Automatic Driving Beam (ADB)

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Requirements:

1. The ADB system shall constantly monitor the current driving conditions and adjust the beam accordingly
    a. The Beam Control Subsystem controls illumination levels and direction of headlight beams
    b. The Beam Control Subsystem receives inputs from the Environmental Detection Subsystem
2. The ADB shall adjust the headlight beam's shape and direction depending on the current scenario
    a. When no other drivers within 160 meters in front of vehicle, use high beams to fully illuminate road [1]
    b. The ADB shall switch to low beam mode and set strength to 1000 lumens in the event of oncoming vehicle detection.
    c. The ADB shall switch to low beam mode and set strength to 1000 lumens in the event of trailing a vehicle by 95 meters in the same lane [1]
3. The Environmental Detection Subsystem will detect other vehicles, road signs, and environmental conditions through a combination of built in sensors and cameras
    a. Radar sensors on the front of the vehicle will detect approaching vehicles
    b. The front view camera will capture the forward facing image and detect other vehicles and road signs using deep learning
4. The Vehicle Positioning Subsystem will work with the Environmental Subsystem to map out the relative position of the vehicle
    a. The Environmental Subsystem will detect the position of other vehicles and the road
    b. The Vehicle Positioning Subsystem will take these inputs and calculate the position and direction of the vehicle relative to these other entities
5. The ADB system should constantly monitor what is in front of the vehicle
    a. The Environmental Detection Subsystem and the Vehicle Positioning Subsystem will work in conjunction to determine where the vehicle is in relation to the road and other vehicles
6. The ADB system must be capable of responding to environmental changes, such as fog, precipitation, and road curve.
    a. In the event of heavy fog, switch to low beam mode
    b. In the event of heavy rain, switch to low beam mode
    c. The Environmental Detection Subsystem will monitor the curve of the road and send messages to the Beam Control Subsystem. The Beam Control Subsystem will interpret these messages to adjust the brightness and direction of the beams.
7. The ADB shall revert to low-beam mode in the event of sensor failure.
    a. The ADB shall alert the driver of reverting to low-beam mode.

8. The Human Machine Interface (HMI) Subsystem provides feedback to the driver of the status and warnings of the ADB
    a. If all conditions are met (no oncoming traffic within 160 meters, not trailing a vehicle within 95 meters, clear weather conditions) activate high beam and set strength to 3000 lumens [2]
    b. If an error is detected in the system, the HMI will send a warning message to the vehicle's infotainment system with an audio cue
    c. If an oncoming vehicle is detected by the Environmental Detection Subsystem, the HMI will send a message to the infotainment system that low beam mode has been activated
    d. If extreme weather conditions (fog or heavy rain) are detected by the Environmental Detection Subsystem, the HMI will send a message to the infotainment system that low beam mode has been activated
    e. When the ADB On/Off button is pressed, the HMI will send a message to the infotainment system that the ADB has been activated/deactivated
9. The ADB shall be activated/deactivated with an On/Off button located to the left of the steering wheel
    a. When the button is pressed and the ADB is deactivated, the Environmental Detection Subsystem checks if the environment is dark enough to activate the ADB. If it is, then the ADB activates first in low beam mode
    b. When the button is pressed and the ADB is activated, then it will become deactivated
    c. If the ADB is activated and the Environmental Detection Subsystem validates that the environment is not dark enough for the ADB, then it will deactivate it
10. The ADB shall be equipped with a cybersecurity subsystem that should be capable of protection, monitoring, detection, and mitigation of cyber threats.
    a. The ADB's cybersecurity subsystem should call for secure communication between subsystems, authentication protocols for system updates, and real-time threat detection mechanisms.

Invariants:

