ADSP ACC function Overview

Feb 2024

Agenda

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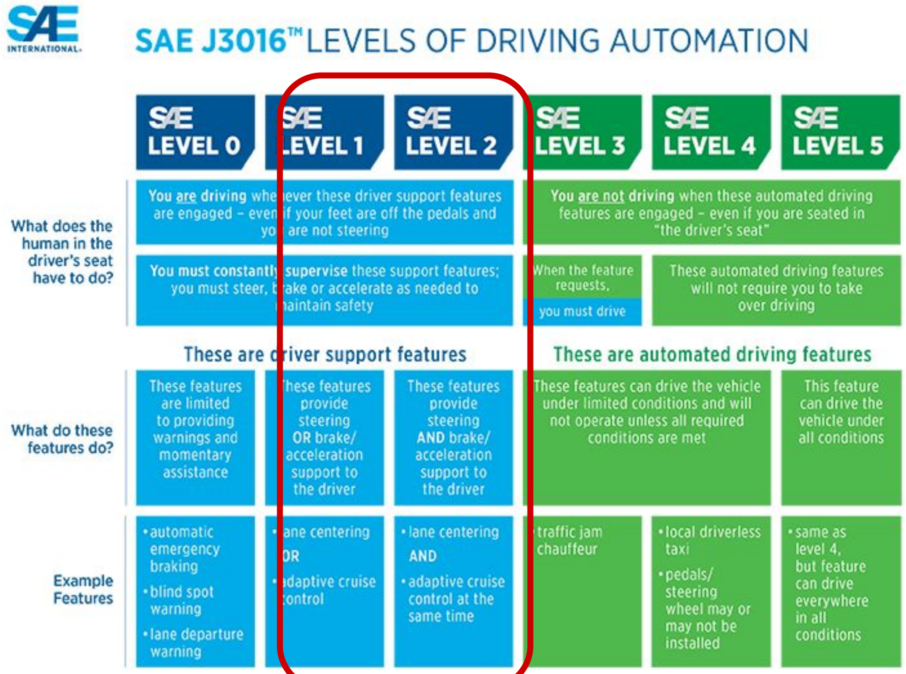
- Function Description
- New Features under development
- Architecture (simplified)
- Concept Description
    - Environment Model (Perception)
    - Function logic
    - Rating (Target selection)
    - Planning and Motion control (Longitudinal Controller)
- Application Guideline
- Safety

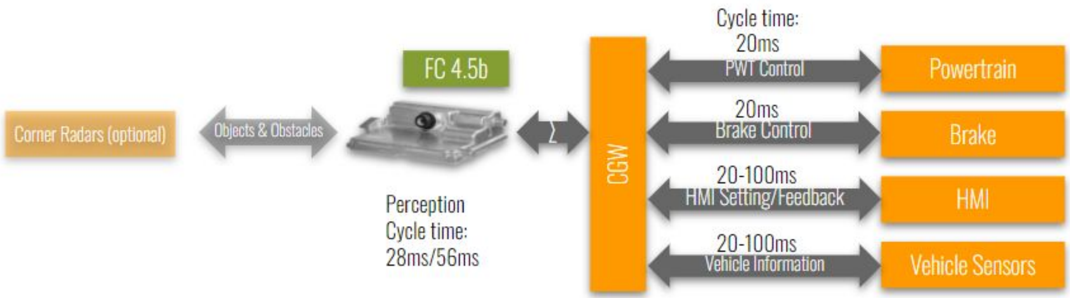
Introduction

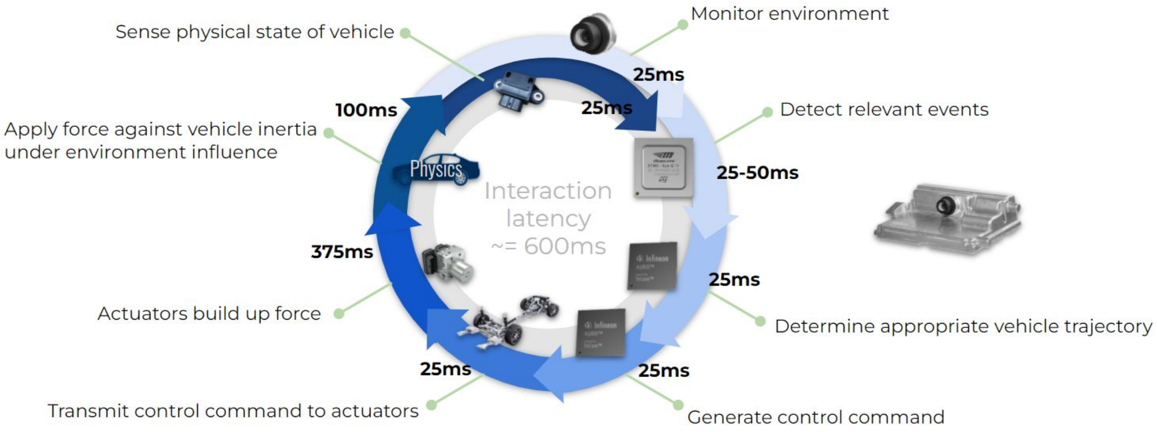


**Source: sae.org

- Adaption Cruise Control (ACC) is a **SAE level 1** Autonomous driving system.
- ACC function goal is to help reducing **driving stress** by automatically adjusts the vehicle speed to maintain a **safe distance** from vehicles ahead. When there is no preceding vehicle or the preceding vehicle is fast, the function can accelerate until the **set speed**.
- It includes the **stop & go** functionality.
- ACC function is mainly focused on comfort. Therefore the amount of dynamic request (via acceleration request and jerk) provided to the low level control **is limited**.
- ACC function in combination with a Lane Centering System (LCS) is categorised as **Level 2 driver automation**.

Introduction : Close loop interaction of ACC





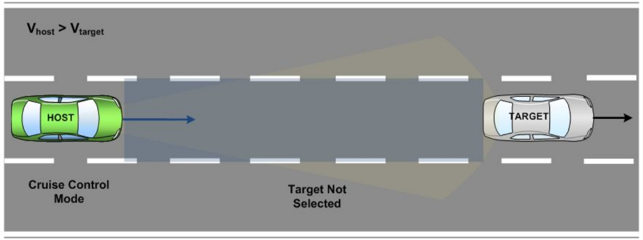
Function Description

Operating Design Domain and characteristics

- Operating Speed and function modes: 0 – **180 km/h**
- **Max Acceleration/Jerk** request range compliant with ISO 15622
- Relative speed range to the target: up to **90 kph**. ACC still keeps operating with higher relative speed
- ACC **relevant objects**: cars, trucks, motorcycles and cyclists
- Control **interface**: acceleration or torque request
- **Collision warning** is available in case the situation cannot be handled by ACC
- In **manual transmission**, smooth acceleration during gear change and deactivation at low speed (S&G not included)
- Driver adjustable settings:
  - clearance distance to the target ahead: **4 Timegaps** (extendable up to 8)
  - **Set Speed**: 30-180 kph (can be market-dependent)
- Driver/System interactions
  - The driver can **activate/deactivate** the system
  - The driver can **set/resume** the cruise control speed
  - When the system is active, the driver must **deactivate** the function with brake pedal or with cancel button
  - When the system is active, the driver must be able to **override** longitudinal with acceleration pedal

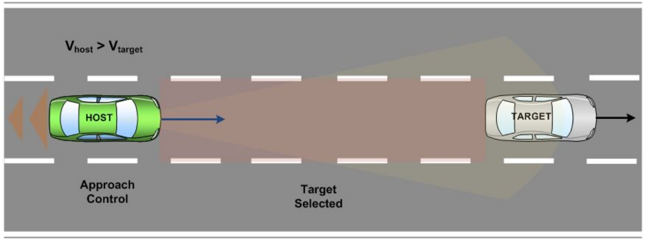
Main Use cases (1/3)

In bolt what needs to be achieved from the controller



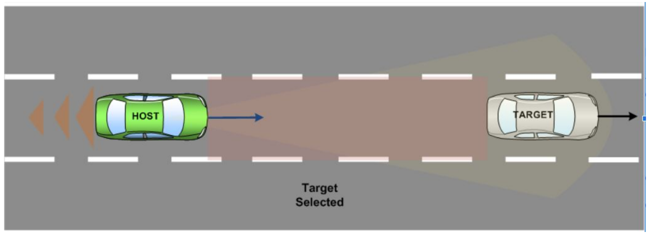
Cruise Control (acceleration, deceleration and steady)

- No target selected in region of interest
- **System achieves set speed (acceleration, deceleration and steady cruise)**
- **Deceleration can also use brake control or only engine brake**
- **More deceleration request if set speed is faster reduced by driver (tap-down logic)**



Approach Control

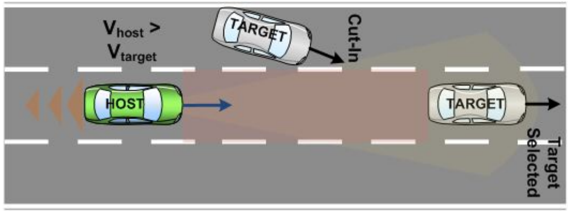
- Relevant target is entering in region of interest
- Relevant Target is selected based on ego speed
- **Release acceleration when the target is selected**
- **Deceleration applied with trapezoid shape at correct time**
- **Speed and distance control with smooth deceleration/jerks with allowed distance undershoot in the comfort zone (elasticity)**



Follow Control (acceleration, deceleration and steady)

- desired distance is determined based on host speed and time gap
- **System follows the target with low values of deceleration/jerks**
- **High system reaction in case target starts to brake**
- **Good system reaction in case target starts to accelerate**

Main Use cases (2/4)



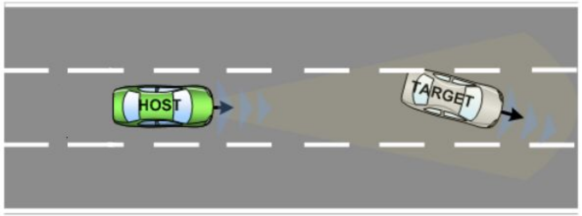
Cut-in detection and intervention:

- Target selected outside Ego lane as “cut-in” target
- Fast target: No brake, and release acceleration in case of fast target cuttin-in
- Slow target:
  - Apply deceleration when a cut-in target is selected
  - Smooth cutin braking logic (only engine brake if enough) to allow more undershoot in the comfort zone (elasticity)
  - Release deceleration when relative speed is positive so final clearance distance can be achieved without unnecessary acceleration

Ego Lane change:

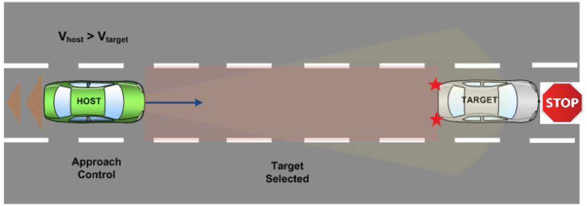
- Early deselection of the following vehicle in ego lane and Early selection of the target in adjacent lane (if available) depends on whether the path prediction “hits” the target (how much driver steers) and state of turn indicators
- Fast adjacent target or no adjacent target: Fast acceleration reaction
- Slow adjacent target:
  - Apply deceleration the adjacent target is selected
  - Smooth ego lane change braking logic (only engine brake if enough) to allow more undershoot in the comfort zone (elasticity)
  - Release deceleration when relative speed is positive so final clearance distance can be achieved without unnecessary acceleration

Main Use cases (3/4)



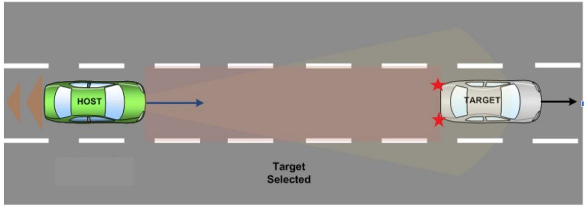
Cut-out detection and intervention

- Early decelection of the target depending of the lateral velocity and distance of target to lane
- If the host was braking, initial fast release of the braking when the cutout get deselected
- Avoid unnecessary acceleration and jerks if another target is in front



Approaching on static target

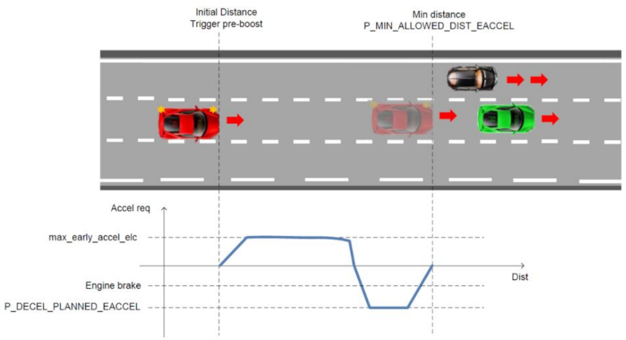
- Relevant target Target is selected based on ego speed (and relative speed)
- Release acceleration when the target is selected
- Deceleration applied with trapezoid shape at correct time
- Control final stopping distance error
- Max allowed deceleration after standstill to keep the vehicle static



Stop and Go

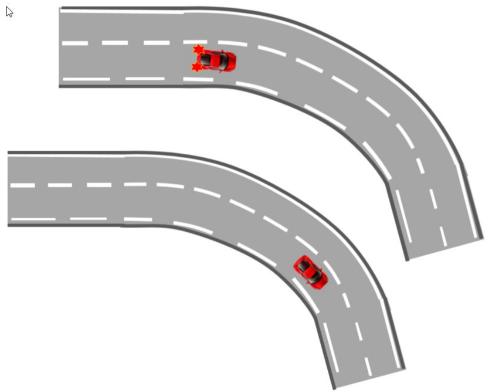
- Good system reaction when the target start to brake
- Good steady follow at low speed
- Control final stopping distance error
- When target starts, host vehicle starts automatically if the time in standstill is lower than certain time (3s extended to 15s tunable if extended auto-restart is included)
- Host vehicle starts with high jerk in the limit of controllable jerk to reach the max acceleration request in very short time
- Good Acceleration/Deceleration applied with trapezoid shape

