Software Requirements Specification (SRS)
Project TJA 2

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Traffic Jam Assist (TJA) system is designed to help drivers deal with driving fatigue and prevent accidents in heavy traffic in limited access highways. TJA allows the vehicle to reach and maintain a constant speed while having a set distance to a target vehicle; where the target vehicle is the closest vehicle in front of the driver's vehicle. TJA uses several sensors that allow it to detect nearby vehicles and calculate their speed relative to the driver’s vehicle.

To display the TJA system, this document provides information regarding the functionality, requirements, global variants, security, and system dependencies. To attain this goal, system models and in-depth explanations are used on each topic covered before.

1.1 Purpose

This document allows the customers to validate the TJA system to check if it fits within their requirements and provides all the information needed to create a design for the system. There's examples and descriptions on how the TJA should act during average usage, as well as during all edge cases. Examples and descriptions are written in detail and shown using diagrams and models as visual aids.

Visual aids included are sequence diagrams, state diagrams, a case diagram, and a domain model. Sequence diagrams explain how classes within the domain model will interact depending on different variables in the system. The domain model shows the connections and relationships between different parts within the system. State diagrams map out the transitions between different states in the TJA. And finally, the case diagrams give high level information regarding how the system is used between actors.

Written descriptions are also available in the form of a software and hardware requirement list, and product descriptions. The requirement list explains what the TJA needs in order to function properly, in regards to hardware and software. The product descriptions expand on the TJA constraints, dependencies, and functions; while also explaining how the user and other systems interact with the TJA.

1.2 Scope

TJA is a driving-aid system, available to the driver when the vehicle is in drive, that allows the vehicle to follow the flow of traffic while on a limited access highway. The driver interacts with the TJA through the ACC buttons. TJA can be activated by the driver
when the system determines the vehicle is currently on a limited access highway and the vehicle gear is set to drive. The driver is able to choose a maximum speed and minimum distance from the target vehicle as TJA parameters. While the TJA is active, its first priority is to stay outside the minimum distance from the target vehicle. Where the minimum distance is a user set mode between three options. TJA's secondary priority is to accelerate to and maintain the user-set max speed. The TJA can apply the brakes of the vehicle, either to bring it to a full stop or slow it down; as well as increase the current speed of the vehicle.

1.3 Definitions, Acronyms, and Abbreviations

- **TJA**: Traffic Jam Assist
- **ACC**: Adaptive Cruise Control
- **Target Vehicle**: The closest vehicle in front of the vehicle using the TJA, which is being track to calculate the closing distance between both vehicles
- **System's Vehicle**: The vehicle that the TJA system is operating in
- **LAH**: Limited Access Highway
- **OTA**: Over-The-Air

1.4 Organization

The organization of the rest of this document is as indicated. **Section 1** introduces and briefly explains the TJA system. By providing explanations to the purpose, scope, and vocabulary of the TJA.

**Section 2** provides in-depth explanations on characteristics of the TJA system. The explanation describes the context of TJA being used and its functions. Section 2 also specifies assumptions, constraints, and dependencies of the TJA.

**Section 3** defines a requirement list focused on the hardware, software, and security measures used by the TJA. As well as, declaring global invariants of the TJA system.

**Section 4** contains diagrams and models used to describe several aspects of the TJA system. Made up of Case diagrams that show how actors interacted with the TJA. Domain models that show the software implementation and design of the TJA system. Sequence diagrams that showcase TJA behavior in different cases. And lastly, state diagrams that show how transitions are made in the TJA system.

**Section 5** provides a prototype of the TJA and a tutorial to using the prototype.

**Section 6** has references used in the paper including a link to the teams website.

**Section 7** is contact information for learning more about this document and project.

2 Overall Description

This section of the document will give an in-depth description of the TJA system. It will begin by giving background context to the system, and then describe the system’s functions, followed by expectations about the system’s users. The section will then conclude with a description of the
system’s constraints, dependencies, and any features that may be added in a future release/update of the system.

2.1 Product Perspective

The TJA (Traffic Jam Assist) system is a product meant to be used in tandem with a vehicle’s ACC (Adaptive Cruise Control) system in order to allow the driver of the vehicle the system is being used in to have a more relaxed driving experience while traveling on particularly limited access highways. While on said limited access highways, the system will be able to aid the driver in the navigation of highway traffic by tracking a target vehicle and maintaining a steady following distance to it.

The driver of the vehicle will interact with the system through a series of buttons either located on the steering wheel of the vehicle or the dashboard of the vehicle. The “on” and “off” buttons on the system will determine whether or not the TJA system will ever activate when on a limited access highway and are only meant to be used when the vehicle is not moving. The “stop” and “resume” buttons are buttons on the steering wheel as well and are used to activate and deactivate the TJA while the vehicle is in motion, and using these two buttons together will keep the predetermined parameters of the system in use. The “cancel” button is also on the steering wheel and has a very similar functionality to the “stop” button, but instead of keeping the parameter information, the parameter information is forgotten by the system. Finally, there is a distance selection button that is used to determine the following distance the system will use when following its target vehicle.