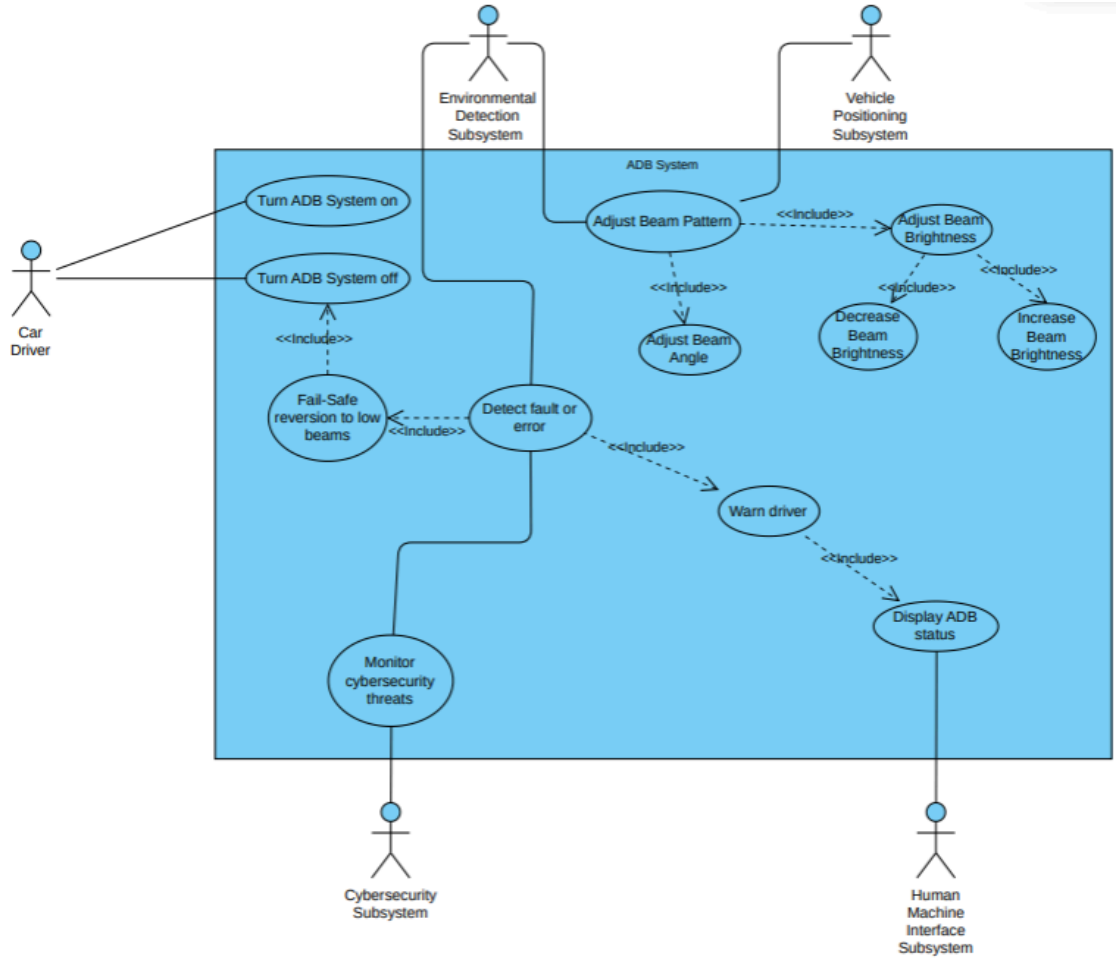
1. The ADB shall revert to low-beam mode in the event of sensor failure.
2. User must be able to deactivate ADB system by pressing On/Off button
3. The ADB's cybersecurity subsystem should call for secure communication between subsystems, authentication protocols for system updates, and real-time threat detection mechanisms.
    a. The system must only respond to secure communication between the ADB components.
4. When there is oncoming traffic/vehicles it should change to low beam in that opposing vehicles direction
5. The ADB system should never exceed 3000 lumens [2]

Questions:

- How does the system determine what is sensitive to and should be protected from the high beam?
    - driver, pedestrian, animal?

- What are the maximum and minimum illumination levels?
- What levels of interaction does the driver have with the system?
    - Activate/Deactivate?
    - Adjust Minimum/Maximum beam strength?
    - Alert severity levels?
- Where/How will the user receive HMI alerts from?
- How should the system respond when there is a change in environment brightness?
    - At what brightness should the system activate/deactivate?
- What happens when another vehicle suddenly appears in front of the vehicle?
    - What is the distance between the user's vehicle and the vehicle in front to be considered “close”?
    - How fast should the system switch between modes?
- How quickly should the ADB system react when there is a sudden change in scenario?
- In a scenario in which multiple ADB triggering events are occurring or have occurred, which events take precedence? (e.g., turns, weather, vehicle detection all at once)
- Will the position of the driver’s eyes need to be accounted for in the ADB system?

Use Case Diagram:



Use Case:	Turn Adaptive Driving Beam System (ADB) on
Actors:	Car Driver
Description:	After the user/driver turns on the car they have the option to press a button to activate the ADB system (turn on), from here the ADB system will then engage and begin to change the beam pattern based on the situation its currently in
Type:	Primary (essential)
Includes:	-
Extends:	-
Cross-refs:	-
Use cases	-

Use Case:	Turn Adaptive Driving Beam System (ADB) off
Actors:	Car Driver
Description:	When the system runs into an issue where it struggles to calculate where other vehicles are in its current situation it will disengage (turn off) the ADB system to prevent harm to other actors in that current scenario. If there is a cyberattack the ADB will automatically turn off. Lastly, the user has the option to manually turn off the ADB system if they want to simply manually adjust the headlights.
Type:	Primary (essential)
Includes:	-
Extends:	-
Cross-refs:	-
Use cases	Fail-Safe Reversion to low beams