Main Use cases (4/4)



Overtaking pre-boost

- overtaking preboost is an acceleration support to be used during overtaking maneuver to allow host vehicle to accelerate before deselect the vehicle in front
- If logic is activated without change lane, the acceleration profile shall finish at one point and a planned brake shall start in order to avoid collision with the vehicle in front
- If deactivated before lane changing, the function shall release smoothly the acceleration in order to reach the steady steady in comfort way



Adaptive Curve Control

- Curve control is an additional logic in controller able to support braking and acceleration in curve in order to reduce lateral acceleration
- Current curve control is not using map information so the input to the function are provided from perceived lane (if available) and odometry
- Small prediction is possible to allow braking before enter in the curve and the function shall continue braking in the curve in order to have lateral acceleration in the margin defined

Function Limitations, Out of scope

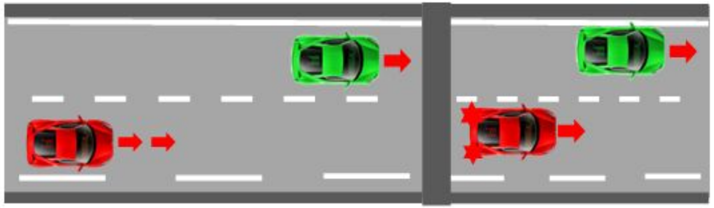
- Severe Weather conditions leading to sensor blockage (eg. snow, deep fog, heavy rain)

- Following target deceleration in the limit of acceleration/deceleration and jerk limits defined in ISO norm ISO-15622(2018-09)

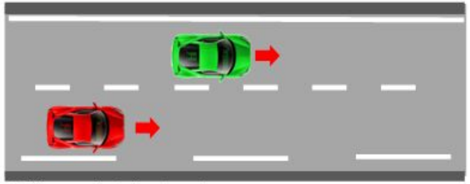
New features under development

Undertake prevention

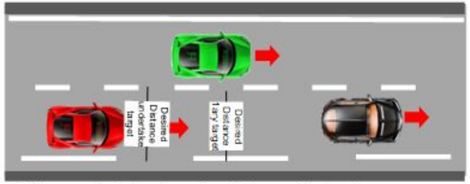
Undertake prevention (avoid host vehicle to overtake vehicles on faster lane)



Approach undertake target



Follow undertake target



Follow undertake target with target in front

- The feature is working with multiple controlling targets: keep controlling the primary ACC target (as reference for all ACC scenarios) together with undertake target (target in faster lane and a little bit beyond the faster lane)

- The feature have most of the activation/deactivation setting of overtaking preboost in term of country/faster lane direction and speed thresholds.

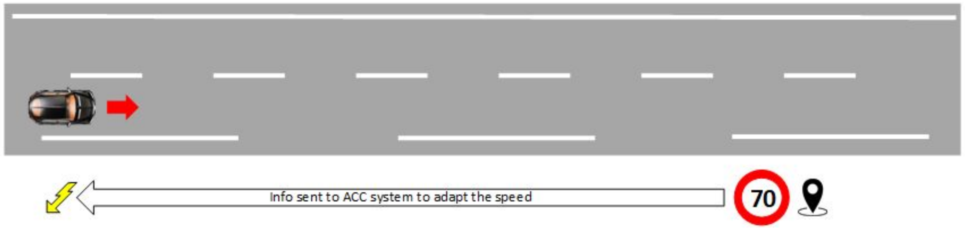
- Approaching to undertake target:
  - Same as ACC approaching scenario with different tuning:
    - Smooter Max Deceleration (additional tuning param)
    - Smooter braking and release jerk (different param to tune)
    - Final undertake target desired distance (can be close to 0 : no elasticity so no recovery phase needed)

- follow the undertake target (e.g. after approaching)
  - Keep the same speed and distance using undertake target desired distance as reference
  - If the undertake target brakes, the host will also brake within undertake target max deceleration and jerks (smooth braking)

- The undertake prevention is disengaged when host speed is below under certain threshold or undertake target (after maneuvering or overtaking) is not anymore available in front:
    - The host vehicle has to release the brake and start accelerate smoothly (dedicated param for jerk and max acceleration)
- Catching up (also happening after ego lane change to slower lane)
  - After smooth acceleration, host is starting to brake with engine brake in order to reach final undertake target desired distance

Predictive ACC

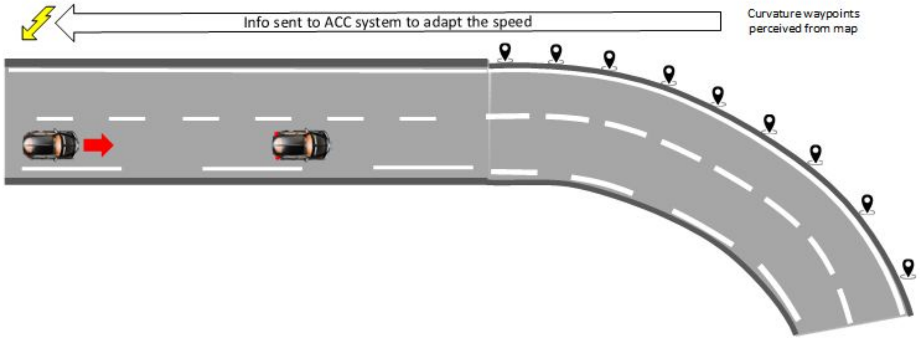
Speed limit ahead



Expected system behavior:

- The system shall perceive speed limits ahead from the map provider (explicit and implicit speed limits)
- Fusion of map/FC information can be taken into account to increase robustness of the perception (For instance to correct the speed limit from map in the proximity of the speed limit sign perceived by the TSR).
- The system shall **adapt** the ACC set speed based on the incoming speed limits
- The driver shall be informed about the oncoming speed limits through the HMI
- Two modes:
  - **Automatic** mode
  - **Manual** mode
- The driver can add a positive or negative **constant offset** which is applied to all legal speed limits.
- The request acceleration is tunable in term of maximum and minimum values, braking and releasing jerks

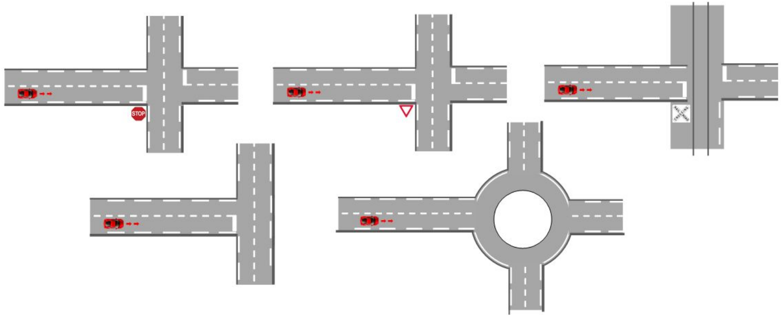
Curve ahead



Expected system behavior:

- The system shall perceive the curvature ahead of the current road
- The system shall adapt the ego speed based on the curvature perceived, in order to approach it in a safe and comfortable way.
- The driver is informed about the road event once the system starts braking because of the curvature ahead
- Runtime configuration for the *“curve driver mode”* available: further specific setting to set the speed/max lateral acceleration in the bends
- The request acceleration is tunable in term of maximum and minimum values, braking and releasing jerks

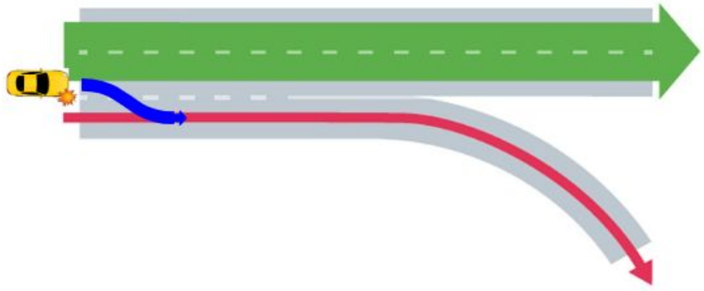
Intersection ahead



Expected system behavior:

- The system shall perceive intersections ahead. The type of available intersections are:
  - Roundabouts
  - Intersection regulated with stop sign
  - Intersection regulated with give way sign
  - T-Junctions
  - Railway cross
- <u>Common concept</u>: adapt the ego vehicle speed in order to approach the intersection in a safe and comfortable way with proper speed
- Specific strategy are considered, depending on the intersection type. For example, for the roundabout, the system shall maintain a comfortable speed (variable according to the roundabout radius) inside the roundabout and accelerate once a roundabout exit is taken.
- The driver is informed about the road event once the system starts braking because of the curvature ahead
- The request acceleration is tunable in term of maximum and minimum values, braking and releasing jerks

Highway exit ahead



Expected system behavior:

- The system shall perceive highway exit(s) ahead from the map provider
- This information shall be perceived at a reasonable distance
- If the highway exit ramp is in the most probable path (for example, part of the navigation route), the system shall extract the information about:
  - Speed limit on the highway exit ramp
  - Curvature on the highway exit ramp
- The system shall adapt the ego speed in order to take the highway exit in a safe and comfortable way according to the speed limit and curvature of the exit ramp extracted from the map data.
- The system shall inform the driver about the upcoming highway exit through the HMI at a reasonable distance while the ego vehicle is still driving on the highway
- The request acceleration is tunable in term of maximum and minimum values, braking and releasing jerks

Toll booth ahead

Expected system behavior:

- The system shall perceive toll booth ahead from the map provider (explicit and implicit speed limits)
- The system shall adapt the ego vehicle speed in order to approach the toll booth in a safe and comfortable way with proper speed
- The driver is informed about the road event once the system starts braking because of the toll booth ahead
- The request acceleration is tunable in term of maximum and minimum values, braking and releasing jerks

Architecture (simplified)

ACC system high level architecture (used for Renault SWEET400project)

ACC system is organized in 6 main subsystems:

Environment Model

- additional logic to improve signal accuracy
- Determine lanes

Rating

- Selects the most relevant targets for ACC to be used as reference for controller

Functional logic

- Determines the ACC states based on ACC scenarios

Host state

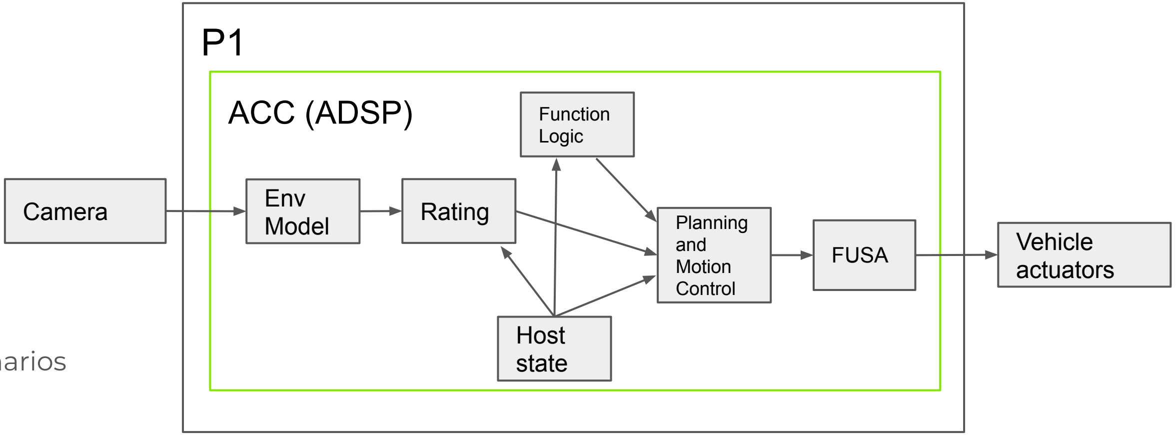
- Provides host state from odometry and path prediction

Planning and Motion control

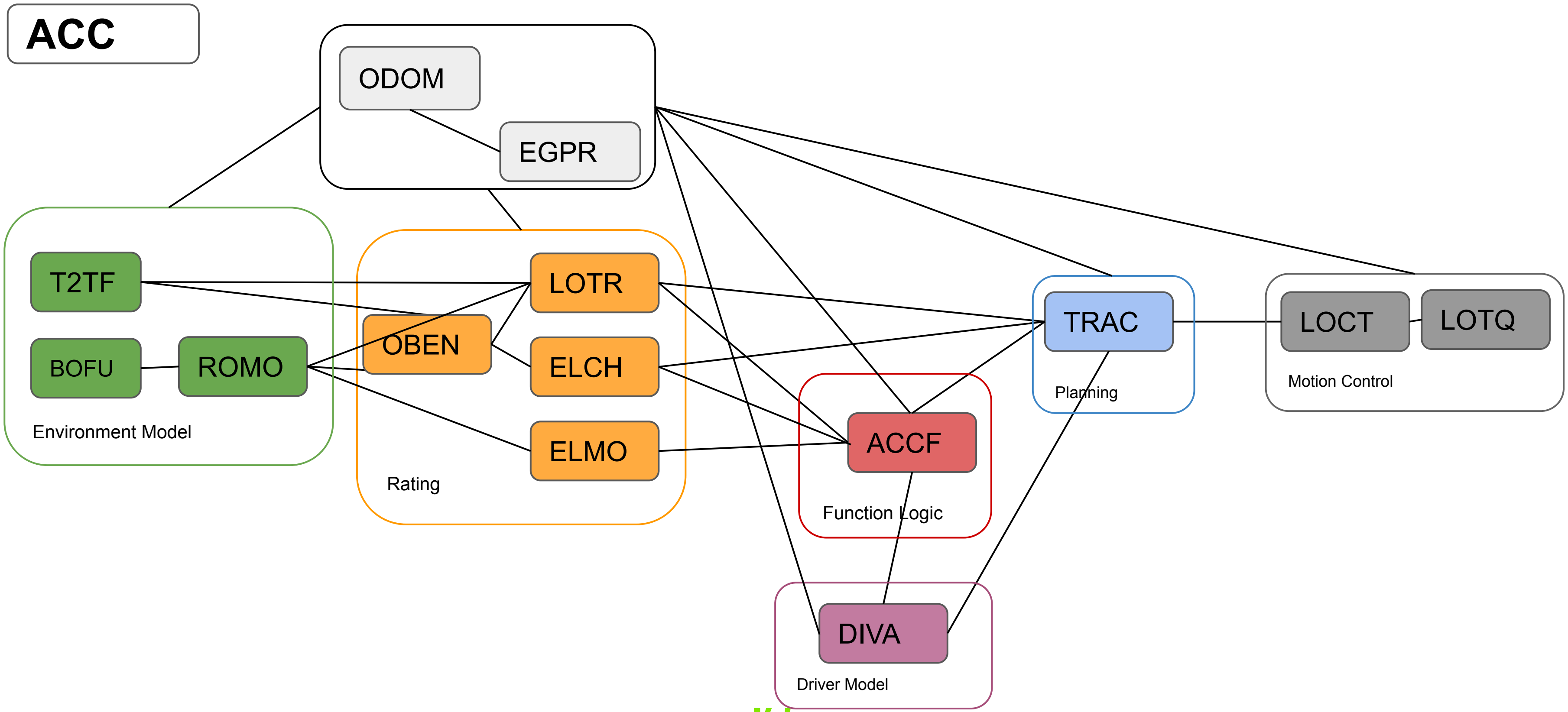
- Provides Longitudinal control including planning to determine the ACC performance in all different ACC scenarios

