

# *Cruise Control Software Development Version 0.09*

We pledge our honor that we have abided by the  
Stevens Honor System.

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*CS347: Software Development Processes — Spring  
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# 1 Executive Summary

Team Mike is a startup initiative aimed at solving problems that come to light as society begins to adopt new technologies. One of which pertains to autonomous driving and “smart cars” as they are beginning to break into the automobile market more and more every year with examples such as Tesla and Ford. In a perfect world, if every driving car were to be a smart car with “autopilot,” then it would make sense for each of them to communicate cruise control data with each other to reduce traffic build-up and make traveling more efficient. Through rotational leadership on a monthly basis, each team member possesses a set of distinct skills that can translate to highly efficient work sessions. Aside from developing a traditional cruise control, the aim is to make the software open source as it will serve as the foundation to a more interconnected logistical future in which autonomous cars can fully achieve their potential within a growing technologically advanced society.

## 2 Introduction

The past century has seen an explosion of innovation on a scale never before seen in human history. The rapid development and refinement of a myriad of motor technologies catalyzed the innovation process by allowing ideas to transfer at rates never before seen. With the constraint of distance loosening thanks to every iteration of the automobile, people have been granted more freedom to do what they please. While the automobile has enhanced society in several ways, there are some glaring problems that need to be addressed to continue the current rate of human progress and innovation. One of the biggest problems is driver fatigue, which is responsible for approximately 72,000 crashes annually. Programming the automobile to be reliably autonomous to a degree is one way to circumvent the issue of driver fatigue and making roads safer. That's exactly what cruise control aims to do. By moderating the speed of the vehicle by itself, cruise controls aim to lessen the effects of driver fatigue on the road. However, the technology is not perfect, and Team Mike aims to resolve that by creating the perfect cruise control system.

When it was implemented in 1958, cruise control was suitable for that era, however, as technology continually improves, the embedded software must as well. For longer car trips, it does not make sense for users to constantly accelerate and decelerate for several miles; this is where cruise control comes in. By being able to set the speed, the user is now able to accurately set and maintain the speed they wish to without having to constantly intervene which, over time, would cause less harm to the vehicle as variable speed and RPMs are not as desirable as that of near-constant.

Our group intends to use an Agile method to implement our version of cruise control. This would encourage code sprints in two-week lengths where work will be divided into smaller sections and distributed based on each members' strengths. The Agile method may vary as to which one we specifically choose but regardless, this project will not come to fruition using Waterfall or other methods. The way that we are going to organize our group is through weekly meetings and ensuring that everyone knows their tasks for the week. These weekly meetings can also serve as a place where team members mention any obstacles that have come in their way when trying to resolve a problem, and also serve as a time where the team as a collective can try to think of solutions around those obstacles. We also plan on giving real-time updates about any progress made through Slack in order to ensure all members of the team are equipped with the most recent developments of the project. We also intend on using Java or C++ to

implement our cruise control system. We believe that the high-performance Java provides and the fact that its part of the Object-Oriented Programming (OOP) paradigm makes it perfect for embedded systems.

There are a plethora of features that make up cruise control. As most cruise controls are seen on vehicles, there are generally a few buttons: increase speed (and sometimes decrease speed) and the button that starts cruise control. Once cruise control is set, the user then has the ability to increase, decrease, or maintain the speed of a vehicle. Furthermore, if the user presses on the brake, then cruise control is automatically deactivated. The system also allows for the operator of a vehicle to manually deactivate it.

To successfully implement the features of maintaining a steady speed and a safe distance away from other cars, there are certain requirements to fulfill. At a high level, proper hardware with fast, reliable sensors is critical for this project. Furthermore, lives are fundamentally dependent on this product and therefore it requires software that is error-resistant and thus a strong development and QA (quality assurance) team. In addition, the software must also perform it's expected tasks of moderating speed, maintaining a safe distance and switching back control to the driver when prompted to quickly. Having a cruise control software that is slow would be ineffective, so speed and accuracy are critical requirements for the software as well as the hardware. This is a mission-critical system because if it were to fail, it would put the lives of people in danger.

## 3 Requirements

### 3.1 Input

1. The system shall accept electric power from the alternator.
2. The power button that allows for the state of the system to change from on to off or vice versa.
3. When pressed, a button will either accelerate or decelerate in 1 mph increments.
4. When the brake is pressed, the cruise control system will unset the speed and give control back to the user until the user specifies a new speed to be set.
5. If the entire car turns off, then a signal will be sent to turn off the cruise control system.
6. RPM (Rotations Per Minute) sensor should be connected to the front axle and able to take readings for accurate speed calculations.
7. Engine sensor must be able to take input from the engine to tell the cruise control system to turn on or off.
  - (a) If the engine is turned on, the cruise control system must be ready for use within 3 seconds of the engine being turned on.
8. If the gas pedal is pressed, the vehicle will continue to accelerate at the control of the user, but when the gas pedal is released the cruise control system will continue to the previously set speed.

### 3.2 Output

1. Keep a log of activity in the system files to help debug in the event of a malfunction.
2. For every speed increase made by the user in the cruise control system, a visual indication by the software is necessary. This is so that the user minimizes their own human error. So, every time you increase the speed, you can see the cruise control speed on the car menu increasing by however much the user wants it to.
3. The system displays successful activation or deactivation in 10 milliseconds.

