

# A Review On Automatic Steering Control Using Nested PID Controller



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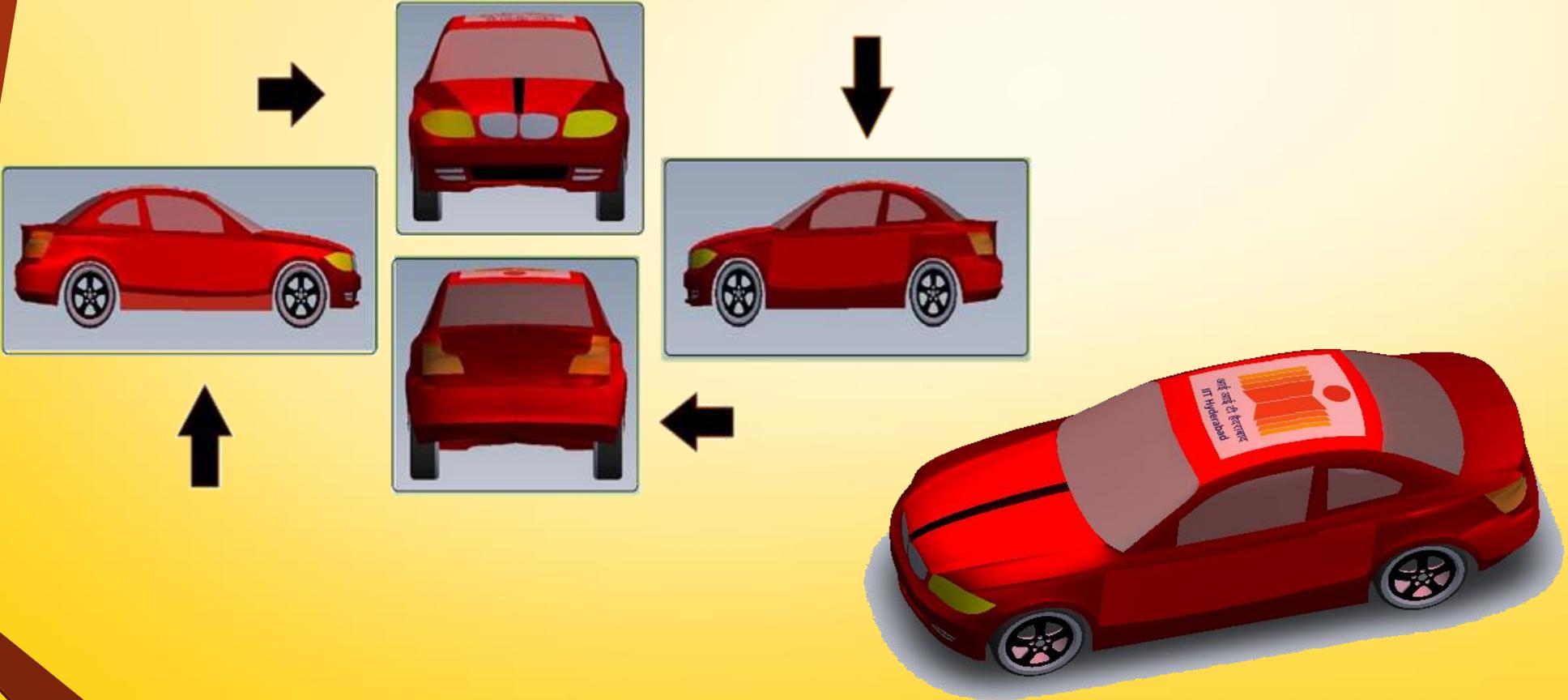
# CONTENTS

- Introduction
- PID Controller
- Vehicle model
- CAR SIM
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# Vehicle model