FUSA (Safety)

- Block to support safety goals assigned to platform/P1



Logical architecture - simplified



ACC with fusion system

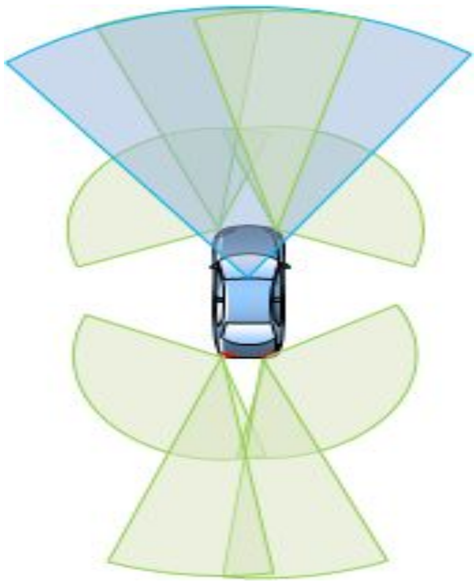
The ACC function operates with varying sensor setups: Vision Only and the advanced Fusion System, which incorporates radar technology.

- Fusion FCAM + Radars gives the following advantages :
  - Reduce FP rate
  - Assures ACC reliability in all conditions
  - early information for lateral objects (close cut-in)
  - more stable steady following, with high accurate objects distances and speeds
  - detection of several vehicles in the on the same ego lane
  - function availability (less impact of weather)
    - Light-condition-independent ensures no effect from low-sun/tunnels
    - Weather-condition-independent (clutter filter)

The usage of RADAR sensors will increase object recognition availability and accuracy together with improvements on object detection capabilities.

-> This will determine better target selection KPIs and more accurate and smooth controlling during target following and target transition

FCAM + 4 Valeo 77G mmWave BSD Radars

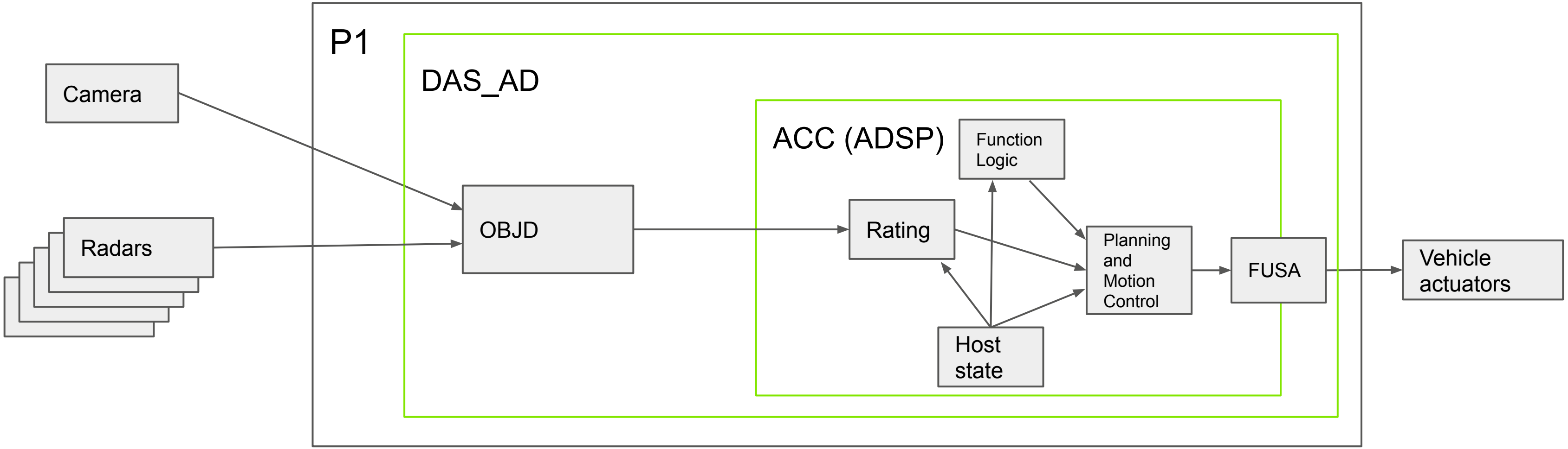


ACC Systems, Comparison

In order to enhance ability of Valeo Lane keeping functions, several countermeasures have been implemented. Some of them are summarised below.

Vision Only	Vision Only with Radar (Fusion)	Degraded Mode (Unavailability of Vision Sensor)
+ Precise Target Lane assignment using lane information (when available) resulting in more precise Target selection + Single sensor solution - Reduced position accuracy at higher distances reduces braking ability at high approach speeds - Inclement weather conditions leading to system unavailability	+ Precise Target Lane assignment using lane information (when available) resulting in precise Target selection + Fusion of vision and radar data enhances ACC performance increases braking ability at high approach speeds + Higher stability at steady follow + Higher reliability + Earlier cut-in/cut-out detection (this will depend on radar sensor configuration) + Higher availability in worst weather condition - In the absence of vision sensor data, ACC will function in a degraded mode - Multiple sensor solution	In the absence of a vision sensor, pure radar based ACC performance will be degraded: ● Reduced Target lock-on distance to mitigate possible False Target selections ● Late cut-in/cut-out detection owing to lane unavailability for precise lane assignment

ACC system high level architecture with fusion (1VxR)



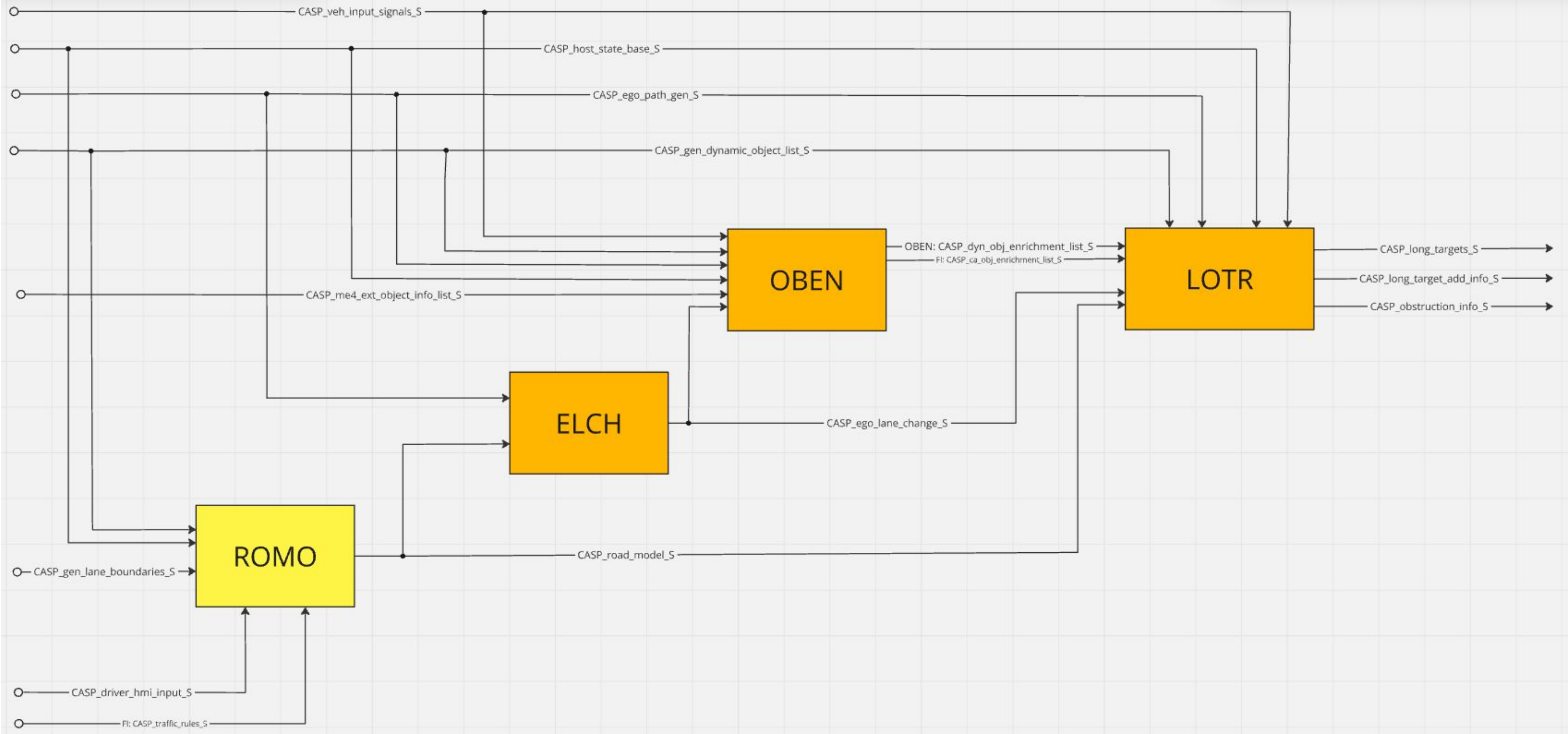
ACC with fusion system (1VxR) is possible using new DAS_AD architecture that also include OBJD

OBJD (object detection) is used to:

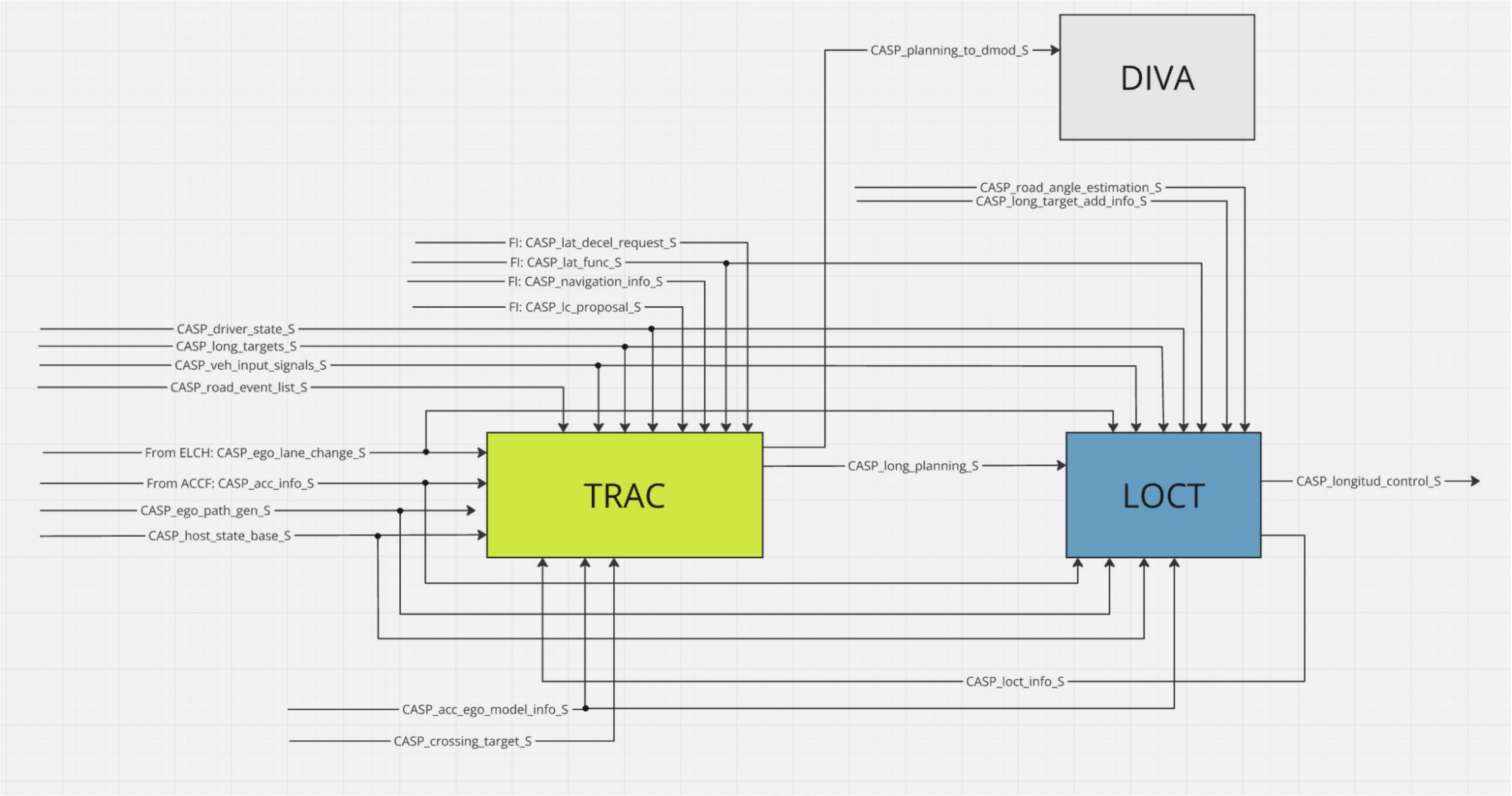
- Fuses the objects from different sensors (from 1V and multiple radars)
- Determine lanes
- additional logic to improve signal accuracy

OBJD can have all different sensor configurations setup: 1V5R, 1V4R, 1V2R, 1V1R, 1V
It can be also used for vision only (OBJD fully replaced EMOD used for Renault SWEET400 Project)

Architecture (for Rating Components)



Architecture (for Planning/controller Components)



Concept Description

Environment Model
(Perception)

Environment Logics for perception improvements

Valeo has developed **FC-Only** ACC function that operates utilizing object and lanes detection.