- (a) Numbers are subject to change depending on how inputs are received from surrounding system, but are expected to be in around that same ballpark.
- 4. Keep a log of every time the cruise control system is used and at what speed written to the system files.
- 5. Once the cruise control system is turned on, it must be readily available. The engine sensor must be able to understand that the engine is on and tell the cruise control system that, if the user so wishes, it must activate.
- 6. With all the inputs it is taking from all the sensors, the software must be able to deliver the desired output for each function in less than 15 milliseconds.
  - (a) The brake pedal sensor must be able to tell the software that the user has stopped, and stop the cruise control system. \*Numbers are subject to change depending on how inputs are received from surrounding system, but are expected to be in around that same ballpark.\*

### 3.3 Functional

- 1. The system shall accept direct current from the car battery to support logging after engine shut down.
- 2. The system shall receive the time and date from the car's clock every second.
- 3. A physical will be provided by the system for technicians to access the unit.
- 4. Hardware shall have a 4 nine (99.99%) availability.
- 5. Software shall have a 5 nine (99.999%) availability.
- 6. While the cruise control system is on and a speed is set, it must be able to increase and decrease the speed by 1 mph.
- 7. Able to switch the cruise control system on or off provided the engine is on.

8. Interpret engine on and off signal to allow for the cruise control system to be turned on within 3 seconds of received the signal.
9. Only allow the cruise control system to be activated when at a minimum speed of 25 mph.
  - (a) If the speed is set to 25 mph, the user cannot decrease the speed below 25 mph.
10. Maximum speed that cruise control system can be set to is at 125 mph.
11. While the cruise control system is on, if a user is driving at a speed of at least 25 mph and decides to set the speed, the cruise control system will maintain that speed.
12. If the user presses and continues to press the brakes, the user will not be able to set the speed.
13. If the user presses and continues to press the gas pedal, the user can set the current speed for the cruise control system, but it will immediately pause as stated in the input requirements then resume after the user releases the gas pedal.

### **3.4 Security**

1. No external interface to reduce potential tampering. This applies to both the hardware such as sensors and the general cruise control system software. There would be no easy access to the cruise control system hardware or software so that the likelihood of someone being able to create issues is reduced substantially.
2. No Internet or Bluetooth connection. This is so that no bad actors can meddle with the car's system and hence, keeps the drivers safer as cyber security becomes more of an issue.
3. An administrator will need hardware to make changes to the mechanisms. The administrator must be authorized to make these changes and they must be a trusted third party or those who created the cruise control system themselves.



## 4 Requirements Analysis Model

### 4.1 UML Use Cases & Diagram

See Figure 1 for general use cases of cruise control system.

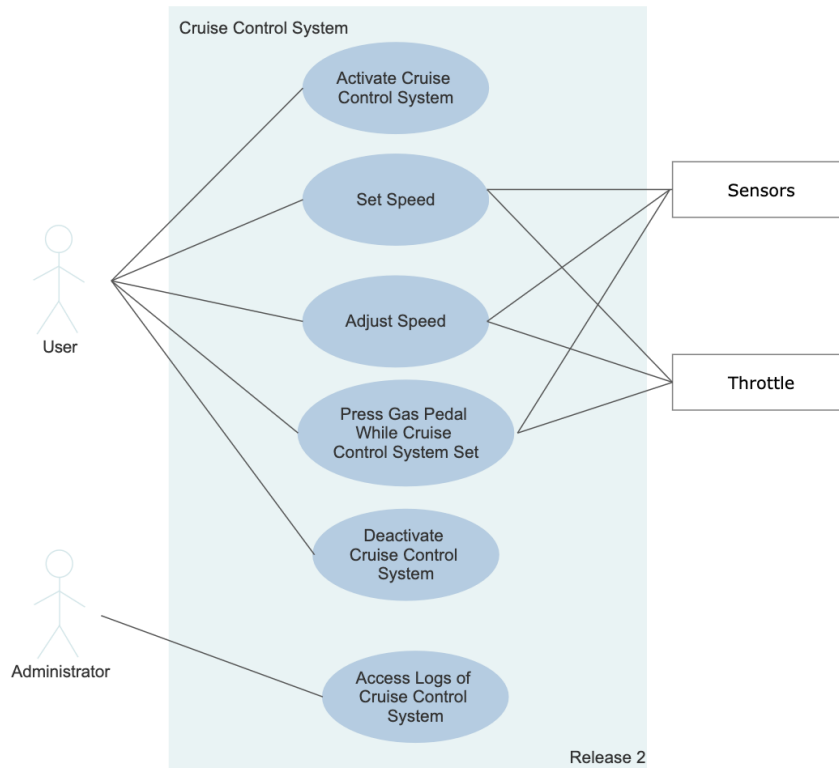


Figure 1: Sample UML diagram for cruise control system use cases.

It should be mentioned that there are two similar sounding states that need to be clarified:

- Activated
  - Granted the vehicle is on, the cruise control system is also now waiting for the speed to be set by the user.
- Set/Unset

- Given that the cruise control system has been **activated**, the user has requested for the speed to be maintained at its current speed.
- Given that the cruise control system has been **activated** and the cruise control system is in the **set** state, the user can either press the brake or press a button to unset the speed and revert back to the **activated** state.

1. Use Case 1:

Primary Actor: User

Description: User activates the cruise control system

Outcome: The cruise control system is now activated

Basic Flow:

- (a) Given that the vehicle is on, the user requests an activation of the cruise control system.
- (b) Cruise control system activates.
- (c) The cruise control system provides a visual feedback that it has been activated.

2. Use Case 2:

Primary Actor: User

Description: User sets the speed

Outcome: The speed of the cruise control System is set to a specific speed

Basic Flow:

- (a) Given that the vehicle is on and the cruise control system is in the activated state, the system requests values from sensors.
- (b) Sensors provide values for approval to set cruise control system at current speed.
- (c) Cruise control system requests the Engine Management System (EMS) set the speed at current position.
- (d) EMS Speed (Throttle) is set at current speed.
- (e) Cruise control system provides visual feedback to the user that the cruise control is set and working.

- (f) Sensors provide the changing environmental information to the cruise control unit (such as speed, request for increase/decrease speed, and brake).
- (g) Cruise control system detects the changes from the sensors and request adjusting speed or deactivating Cruise Control system accordingly.
- (h) Speed (Throttle) position is continuously set to new values to ensure that the speed remains constant.
- (i) Speed is continuously reported to the cruise control system.