Use Case:	Adjust Beam Pattern
Actors:	Environmental Detection Subsystem, Vehicle Positioning Subsystem
Description:	Uses inputs from the Environmental Detection Subsystem and the Vehicle Positioning Subsystem to dynamically adjust the angle and brightness of the beam.
Type:	Primary (essential)
Includes:	Adjust Bream Brightness, Adjust Beam Angle
Extends:	-
Cross-refs:	-
Use cases	Adjust Bream Brightness, Adjust Beam Angle

Use Case:	Adjust Beam Brightness
Actors:	-
Description:	Adjust brightness of the headlight beam depending on the given information, its primary job is to increase or decrease brightness of the headlight beam
Type:	Primary (essential)
Includes:	Increase Beam Brightness, Decrease Beam Brightness
Extends:	Adjust Beam Pattern
Cross-refs:	-
Use cases	Increase Beam Brightness, Decrease Beam Brightness

Use Case:	Increase Beam Brightness
Actors:	-
Description:	Increase the brightness of the headlight beam
Type:	Primary (essential)
Includes:	-
Extends:	Adjust Beam Brightness

Cross-refs:	-
Use cases	-

Use Case:	Decrease Beam Brightness
Actors:	-
Description:	Decrease the brightness of the headlight beam
Type:	Primary (essential)
Includes:	-
Extends:	Adjust Beam Brightness
Cross-refs:	-
Use cases	-

Use Case:	Adjust Beam Angle
Actors:	-
Description:	This use case includes all beam adjustments related to angle, including minor left, right, upward, and downward corrections performed by the Beam Control Subsystem
Type:	Primary (essential)
Includes:	-
Extends:	Adjust Beam Pattern
Cross-refs:	-
Use cases	-

Use Case:	Warn driver
Actors:	-
Description:	Notification that appears on the drivers dash to alert the driver that the ADB system that something has changed?

Type:	Primary (essential)
Includes:	-
Extends:	-
Cross-refs:	-
Use cases	Display ADB Status

Use Case:	Display ADB Status
Actors:	HMI
Description:	Shows system status, including any errors that may need to warn driver.
Type:	Primary (essential)
Includes:	Warn Driver
Extends:	-
Cross-refs:	-
Use cases	-

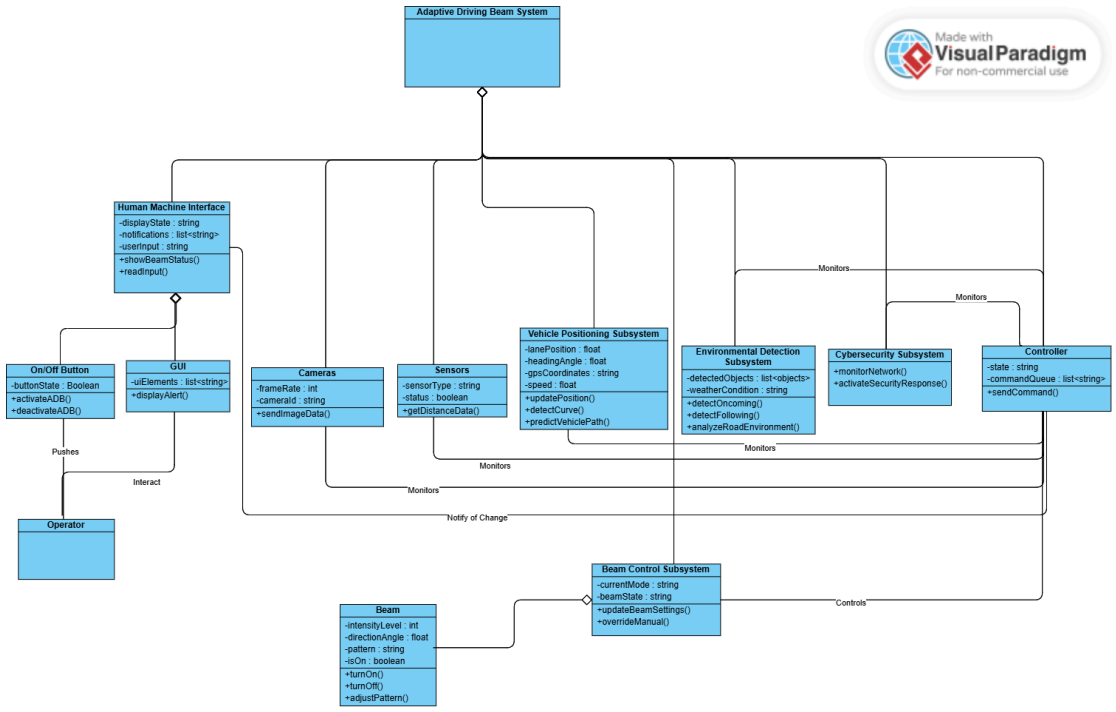
Use Case:	Monitor Cybersecurity Threats
Actors:	Cybersecurity Subsystem
Description:	Actively monitors system to reduce/prevent cybersecurity threats to the system.
Type:	Primary (essential)
Includes:	-
Extends:	-
Cross-refs:	-
Use cases	Fail-Safe Reversion to low beam