Valeo camera demonstrated **robust** operation also in various **adverse weather and light conditions, such as rain, fog**, etc.

To further enhance the stability of ACC operation Valeo developed a **set of countermeasures** improving stability of the control:

Detection problem that may occur	Loss of object detection	Misperception of speed/distance of the object	Loss of lane detection	Environment conditions are out of operation range for the camera
Valeo countermeasure	**Object LOST functionality**	**Object Tracking filter**	**Lane filtering and virtual lanes**	**Adverse weather failsafe logic (MobilEye+Valeo)**
Description	Prevents false acceleration to the target if the target object detection is temporarily lost (for example: during rain or entering a tunnel).	Detecting erroneous measurements, and disqualifying them and replacing it with internal estimation.	If the lane marking is lost, a virtual lane will be reconstructed. Besides, the lane measurement stability is generally enhanced with internal logic.	Fusion between: MobilEye Weather Failsafe logic + Valeo confirmation logic for the cancellation (verifying the ability to continue operation).

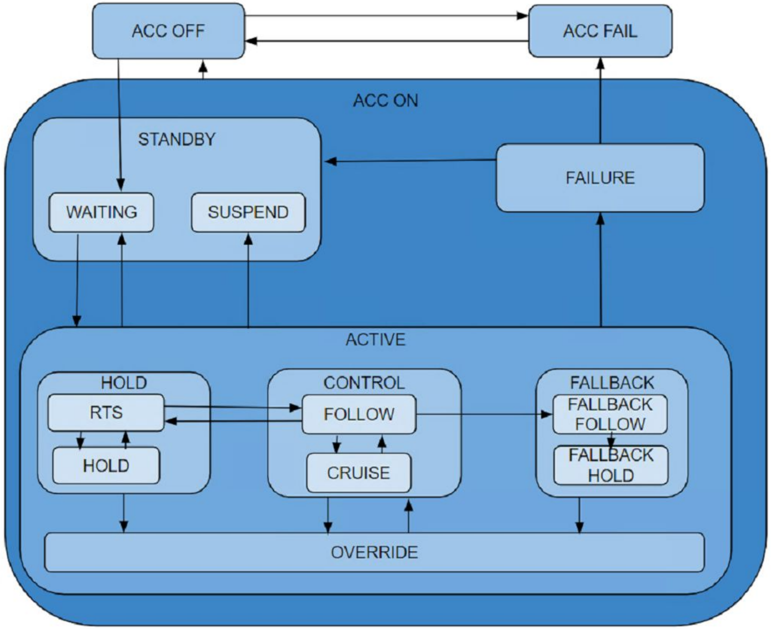
All those countermeasures improve ACC availability on top of Front camera detections availability. Mass production maturity level.

Valeo

Functional logic

SMART TECHNOLOGY FOR SMARTER MOBILITY

Main ACC state



The expected behavior in each state specified below:

ACC-OFF:
ACC is not enabled by the driver or by the settings. No ACC control or HMI will be provided in this case.

FAILURE: the system encountered failure
ACC is in failure mode due to one or multiple sub-components communicating non-operating status that is affecting ACC control.
No ACC control will be provided. An HMI about the system status shall be provided.

STANDBY_WAITING: ACC was enabled by the driver, but the ACC was not activated. System was not activated before and therefore, no <<set speed>> exists.

STANDBY_SUSPEND: ACC was enabled by the driver and was activated in the previous <<operation cycle>> by the driver but was deactivated, i.e. SUSPENDED (either by driver or by another system). Since the system was activated before, there is existing <<set speed>>.

CRUISE: the system activated by the driver and performing acceleration/deceleration control to based on the <<set speed>>.

FOLLOW: the system activated by the driver and performing acceleration/deceleration control to based on the <<set speed>> and the speed/distance of the selected target.

OVERRIDE: the system was activated by the driver and it is overridden by driver pressing the accelerator pedal.

READY_TO_START: the system is holding vehicle standstill during ACC stop&go and is ready to restart the vehicle automatically when the <<target drive off>> is detected. The state has finite time duration.

HOLD: the system is holding vehicle standstill during ACC stop&go but can only restart vehicle with the driver request (no automated restart based on the <<target drive off>> status.

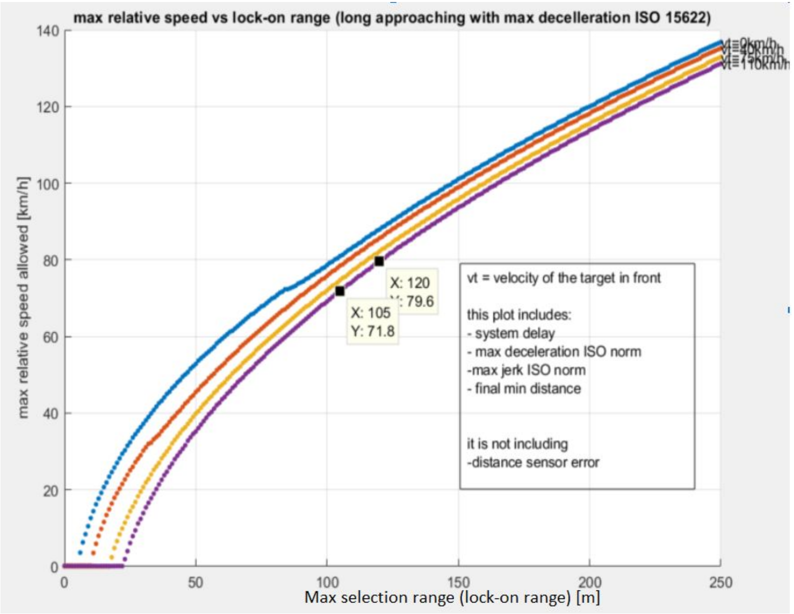
FALLBACK: in degraded mode, the system is performing only in braking request

Rating
(Target Selection)

Max Relative Speed determination (in approaching scenario)

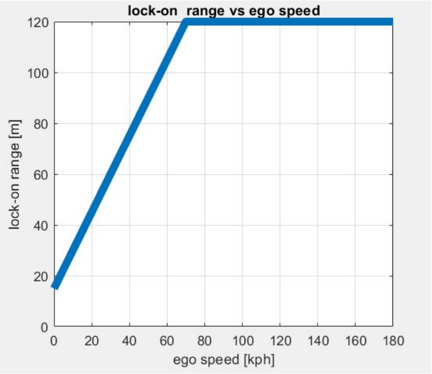
In long approach scenario, the max relative speed allowed depends from:

- Max selection range (lock-on range) defined
- Delay of the system
- max deceleration/jerks defined
- Max error of the sensor at detection distance
- Final min distance



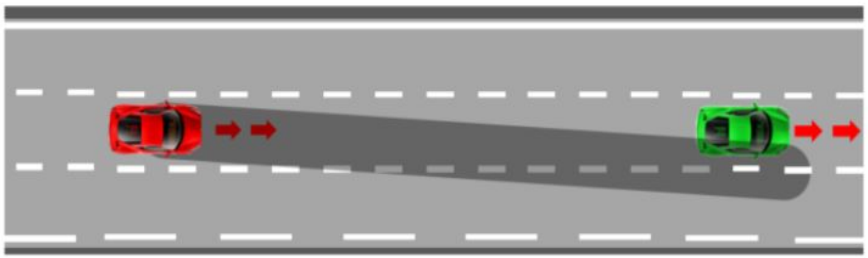
The lock-on range is lower than sensor detection and to reduce FP at low speed, it is also proportional with ego speed.

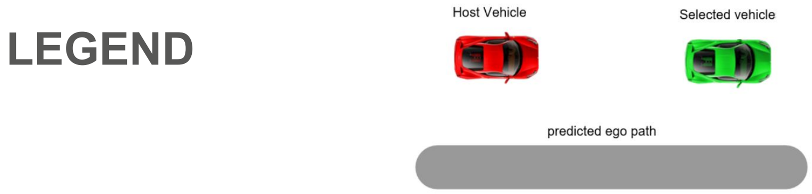
- It can also be proportional with relative speed
- It can be depended of target motion type: static/dynamic



The max relative speed 80 km/h can be achieved at ego speeds of 180 kph

General Target Selection Concept





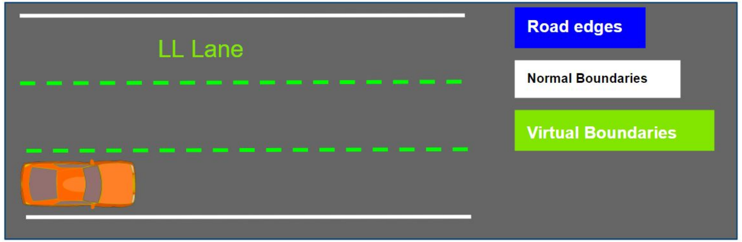
Target selection goal is to select the most relevant targets to be controlled

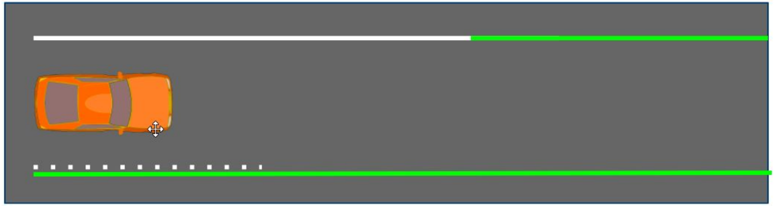
- is based on objects detection and detected lane

- It includes the following features:
    - Arbitration lane target and path target
        - Quality of lane is not high (lane jumping)
        - Lanes detection range is insufficient or no lanes information
        - Ego vehicle is moving according to lane markings
    - Cutin and cutout anticipation (avoiding FP/FN)
    - Ego lane change (with and without blinker)
    - Avoiding deselection in simultaneous ego lane change
    - Selection of the static target (trying to avoid parked car)

Perceived Lane (BOFU/ROMO)

- Boundaries are perceived from Front Camera and mathematically represented with **third order polynomial**
- Boundaries are improved using **Kalman filter** using a prediction model determined from previous states and vehicle motion
- Lanes are determined from boundaries:
    - From available boundaries the lanes are created (ego lane and adjacent lanes)
    - In case only one boundary is available, the others are created virtually to determine the lanes
    - Lanes are also extended (extrapolate) if they are too short

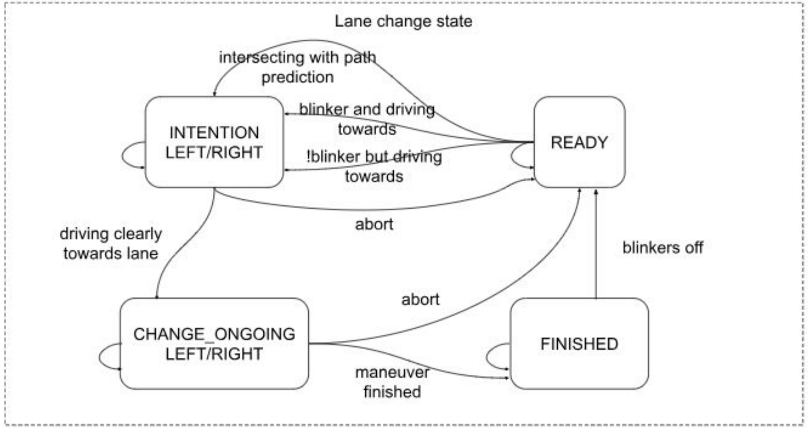




ELCH: Ego lane change with and without blinker

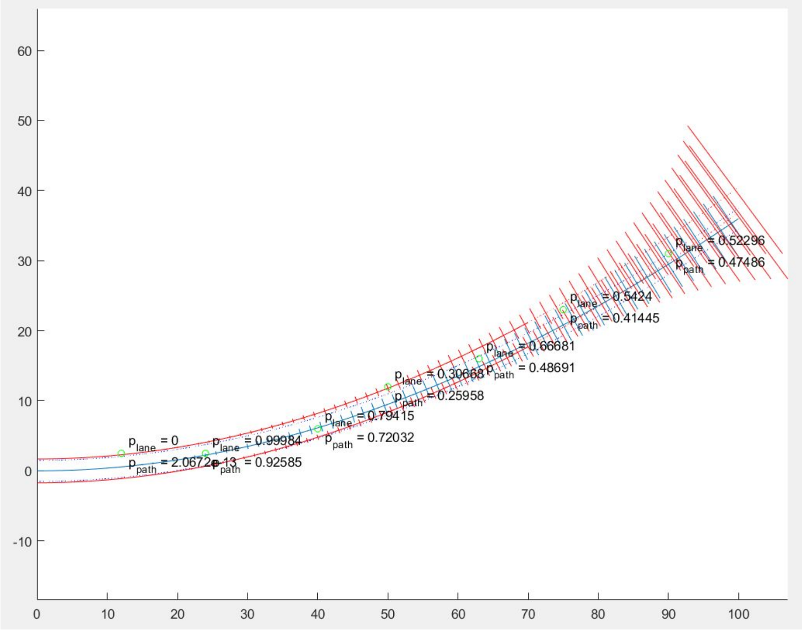
- Using blinker:
  - INTENTION means blinker is set and ego is not moving away from target lane.
    - If the blinker is turned off mid-maneuver, ego lane change state remains active for some time because some drivers like to just briefly tip the indicator
  - CHANGING means ego is also clearly moving towards the target lane now
    - Lateral movement for the purpose of ELCH is determined as the moving-average filtered derivative of the lateral distance to the respective lane marker.
  - MANEUVER FINISHED is detected by a characteristic jump of the lane marker
  - After FINISHED blinkers need to be both off before another lane change will be detected