3. Use Case 3:

Primary Actor: User

Description: User increases speed

Outcome: The speed of the Cruise Control System is increased

Basic Flow:

- (a) If the cruise control system is in the set state, the user requests an increase of cruise control system speed.
- (b) Cruise control system provides visual feedback that the system will alter the speed of the vehicle.
- (c) Cruise control system slowly increases the speed of the vehicle to match that of the request.
- (d) When the desired speed is reached, the cruise control system will provide visual feedback that the adjustment has been completed.

4. Use Case 4:

Primary Actor: User

Description: User decreases speed

Outcome: The speed of the Cruise Control System is decreased

Basic Flow:

- (a) If the cruise control system is in the set state, the user requests a decrease of cruise control system speed.
- (b) Cruise control system provides visual feedback that the system will alter the speed of the vehicle.
- (c) Cruise control system slowly decreases the speed of the vehicle to match that of the request.

- (d) When the desired speed is reached, the cruise control system will provide visual feedback that the adjustment has been completed.

5. Use Case 5:

Primary Actor: User

Description: User presses gas pedal while the cruise control system is set

Outcome: The speed of the vehicle increases while the gas remains pressed. When the gas is released, the speed will return to the speed of the Cruise Control System

Basic Flow:

- (a) If the cruise control system is in the set state, the user presses on the gas pedal.
- (b) In the event that the vehicle accelerates, the cruise control system will continually request the EMS to be set to the previously specified speed.
- (c) Speed will be continuously reported to the cruise control system.
- (d) After the user releases the gas pedal and the vehicle stops accelerating, the cruise control system will request for the EMS to be set to the previous specified speed.
- (e) The vehicle will naturally decelerate nearing the old set speed, and once reached, the cruise control system will resume with the set speed.

6. Use Case 6:

Primary Actor: User

Description: User applies brake while the cruise control system is set

Outcome: The speed of the vehicle decreases while the brake remains applied. When the brake is released, the speed will return to the speed of the Cruise Control System

Basic Flow:

- (a) If the cruise control system is in the set state, the user presses on the brake.
- (b) In the event that the vehicle decelerates, the cruise control system will continually request the EMS to be set to the previously specified speed.

- (c) Speed will be continuously reported to the cruise control system.
- (d) After the user releases the brake and the vehicle stops decelerating, the cruise control system will request for the EMS to be set to the previous specified speed.
- (e) The vehicle will naturally accelerate nearing the old set speed, and once reached, the cruise control system will resume with the set speed.

7. Use Case 7:

Primary Actor: User

Description: User deactivates cruise control system

Outcome: The Cruise Control System is now deactivated

Basic Flow:

- (a) If the cruise control system is activated, the user requests a deactivation of the cruise control system.
- (b) Cruise control system deactivates.
- (c) Cruise control system provides visual feedback that it has been deactivated.

8. Use Case 8:

Primary Actor: Administrator

Description: Administrator accesses logs of cruise control system

Outcome: The administrator is given access to the log of the Cruise Control System

Basic Flow:

- (a) With the vehicle turned on and the cruise control activated, an administrator will have to use a proprietary physical hardware key in order to gain root access.
- (b) Once access has been granted, the administrator can download the logs to an external storage device through a USB port.
- (c) Once downloaded, the administrator must log out using the same proprietary physical hardware key.