There are many different pieces of hardware that are necessary for this system to function properly. One hardware constraint for the system is that the system is going to require a front facing sensor system that can be used by the system in order to locate and track a target vehicle. Another hardware constraint for the system is an internal sensor system consisting of a steering wheel sensor and an in-vehicle camera which are both used in order to make sure that the driver is paying attention to where they are driving. Also, the system will require buttons for all previously mentioned systems.

2.2 Product Functions

There are three main components to the TJA system that allow it to function properly. These are the User Settings Buttons, the Internal Sensor System, and the Front Facing Sensor System. These three components, along with the typical hardware pieces found in a vehicle such as a braking system, allow proper functioning of the TJA System.

Using the TJA system, when the user enters a pre-approved limited access highway and has the system activated, the system will immediately begin looking for a target vehicle. When a target vehicle is found, the system’s vehicle will begin following the target vehicle at a steady
pace that coincides with the predetermined parameters that were decided by the driver such as
distance and maximum speed. This will continue until either the followed target system is lost for
some reason and the vehicle then begins looking for a new target vehicle, or the driver leaves
the pre-approved limited access highway which will cause the TJA system to deactivate.

2.3 User Characteristics

The user must be able to drive the vehicle that the TJA system is being used in, and also be
able to interact with the control system to use the system properly. The user must also be
always aware of their surroundings and be a conscious driver in case the system has to
deactivate for an unexpected reason.

2.4 Constraints

Hardware constraints are very important to the TJA system because if there is even one faulty
piece of hardware, the system will deactivate and will only allow itself to reactivate when the
vehicle is parked and the entire system is fully functioning again. This means that the entirety of
the front facing sensor system and the internal sensor system must be fully functional for the
driver to be able to activate the system after parking the cat.

As for software constraints, it is imperative that there is a present and functioning ACC system
in the vehicle. Without one, the TJA system will not be able to function properly and will not
allow itself to activate under such conditions. Another software constraint is that the system
must have very minimal lag because of how critical it is to the safety of the driver for them to be
able to immediately modify the system’s parameters and activation status while in possibly
dangerous road conditions.

2.5 Assumptions and Dependencies

It is assumed that a vehicle that is using the TJA system has all of the usual features that a
driver can expect to find and use in their vehicle. Some examples of these features include a
steering wheel, automatic transmission, infotainment system, and a brake pedal. It is also
assumed that the vehicle also has an ACC system, as the TJA system would not be able to
function without it.

2.6 Approporportioning of Requirements

Due to the nature of the system needing to know the location of pre-approved limited access
highways, the system will need to over time be updated with new information on these locations
as there is a possibility that there may be more limited access highways that are approved of or previously used highways that are now disapproved of.

3 Specific Requirements

This section contains a hierarchical list of requirements for the TJA system. According to the importance of the requirements, they can be divided into global invariant, primary, and secondary requirements. The primary requirements need to consider three aspects, hardware requirements, software requirements, and cybersecurity requirements.

1. Global Invariant Requirements

1.1. The system should always deactivate if the brake pedal has been pressed by the driver. Even the slightest pressure on the brake pedal will deactivate the system.

1.2. The system should never attempt to move the vehicle backwards. The scope of this system only relates to the forward motion and stopping of the vehicle, and has no behavior related to the vehicle being put into reverse or moving backwards.

1.3. The system will only activate if a GPS confirms that the vehicle is on a restricted access highway. If the GPS is malfunctioning or it does not have a signal, the system will not activate.

1.4. The safety of the passengers is always a priority for the system and should never be the cause of an accident

2.1 Hardware Requirements:

2.1.1 The system requires a functional GPS to detect if it's on a limited access highway. The GPS must be accurate within 16ft of the vehicle and refresh every second.

2.1.2 There must be a speaker capable of alerting the driver with sound notifications ranging from 50db - 80db.

2.1.3 The vehicle must have an infotainment system capable of showing alerts to the driver by flashing different colors, including red and blue.

2.1.4 The system must use a set of buttons that can either be placed on the steering wheel or dashboard within the driver's reach. The buttons allow the driver to choose how and when TJA functions.

2.1.5 On the dashboard, there must be an on and an off button that engages or disengages the system accordingly.
2.1.6 The steering wheel must have stop/pause, resume, and cancel buttons that engage and disengage the TJA accordingly.

2.1.7 The dashboard must also have plus and minus buttons. Both buttons will be responsible for telling the TJA system to increment and decrement the max speed user parameter. The change to the max speed should be 5mph.

2.1.8 TJA requires a high definition camera that works in low-light and is able to see the driver’s eyes.

2.1.9 The dashboard of the system must have lights to indicate what user settings are currently selected and the mode of the TJA.