Software Used- Solid Works



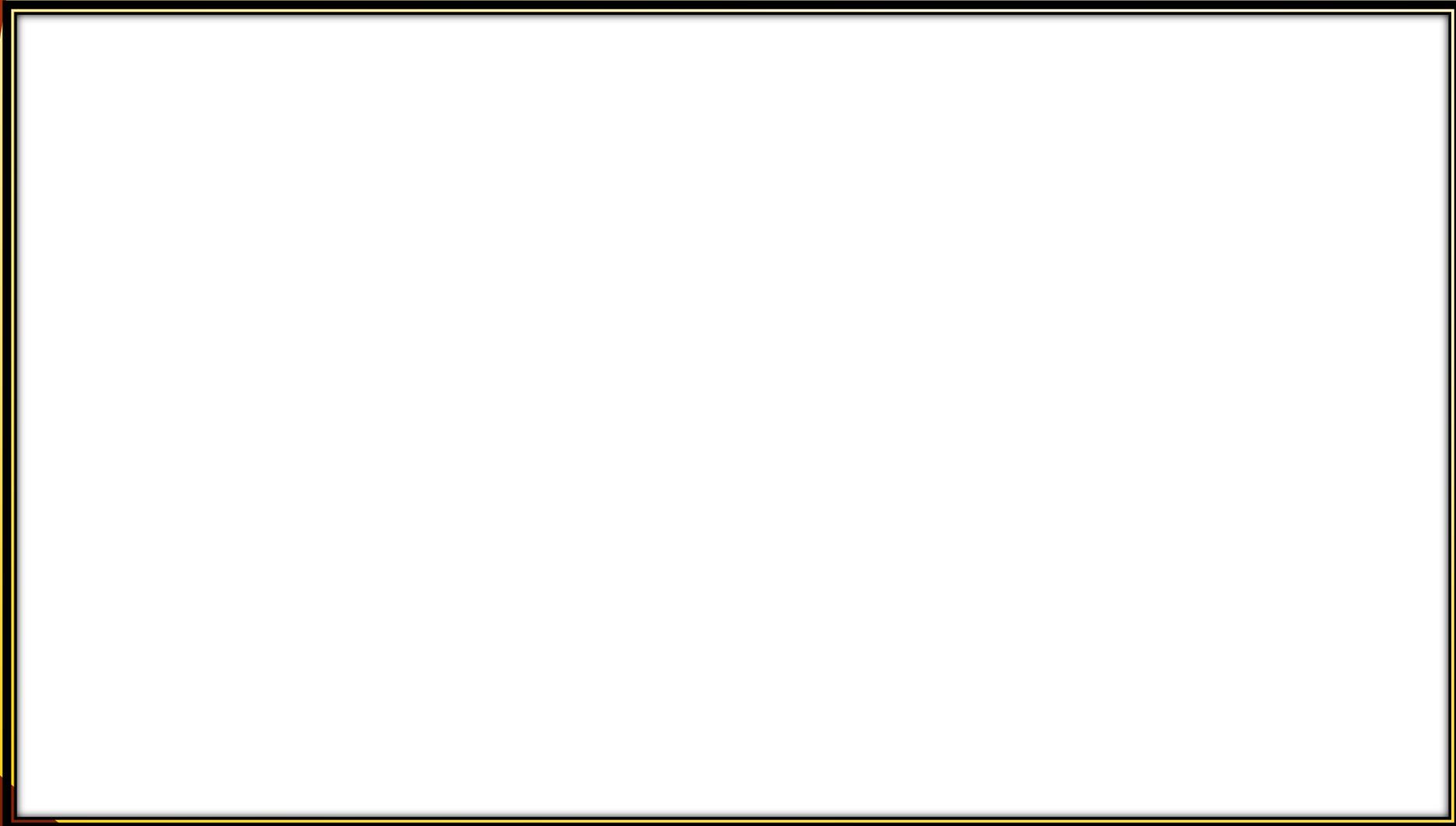
# INTRODUCTION

- The main aim of using active steering control is to increase safety and to reduce both accidents and drivers work load.
- According to the NHTSA survey 37% of all transportation fatalities in USA are caused by running of the road
- Lane Keeping Assist technology is designed to alert the driver when the system detects that the vehicle is about to deviate from a traffic lane which helps keep drivers with in the lane.