## 4.2 UML Class-Based Modeling

1. See Figure 2 for the class-based modeling for the cruise control system.

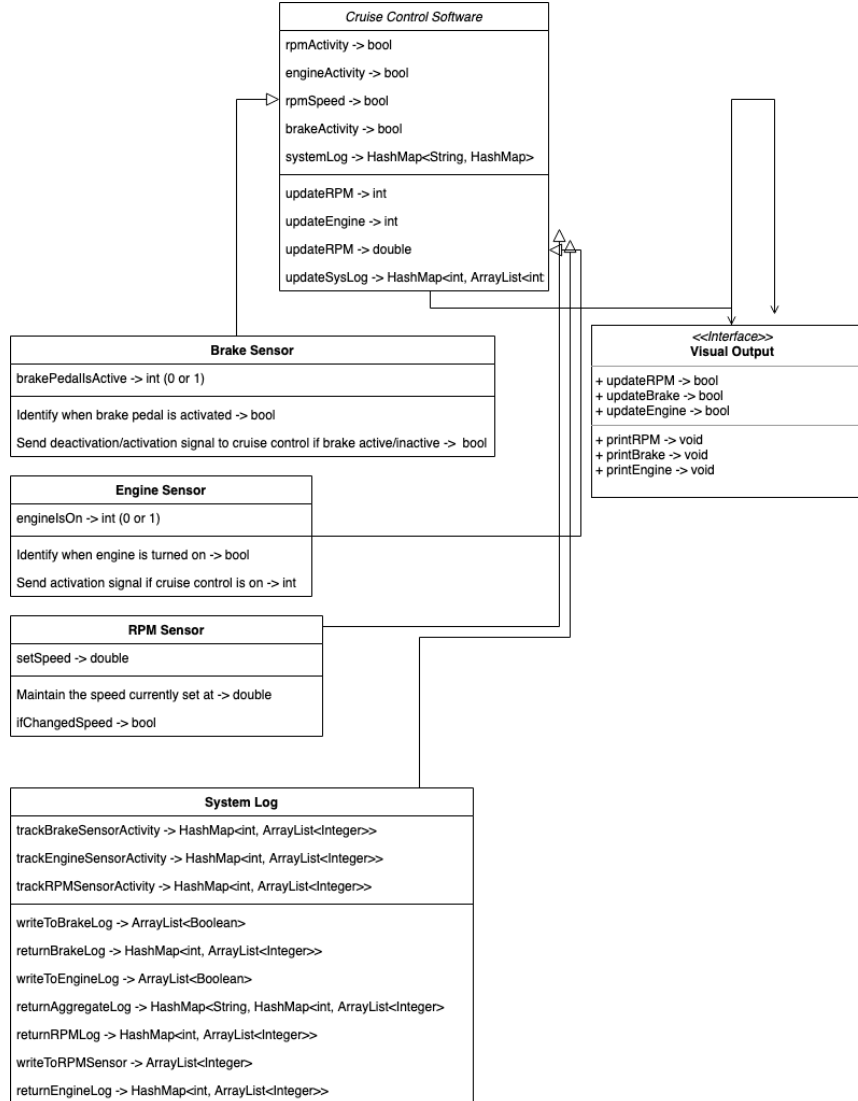


Figure 2: Sample UML class-based model for the cruise control system.

### 4.3 UML CRC Model Index Card

1. See Figure 3 for the CRC Model Index Cards for the cruise control system.

<b>Brake Sensor</b>  System Status = On Display Message = N/A Display Status = N/A  Entry/Subsystems ready Do: If brake is pressed, stop cruise control Do: If brake is not pressed, do not stop cruise control Do: If cruise control is on/off, do things accordingly	<b>Engine Sensor</b>  System Status = On Display Message = On/Off Display Status = On if On, if Off, no message shown  Entry/Subsystems ready Do: If car is on, the engine should be on as well Do: If car is off, engine should be off Do: In order for engine to turn on, the brake must be pressed when turning on the car	<b>RPM Sensor</b>  System Status = All internal, sensor is turned on Display Message = N/A Display Status = N/A  Entry/Subsystems ready Do: When cruise control is on, maintain the speed set with cruise control. Do: When it is off, default to the user
<b>System Log</b>  System Status = On Display Message = N/A Display Status = N/A  Entry/Subsystems ready Do: poll user input Do: read user input (if given user input) Do: interpret user input	<b>Visual Output</b>  System Status = On Display Message = N/A Display Status = N/A This is internal.  Entry/Subsystems are ready Do: ensure that everything is working and providing feedback to the system log Do: ensure that user input is interpreted correctly	

Figure 3: Sample UML CRC model index cards for the cruise control system.

### 4.4 UML Activity Diagram

1. See Figure 4 for the activity diagram of the cruise control system.

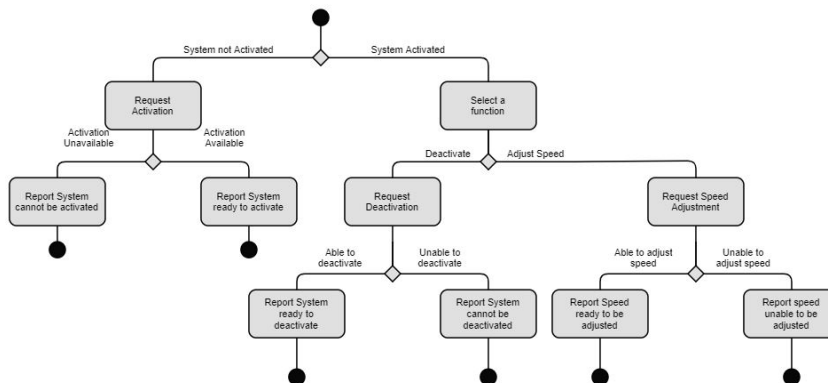


Figure 4: Sample UML activity diagram for the cruise control system.

## 4.5 UML Sequence Diagram

1. See Figure 5 for sequence diagram of the activation of the cruise control system.

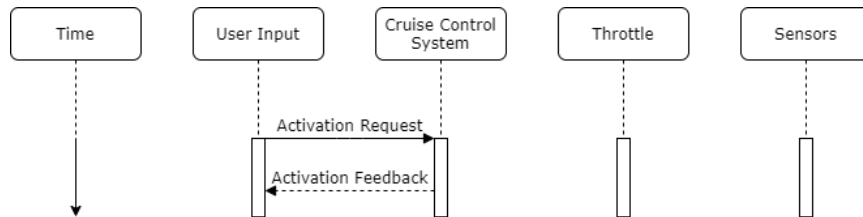


Figure 5: Sequence UML diagram for activation of the cruise control system.

2. See Figure 6 for sequence diagram of cruise control system setting speed.

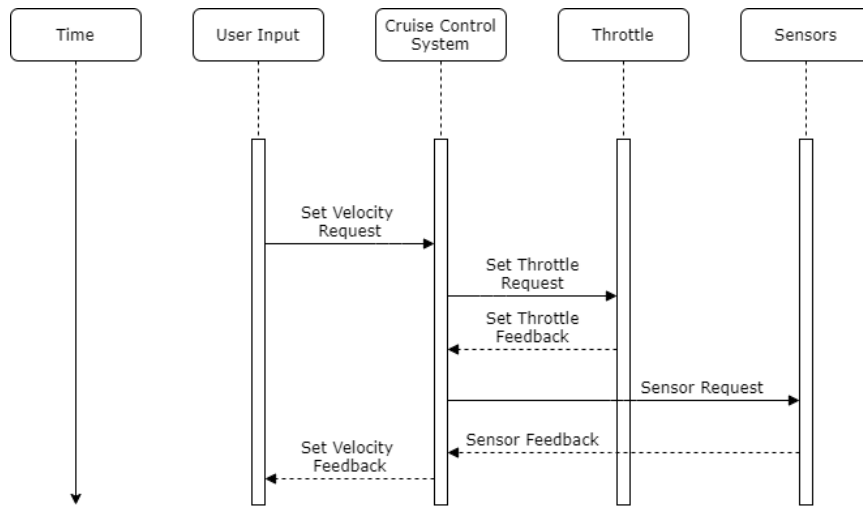


Figure 6: Sequence UML diagram for the cruise control system setting speed.