2.1.10 The dashboard should have buttons that allow that driver to choose one of three TJA's minimum distance from target vehicle parameters.

2.1.11 The vehicle should have front facing sensors that can detect data used to calculate closing rate between obstacles in front of the vehicle. These sensors should be a front camera, a radar sensor and/or a LiDAR sensor. The vehicle must also be able to detect when these sensors malfunction.

2.1.12 The steering wheel needs to have a capacitive touch sensor that can detect whether the driver is touching it.

2.1.13 The TJA system must be alerted by the vehicle's slip detection system during a loss of traction.

2.1.14 The vehicle must provide a way for the TJA to request brakes and gas to be applied.

2.1.15 The vehicle should have a speed management system that interacts with the on-board computer and is able to accelerate and decelerate the vehicle.

2.2 Software Requirements:

2.2.1 If the GPS loses signal or detects that the vehicle has left a limited access highway for more than three seconds, TJA will deactivate. During a standard deactivation of TJA a light beep (50db - 60db) will be emitted and the infotainment’s system will flash red.

2.2.2 The on button must initialize the TJA system with default or user set parameters if it's off. If TJA is already active the on button does not do anything.
2.2.3 The off can only be used if TJA is active. If the off button is used, TJA is disengaged and user parameters are reset back to TJA’s default values.

2.2.4 If the resume button is used while the TJA is in stop mode, it reengages the TJA system with previous user parameters. Otherwise, the resume button doesn’t do anything.

2.2.5 If the stop button is used while the TJA is active, the system should switch to stop mode. While in stop mode, TJA will be disengaged and have saved users parameters. When pressed while in stop mode or TJA is inactive the system will do nothing.

2.2.6 The cancel button acts similar to the stop button. The only difference is if TJA disengages the user parameters will be reset to their default values.

2.2.7 The on-board computer of the vehicle should be able to communicate with the TJA system. It should be able to activate and deactivate the system and also receive the data from the internal and external sensors and determine the speed for the speed management system. If the malfunction is detected in any of the front-facing sensors used in the system, the system should immediately deactivate and should not be able to be turned back on for the rest of the vehicle ride.

2.2.8 TJA will use the driver facing camera to check every second if the driver is paying attention to the road. If the driver is distracted for five seconds or more, the TJA system will alert the driver with a single 80db beep and a flashing light from the infotainment system. If the driver gets distracted another time or fails to pay attention to the road within three seconds. TJA will deactivate and emitted another 80db beep to alert the driver.

2.2.9 The System will allow the driver to pick between three minimum distances from the target vehicle. The three parameter names are “CLOSE”, “STANDARD”, “FAR”. Each parameter name corresponds to 30ft, 40ft, and 60ft respectively.

2.2.10 The system will determine a value for the closing rate based on data obtained by a front camera, a radar sensor and/or a LiDAR sensor in front of the vehicle. The system should also use a different way to access the brakes and accelerator than the driver’s brake pedal and accelerator pedal. If the vehicle already has an adaptive cruise control with the required sensors and front facing camera, the adaptive cruise control can be used.

2.2.11 If the closing rate is zero or positive, the vehicle should not slow down due to the vehicle in front of it because the vehicle in front is not coming too close. If the closing rate is negative, then the vehicle should slow down and try to maintain a steady distance to the target vehicle.
2.2.12 In case of malfunction, the system will alert the driver that it has deactivated with an audible beep (60-70db) and notify the driver with a notification on the infotainment screen that the system was deactivated due to a malfunction. The notification should also notify the driver of which sensor has malfunctioned and that the system will not turn on for the rest of the vehicle ride.

2.2.13 The system should require the driver to touch the steering wheel every 30 seconds. The vehicle will alert the driver that the steering wheel needs to be touched in 3 seconds by emitting a light beep (50db-60db) and a flashing blue light on the infotainment system. If the driver fails to touch the steering wheel in time, the vehicle will emit louder beeps (70db- 80db) every three seconds and the system will disengage. The beeps will not stop until the driver touches the steering wheel again.

2.2.14 If the vehicle’s slip detection system detects a loss of traction for the vehicle, the TJA system should deactivate and the user should be alerted with a notification on infotainment system and an audible beep (60db -70db).

2.2.15 At all times the TJA is on the dashboard must display the current user parameters and state of the system. This includes min distance from target vehicle, max allowed speed, stop/resume mode, and if TJA is currently on.

2.3 Security Requirements

2.3.1 The TJA is isolated from all non-dependency systems and only has read privileges for any shared data between other systems.

2.3.2 All OTA updates are verified to be valid and from official sources and must be initiated from the vehicle's controller. The TJA does not have any independent access to wireless forms of connection.