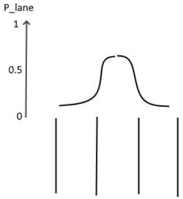
- Without blinker
  - Evaluation if path lane intersection proportional to speed and curvature
  - Distance to lane marking
  - Avoid to use this at curve entrance/exit

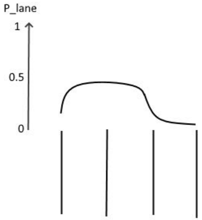


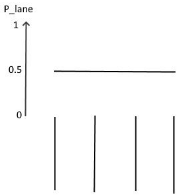
Lane Assignment in ADSP (Detail)

- Lane and path assignment are determined using probabilistic approach:
  - accumulated probability using Harmonic mean p-value calculated every timestamp (Recursive Bayesian estimation
    Or estimating Variance based on observations)
  - For lanes
    - Lane can be outside left, left, ego, right, outside right (it is assumed that all lane have same ego width lane)
    - The uncertainty is estimated as a function of distance (uncertainty grows exponentially beyond detection range)
  - Path
    - Path is assigned independently, can be left of ego, ego, right of ego
    - The uncertainty depends on ego speed and distance (speed not used at very close distance)
- Scenarios
  - Lane assignment probability for one lane is high enough and is clearly higher than adjacent - **assign to this lane**
  - Lane assignment probability for 2 adjacent lanes is similar, but it is clearly higher than other lanes -
    - this is considered a lane change scenario (**cutin or cutout**) (with additional condition of object speed towards target lane), as object must be between lanes
  - Lane assignment probability for all the lanes is ~0.5 indicates **high uncertainty** (either due to low lane detection range, or high distance to object) and makes it impossible to determine lane assignment







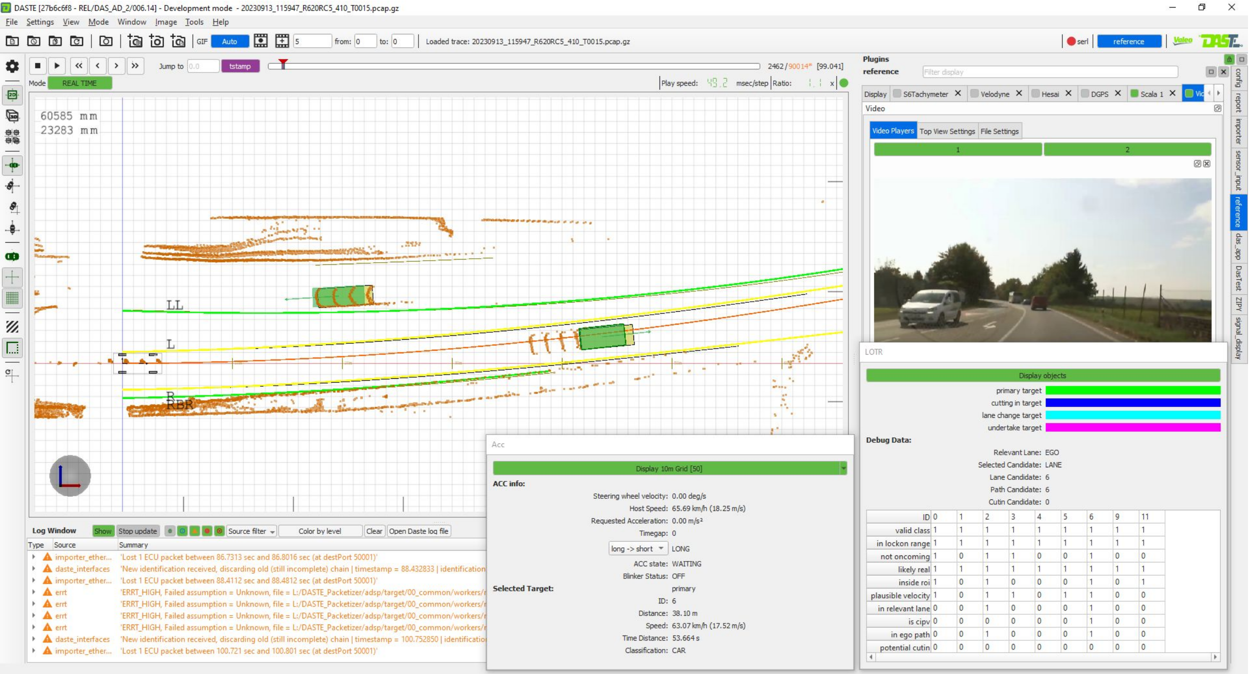


Target Arbitration in ADSP (Detail)

- Criteria Objects candidates
  - Existence probability > 20%
  - Not oncoming
  - Within lockon range (for new target), lockoff range (for current target)
  - Object class should be Car, Truck (Bus), Motorbike, Bicycle (consider not selecting bicycle)
- Lane target is chosen as the closest selectable among candidates
  - Lane target is chosen between ego, left and right lane targets, based on Ego Lane Change input
- Path target is selected as the closest target with EGO path assignment
- Primary target: lane target is preferred, otherwise select the CIPV (that is the path target)
- Cutting target: left or right lane target is selected, based on objects' cutin status
- (New) Target on faster lane: lane target on the adjacent faster lane

- LOST: If the target disappears from the object list, LOST is triggered (causes the controller to continue braking for some time, if was already braking)

Example of DASTE visualization



DASTE is a Valeo tool that can be improved based on our requests

Same as ADTF, with DASTE it is possible to visualize:

- Ego lane and adjacent lane determined from boundaries
- Path prediction
- Objects perceived (from different sensors and output of OBJD)
- Target selected

Thanks to this visualization it is possible to compare the input and output of target selection logic with real scene recorded using webcam

DASTE provides enhanced debugging capabilities with meticulously organized data and expanded plotting tools, facilitating comprehensive analysis of individual components

target selection validation results

Results from target selection cannot be validated precisely because there are a lot of factors that are determining target selection performance (that are also depending a lot from perceived lane and objects)

Instead the results are evaluated with statistical KPI:

- **False positive rate**: there are NO real valid ACC object AND an object is selected by ACC system
  OR an object is selected and it is much closer than the actual valid ACC object

- **False negative rate**: there are real valid ACC object AND No object is selected by ACC system
  OR an object is selected and it is very far than the actual valid ACC object

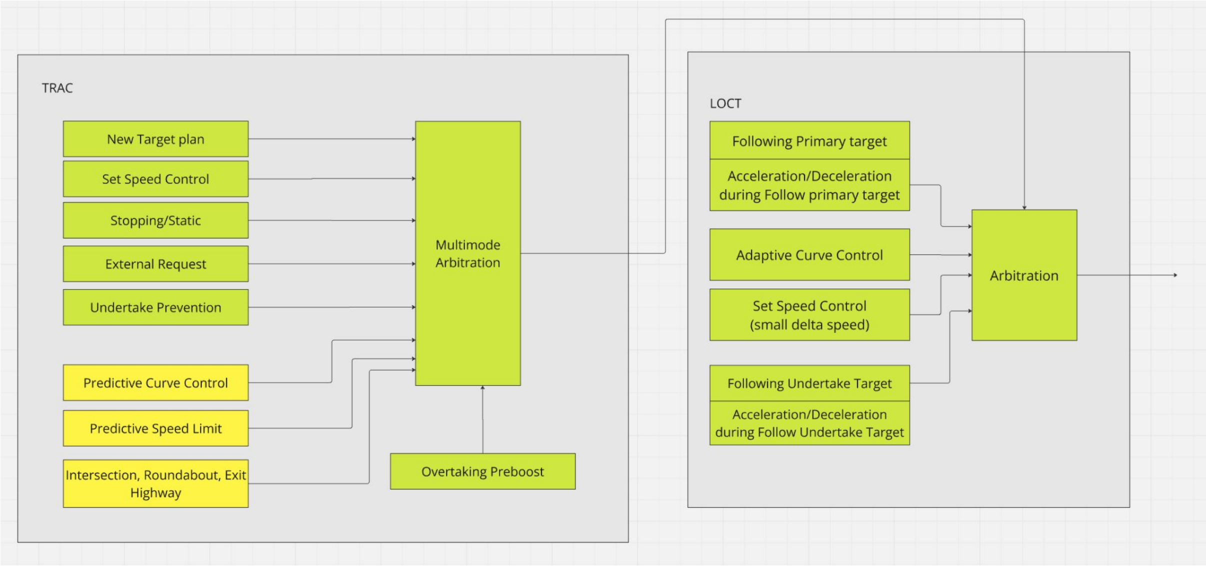
- **Late approach events**: The ego vehicle is approaching the object with initial distance higher or equal than LOCK_ON and the selection algorithm is late to select the object
  (To be only applied if initial relative speed less or equal than 70kph)

- **Cutin/cutout rate**: cut-in/out selection by ACC function with respect to real cut-in/out event

These KPI are determined using data collection comparing system result with annotated ground truth

Planning and Motion control
(Longitudinal Controller)

Introduction Longitudinal Control



ACC Longitudinal Control Overview

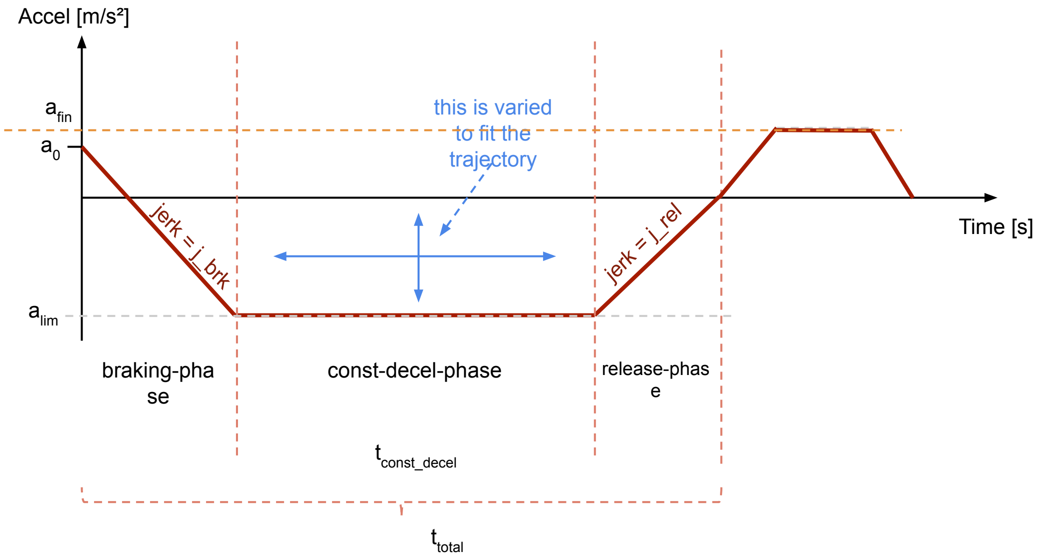
Planning Control (TRAC) – Handles acceleration requests in scenarios where planning is feasible:

- **New Target Plan:** Approaching, cut-in, catch-up, and cut-out with another vehicle ahead
- **Set Speed Control:** Manages high-speed variations
- **Stopping/Static:** Ensures accurate stopping distance
- **External Requests:** Deceleration triggered by external interfaces (e.g., lateral functions)
- **Undertake Prevention:** Prevents unintended lane undertakes
- **Predictive:** Planning acceleration/deceleration from map inputs

Motion Control (LOCT) – Manages acceleration when planning is not viable:

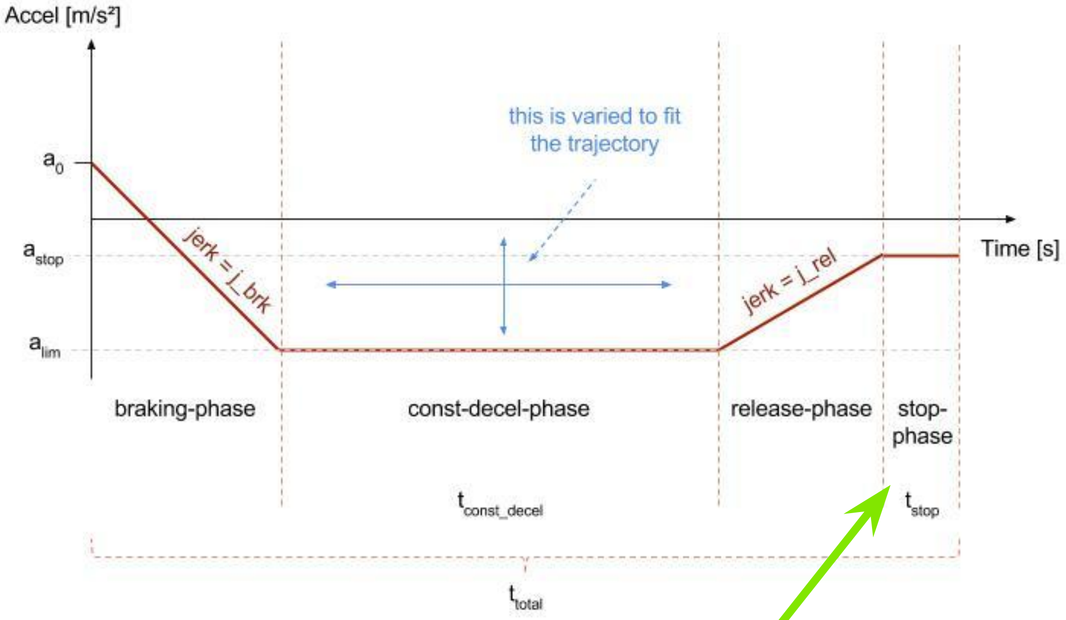
- **Primary/Undertake Target Following**
- **Adaptive Curve Control** for small delta speed variation