3. See Figure 7 for sequence diagram of cruise control system adjusting speed.

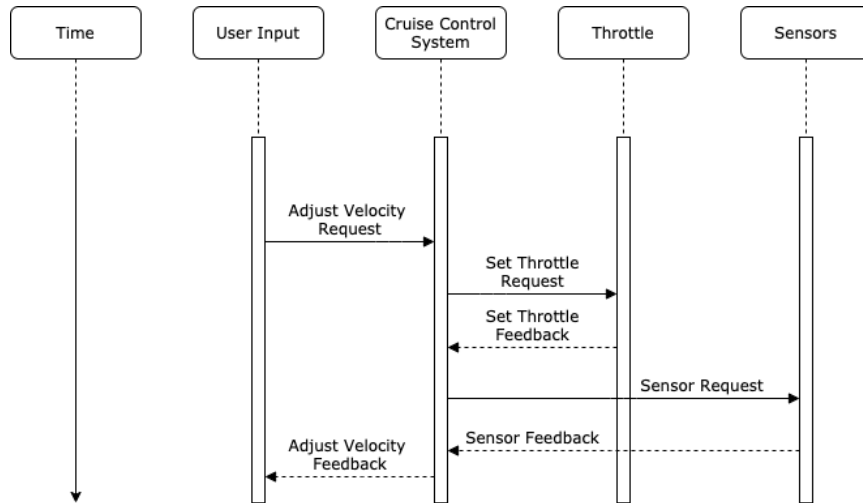


Figure 7: Sequence UML diagram for the cruise control system adjusting speed.

4. See Figure 8 for sequence diagram of the cruise control system being suspended when the user presses the gas pedal.

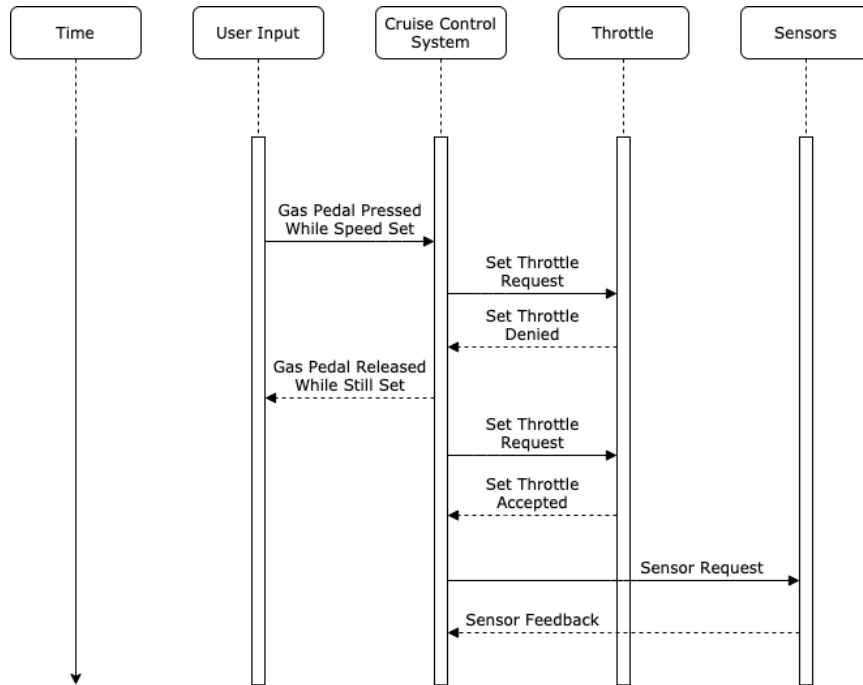


Figure 8: Sequence UML diagram for the cruise control system suspending during gas pedal being pressed.

5. See Figure 9 for sequence diagram of the cruise control system being deactivated.

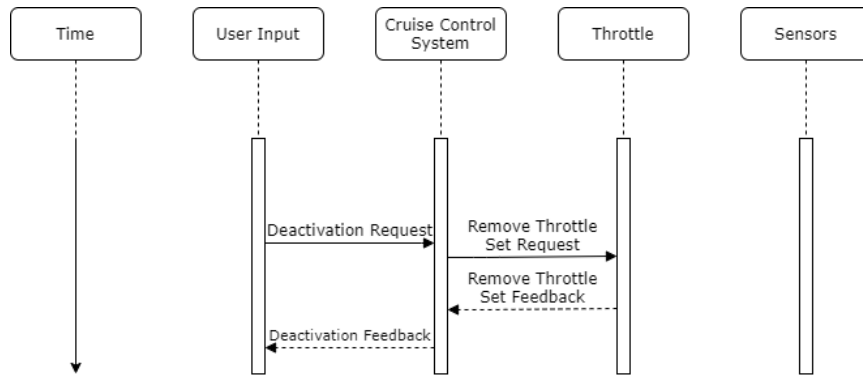


Figure 9: Sequence UML diagram for the cruise control system being deactivated.