Use Case:	Detect fault or error

Actors:	Environmental Detection subsystem
Description:	Manages faults and/or foul conditions, activating the fail-safe and warning driver of error.
Type:	Primary (essential)
Includes:	Fail-Safe Reversion to low beams, Warn Driver
Extends:	-
Cross-refs:	-
Use cases	Fail-Safe Reversion to low beams, Warn Driver

Use Case:	Fail-Safe Reversion to low beams
Actors:	
Description:	In event of system failure or adverse weather conditions, ADB system will revert to low beams and deactivate.
Type:	Primary (essential)
Includes:	Warn Driver
Extends:	-
Cross-refs:	-
Use cases	Turn Adaptive Driving Beam System (ADB) off

Domain Model



Element Name	Camera
Description	Captures and sends image data for environment analysis and detection.
Attributes	frameRate : int cameraId : string
Operations	sendImageData()
Relationships	ADB System – Aggregation Controller – Monitored for changes by controller
Export Control	Public

Element Name	Controller
Description	Central control unit responsible for processing data and issuing beam commands.
Attributes	state : string commandQueue : list<string>
Operations	sendCommand()

Relationships	ADB System - Aggregation Human Machine Interface– Sends notifications of change Cybersecurity Subsystem, Environmental Detection Subsystem, Vehicle Positioning Subsystem, Cameras, Sensors – Monitors for changes
Export Control	Public

Element Name	Cybersecurity Subsystem
Description	Monitors communications and activates responses to detected security threats.
Attributes	
Operations	monitorNetwork() ctivateSecurityResponse()
Relationships	ADB System – Aggregation Controller – Monitored for changes by controller
Export Control	Public

Element Name	Environmental Detection Subsystem
Description	Detects oncoming/following vehicles and analyzes weather/environment.
Attributes	letectedObjects : list<object> veatherCondition : string
Operations	letectOncomingVehicles() letectFollowingVehicles() nalyzeRoadEnvironment()
Relationships	ADB System – Aggregation Controller – Monitored for changes by controller
Export Control	Public

Element Name	GUI
Description	Visual display layer providing operator alerts and beam status.
Attributes	iElements : list<string>

Operations	displayAlert(message : string)
Relationships	Human Machine Interface – Aggregation Operator – Operator interacts with GUI to get information about system
Export Control	Public

Element Name	Human Machine Interface
Description	Interface between operator and ADB system for displaying information and capturing input.
Attributes	displayState : string notifications : list<string> userInput : string
Operations	showBeamStatus() readUserInput()
Relationships	ADB System – Aggregation Controller – Recieves notifications of change
Export Control	Public

Element Name	Sensor
Description	Detects environmental information such as lighting and distance.
Attributes	sensorType : string status : boolean
Operations	GetDistanceData()
Relationships	ADB System – Aggregation Controller – Monitored for changes by controller
Export Control	Public

Element Name	Beam
Description	Controls light emission direction, pattern, and on/off behavior.
Attributes	intensityLevel : int directionAngle : float pattern : string isOn : boolean

Operations	urnOn() urnOff() djustPattern()
Relationships	Beam Control System - Aggregation
Export Control	Public

Element Name	Beam Control Subsystem
Description	Determines proper beam settings based on nvironment and road conditions.
Attributes	urrentMode : string eamState : string
Operations	pdateBeamSettings() verrideManual()
Relationships	ADB System – Aggregation Controller – Monitored for changes by controller
Export Control	Public

Element Name	On/Off Button
Description	Enables or disables the automatic driving beam eature.
Attributes	uttonState : boolean
Operations	ctivateADB() eactivateADB()
Relationships	Human Machine Interface – Aggregation Operator – Operator pushes to activate system
Export Control	Public

Element Name	Vehicle Positioning Subsystem
Description	Determines lane, heading, and path to support eam direction decisions.
Attributes	anePosition : float eadingAngle : float psCoordinates : string peed : float

Operations	updatePosition() detectCurvature() predictVehiclePath()
Relationships	ADB System – Aggregation Controller – Monitored for changes by controller
Export Control	Public

Element Name	Operator
Description	Human drivers who receive info, and may override ADB systems at any time.
Attributes	
Operations	
Relationships	On/Off button – Operator pushes to activate system GUI – Operator interacts with GUI to get information about system
Export Control	External Actor

References

[1] **“**California Driver’s Handbook, ” State of California DMV, 2025, Web..

[2] “Michigan Headlights Laws,” Kensun, 2025, Web.