. If an alert is required, the antenna in the vehicle will send a bit signal to the key fob antenna and alert the holder (Vetco Electronics).

Pros: allows for wireless notification, low cost, alarm portability

Cons: unknown reliability (for our system), increased programming complexity

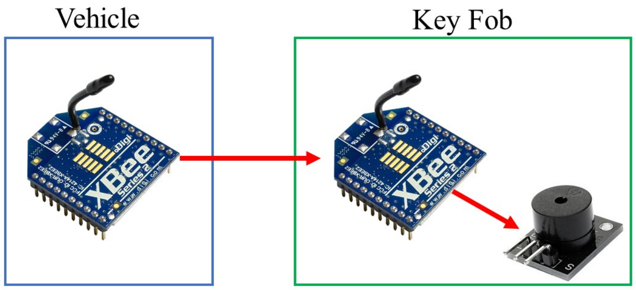

Figure 8. This figure shows the concept of two antennas to wirelessly notify the holder (Gravitech and Vetco Electronics).

Concept 2. Cellular

This concept utilizes a GSM microcontroller shield with an integrated antenna to notify the parents by SMS or phone call. The shield would work in conjunction with the microcontroller to send the alerts to the user's cellphone. A benefit to using this concept is that it allows the vehicle information to be relayed to the user. An example would be sending the interior vehicle temperature by text message and level of urgency straight to the user's cell phone.

Pros: allows for more information to be transmitted to the user, cellular integration is desirable from market

Cons: requires SIM card, higher programming complexity, cost

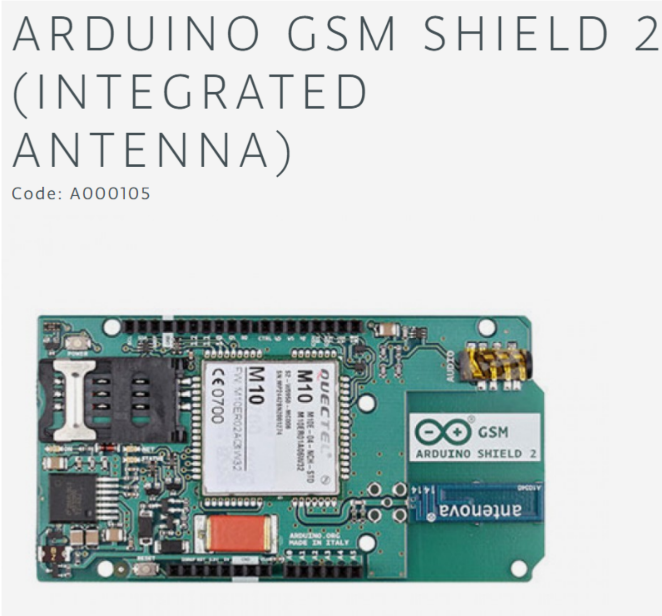

Figure 9. This figure shows the shield to use GSM capabilities with Arduino based microcontrollers (Arduino).

1.6 Concept Selection

To figure out the design of our aftermarket baby detection device, we needed to use a concept selection technique so that we can get a clear path for building our prototype. It was difficult to create a Pugh Matrix that adequately compares our generated concepts to a datum. Because of this, our team decided to use a standard ranking system. This will take each of the systems in our design and compare all our generated concepts against each other. This method avoids the issue of requiring a datum to compare concepts to, while providing for a method to compare concepts using weighted categories to filter out the most effective product we can create. This ranking system employs three different scores that can be applied to each evaluation variable. The numbers chosen for the ranking system were 5 (satisfaction of evaluation variable ≥ 85%), 3 (satisfaction of evaluation variable between 65% and 85%) and 1 (concept does not satisfy evaluation variable). These values where chosen because the ranking matrixes values needed to be exaggerated, since the matrixes have a limited number of parameters.

Temperature Detection

For Temperature detection shown in Table 2 below, the selected evaluation variables are temperature resistance, accuracy, response time, and price. The parameters were selected because they provide enough grounds for comparing each of the temperature-sensing concepts. Temperature resistance is a measure of how well the device functions in high-temperature environments, which is essential because it will be left in the car, where temperatures when parked in the sun can reach 200°F. Accuracy is a critical variable, since it will allow the device to accurately determine the temperature so that, if it becomes too hot, there is as little of a window of error in temperature sensing as possible. Response time was chosen as a variable because the device needs to act and react as quickly as possible. Finally, price was a chosen variable to increase the cost-effectiveness of the device.