6. See Figure 10 for sequence diagram of the administrator accessing the cruise control system logs.

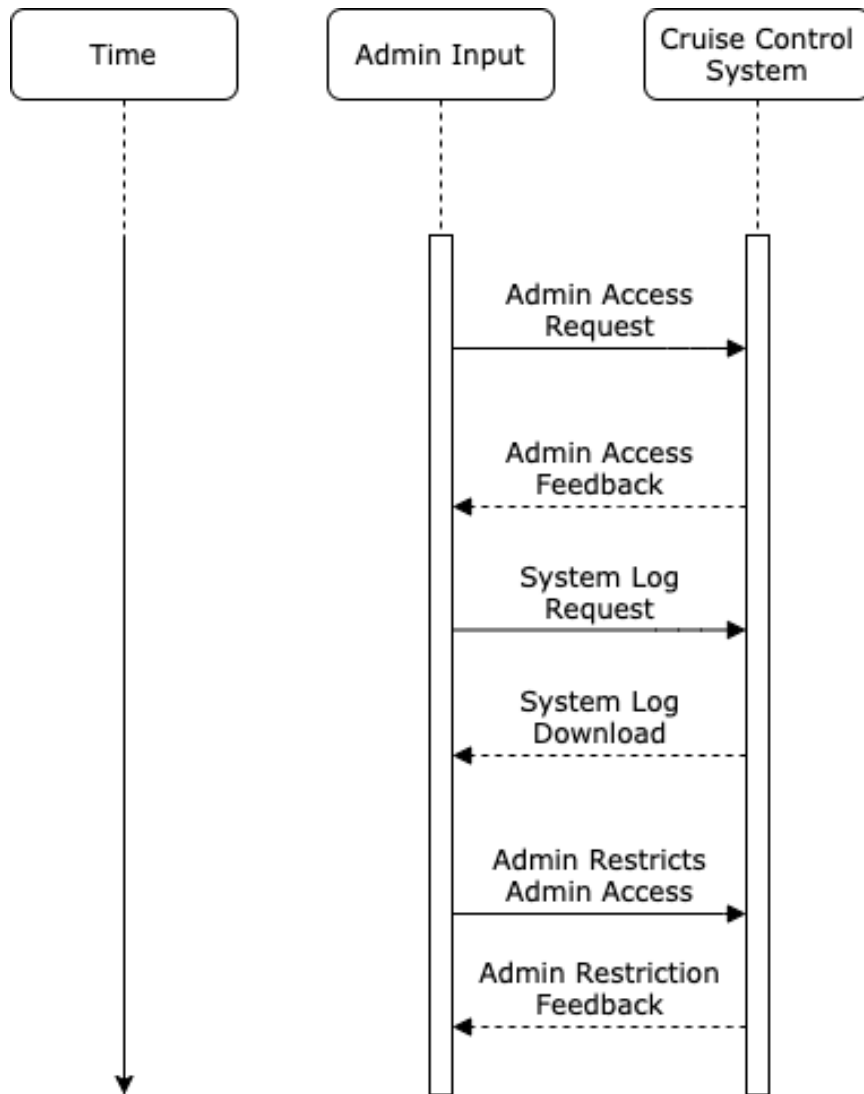


Figure 10: Sequence UML diagram for the administrator accessing cruise control system logs.

## 4.6 UML State Diagram

1. See Figure 11 for the state diagram of the cruise control system.

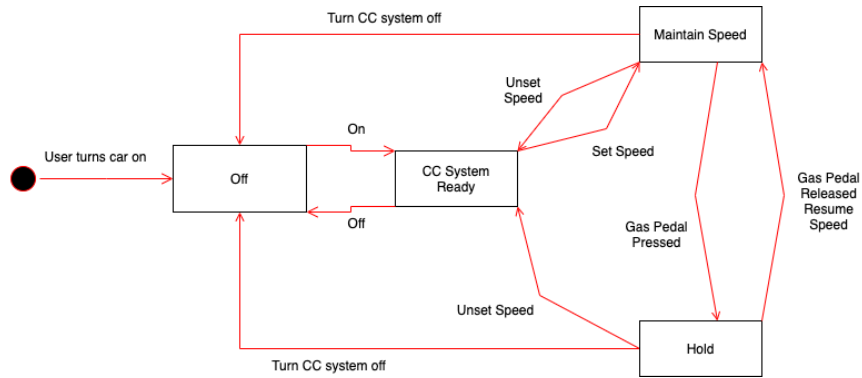


Figure 11: Sample UML state diagram for the cruise control system.

## 5 Software Architecture

### 5.1 Architecture Style

We decided to implement our Cruise Control System by using Object Oriented Programming.

1. We chose this architecture style because it will allow us to represent the different aspects of the cruise control system as different objects. For example, we will be able to represent the engine, the brake, the throttle, the sensors, and the log as different objects. These objects will have different attributes which will allow the program to closely resemble the real world. The brake object will contain a boolean that determines if the brake is being pressed or not. It will also have a function that will decrease the current speed of the vehicle. The sensors will have variables that determine if the current speed is less than, greater than, or equal to the desired cruising speed. The throttle will contain a boolean that determines if the user is trying to manually increase the speed of the vehicle. It will also have a function that will increase the speed of the car. The engine object will contain a boolean that determines if the vehicle is on or off. The log will be an array. Whenever any action is taken by the driver or the cruise control system, it will be added to the log as a tuple that contains a time stamp and the action that was taken. All of these objects will be used as components of a larger Cruise Control System object.
2. Using object-oriented design will limit the number of programming languages that we would be able to use. Using object-oriented programming can result in more resources being used because the programs can become very large. It is also difficult to determine all of the classes that will be necessary in order to properly implement the Cruise Control System at the beginning of the project.
3. We also considered implementing our Cruise Control System with call and return architecture. This architecture design would have allowed us to split the main program into subprograms. It would have been easier to build upon the program by adding more subprograms. It would have also been able to set a hierarchy for different programs if we used the main program/subprogram style of this architecture.
4. We opted not to use a call and return architecture because this architectural design often does not adequately support the data structures

which would be important for the implementation of the Cruise Control System. Furthermore, due to a large number of subprograms, it may have become difficult to navigate and manage.