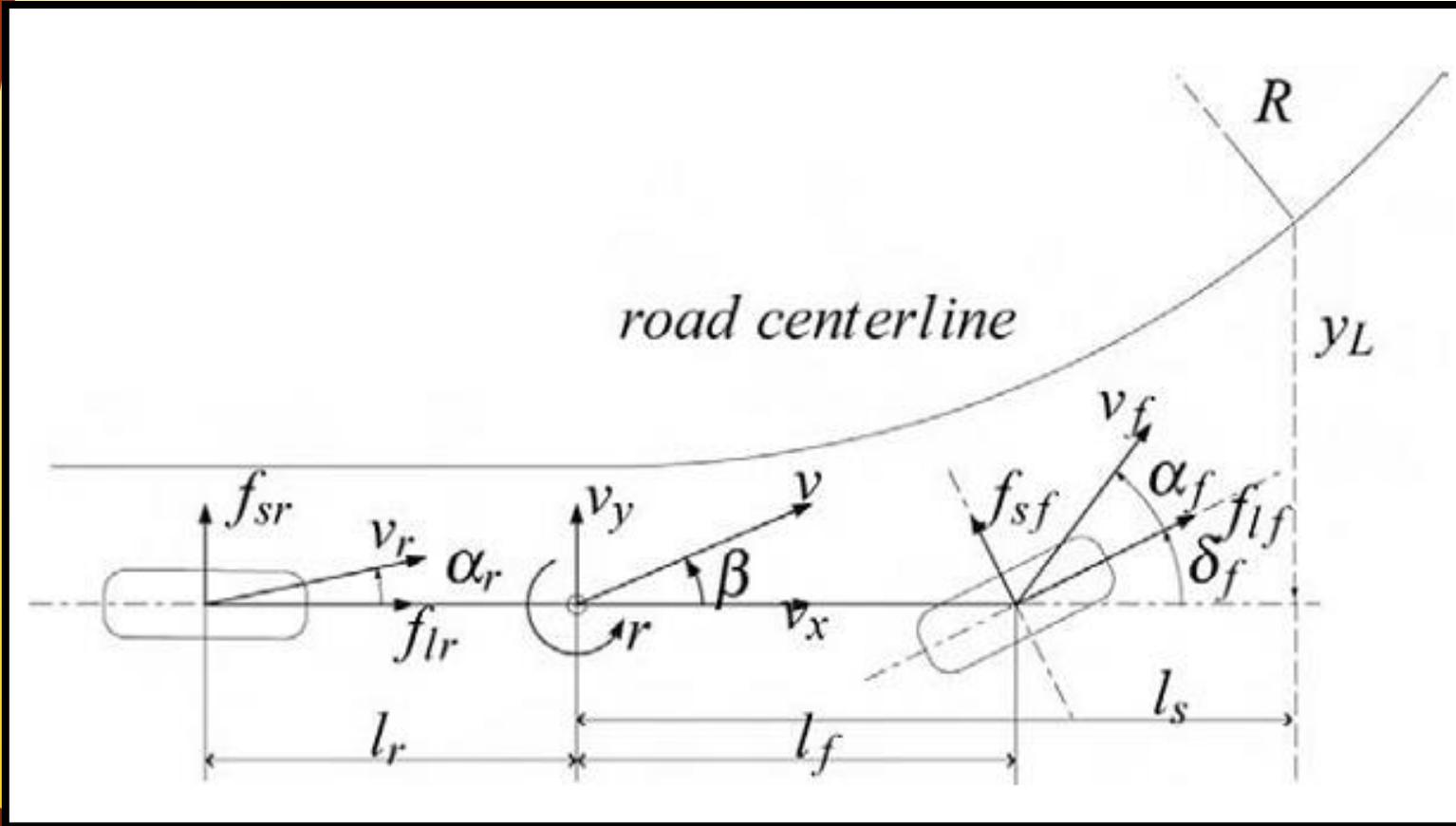
# LANE KEEPING ASSIST

- The Lane Departure Warning
  - Alerts the driver when the vehicle starts to deviate from its lane with a warning buzzer, alert lamp and the application of a small counter-steering force to the steering wheel.
- Lane Keeping Assist
  - When the Rader Cruise Control is activated and the system senses the vehicle deviating from its lane, the system helps the car stay on course near the centre of the lane by continuously applying a small amount of counter-steering force.