The concept with the highest resulting total was the NTC thermistor, as it performed better (score=18/20, average=14/20) in the four chosen evaluation parameters than the other concepts. For this reason, the NTC thermistor will be the pursued concept. The NTC thermistor satisfies the associated targets of withstanding temperature range and detecting temperature, as well as the customer need of determining if conditions in the car are dangerous.

Table 2:

Temperature Detection Decision Matrix

	NTC Thermistor	*Thermocouple*	*Resistance Temperature Detector*	*Semiconductor Based Sensor*
Temperature Resistance	5	5	5	3
Price	5	5	1	5
Accuracy	3	1	5	1
Response Time	5	3	3	1
Total	18	14	14	10

NOTE: 5 = satisfaction of evaluation variable ≥ 85%; 3 = Satisfaction of evaluation variable between 65% and 85%; 1 = Concept does not satisfy evaluation variable

Temperature Calculation

In the Table 3 on the following page, the Temperature Calculation section has two components. Temperature Rate Extrapolation, which predicts future temperatures by calculating the rate of temperature change extrapolated. Temperature Detection is where a physical temperature is reached, causing the user to be alerted of the potentially dangerous condition. The first parameter for this section is accuracy. To be a usable system, the calculations must be accurate. The next parameter is cost. To be a desirable business venture, the system must be cost effective. The next parameter is business incentive. This idea considers what the investors or clients would want to see in this product. Feasibility takes into consideration how likely a design is to function in the system as intended.

According to the decision matrix, Temperature Detection is the better option (scored an 18/20); however, Temperature Rate Extrapolation (which scored a 14/20) is how the system will be designed. Because of this projects entry in the InNOLEvation challenge, the business incentive is incredibly important to the team's success. Furthermore, customers and investors would rather have a device that warns the user ahead of time of a dangerous situation instead of being warned if a default temperature is reached.

Table 3:

Temperature Calculation Decision Matrix

	Temperature Rate Extrapolation	*Temperature Detection*
Accuracy	3	5
Cost	3	5
Business incentive	5	3
Feasibility	3	5
Total	14	18

NOTE: 5 = satisfaction of evaluation variable ≥ 85%; 3 = Satisfaction of evaluation variable between 65% and 85%; 1 = Concept does not satisfy evaluation variable

Child Detection

Table 4 on the following page, shows the decision matrix on Child Detection. The selected evaluation variables are price, ease of use, installation, reliability, durability, adaptability. Ranking the devices according to the best price will allow us maximize the cost effectiveness of the device. "Ease of use" was chosen as a variable because a product's ease of use will result in less effort from the customer and therefore a more user-friendly device. The variable "Installation" is a measure of how easy the concept is to install. This will lower the likelihood that any concepts which pose serious challenges when installing will end with high scores in the decision matrix. Reliability is critical, as the device will need to function correctly over a long period of time, and a child's life is potentially at risk. Durability is a measure of how well the device will stand up to use, especially considering it is within arm's reach of a child. Finally, adaptability is a measure of the device's capability to be implemented across multiple different car seat brands and models.

The concept with the highest resulting total was the pressure switch, as it outperformed each of the other concepts in the given variables (which scored a 22/30). In order to maximize the efficiency and provide ourselves with a fail-safe, the Harness Clip (which score 20/30) will also be pursued. Our team chose to pursue these two designs in parallel, because both scored so closely. Furthermore, it is possible that potential problems with patents could arise when pursuing the pressure switch. The harness clip provides a back-up if there are legal ramifications to pursuing the pressure switch. These both satisfy the customer needs associated with child detection, namely "detecting an infant in the automobile," "Aftermarket," and "Attachable to every car seat." They also satisfy the target of identifying the presence of a child.

Table 4:

Child Detection Matrix

	Harness Clip	*Pressure Switch*	*Pressure Mapping*	*Coupled Motion & IR*	*Heartbeat Sensor*
Cost	3	5	1	1	1
Ease of Use	5	5	3	5	1
Reliability	5	3	5	1	1
Durability	3	3	3	5	3
Installation	3	1	1	1	3
Adaptability	1	5	3	5	5
Total	20	22	16	18	14

NOTE: 5 = satisfaction of evaluation variable ≥ 85%; 3 = Satisfaction of evaluation variable between 65% and 85%; 1 = Concept does not satisfy evaluation variable