2.3.3 The TJA system monitors all systems it's dependent on and only works if everything is functioning properly.

3 Secondary Requirements

3.1 The transitions between TJA and ACC are seamless
3.2 Avoid aggressive braking and acceleration
3.3 Have clear and accessible alerts to the user
3.4 Allow the driver to be more relaxed while in heavy traffic
4 Modeling Requirements

This section of the document describes multiple models that represent the TJA system. Models include use case tables, use case diagrams, and domain model diagrams. Each model has a description that details the information shown and used Unified Modeling Language Notation.

4.1 Use Case Diagram

Figure 1 below shows a use case diagram which describes all the major use cases in our system. The actors include driver, ACC, GPS, steering wheel, brake pedal, slip detection system, brake, accelerator, and target vehicle. The actors are placed outside the blue box and are represented by stick figures. Each actor plays a role in the system and has use cases that interact with other actors. The use cases are shown in the diagram as oval shapes with the use case title, with lines connecting them to their actors. Use cases are connected using lines. The dotted arrow labeled as ‘extend’ signifies that the use case being pointed to is an extension of the other. For example, self-deactivation is an extension of deactivation. The other lines represent cross references between use cases. What it means is a particular use case is mentioned in another use case. An example is self-deactivation being mentioned in camera watching driver use case. Below the diagram is a series of tables which further describes each use case and their relationships.
Use Case: Self-Deactivation

Actors: GPS, Steering Wheel, Slip Detection System

Description: The system will automatically disengage in any of these occasions:

1) If the GPS is faulty or detects that the vehicle has left a pre-approved limited access highway for 3 seconds
2) If any of the front-facing sensors is detected to be faulty
3) If the driver has not touched the steering wheel in the last 30 seconds
4) If the camera watching the driver has detected that the user has not looked at the road in the last 10 seconds.
5) If the vehicle slip detection system detects that the vehicle has a loss of traction

In all cases the system will emit an audible (60-80 db) beep and alert the driver about the reason of the deactivation with a notification on the infotainment system. This use case extends the deactivation use case.

Type: Primary

Includes: N/A

Cross-refs: Requirements 2.1.1, 2.1.12, 2.1.13, 2.2.1, 2.2.7, 2.2.8, 2.2.12, 2.2.13, 2.2.14, 2.3.3

Use cases: Faulty front facing sensors, distracted driver, leaving a limited access highway, vehicle has a loss of traction typical of bad weather situations
### Use Case: Deactivation

**Actors:** Driver, ACC

**Description:** The system can be deactivated manually at any time and the user can choose between these options to deactivate the TJA system:

1. By pressing the brake pedal (even the lightest pressure is sufficient)
2. By using the Stop/Resume button on the steering wheel. This button will temporarily disable TJA and ACC but will keep all the settings in memory so that it can be activated with those settings if the ACC is resumed.
3. The Cancel button on the steering wheel that will disable the ACC and the TJA and reset the settings.
4. By pressing the On/Off button that will stop the ACC and the TJA from engaging for the rest of the vehicle ride or until it is pressed again.

**Type:** Primary

**Includes:** N/A

**Cross-refs:** Requirement 2.1.5, 2.1.6, 2.2.3, 2.2.5, 2.2.6

**Use cases:** Braking while using TJA, Temporarily disabling the system, Turning off the system, Canceling system settings

### Use Case: Activation

**Actors:** Driver, ACC, GPS

While the vehicle is not moving, the driver can press the “on” button for the TJA system so that the system will activate when ACC is also on and the vehicle is on a pre-approved limited access highway. The driver can also press the “resume” button to reactivate the TJA system if the driver had previously used the “stop” or “cancel” button beforehand. The system will only activate when entering a pre-approved limited access highway if the TJA system is on, the ACC system is on, and the highway is a pre-approved limited access highway.

**Type:** Primary

**Includes:** N/A

**Cross-refs:** 2.1.4, 2.1.5, 2.1.6, 2.2.2, 2.2.4

**Use cases:** The vehicle has driven onto a limited access highway while using ACC and the system activates, and The system reactivates from the driver pressing the “resume” button, after previously pressing either the “stop” or “cancel” button

### Use Case: Distance selection
### Use Case: Speed selection

**Actors:** Driver

**Description:** Allows the driver to select the maximum speed that the TJA system will use, and increment or decrement the max speed by 5 mph.

**Type:** Primary

**Includes:**

**Cross-refs:** 2.1.3, 2.1.7, 2.1.9, 2.2.15

**Use cases:** The driver of the vehicle wants to go faster/slower so they increment/decrement the maximum speed of the TJA system.

### Use Case: Camera watching driver

**Actors:** Driver

**Description:** The system will use a camera that will watch the driver and determine whether or not they are paying attention to the road in front of them. If five seconds goes by without the driver paying attention, an audio beep is used to alert the driver that they are not paying attention. If another five seconds goes by without the driver paying attention, the TJA system is deactivated.