# Motivation Video on Automatic Steering Control

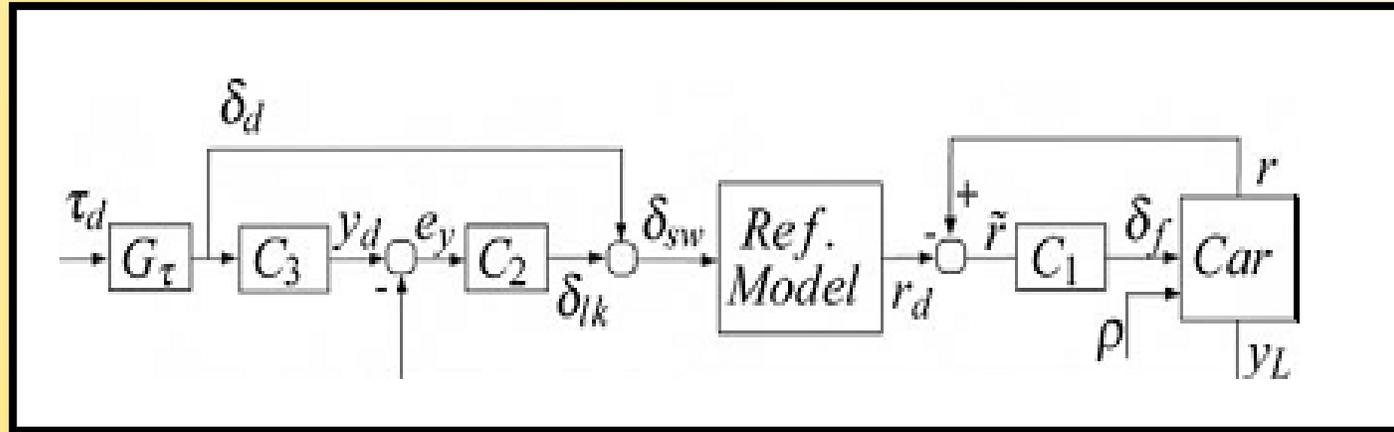


# SINGLE TRACK VEHICLE MODEL



$\delta$ - Steering Angle  
 $\alpha$ -Side Slip Angle  
 $f_s$ -Lateral Forces  
 $f_l$ -Longitudinal Forces  
 $y_L$ -Lateral Offset  
 $\beta$ -Vehicle side slip angle

# INTEGRATED DRIVER AND CONTROL SCHEME(PID)



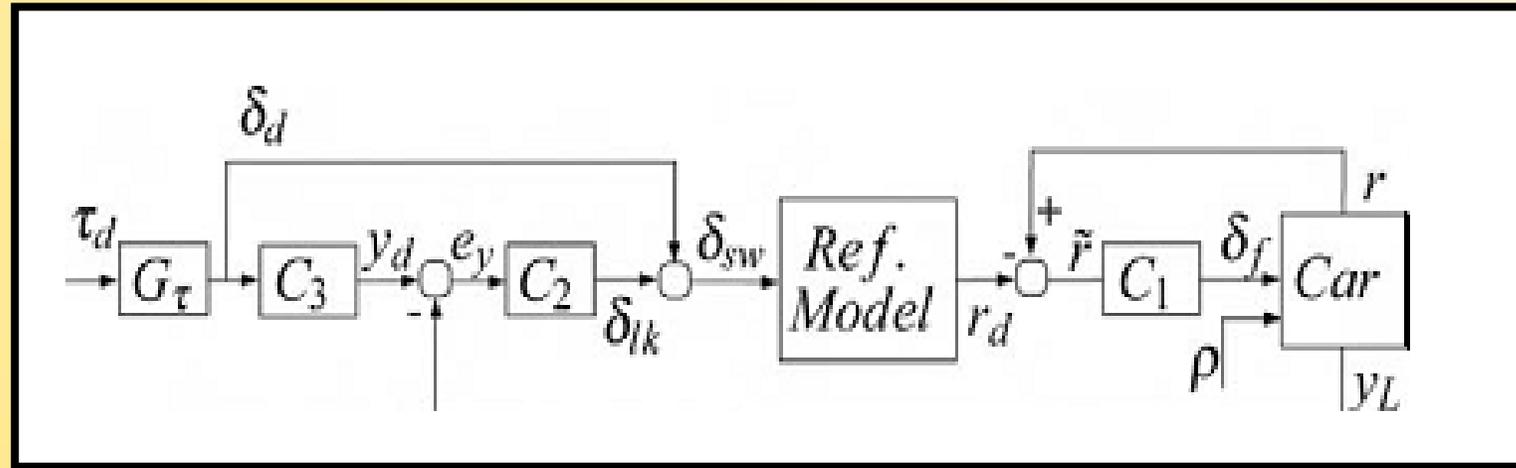
- C1- PI Active front steering control is designed on the basis of yaw rate error ( $r-r_d$ )
  - $r$ - Yaw Rate
  - $r_d$ - Yaw rate reference (Input by either Driver/ Autonomous lane keeping system )