Response Initiation

Table 5 on the following page, shows the Response Initiation. There are two categories in this table. The first involves the device sending a signal to a key fob (attached to the keys of the user). This device will make a sound whenever a dangerous situation is detected. The second response is that whenever a dangerous situation presents itself, a text message can be sent to the appropriate parties. The first parameter is about the cost. The second parameter is signal distance. The device needs to be able to relay that a dangerous situation is imminent to the user over a decent distance. The next category is effectiveness. Effectiveness is the likelihood that the device works in alerting the user. Time is how quickly it can initiate a response. Business incentive is what the investors or clients may desire to see in their product. The result where that the products tied (both scored 19/25), but the option that will be incorporated into the design will be the key fob alarm. The reason for this is because our project has a very short time span before it needs to be completed. Because of this, we need to choose a design that has a shorter timetable to incorporate. If cellular was chosen, then sim card programming would have to be incorporated. This would add a significant amount of time to the design. If this design is pursued long term, then the cellular aspect would be incorporated since more avenues can be explored if cellular is use.

Table 5:

Response Initiation Decision Matrix

	Key Fob Alarm	*Cellular*
Cost	5	1

Signal Distance	3	5
Effectiveness	3	5
Time	5	3
Business Incentive	3	5
Total	19	19

NOTE: 5 = satisfaction of evaluation variable ≥ 85%; 3 = Satisfaction of evaluation variable between 65% and 85%;

1 = Concept does not satisfy evaluation variable

Concept Selection Summary

Table 6:

Summary of selected concepts

System	Concept
Temperature Detection	NTC Thermistor
Temperature Calculation	Temperature Rate Extrapolation
Child Detection	Harness Clip & Pressure Switch (Parallel Design)
Threatening Condition Indication	Verification of Sensors
Response Initiation	Key Fob Alarm

1.8 Spring Project Plan

We plan on spending the beginning of the holiday break researching suppliers and prices on parts, including: NTC thermistor, pressure switch, microcontroller, and a key fob alarm. After school has begun again, we will have access to the given funds for our project, so orders will be placed on the first day of Spring semester, January 8th. Because these parts are commonplace and widely available, the time to receive each one after an order has been placed should be minimal (~2 weeks). The overall costs of these electronics should be less than or equal to $100, well under our total budget.

Beginning December 11th, work on the software of this project will begin, specifically for programming GPS functionality, as well as the temperature extrapolation algorithm. Test of housing will also begin over the holidays, using 3D printing to manufacture basic housing. Further research will also be done, since the "research" aspect of any project is never over. After each design review, our team has received input and opinions, some of which may be implemented into the design.

Our focus will also have to partially shift over to the entrepreneurial side. The Stage 2 Submission deadlines for the InNOLEvation Challenge is January 16th, which requires the Business Model Canvas. A preliminary draft has already been completed as of December 8th, and will then be judged by our sponsor, Dr. Devine. Necessary changes will be made based on his instruction. Our goal is to implement these changes in the days following our meeting on December 8th, giving us an ample buffer zone before it is due on January 16th. We will continue to bring it to Dr. Devine for revisions. Provided we advance through to the semi-finals, the next deadline is February 8th, which is a finalized Business Model Canvas. Semi-finalists are announced on the 26th of January, which gives us 2 weeks to meet with our sponsor, as well as any other individuals that may be able to provide feedback on our Business Model Canvas. Then, we will implement any alterations. Finalists are announced February 12th, and the next deadline is February 27th, where the Executive Summary is due. Work for the executive summary will be done after February 12th, provided we advance to the finals. The final presentation is on March 2nd, which gives us just under a month to rehearse if we make it through to the finals. Given the time required to rehearse for the Virtual Design Reviews thus far, this is an ample amount of time to appropriately prepare for the final presentation.

In addition to the dates mentioned above, there are many more important dates throughout the spring 2018 semester, all of which are shown in Table 7. Our Gantt chart can also be seen in Appendix D.