**Type:** Primary

**Includes:**

**Cross-refs:** 2.1.2, 2.1.8, 2.2.8

---

**Actors:** Driver

**Description:** When the TJA system is first enabled, the TJA system will choose a default distance. If the vehicle is not in motion, the driver has the option to choose one out of the three distance measurements. The three settings will be displayed as “CLOSE”, “STANDARD”, “FAR” and will stay at a distance from the target vehicle of 30ft, 45 ft and 60 ft respectively. The system will display the selected distance to the driver, using the dashboard.

**Type:** Primary

**Includes:**

**Cross-refs:** 2.1.10, 2.2.9, 2.2.11, 2.2.15

**Use cases:** A vehicle is currently on a limited access highway and the driver has the TJA system turned on, the system will keep the distance selected from the driver away from the target vehicle.
Use cases: Watching the driver in order to see if the driver is consistently paying attention to the road in front of them.

Use Case: Speed management

Actors: Brake, Accelerator

Description: The vehicle will always try to keep a steady speed while following the target vehicle, slowing down and speeding up when necessary in order to keep the desired distance with the vehicle.

Type: Primary

Includes: N/A

Cross-refs: 2.1.3, 2.1.14, 2.1.15, 2.2.7, 2.2.10

Use cases: The vehicle has a target vehicle in front and will slow down or accelerate based on the distance from the target vehicle in front and the settings selected by the driver.

Use Case: Target vehicle detection/sensing system

Actors: Target vehicle

Description: The vehicle will be able to consistently detect the distance between itself and the target vehicle in front of it. Using this information to calculate and update the current closing distance between both vehicles.

Type: Primary

Includes: N/A

Cross-refs: 2.1.11, 2.2.10

Use cases: Giving data to the speed management system that allows it to function correctly.

4.2 Domain Model

Figure 2 below shows an object-oriented model, or domain model, for our system. It uses UML class diagram notation for showing relationships. The line with a diamond on the end signifies aggregation, which means that one class is part of another. For example, Cancel Button is part of User Settings Button. Other relationships are shown with a dotted line with an arrow at the end that represents dependency. For example, the brake pedal is dependent on the
driver. Every class in the diagram has a data dictionary below which describes in detail the class, its attributes, its operations, and its relationships.

Figure 2: Domain model
<table>
<thead>
<tr>
<th>Element Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Board Computer</td>
<td>On-board computer of the vehicle that will process the inputs from the vehicle’s sensors and the user settings buttons. This is the general computer of the vehicle and is not specific of the TJA system.</td>
</tr>
</tbody>
</table>

### Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TJAAllowed: boolean</td>
<td>Boolean that confirms that the TJA can be activated. This is set to false after a detected malfunction and should not be changed until the end of the current vehicle ride.</td>
</tr>
<tr>
<td>TJASettings</td>
<td>Settings for distance from the target vehicle and for max speed</td>
</tr>
<tr>
<td>ACCTurnedOn</td>
<td>Turns on the TJA system</td>
</tr>
</tbody>
</table>

### Operations

<table>
<thead>
<tr>
<th>Operation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pauseTJA()</td>
<td>Pauses the TJA system when the driver presses the pause button. It will also run saveSettings so that the latest settings for the TJA will be restored when resumed</td>
</tr>
<tr>
<td>activateTJA()</td>
<td>Activates TJA system with the default settings</td>
</tr>
<tr>
<td>deactivateTJA()</td>
<td>Deactivates TJA system</td>
</tr>
<tr>
<td>resumeTJA()</td>
<td>Resumes the TJA system functionalities with the previously selected settings</td>
</tr>
<tr>
<td>saveSettings()</td>
<td>When TJA system is paused, the on-board computer will save its current settings for when it is resumed</td>
</tr>
<tr>
<td>disallowTJA()</td>
<td>Called when a malfunction is detected in the front-facing sensor. This sets TJAAllowed to false and stops the vehicle from activating TJA for the rest of the vehicle ride</td>
</tr>
</tbody>
</table>

### Relationships

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS system</td>
<td>The computer receives report about position from the GPS system</td>
</tr>
<tr>
<td>Brake Pedal</td>
<td>Sends deactivate signal to the computer</td>
</tr>
<tr>
<td>Internal Sensors</td>
<td>Sends deactivate signal to computer</td>
</tr>
<tr>
<td>User Settings Button</td>
<td>Sends signal to computer for either activation/deactivation or to change the settings of the TJA system</td>
</tr>
</tbody>
</table>
### GPS System
- **System**
  - Provides geolocation and time information

<table>
<thead>
<tr>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>reportPosition()</td>
</tr>
</tbody>
</table>

**Description**
- Gets position of the vehicle and reports it to the On-Board Computer

### TJA System
- **System**
  - Monitors the current speed of the vehicle and does not allow it to get closer to the target vehicle in front of it than a set distance. This system is an assistant for the driver and is not meant to be autonomous.