Planning: Approaching on dynamic target (approaching/cutin scenario)



- ensure a good trapezoid-shaped profile
- control the initial and final jerks
- Keep low jerk in the constant brake zone
- smooth deceleration request (engine brake) unless this will cause critical distance undershoot (predefined threshold), then brake more

Planing: approaching on stopping/static target

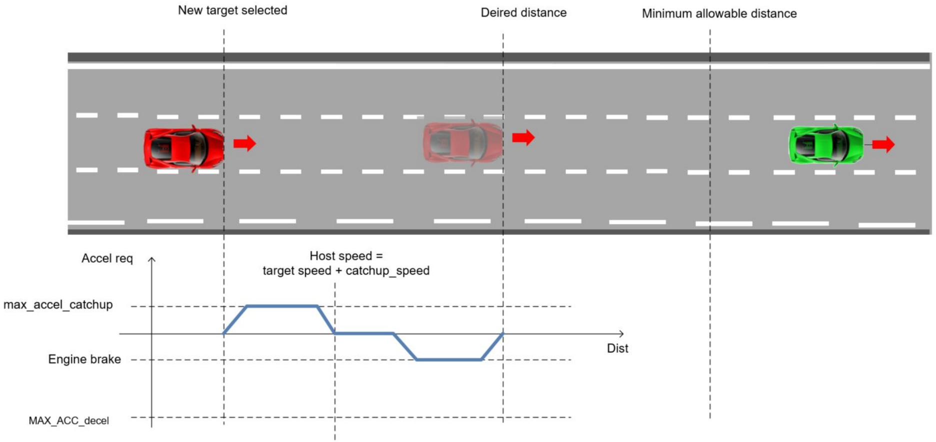


For stopping-trapezoid there is this final stop-phase to ensure standstill is achieved

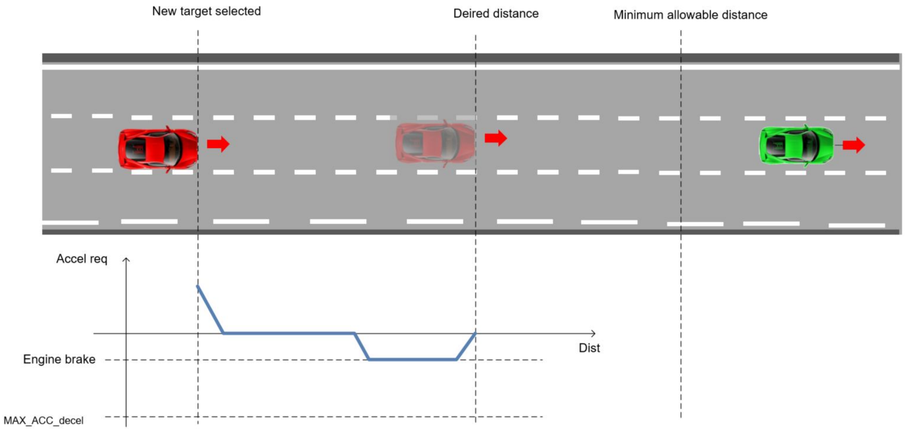
- ensure a good trapezoid-shaped profile
- control the initial and final jerks
- Keep low jerk in the constant brake zone
- precisely control the stopping distance
- Before to reach the standstill, provide a_stop (engine brake) for t_stop time to avoid to have the final strong jerk before standstill

catch up and smooth approach with engine brake to des distance w/o elastic effect

Host speed < target speed + catch up speed

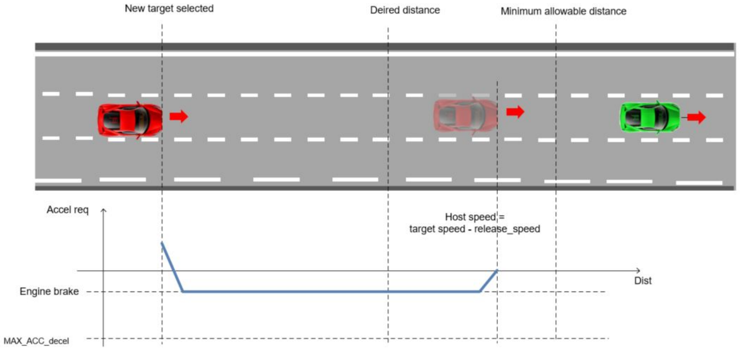


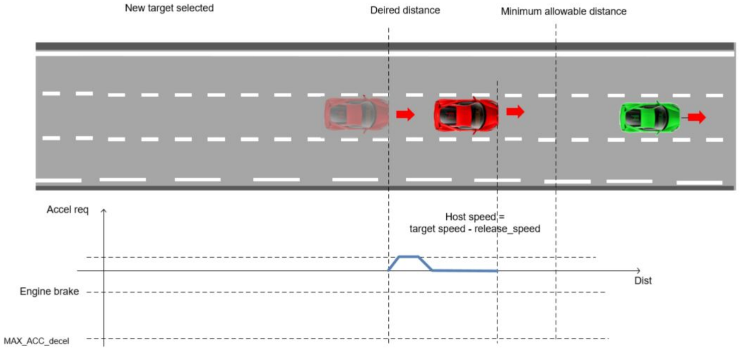
Host speed > target speed + catch up speed



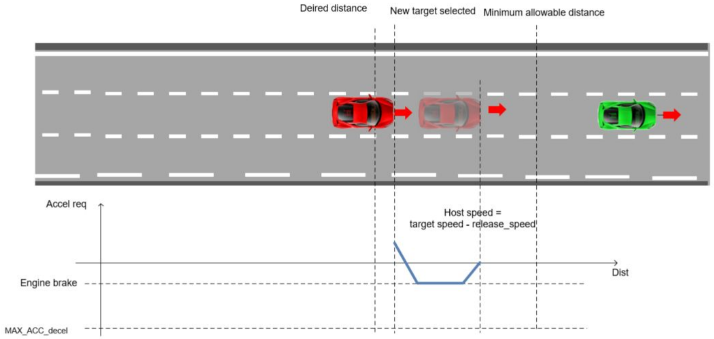
Approach/cutin soon with engine brake to desired distance w elastic effect

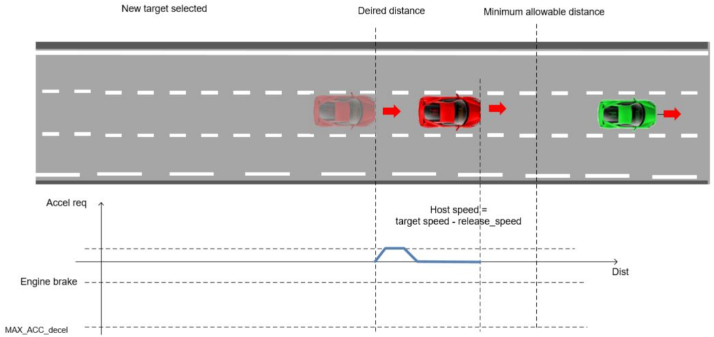
Approach (distance > desired distance)





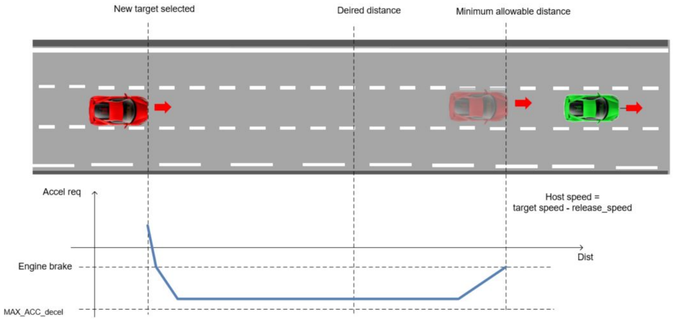
Cutin (distance < desired distance)

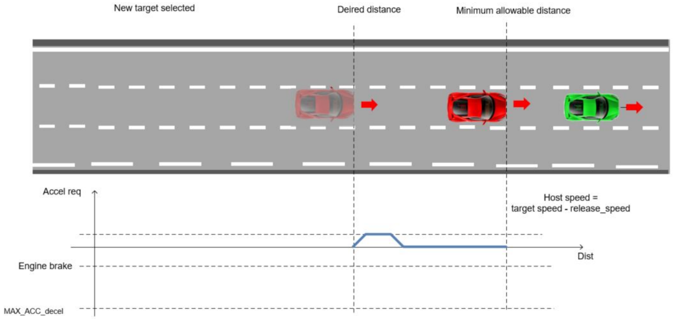




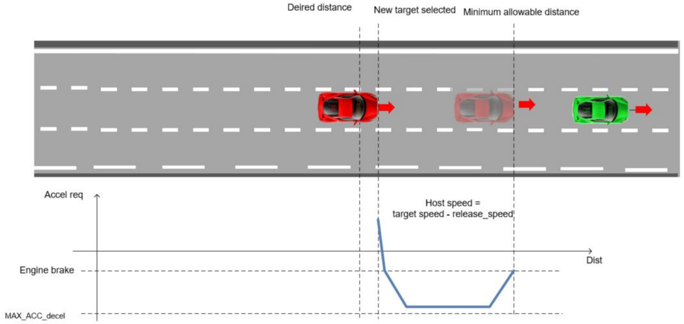
Approach/cutin soon more than engine brake to desired distance w elastic effect

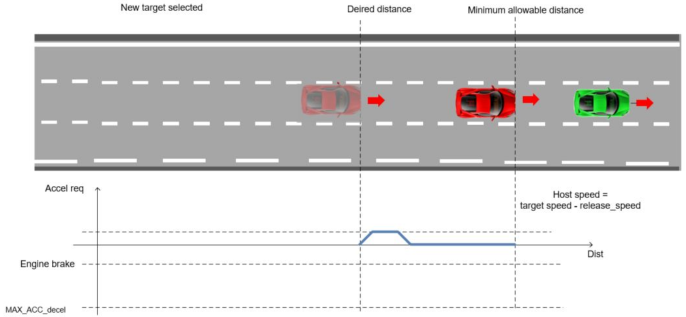
Approach (distance > desired distance)





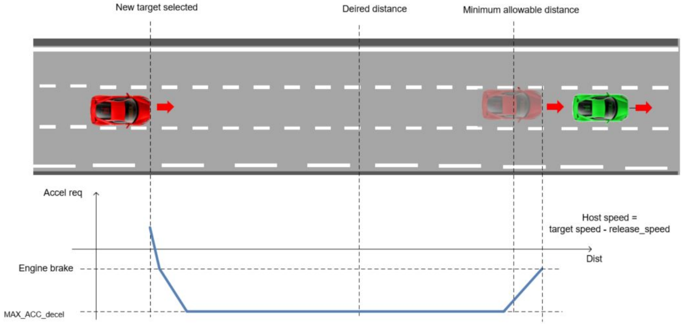
Cutin (distance < desired distance)

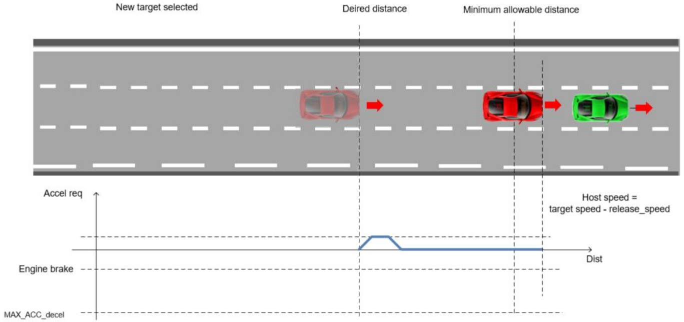




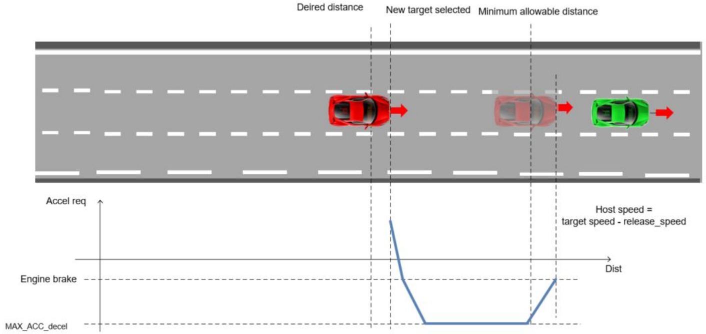
Approach/cutin saturated w elastic effect (undershooting min allowance distance)

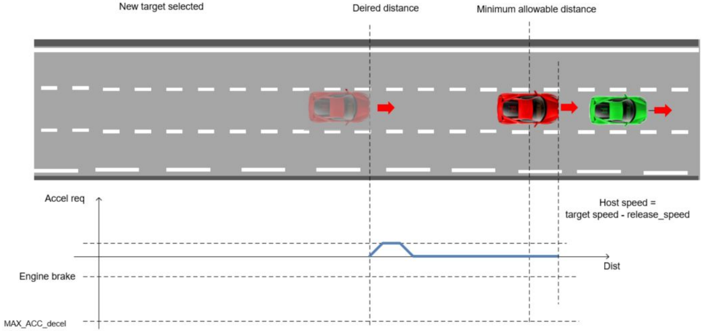
Approach (distance > desired distance)