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Table 7:

Important Spring 2018 Dates

11-Dec	Prototype Proof of Concept, Continues Through February 5
8-Jan	Business Research, Continues Through Jan 22
9-Jan	Business Model Canvas, Continues Through January 11
16-Jan	InNOLEvation Workshop 8: Revenues, BMC and Budget Analysis
24-Jan	InNOLEvation Workshop 9: Pitches, Speeches and Presentations
26-Jan	InNOLEvation First Cut (down to 15 finalists)
8-Feb	~~InNOLEvation Stage 3 Submission and Final BMC~~
9-Feb	~~InNOLEvation Presentation 1~~
12-Feb	~~InNOLEvation Second Cut (8 Finalist)~~
27-Feb	~~InNOLEvation Stage 4 Submission Including 1 Page Business Summary~~
2-Mar	~~InNOLEvation Final Judging and Awards Ceremony~~
12-Mar	Spring Break, continues onto March 16
12-Apr	Engineering Day
4-Apr	Finals, Continues onto May 4
5-May	Engineering Graduation

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2.1 Spring Plan

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Timeline

Phase 1: Design and Purchasing

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This phase involves the design and purchasing of the prototype components. The final concepts were previously chosen using a decision matrix. The concepts are then broken down into individual components to determine the required materials and resources needed. It is necessary to also consider the tools and methods needed to construct the prototype.

Since we are an entrepreneurial team, we are not limited to purchasing from the list of FAMU-FSU approved vendors. This allows us to have more flexibility in our purchasing decisions. Once the necessary components and materials are determined, we must consider how many spare parts we must order. Budget and shipping times must also be taken into consideration when determining the amount of spare parts.

Phase 2: Prototype Constructions

Prototype construction involves three processes that will be worked on simultaneously: algorithm coding, electronics assembly, and housing design.

Algorithm Coding

This process will be started after the components are selected. Once the microcontroller is selected, we will know which language we will be programming in. This will allow us to have a framework for our code while we wait on the components to ship. Our algorithm must allow for reliable detection, it must be efficient for low power consumption, and contain the selling features we want.

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Electronics Assembly

Electronics assembly will occur once the components have arrived. It involves the soldering and assembly of the electronic components of our device.

Housing Design

Housing design will occur after the components are selected. The device must be able to survive and operate reliably in vehicle environments with temperature and humidity fluctuations and possible UV light exposure. It is also desirable to design an aesthetically pleasing product.

Phase 3: Testing

The testing phase will involve the function and reliability of the prototype. We will test the function of the prototype to ensure that the device gives no false negatives. Another function test will be the range of the alert. This will also include the function of the key fob in the presence of RF reflective objects (other cars, around a building, etc.). We will also test the reliability of the prototype. This will involve leaving the device in a vehicle and subjecting it to the average heat cycles of a daily driver and determining which components may fail.

Phase 4: Finalizing

Once the testing phase is complete, we will determine any flaws in our prototype. This will allow us to fix problems that may occur in the next iteration of the prototype. The team will also consult with faculty advisors for suggestions on improvements to decide on future work and possible directions.

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Task Ownership

Design and Purchasing

Design and component selection will be worked on by the team so that everyone is knowledgeable of the product components. Purchasing will be completed by Justin (Team Leader) once the budget is confirmed with Stephen (Financial Advisor) and the team.

Algorithm Coding

The algorithm framework will be completed by the team. Coding will be performed by Charlie (Software Architect). Support and debugging will be performed by Spencer (Lead Researcher).

Electronics Assembly

The electronics assembly will be performed by Troy (Senior CAD Designer) with support from Justin and Stephen.

Housing Design

The housing will be designed by the team. The team will decide on a suitable housing that is also aesthetically pleasing. Troy will design the housing in CAD with support from Justin and Spencer.

Testing and Finalizing

Testing and finalizing will be completed by the team once each task is completed.

Budget

The total budget allotted for this project is $1000. Since we have designed a first iteration prototype, we have budgeted $500 for the product. This will allow us to have a safety net for

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Formatted: Space After: 0 pt, Line spacing: double spare parts and necessary improvements. We believe this budget will be attainable because our design contains readily available and inexpensive components.

Bottlenecks

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One of the main bottlenecks we must overcome is shipping times. Once the components are purchased we will work on the framework of the code. This will allow us to progress the project while waiting on the components to ship. Another bottleneck is code debugging. During this time the electronics assembly and housing design will be performed simultaneously since debugging can take a variable amount of time. Another bottleneck we are anticipating is the purchasing process. Since the department is handling the purchasing not only for the senior design program, but also research for professors, it may take time for the order to be placed. We plan to mitigate this by purchasing what we can on our own and having the department reimburse the costs.

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Appendices

Appendix A: Code of Conduct

Mission Statement

Our mission is to work cohesively as a team in order to innovate products and concepts to make the automotive industry safer. As a team, we will strive to be professional, respectful, and ethical in order to deliver the best product possible.

Role Descriptions

Team Leader

The team leader will manage the team and supervise various tasks of the project. The team leader will be responsible for relaying all communications from the sponsor and faculty advisor to the team as a whole. The team leader will also finalize and deliver all required documents. The team leader will initiate planning for the project and meetings, but all team members will collaborate on the plans.