<table>
<thead>
<tr>
<th>Attributes</th>
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<tbody>
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</table>

<table>
<thead>
<tr>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>turnOn()</td>
</tr>
<tr>
<td>turnOff()</td>
</tr>
</tbody>
</table>

**Description**
- System turns on when communicated by the On-Board Computer Class
- System turns off when communicated by the On-Board Computer Class

**Relationships**
- On-Board Computer. Receives information about turning on and off the system
<table>
<thead>
<tr>
<th>Element Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Settings Button</td>
<td>The buttons that control the TJA system.</td>
</tr>
</tbody>
</table>

**Attributes**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressed: boolean</td>
<td>If a button is pressed</td>
</tr>
</tbody>
</table>

**Operations**

**Relationships**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver. The driver operates the buttons being pressed</td>
<td></td>
</tr>
<tr>
<td>Speed management system. It sets the speed based on a particular button</td>
<td></td>
</tr>
<tr>
<td>Cancel Button. One of the buttons a driver can press is cancel</td>
<td></td>
</tr>
<tr>
<td>Select the Distance mode button. Button that would assist in the driver selecting distance</td>
<td></td>
</tr>
<tr>
<td>On/ Off Button. One of the buttons that turns on/off the TJA system</td>
<td></td>
</tr>
<tr>
<td>Stop/Resume Button. One of the buttons that can stop/resume the TJA system</td>
<td></td>
</tr>
</tbody>
</table>

**UML Extensions**

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Sensors</td>
<td>Checks if the driver is still attentive while the TJA system is active.</td>
</tr>
</tbody>
</table>

**Attributes**

**Operations**

**Relationships**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Steering wheel sensor. A sensor that reports to the system if the driver is attentive at the wheel</td>
<td></td>
</tr>
<tr>
<td>In-vehicle camera. The camera that reports to the system if the driver is attentive at the wheel.</td>
<td></td>
</tr>
</tbody>
</table>

**UML Extensions**
### Front Facing Sensors

**Attributes**

**Operations**

- reportMalfunction()  
  If there is an error with a sensor or camera

- sendData()  
  Sends data collected from the sensors

**Relationships**

Radar/LiDAR. It detects objects in front of the vehicle

Front-facing camera. Records the view from the front of the vehicle

**UML Extensions**

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancel Button</td>
<td>A button that deactivates the TJA systems and does not keep track of the settings</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select Distance Mode Button</td>
<td>A button that the driver can select the three possible distances from the target vehicle</td>
</tr>
<tr>
<td>Element Name</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>On/ Off Button</td>
<td>A button that turns on/off the TJA system</td>
</tr>
<tr>
<td>Attributes</td>
<td></td>
</tr>
<tr>
<td>Operations</td>
<td></td>
</tr>
<tr>
<td>Relationships</td>
<td></td>
</tr>
<tr>
<td>UML Extensions</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop/ Resume Button</td>
<td>A button that stop/resume the TJA system. When the TJA system is stopped the current settings are saved</td>
</tr>
<tr>
<td>Attributes</td>
<td></td>
</tr>
<tr>
<td>Operations</td>
<td></td>
</tr>
<tr>
<td>Relationships</td>
<td></td>
</tr>
<tr>
<td>UML Extensions</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steering wheel sensor</td>
<td>The capacitive sensor that detects if the steering wheel is being touched by the driver</td>
</tr>
<tr>
<td>Attributes</td>
<td></td>
</tr>
<tr>
<td>Operations</td>
<td></td>
</tr>
<tr>
<td>Relationships</td>
<td></td>
</tr>
<tr>
<td>UML Extensions</td>
<td></td>
</tr>
</tbody>
</table>
### Element Name

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera that monitors the driver for attentiveness</td>
</tr>
</tbody>
</table>

### Attributes

### Operations

### Relationships

**Driver.** The driver needs to show that they are attentive at the wheel and will be monitored by the in-vehicle camera

---

### Element Name

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detects the distance from the target vehicle</td>
</tr>
</tbody>
</table>

### Attributes

### Operations

### Relationships

**Target Vehicle.** Detects the distance from the target vehicle

---

### Element Name

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A pedal in the vehicle when pressed it activates the brakes and deactivates the TJA system</td>
</tr>
</tbody>
</table>

---
## Attributes

| Pressed: boolean | If the pedal is pressed |

## Operations

## Relationships

Driver. A pedal in the vehicle when pressed deactivates the TJA system

## UML Extensions

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver</td>
<td>The person who operates the vehicle</td>
</tr>
<tr>
<td>Attributes</td>
<td></td>
</tr>
<tr>
<td>Operations</td>
<td></td>
</tr>
<tr>
<td>Relationships</td>
<td></td>
</tr>
<tr>
<td>UML Extensions</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Vehicle</td>
<td>The vehicle that is in front of the driver</td>
</tr>
<tr>
<td>Attributes</td>
<td></td>
</tr>
<tr>
<td>Operations</td>
<td></td>
</tr>
<tr>
<td>Relationships</td>
<td></td>
</tr>
<tr>
<td>UML Extensions</td>
<td></td>
</tr>
<tr>
<td>Element Name</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Speed Management System</td>
<td>Manages the speed the vehicle’s speed</td>
</tr>
<tr>
<td>Attributes</td>
<td></td>
</tr>
<tr>
<td>Operations</td>
<td></td>
</tr>
<tr>
<td>setSpeed()</td>
<td>Sets the speed the driver wants the speed of the</td>
</tr>
<tr>
<td></td>
<td>vehicle to be at</td>
</tr>
<tr>
<td>Relationships</td>
<td></td>
</tr>
<tr>
<td>UML Extensions</td>
<td></td>
</tr>
</tbody>
</table>