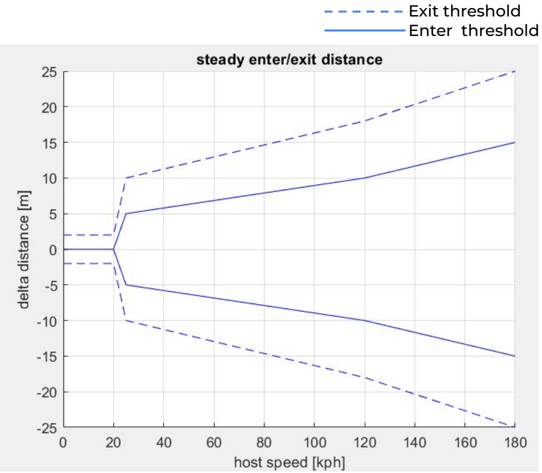


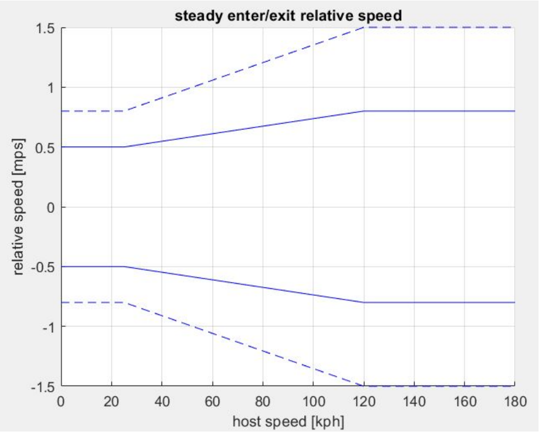
Cutin (distance < desired distance)





Steady State





Steady state (with vehicle in front): important state to determine when the vehicle in front is following in steady state or not:

Theoretical steady state:

- distance = desired distance; relative speed = 0; request acceleration = 0

The sensor noise grows with the distance:

- enter and exit thresholds based on distance (or host speed) has been introduced to enter and exit steady state.
- When the target is far away, the perception is noisier but at the same time is less critical for ACC scenarios so it is not a problem to extend the steady state margins

Enter conditions steady (all of these conditions need to be satisfied):

- Delta distance < delta distance enter threshold
- Relative speed < relative speed enter threshold
- abs(request acceleration) < 0.3 m/s^2 (param)

Exit condition steady (one of these conditions needs to be satisfied):

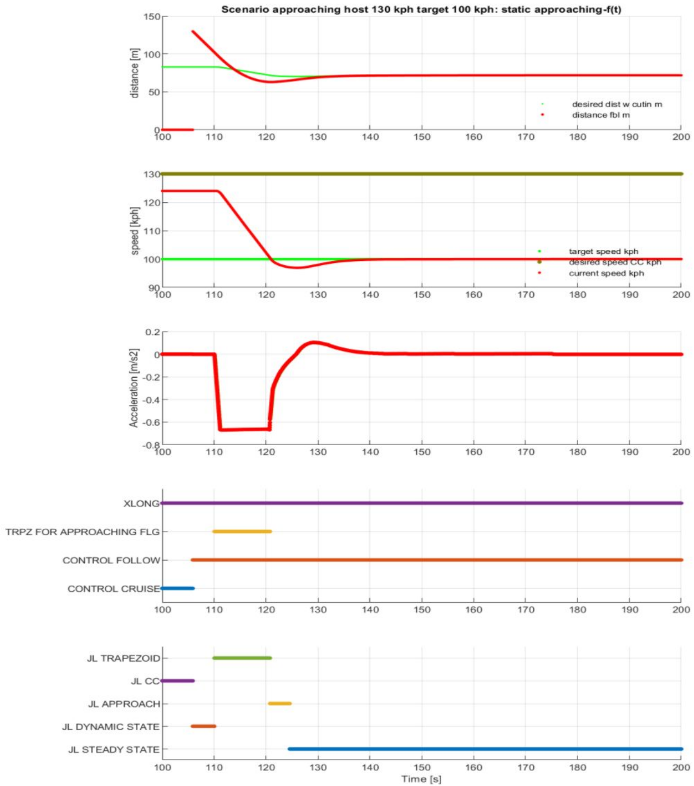
- Delta distance > delta distance exit threshold
- Relative speed > relative speed exit threshold

In Steady state, the host is following the vehicle in front using very low jerk value (low variation of the acceleration request).

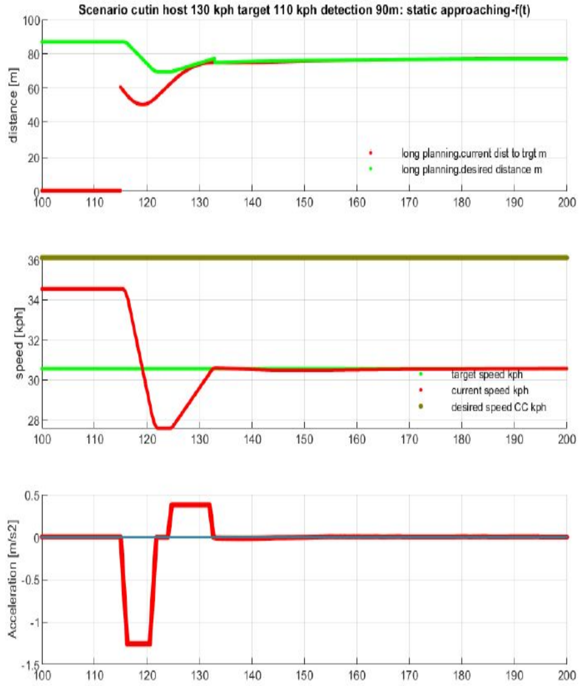
The thresholds are calibrated based on sensor accuracy (from measurement and KPI reported)

Regression test results (1/3) (simulation)

Approaching

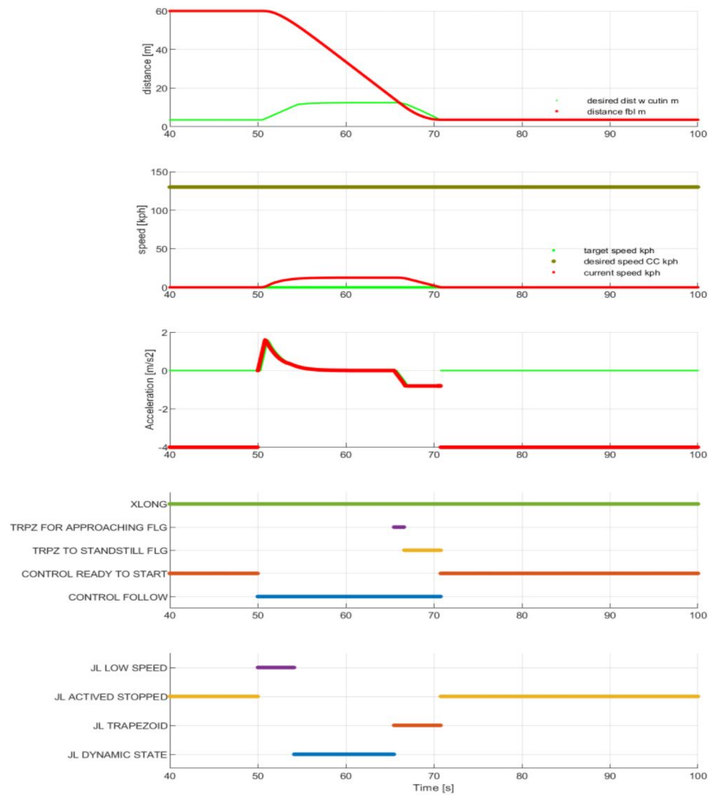


Cutin, Ego lane change to slow vehicle, new target after override, new target after system activation

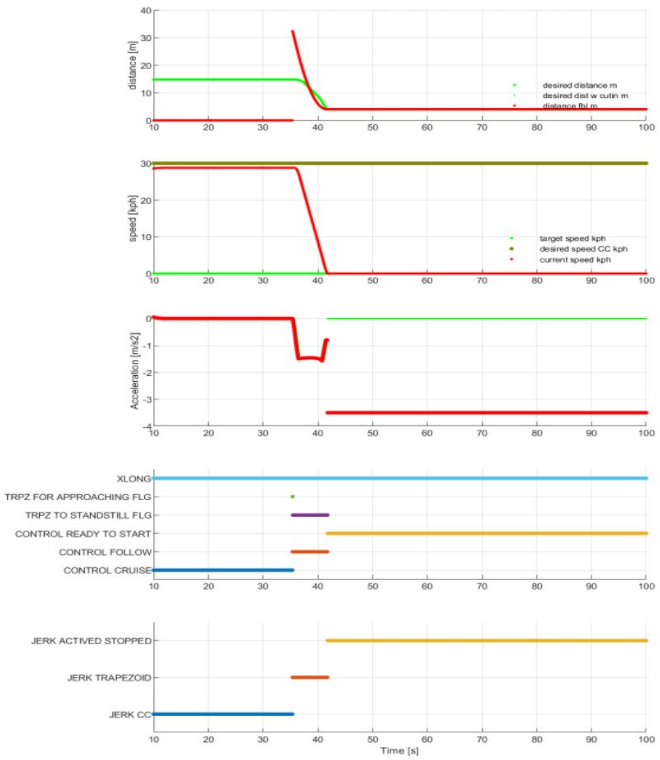


Regression test results (2/3) (simulation)

Catch up (from standstill)

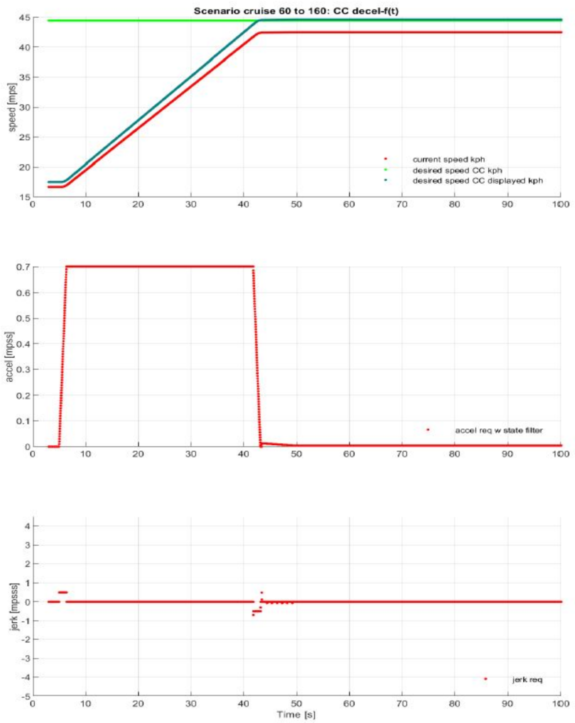


Approaching on static target

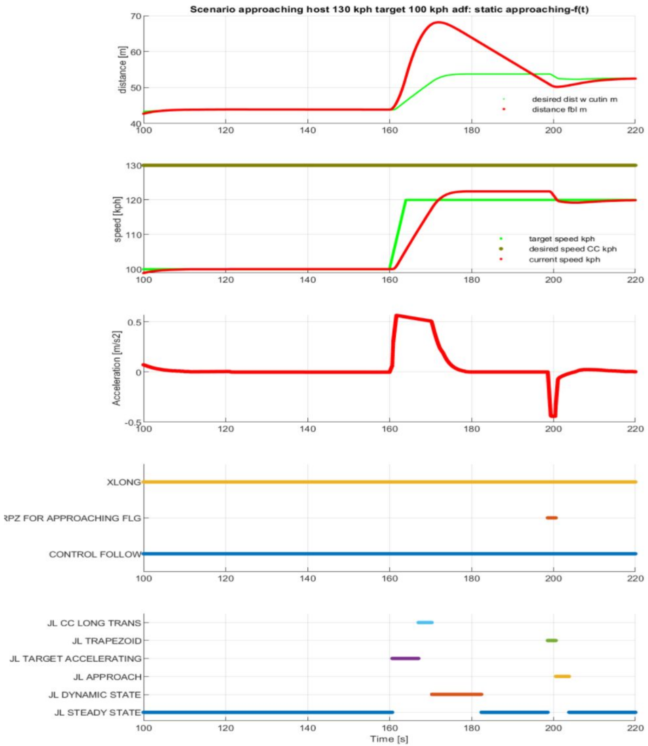


Regression test results (3/3) (simulation)

Starting to Cruise



Catch up high speed



Torque Control

Torque Control Objectives

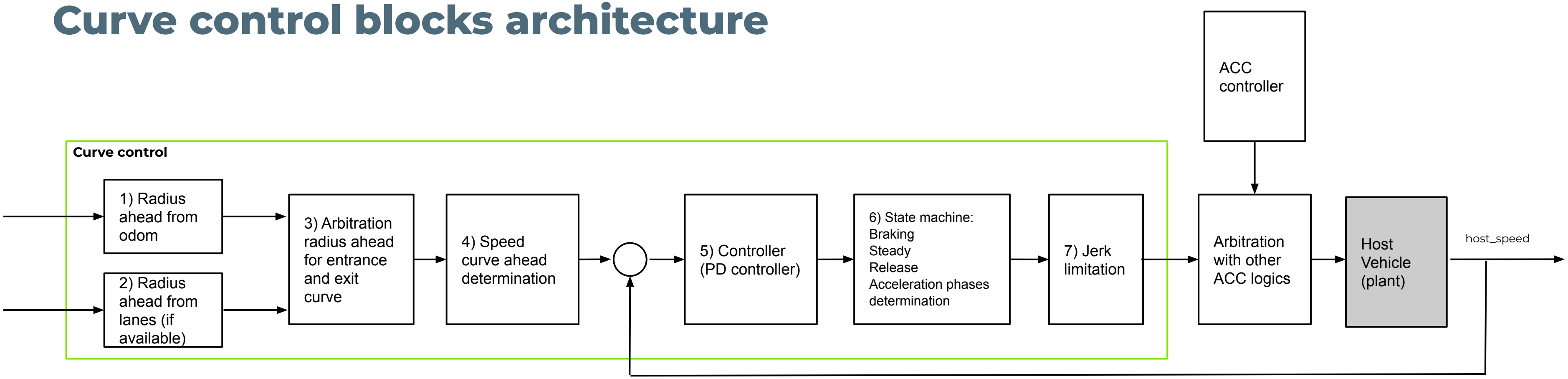
- Torque Control shall be able to determine wheel torque using as input the acceleration request provided from ACC Longitudinal control with the following objective :
    - Smooth activation and deactivation behaviour
    - Smooth torque request for **drive off** (slopes up to 10% gradient)
    - Compensation for **road slope** and **tyre resistance** changes
    - Compensation for **air drag** changes, e.g. headwind
    - Compensation for vehicle **parameter uncertainties**, e.g. vehicle mass changes and tyre radius changes
    - Smooth torque control during **gear changes**
    - Handling of engine brake (slow deceleration with small positive or negative engine torque)
    - Smooth switching between braking and engine torque
    - Determine a smooth braking torque for stopping

Curve control (details)

Curve Control introduction

- Curve control is an additional logic in the controller which is able to support braking and acceleration in curve in order to reduce lateral acceleration
- Current curve control is not using map information so the input to the function are provided from perceived lane (if available) and odometry
- Small prediction is possible to allow braking before entering the curve. The function shall continue braking in the curve in order to have lateral acceleration in the margin defined.