5. We did not consider the following architectures:
  - (a) The components of a system encapsulate data and the operations that must be applied to manipulate the data. Communication and coordination between components are accomplished via message passing.
  - (b) Pros: It models the real world very well. With OOP, programs are easy to understand and maintain. OOP offers code re-usability. Already created classes can be reused without having to write them again. OOP facilitates the quick development of programs where parallel development of classes is possible. With OOP, programs are easier to test, manage and debug.
  - (c) Cons: With OOP, classes sometimes tend to be over-generalized. The relations among classes become superficial at times. The OOP design is tricky and requires appropriate knowledge. Also, one needs to do proper planning and design for OOP programming. To program with OOP, the programmer needs proper skills such as that of design, programming and thinking in terms of objects and classes etc.

## 5.2 Components

A software component is an architectural entity that encapsulates a subset of the system's functionality and/or data. A set of components will perform a function that is required by a system. This restricts access to that subset via an explicitly defined interface. The components of a software system are the following (but not limited to):

1. Network and Internet services
2. Hardware level of operating system
3. Logical level of operating system
4. Graphics engine
5. User interface
6. System services

## 7. Command shell

## 8. System utilities

Regarding cruise control specifically, the main component of our cruise control is the engine management system. In order to do this, the cruise control will receive data from the sensor components in which it relays data from the components of the car (take for example, the brake and the sensors).

Components and connectors are used to accomplish a system's goal. This is expressed through an architectural configuration. More precisely, an architectural configuration is an association between components and connectors of software architecture. A connector is not equivalent to a component as components provide application-specific functionality while connectors provide application-independent interaction mechanisms.

Connectors are between the sensors to deliver the data to the cruise control module. This processes the data to determine the speed of the car. The connectors between the cruise control and the engine management system will continually deliver this data to each other.

A software constraint defines how components can be integrated to form the system. A software constraint is a restriction on the degree of freedom you have in providing a solution. Constraints are effectively global requirements, such as limited development resources or a decision by senior management that restricts the way you develop a system.

The information that is shared between the sensor components to the signal that the engine has been started must be delivered very quickly before cruise control can be turned on. The activation and deactivation of cruise control must be done in a specific time constraint. These are all constraints of the system.



### 5.3 Control Management

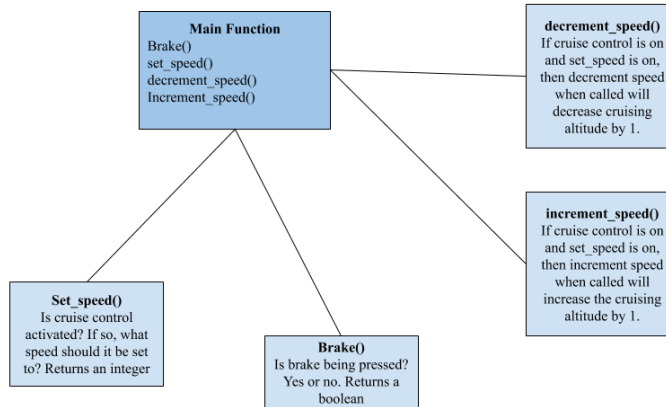


Figure 12: Control management diagram

We are going to have a main function that will have calls to the functions listed above as you can see: `set_speed()`, `brake()`, `increment_speed()`, `decrement_speed()`. These functions are essentially what are going to control our cruise control module. Brake will be a boolean as it is either true that the brake is being pressed or false if it is not being pressed. If cruise control is on and there is a set speed that is greater than 25 (which is the only way that cruise control can be activated in the first place), then if the brake function goes from false to true, then we shut off the cruise control entirely.

This is similarly listed out in the diagram as shown. All of our functions interact with our main function which is essentially the driver of our cruise control program.

### 5.4 Data Architecture

In terms of data architecture, the plan is to adopt a scalable, object-oriented, NoSQL database like MongoDB. Considering that the project is going to be programmed in an object-oriented language such as Java or C++,

having the data schema represented in the same programming paradigm streamlines the technical thought process behind the project. Furthermore, MongoDB is known for its high availability and performance. Having a data schema known for reliability is imperative for a mission-critical piece of software like cruise control.

Due to the use of Java/C++ and MongoDB, the general paradigm of the data architecture is object-oriented. Communication between the components is done via passing information as parameters to functional components such as methods and classes. Cruise control software requires information to be readily available to make critical decisions. We would not use a data center oriented architecture because it would not be fast enough for a cruise control system. An architecture based on passing information as parameters allows us to continually pass around data within the system, making data access trivially fast and facilitates quick decisions and computations that can mitigate the risk of fatal injury or things spiraling out of control.

To optimally implement this structure, we would need to define several functional components that each handles it's own individual task and can be called as a function call to perform its individual task quickly. So, the cruise control system can have its own functional component for controlling the speed, controlling the brake, and sending visual and audio information to the user to inform about cruise control status such as whether it is on or off. The data components would always be available for use for functional components (such as program methods) in the cruise control software. This is because the functional components will need to repeatedly query the data components to accurately compute what speed is necessary, whether a brake is needed, and whether the user has requested for the system to turn on or off.

## 5.5 Architectural Designs

1. See Figure 13 for the architecture context diagram in which the external entities that the software interacts with are defined. Some include other systems, devices, and actors.