### 4.3 Sequence Diagrams

This section will present a series of sequence diagrams to showcase the behavior of the TJA system in certain scenarios. The blue boxes represent our components and the dotted lines beneath them are their respective object lifelines. An arrow pointing from one object lifeline to another represents a message sent from the left object to the right object. The arrow’s label will always contain an attribute or operation of the object to the right, to indicate what gets triggered because of the message. A bracketed statement at the start of an arrow’s label indicates a condition that must be true for the message to trigger the next operation. These conditions are usually referred to as guards. When an arrow points at the same object lifeline it started from, it indicates that the object will trigger an action on itself.

#### 4.3.1 Vehicle Getting on a TJA-Viable LAH

Figure 3 shows what behavior the system will assume once the GPS detects that the vehicle is on a TJA-Viable LAH and ACC is turned on. Once the GPS reports a position that is confirmed by the on-board Computer to be a on TJA-Viable LAH, the on-board computer will check if the attributes TJAAllowed and ACCTurnedOn are true. If they both are True then the on-board computer will run the activateTJA operation. If they are not both true, nothing will happen since the vehicle should not activate TJA. The activateTJA operation will cause the TJA System to run the turnOn operation and activate all the TJA functionalities.
4.3.2 Vehicle Getting off a TJA-Viable LAH

Figure 4 shows what behavior the system will assume once the GPS detects that the vehicle has left a TJA-Viable LAH and ACC was turned on. Once the GPS reports a position that is confirmed by the On-Board Computer not to be on a TJA-Viable LAH for more than three seconds, the On-Board Computer will run the deactivateTJA operation. The deactivateTJA operation will cause the TJA System to run the turnOff operation and deactivate all the TJA functionalities.

4.3.3 Slip Condition Detected

Figure 5 shows what behavior the system will assume if the On-Board Computer detects a slip condition while TJA is active. This can happen when the On-Board Computer receives specific data from the vehicle’s wheels sensors and traction sensors. Once the On-Board Computer detects a slip condition, the On-Board Computer will immediately trigger the turnOff operation on the TJA system, deactivating all functionalities.
4.3.4 Brake Pedal Pressed While TJA Is Active

Figure 6 shows what behavior the system will assume if the brake pedal is pressed while TJA is active. Once the On-Board Computer detects that the brake pedal has been pressed it will run the deactivateTJA operation. Once that is run, it will cause the TJA System to run the turnOff operation that will deactivate all the TJA system’s functionalities.
4.3.5 TJA Paused and Resumed

Figure 7 shows what behavior the system will assume if the brake pedal is pressed while TJA is active. Once the On-Board Computer detects that the brake pedal has been pressed it will run the deactivateTJA operation. Once that is run, it will cause the TJA System to run the turnOff operation that will deactivate all the TJA system’s functionalities.

4.3.6 Sensors Detect Malfunction when TJA is Active

Figure 8 shows what behavior the system will assume if the front sensors detect a malfunction while the TJA system is active. Once the front sensors send data that may indicate that a malfunction is happening, the on-board computer will run the deactivateTJA operation. Once that is run, it will cause the TJA System to run the turnOff operation that will deactivate all the TJA system’s functionalities. The on-board computer will also run the disallowTJA operation that will set the TJAAllowed boolean attribute to false. This will cause the TJA system functionalities to not be available for the rest of the vehicle ride.
4.4 State Diagrams

In this section, various state diagrams will be presented to showcase the possible states and the transitions between them for a component. The state diagrams follow a simple notation. The initial state is depicted by a black-filled circle with an arrow pointing to a blue rectangle. Every blue rectangle represents a possible state and it is labeled with the state’s name. Each arrow indicates a transition between two possible states and is labeled with a condition that is necessary to be true for the transition to happen. A condition, also referred to as a guard, can be either an object’s operation or a certain event that happens.

4.4.1 TJA System

Figure 9 depicts the state diagram for the TJA System component. The initial state of the system is Active and happens when the turnOn operation is run. If the turnOff operation is run the system will enter the Disabled state and the TJA functionalities will be deactivated. If the system is in the Disabled state and the turnOn operation is run, the system will go back to the active state and the TJA functionalities will be restored.