Curve control blocks architecture



1) Radius ahead from odometry (radius_ahead_odom): determined with the formula ra = r - T*(L 𝛿' / sin^2(𝛿))
2) Radius ahead from lanes (if available) (radius_ahead_lane): determined with the curvature ahead polynomial using the formula: ca= 6*a*T+2*b where ra= 1/ca

3) Arbitration radius for entrance and exit curve (arbitrated_radius):
if the lane radius signal quality is high, **during braking:** arbitrated_radius is equal the min radius(radius_ahead_lane, radius_ahead_odom) else
if the quality of the lane radius is high, **during releasing**: arbitrated_radius is equal the max radius(radius_ahead_lane, radius_ahead_odom) (optional)
else the arbitrated_radius is radius_ahead_odom

4) Speed curve ahead determination (velocity_ahead): simple formula velocity_ahead = sqrt(P_MAX_LAT_ACCEL * arbitrated_radius_ahead)

5) Controller (PD controller): proportional/derivative controller with speed_error as input (velocity_ahead-host_speed). Output is acceleration_raw

6)State machine: using the lateral accel, speed_error and steering wheel angle: determine the phases: Braking, Steady, Releasing (and constant speed) and acceleration.

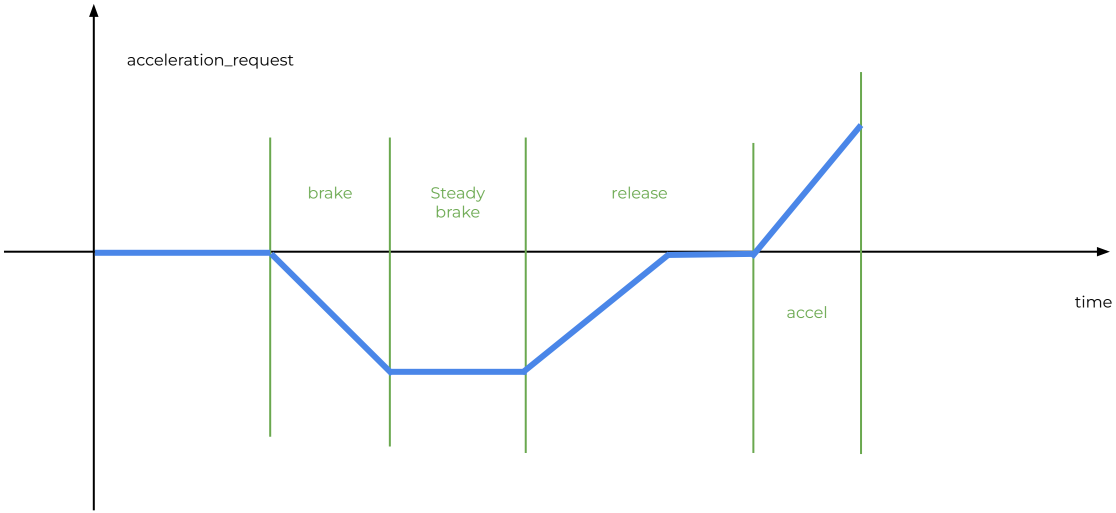
7) Jerk limitation: using the phases determined in the state machine, this jerk limitation is able to provide correct rate limiting (tunable param) to output acceleration_request:
- High negative jerk and very low positive jerk in the braking phase
- Very Low negative jerk and very low positive jerk in the steady brake phase
- Very Low negative jerk, high positive jerk in the release phase for negative acceleration and very low positive jerk in the release phase for positive acceleration
- Very Low negative jerk and high positive jerk in the acceleration phase for both negative and positive acceleration

the curve control output needs to be arbitrated with other ACC logic before to send it to other ECU (torque controller) located in host vehicle plant

Acceleration profile output

Using the phases determined from state machine, the shape of the acceleration request is modeled with jerk limitation following the calibration values defined in the jerk limitation logic:

- High negative jerk and very low positive jerk in the braking phase
- Very Low negative jerk and very low positive jerk in the steady phase
- Very Low negative jerk, high positive jerk in the release phase for negative acceleration and very low positive jerk in the release phase for positive acceleration
- Very Low negative jerk and high positive jerk in the acceleration phase for both negative and positive acceleration



Overtaking pre-boost (details)

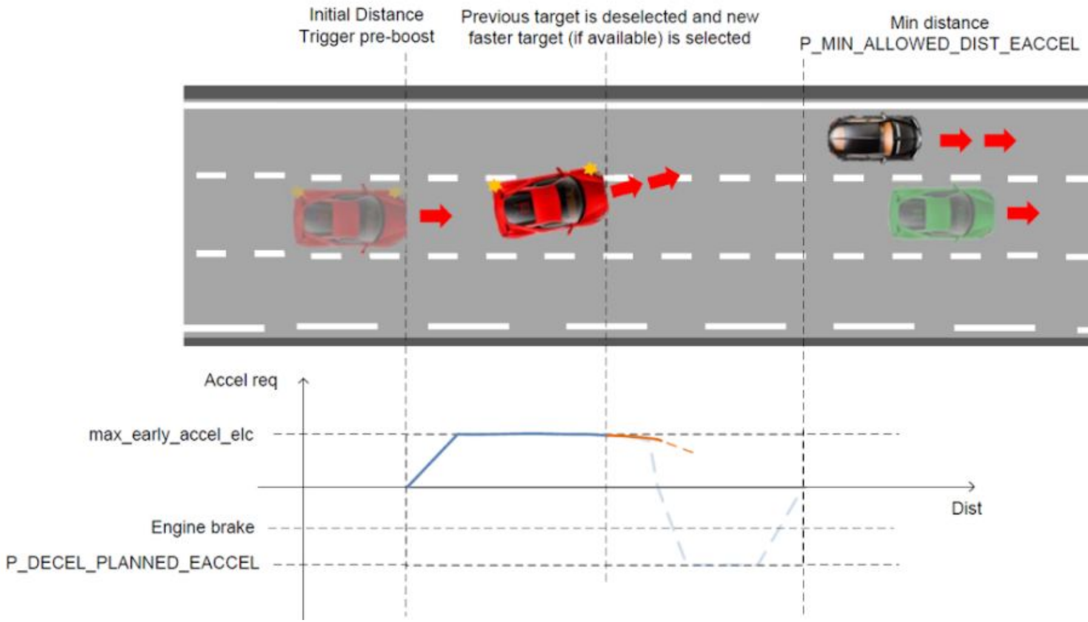
Overtaking Pre-Boost introduction

- overtaking preboost is an **acceleration support** to be used during overtaking maneuver to allow host vehicle to accelerate before deselect the vehicle in front
- If logic is activated **without change lane,** the acceleration profile shall finish at one point and a planned brake shall start in order to avoid collision with the vehicle in front
- If **deactivated** before lane changing, the function shall release smoothly the acceleration in order to reach the steady steady in comfort way

    - The overtaking pre-boost can be activated when all following condition are valid:
        - the fast lane is available without adjacent vehicle or with a faster adjacent vehicle
        - within defined distance from vehicle in front and defined speed
        - Turn indicator is applied

    - The overtaking pre-boost can be deactivated (before changing lane) when:
        - Turn indicator is released
        - Fast lane not anymore available

Overtaking Pre-Boost changing lane

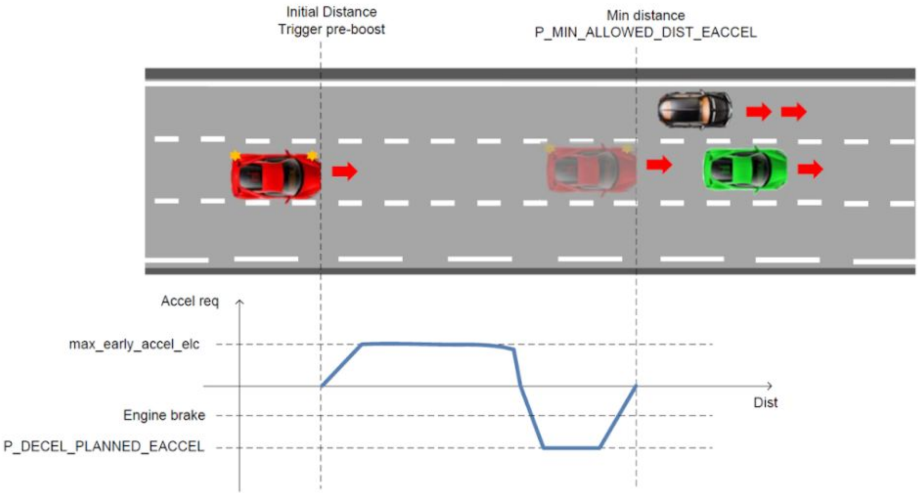


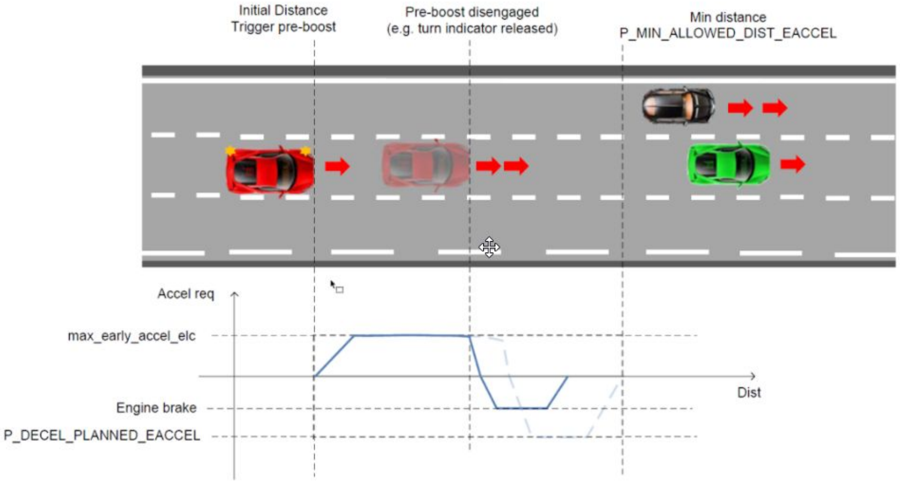
Transition phase in lane change:

After deselecting the target in front during ego lane change maneuver, the acceleration request shall continue without variations: similar acceleration and smooth jerk during the transition phase (*)

(*) this only in case the target is deselected when still the contribution of evertaking pre-boost is equal to max_early accel_elc

Overtaking Pre-Boost without changing lane





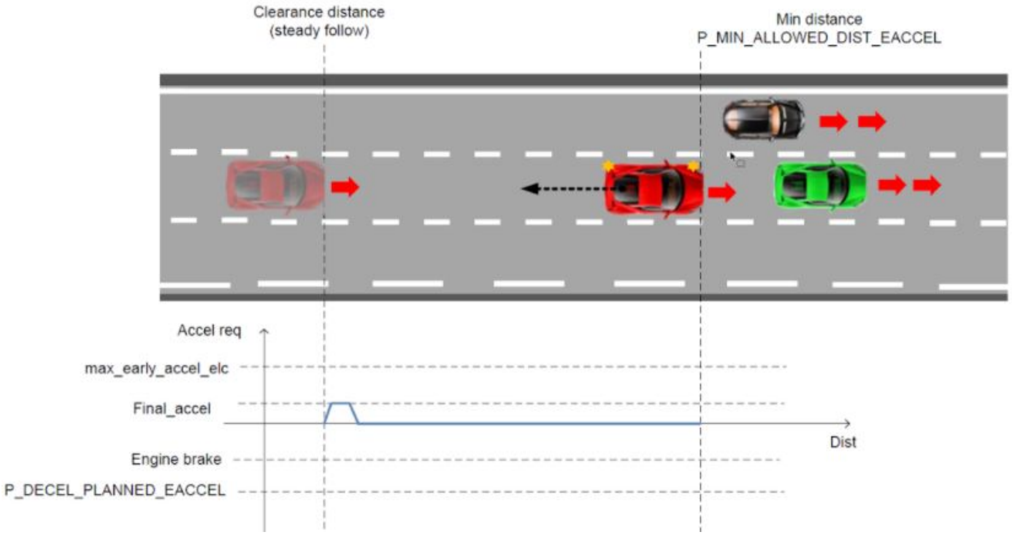
Overtaking Pre-Boost without changing lane until reaching Min distance

The host is accelerating and deceleration with defined jerk in order to reach Min Distance.
When the brake is finished, the host speed is 5kph (tunable) slower than target vehicle

Overtaking Pre-Boost without changing lane deactivated before reaching Min Distance

When deactivated, the host shall soon apply braking. This will be engine brake if this is enough if the final distance is higher than Min Distance.
Also in this case, when the brake is finished, host speed is 5kph (tunable) slower than target vehicle

Overtaking Pre-Boost without changing lane



Releasing phase:

If the host vehicle reaches the Min Distance or it get deactivated after the braking phase, it starts the distance recovery.
Due to the relative speed 5kph planned after the braking (see previous slide), this distance recovery can be achieved with 0 acceleration.
An acceleration (with max accel and jerk value tunable) is finally necessary in order to remove this relative speed before to reach the clearance distance

Predictive ACC (details)

Reference slides:
https://docs.google.com/presentation/d/1lQaRm14dh_F9DcyAChERuYPWtdSD2kPZb5m8AHerMLU/edit#slide=id.g33714a6ee93_5_5