$$C1 = -K_{P1}(r - r_d) - K_{I1}\alpha_0$$

$\alpha_0$ -Additional State introduced by dynamic control



# INTEGRATED DRIVER AND CONTROL SCHEME(PID)



- C3- To obtain full control of vehicle
  - Active when  $\tau_d \neq 0$
  - Goal is to keep  $e_y = 0$
  - Automatic Lane changing is never switched off

$$C_3 = K\bar{P}_0$$

$$\bar{P}_0 = \frac{(d_3s^3 + d_2s^2 + d_1s + d_0)}{s^2(-s^3 + c_2s^2 + c_1s + c_0)}$$

$\bar{P}_0$ -Transfer function between  $r_d$  &  $y_L$   
K-Design Parameter

# VEHICLE MODEL

## ➤ Equation of Motion

$$\begin{aligned}m(\dot{v}_x - rv_y) &= f_{lf} \cos \delta_f + f_{sf} \sin \delta_f + f_{lr} \\m(\dot{v}_y + rv_x) &= f_{lf} \sin \delta_f - f_{sf} \cos \delta_f - f_{sr} \\J\dot{r} &= l_f(f_{lf} \sin \delta_f - f_{sf} \cos \delta_f) + l_r f_{sr}\end{aligned}$$

## ➤ In linearized form

$$\begin{bmatrix} \dot{\beta} \\ \dot{r} \\ \dot{\psi} \\ \dot{y}_L \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ 0 & 1 & 0 & 0 \\ v & l_s & v & 0 \end{bmatrix} \begin{bmatrix} \beta \\ r \\ \psi \\ y_L \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \\ 0 \\ 0 \end{bmatrix} \delta_f + \begin{bmatrix} 0 \\ 0 \\ -v \\ 0 \end{bmatrix} \rho$$

- $a_{ii}, b_i$ -Physical Parameters
- Depends on cornering stiffness

# CARSIM SIMULATION

File Edit Datasets Libraries Go To View Tools Help

Back Forward Home Previous Next Duplicate Undo Redo Lib Tool Parsfile Run106 10-15-2013 11:29 Delete

Sidebar Refresh Help Lock

A speed target can be calculated along a path while staying within given limits of lateral and longitudinal acceleration.

One of the most important uses of the Speed (Closed loop) Using Path Preview is to produce realistic driving speed schedules reflecting real highway driving performance levels.

In this example, a car maintains its lane position while accelerating and

**CarSim Run Control: Lane Ke**

- Animator: Camera Setup: 180 de
- Vehicle: Assembly: D-Class, Se
- Procedures: Lane Keeping, Nor

Expand Collapse Refresh Reset

### Test Specifications

Vehicle configuration: Ind\_Ind  
D-Class, Sedan

Procedure  
Lane Keeping, Normal Driving

Show more options on this screen

### Run Control: Built-In Solvers

Run Math Model Models: ▼

Write all available outputs

Some buttons are dimmed because the data set is locked

### Results (Post Processing)

Animate  Set run color

180 deg. Azimuth, 15 deg. El., Veh. Ref. ▼

Plot Show more plots: 0 ▼

Overlay animations and plots with other runs



D-Class, Sedan  
{ CS D-Class }

View Echo file with initial conditions ▼

**carSIM**  
MECHANICAL SIMULATION.

# CARSIM SIMULATION

The screenshot displays the CarSim simulation software interface. At the top, there is a menu bar with options: File, Edit, Datasets, Libraries, Go To, View, Tools, Help. Below the menu bar is a toolbar with icons for navigation (Back, Forward, Home, Previous, Next), file operations (Duplicate, Undo, Redo, Lib Tool, Parsfile), and system functions (Delete, Sidebar, Refresh, Help, Lock). The main window is titled "Proc105" and shows the date and time "10-15-2013 11:26".