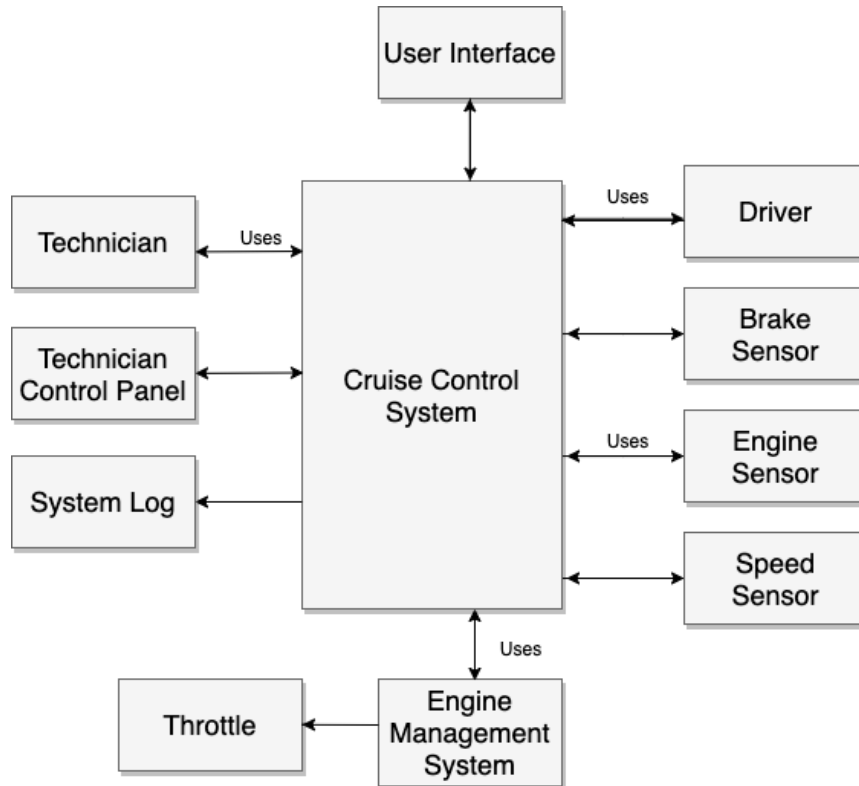


Figure 13: context diagram

2. See Figure 14 for the cruise control archetype. The archetype is an abstraction that represent an element of the cruise control system behavior.

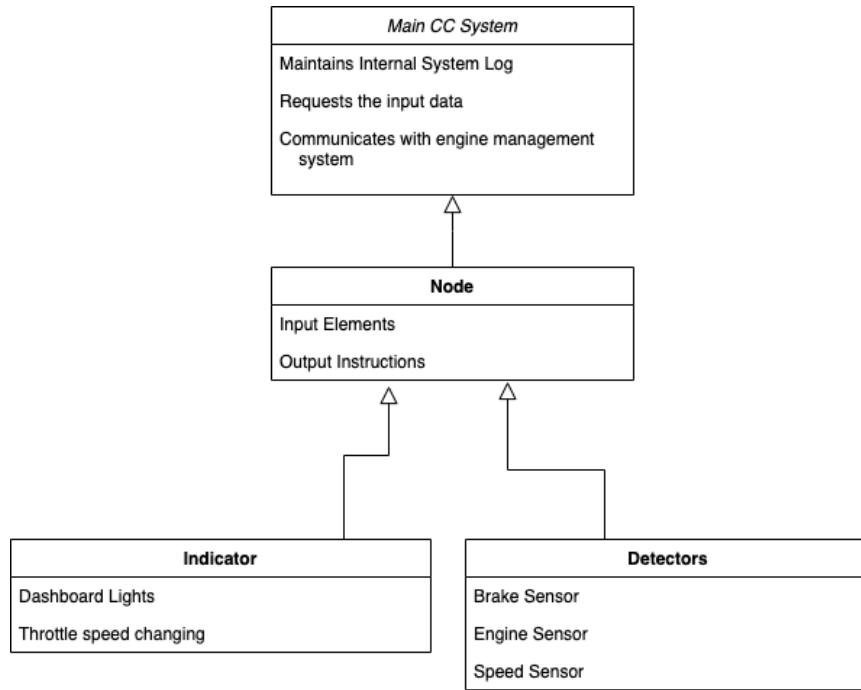


Figure 14: Cruise Control System Archetypes

- See Figure 15 for the cruise control top-Level component in which the archetype is further defined for help with implementation.

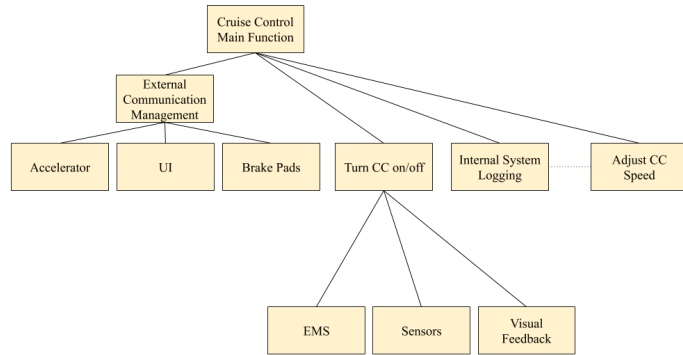


Figure 15: Top-level component

- See Figure 16 for the refined component architecture. This is a more refined version of the top-level component to help with implementation as well.

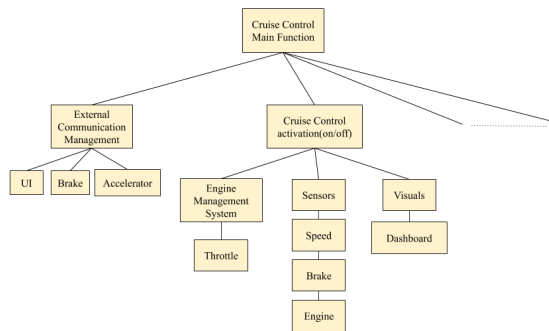


Figure 16: Refined component

## 5.6 Issues

1. Hamzah: The data architecture has not been thoroughly defined. Work through the data architecture and define how exactly the cruise control software will store the data using MongoDB in an object-oriented + call and return architecture. **Resolved: 4/17/2020**
2. Connie: work with Hamzah to identify how control interacts with the Data Architecture and the drawbacks of Object-Oriented design and call and return architectures. **Resolved: 4/17/2020**
3. Eric: Make security contingencies in case of data leak/ security issues. **Resolved: 4/16/2020**
4. Mike: Consider any architectural alternatives to the current design to ensure that the best implementation is chosen. **Resolved: 4/18/2020**