![Figure 9: State Diagram for TJA System](image)

4.4.2 Speed Management System

Figure 10 depicts the state diagram for the Speed Management System component. Once the TJA system is turned on the speed management system will enter its initial state that is the Monitoring state. In this state the System receives the data of the front-facing sensors from the on-board computer and the current. Based on this data the speed management system will enter one of three states: Accelerate, Decelerate and Maintain Speed. If the data reports that the target vehicle is farther than the set distance and the maximum speed is not reached, the system will enter the Accelerate state and accelerate the car. If the target vehicle is at desired distance or farther and maximum speed is reached, the system will enter the Maintain Speed state and maintain the maximum speed. If the target vehicle is closer than the set distance or current speed is greater than max speed, the system will enter the Decelerate state.
where it will lower the speed of the vehicle. Immediately after entering either the Accelerate state, the Maintain Speed state, or the Decelerate state, the system will go back to the Monitoring state to collect new data from the on-board computer. If the TJA system is turned off the speed management system will enter the Deactivated state and its functionalities will be deactivated. The speed management system will stay in the Deactivated state until the TJA system is turned on again, at that point it will enter the Monitoring state again.

Figure 10: State Diagram for Speed Management System

4.4.3 On-Board Computer

Figure 11 depicts the state diagram for the vehicle’s on-board computer for its functionalities regarding the TJA system. The on-board computer should be able to keep track of the TJA at all times while the vehicle is on and turn it off based on the sensor’s and button’s inputs. Once the vehicle is turned on, the on-board computer will have the TJA system deactivated. The on-board computer will then activate, pause, cancel, disallow or deactivate the TJA system again based on the sensor’s and button’s inputs of the TJA system.
5 Prototype

The prototype created for the TJA system was created in order to visually show a multitude of scenarios that a vehicle using the TJA system may find itself in. The prototype will be able to show how the system not only functions on certain pre-approved limited access highways, but also how the system functions alongside the interactions from the driver. Using this prototype should be helpful in understanding the system's design and functionality, and give a better idea of what the system will look like when its hardware requirements are implemented into a vehicle.

5.1 How to Run the Prototype

In order to run the prototype, use our team website, head to the link [https://cse.msu.edu/~hettleal/](https://cse.msu.edu/~hettleal/) and click on the “Prototype” link under the Publicly Accessible Links section. This should lead to a Replit page that contains a runnable version of the prototype. Click the start arrow symbol in the center of the run screen and the program will run after a few seconds (5-10 seconds). This should work on most web browsers, regardless of operating system.

5.2 Sample Scenarios

Due to the system being fully interactive, there are numerous scenarios that a user of the prototype can simulate. Below are a few examples of what is possible with the TJA system.

Scenario 1: Turning on and off the system
In the figure below, what the system will look like can be seen after the “On” button (button on steering wheel that has “On” on it) is pressed. The state of the system is afterwards active and the TJA system is ready to function when on a pre-approved LAH.

![Figure 12: visual of behavior from prototype after “On” button is pressed](image)

In the figure below, what the system will look like can be seen after the “Off” button (button on steering wheel that has “Off” on it) is pressed. The state of the system is afterwards inactive and the TJA system will not function under any circumstance in this state.

![Figure 13: visual behavior from prototype after “Off” button is pressed](image)

Scenario 2: pressing “Cancel” button

In the figure below, what the system will look like can be seen in a normal functioning scenario where the state of the system is already active.
Figure 14: visual behavior from prototype before “Cancel” button is pressed

In the figure below, what the system will look like can be seen after the “Cancel” button (button on steering wheel that has “C” on it) is pressed. The state of the system is afterwards inactive and the TJA system will not function under any circumstance in this state. The previously entered parameters are also forgotten after this button is pressed.

Figure 15: visual behavior from prototype after “Cancel” button is pressed

Scenario 3: Distance selection

In the figure below, what the system will look like can be seen in a normal functioning scenario where the state of the system is already active.
Figure 16: visual behavior from prototype before any buttons are pressed

In the figure below, what the system will look like can be seen after the “Increase Distance” button (button on steering wheel that has “+D” on it) is pressed. After pressing this, the distance between the system’s vehicle and the target vehicle will increase if it is not already at its maximum distance.

Figure 17: visual behavior from prototype after “Increase Distance” button is pressed

In the figure below, what the system will look like can be seen after the “Decrease Distance” button (button on steering wheel that has “-D” on it) is pressed. After pressing this, the distance between the system’s vehicle and the target vehicle will decrease if it is not already at its minimum distance.
Figure 18: visual behavior from prototype after “Decrease Distance” button is pressed

6 References

Our Teams Website: TJA2

7 Point of Contact

For further information regarding this document and project, please contact Prof. Betty H.C. Cheng at Michigan State University (chengb at msu.edu). All materials in this document have been sanitized for proprietary data. The students and the instructor gratefully acknowledge the participation of our industrial collaborators.