Module-Wise Test Plan: Autonomous Emergency Braking (AEB) GROUP 5

NAME	MODULES
DEEPAK (31259)	MODULE 1
USHASRI (31267)	MODULE 2
SUMA (31268)	MODULE 3 & MODULE 4
PRINCE MISHRA (31269)	MODULE 5
JYOTISMAN KIRTI PRAKASH (31261)	MODULE 6

Module 1: Introduction & Objective

Definition of AEB:

Autonomous Emergency Braking (AEB) is a system in a car that can **automatically apply the brakes** if it detects a possible collision — even if the driver is not reacting in time.

Autonomous Emergency Braking (AEB) is a crucial active safety feature in modern vehicles. It is designed to prevent or mitigate collisions by automatically applying the brakes when the system detects an impending forward crash. This test plan aims to evaluate the AEB system's performance under diverse environmental and road conditions to ensure its reliability, safety, and compliance with international safety standards such as NCAP.

So the **objective** of our test plan is:

- To check if AEB is working properly in different situations.
- To see if it meets **international safety standards**, like **NCAP**.

Definition of NCAP:

NCAP (New Car Assessment Program) is a set of rules used worldwide to test the **safety features** of cars.

Example:
Imagine you're driving and suddenly a child runs in front of your car. AEB will quickly apply the brakes to save the child — even before you press the pedal.

Module 2: Test Plan Structure

Definition of Simulation Tools:

These are **software programs** that allow us to create **virtual driving environments** to test car features safely without driving on real roads.

Tools used:

- **dSPACE** – Tests how car electronics behave in real-time.
- **IPG CarMaker** – Makes a fake road and traffic scene on a computer.

Example:
Just like we solve math problems in a notebook before going to an exam, here we test the AEB in a simulator before real-life testing.

The AEB evaluation will follow a structured testing framework that includes the following steps:

1. 1. Define and develop test scenarios that mimic real-world weather and road conditions.
2. 2. Assess the accuracy of the sensor fusion system, which combines data from camera and radar.
3. 3. Utilize advanced simulation tools like dSPACE and IPG CarMaker for virtual testing.
4. 4. Compare AEB performance with established benchmarks set by NCAP guidelines.

Module 3: Test Scenarios

Five key test scenarios will be executed to comprehensively evaluate the AEB system's behavior:

Scenario	Detailed Description
Wet Road with Low Visibility	Simulates heavy rainfall or fog using virtual tools. Tests if AEB detects obstacles and

	responds on low-friction surfaces. Assesses system’s ability to work under camera obstruction and sensor interference.
High-Speed Straight Road	Tests AEB response at speeds exceeding 80 km/h when approaching a static or slower-moving vehicle. Evaluates the reaction time and braking force required to prevent collision in highway conditions.
Low-Speed Urban Traffic	Simulates crowded urban environments with frequent starts and stops. Focuses on the detection of pedestrians, cyclists, and nearby vehicles at low speed, often below 30 km/h.
Night-Time Driving	Evaluates sensor performance and object detection in low-light or no-light scenarios. Important for pedestrian detection using thermal imaging and headlight illumination data.
Inclined Slippery Road	Simulates downhill icy roads with reduced traction. Tests the capability of AEB to calculate distance, speed, and road friction to prevent a skid or uncontrolled stop.

Example:
If the camera sees a person but radar doesn’t, the system may get confused. So sensor fusion helps both sensors **work as a team**.

Module 4: Sensor Fusion Accuracy

Definition of Sensor Fusion:

Sensor Fusion means combining data from **multiple sensors**, like cameras and radars, to understand the surroundings better and make safer decisions.

What we test here:

Are both camera and radar working correctly?

Are they giving the same information?

Can AEB detect objects when lane lines are faint or missing?

Example:
If the camera sees a person but radar doesn’t, the system may get confused. So sensor fusion helps both sensors **work as a team**.

AEB systems rely on sensor fusion – the integration of camera and radar data – to detect and interpret the driving environment. This module tests the synchronization, object tracking, and range accuracy between sensors. Simulation of edge cases like sudden vehicle entry or faded lane markings will be used to verify reliability.

Module 5: Test Automation & Simulation

Definition of Automation:

Automation means using **machines or software** to run tests automatically, without doing everything manually.

Definition of dSPACE and IPG CarMaker:

- **dSPACE** is a tool that connects with the real car computer (ECU) to check how it behaves in different conditions.
- **IPG CarMaker** lets us build fake roads, cars, and weather for testing.