The interface is divided into several panels:

- Left Panel:** Contains a text area with the following text: "This Procedure demonstrates the use of the Target speed from path preview combined with the 3D road dataset 'Handling Course.'" and "Rather than define a stop time or station, Events are used to record the number of laps the vehicle makes on the handling course. Once the vehicle has completed the specified number of laps, the simulation ends." Below this is a tree view showing the simulation setup: "CarSim Run Control: Lane Keeping", "Animator: Camera Setup: 180 de", "Vehicle: Assembly: D-Class, Ser", and "Procedures: Lane Keeping." At the bottom of this panel are buttons for "Expand", "Collapse", "Refresh", and "Reset".
- Driver Controls Panel:** Features dropdown menus for "Target speed from path preview" (set to "Normal Driving"), "Braking:", "Shifting control: Closed-loop shift control" (set to "AT All Gears"), and "Steering: Driver path follower" (set to "1 m Right 1 sec. Preview").
- Start and Stop Conditions Panel:** Includes a dropdown for "Run forever (stop manually or with an event)", input fields for "Time (sec)" and "Path station (m)" (both set to 0), and a dropdown for "Road forward". There is also a checkbox for "Specify initialization details?".
- Additional Data Panel:** Shows a list of data sources, with "Misc.: 3D road" and "Handling Course" selected. Other entries include "Misc.: 3D road", "Misc.:", "Misc.:", and "Misc.:".
- Plot Definitions Panel:** Lists various data plots, with several selected: "Longitudinal vs. Lateral Accel.", "Lateral Accel. of CG's vs. Station", "Longitudinal Accel. of CG's vs. Station", "Throttle: Control Input vs Station", "Brake Control: Master Cyl. Pressure vs Station", "Steering: Handwheel Angle", "Speed Limit, Target, and Actual", and "Vehicle Path with Road Edges". The remaining plots are set to "{No dataset selected}".

# CARSIM SIMULATION

File Edit Datasets Libraries Go To View Tools Help

Back Forward Home Previous Next Duplicate Undo Redo Lib Tool Parsfile SpdPath102 04-18-2015 10:26 Delete
Sidebar Refresh Help Lock

In daily highway driving drivers limit themselves to fairly low acceleration levels. Here we use a maximum of 0.3 G's in all directions.

The limits are modified during the run to account for increasing and decreasing vertical load caused by road camber and elevation changes, as indicated by the checkbox. Unchecking the box keeps the acceleration limits unchanged with vertical load.

### Acceleration Limits in Path Preview

Skill level: 2 - Combine Ax and Ay on friction ellipse

Account for road surface 3D geometry

### Aggressiveness

Aggressiveness is defined with four limits of acceleration that are acceptable by the speed controller.

Advanced users can specify acceleration limits as nonlinear functions of speed. Right-click on the drop-down list for extra keyword information.

Ax Max:throttle (constant) 0.3 g's

Ax Max:braking (constant) 0.3 g's

Ay Max:left turn (constant) 0.3 g's

Ay Max:right turn (constant) 0.3 g's

### Path Preview Lengths

Segment used to calculate curvature: 50 m

Preview start: 2 m

Total preview: 200 m

Preview interval (resolution): 2 m

### Closed-Loop Speed Controller Gains

$Ax$  (target for speed control) =  $KP * Verr + KI * lerr + KP3 * Verr^3$   
 where  $Verr = Vtarget - Vx$ ;  $lerr = \text{integral of } Verr$ ;  $d(lerr)/dt = Verr$

KP: proportional gain: 0 s/m

KI: integral gain: 0 1/m

KP3: cubic gain: 0 s<sup>3</sup>/m<sup>3</sup>

Approximate brake system performance: 0.1 g/MPa

Approx. gain: MC pressure/pedal force: 0.1 MPa/N

Maximum MC pressure from controller: 10 MPa

Account for engine braking in speed control

### Upper Speed Limit

Speed limit as function of station (legacy)

Normal Driving on Road Course

The linked dataset for target speed includes closed-loop controller gains. Those values will be overridden with the values shown on this screen.