Financial Advisor

The financial advisor will account for all purchases and manage the budgeting for the project. All purchases must be confirmed by the advisor. The advisor is responsible for informing the group about the current finances to complete the project within budget. All records of finances will be made viewable to the team but can only be entered with approval from the advisor. For controversial purchases, the team must discuss the matter as a whole to make a decision.

Lead Researcher

The lead researcher will be responsible for managing the research for all aspects of the project, including: entrepreneurship, marketing, and engineering. The lead researcher will be in charge of compiling all research by team members and presenting it in clear and concise manner. The lead researcher will check all citations to make sure they are correct and in the right format.

Senior CAD Designer

The senior CAD designer will be responsible for finalizing all CAD parts, assemblies, and drawings. The senior CAD designer will delegate components to be created by each team member. The senior CAD designer will stay current with all design iterations. Any changes to the design must first be discussed with the team and then confirmed by the senior CAD designer.

Software Architect

The software architect will be responsible for the coding and algorithms needed to complete the project. The software architect will manage all code files. The algorithm will be discussed as a whole with the team but the software architect will be responsible for writing and delegating the necessary code. All changes to the algorithms must be discussed by the team and approved by the software architect.

Organization Matrix

Team 35 Organization Matrix					
	Role				
Name	Team Leader	Financial Advisor	Lead Researcher	Senior CAD Designer	Software Architect
Troy Brumm				X	
Stephen Carr		X			
Justin Craig	X				
Charlie Cruzan					X
Spencer Nguyen			X		

Work Schedule

Due to the varying schedules of each team member, all team members will be expected to work a designated amount of time each week at their own choosing. The designated amount of time to work each week will be the same for each team member. Each team member's schedule will be placed in an excel spreadsheet so that the whole team can easily see available times. If a team member's schedule changes, the member must apply the change to the spreadsheet.

Meeting Times

The team will decide week to week what times will be best for meetings. At the very least, meetings will occur during the senior design class from 2 pm to 6:15 pm.

Communication

Team members will meet at the designated times at a location chosen ahead of time. Each member will communicate via phone calls, text messaging, email, and the app GroupMe. During working hours each member is required to be updated on all forms of communication. Google drive will be used to store files and will be accessible to every member in the group. When communicating with team sponsors and faculty advisors via email, all members will be CC'ed and expected to keep their own copies of emails. Emails between team members should be used as a non-time sensitive form of communication and file sharing. At each team meeting, notes will be taken and sent to all members afterwards. If a member cannot attend the meeting, they must inform the team 24 hours prior to the meeting.

Team Dynamics

Each team member will act respectfully and professionally to each other, team sponsors and faculty advisors. All work will be shared equally among the team. If a team member has a conflict with another team member or the work load, they must bring it to attention of the team so that it may be discussed in order to find a resolution.

Ethics

Our team will follow the National Society of Professional Engineers Code of Ethics. If the team's or a team member's practices are unethical or questionable, a team member is required to bring the conflict to the attention of the team and it will be discussed until the conflict is resolved.

Dress Code

All team members are required to dress business casual or professional when meeting with sponsors. For presentations and other meetings, the team will decide on business casual or business professional but all team members must dress accordingly. For team meetings, there will be no dress code.

Decision Process

All decisions will be made as a team. Decisions will pass with a majority vote. All team members must determine if the decision is ethical and moral. If there is an objection, then that member must bring the objection to the attention of the group so that it may be resolved. Each decision must benefit the team and should contribute to successful completion of the project. The steps for the decision-making process are described below:

1. Problem Definition - Define the problem and understand it as a group.
2. Tentative Solutions- Brainstorm possible solutions. Discuss plausibility of solutions.
3. Data/History Gathering and Analysis- Gather necessary data required for implementing Tentative Solution. Re-evaluate for plausibility and effectiveness.
4. Design- Design the Tentative Solution product and construct it. Re-evaluate for plausibility and effectiveness.
5. Test and Simulation/Observation- Test design for the Tentative Solution and gather data. Re-evaluate for plausibility and effectiveness.
6. Final Evaluation- Evaluate the testing phase determine its level of success. Decide if design can be improved and if time/budget allows for it.

Process to Amend Code of Conduct

If a discrepancy is discovered or a change is needed, the team member will bring it into the light of the team leader. The team leader will then call a meeting where the amendment will be discussed. The team will then vote on the amendment. A majority vote is required to pass an amendment. If the vote does not pass, the team may discuss a compromise and vote again. If the compromise vote does not pass, an amendment will not be made.