Example:
We don't need to drive in the rain to test AEB — we can create a **rainy road inside the computer** and test it virtually.

Test cases will be implemented and executed using virtual platforms such as:
- dSPACE: For real-time ECU-in-the-loop testing.
- IPG CarMaker: For vehicle dynamics and traffic scenario simulations.
This allows reproducible, safe, and cost-effective testing of AEB in various virtual scenarios without real-world risk.

Module 6: NCAP Compliance & Evaluation

Definition of Compliance:

Compliance means **following the rules and standards** properly.

We test:

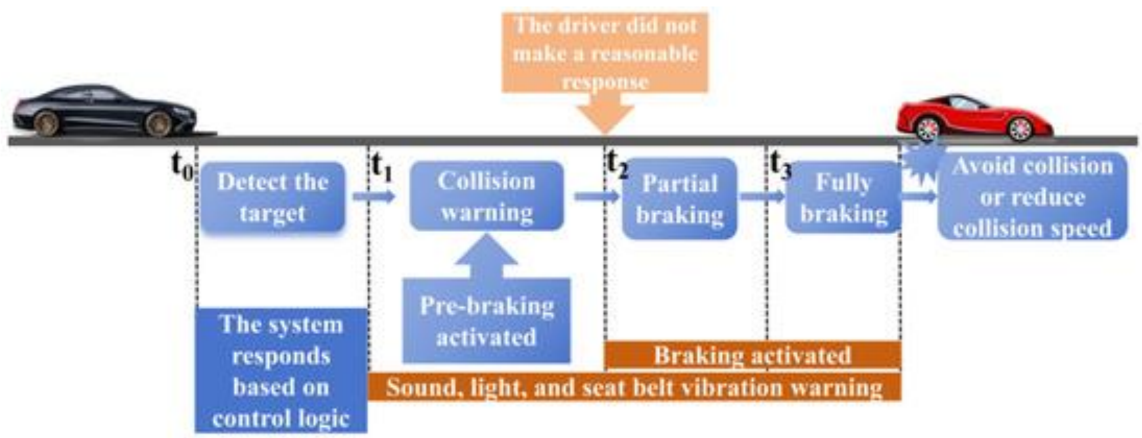
- How quickly AEB starts braking.
- How far it takes to stop.
- Can it avoid hitting a **dummy person or cyclist**?

Example:
If NCAP says the car must stop within 20 meters at 60 km/h, and our AEB does that — then we pass the test!

The AEB system will be validated against Euro NCAP/Global NCAP protocols. Key performance metrics include:
- Braking time and distance
- Collision avoidance in standard test scenarios
- Vulnerable road user (VRU) protection

Compliance ensures the AEB system meets global automotive safety expectations and contributes to higher vehicle safety ratings.

Working principle of the AEB system.



Based on the image you provided, here is a step-by-step explanation of the working principle of an AEB (Autonomous Emergency Braking) system:

1. **t0 : Detect the target.**
    a. The system uses sensors (like radar or cameras) to continuously monitor the road ahead.
    b. It detects a potential obstacle or a preceding vehicle (referred to as the "target" in the diagram).
    c. This initial detection happens at time t0 .
2. **t1 : Collision warning.**
    a. The system's control logic determines that there is a high risk of a collision with the detected target.

   b. The system issues a warning to the driver. This is indicated by the "Collision warning" box.
   c. The warning can be in the form of sound, lights (visual alerts on the dashboard), and/or seat belt vibration. This is the "Sound, light, and seat belt vibration warning" box.
   d. At this stage, the system also activates "pre-braking." This can involve preparing the brakes for a quicker response, such as pre-loading the brake system to reduce reaction time.
3. **Partial braking.**
   a. If the driver does not make a reasonable response (e.g., does not hit the brakes or steer away), the system moves to the next stage.
   b. The system autonomously applies the brakes partially to begin slowing down the vehicle. This is represented by the "Partial braking" box.
4. **Fully braking.**
   a. If the collision risk remains high and the driver still has not responded, the system will apply the brakes with full force.
   b. This is the "Fully braking" box, where the system is now "Braking activated" and performing a full emergency stop.
5. **Avoid collision or reduce collision speed.**
   a. The ultimate goal of the AEB system is to either completely avoid the collision or, if that's not possible, significantly reduce the vehicle's speed at the moment of impact.
   b. This reduction in speed helps to minimize the severity of injuries to the occupants and damage to the vehicles involved.