Statement of Understanding

By signing this document the members of Team 35 agree to all of the above and will abide by the code of conduct set forth by the group.

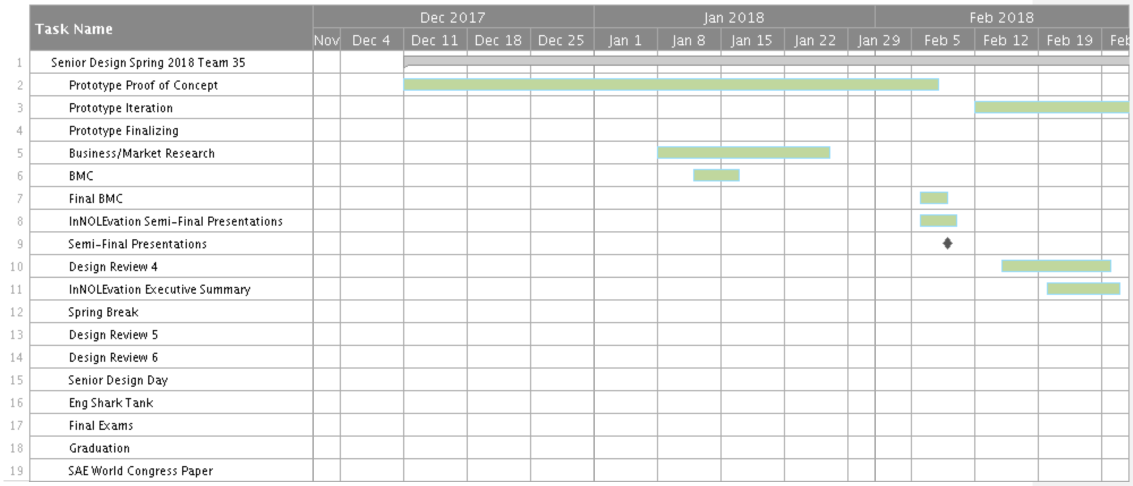
Name	Signature	Date
Troy Brumm	Troy B	9/26/17
Stephen Carr		9/26/17
Justin Craig	Justin Craig	9/26/17
Charlie Cruzan		9/26/17
Spencer Nguyen	Spencer Nguyen	9/26/17

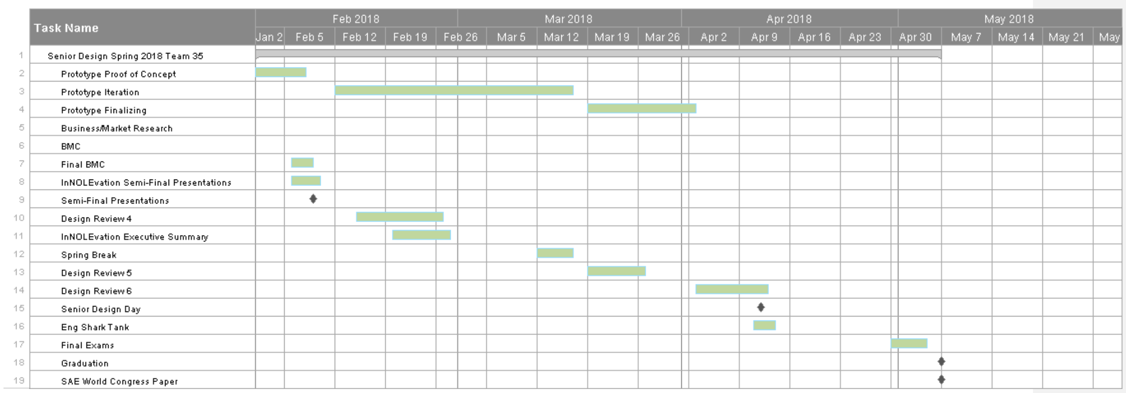
Appendix B: Functional Decomposition

Appendix C: Target Catalog

Metric (Target)	YES	NO
Detect specified tiers of temperature		
Withstand temperatures in the range of 0°F to 200°F		
Detect presence of child in car seat: No false negatives, false positives allowed		
Extrapolate temperature change data from currently known data		
Communicate to user in less than 20 seconds once conditions have been deemed		
Must be attachable to the 5 top selling child car seat brand's product lines		

Appendix D: Spring 2018 Gantt Chart





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