Custom settings

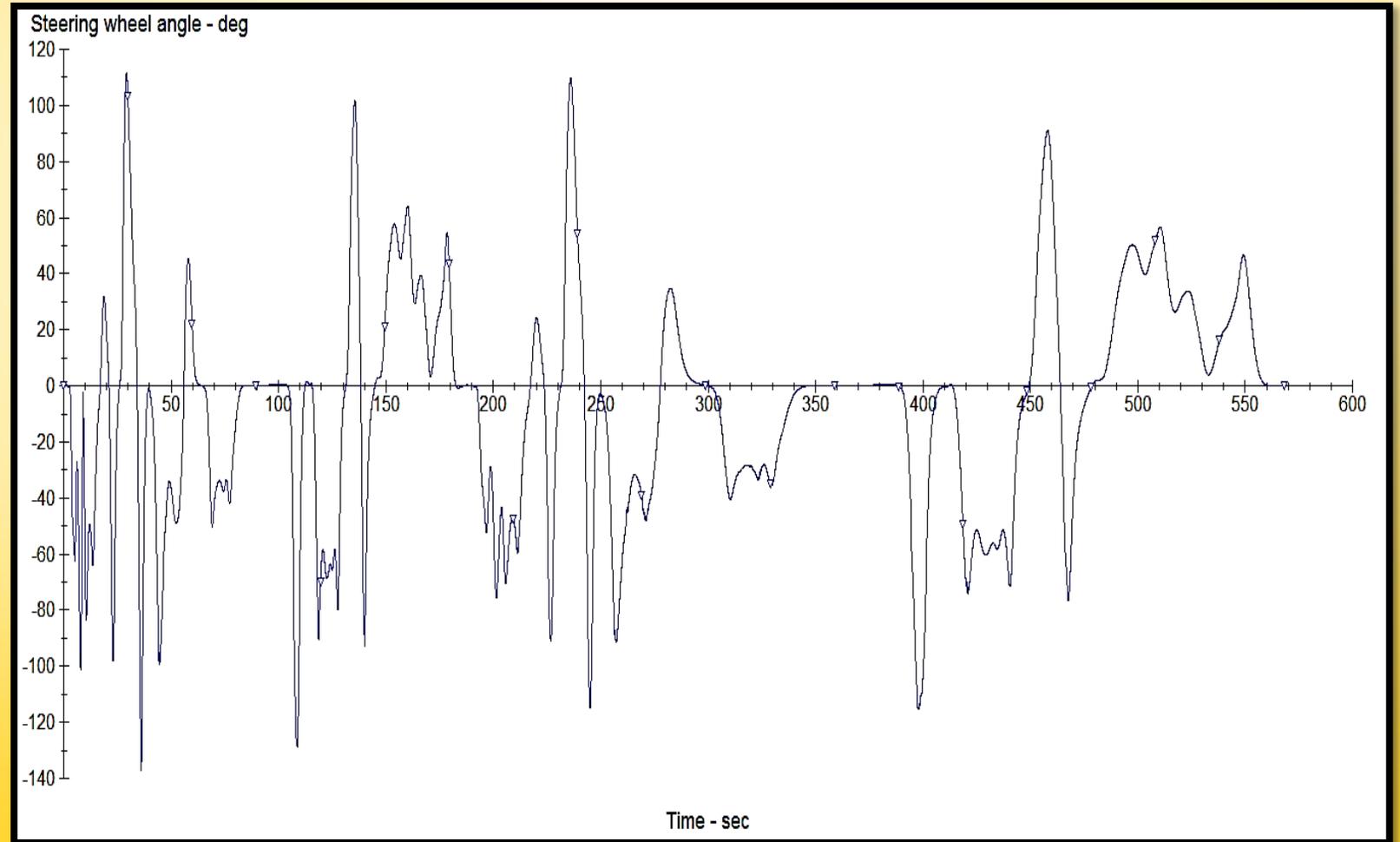
```
lcancel the integral error when it is causing overst
define_variable sv_vx_err_save 0;
eq_out sv_iverr = if_gt_0_then(vx_err * sv_vx_err_
eq_save sv_vx_err_save = vx_err;
```

Miscellaneous:

Expand Collapse Refresh Reset

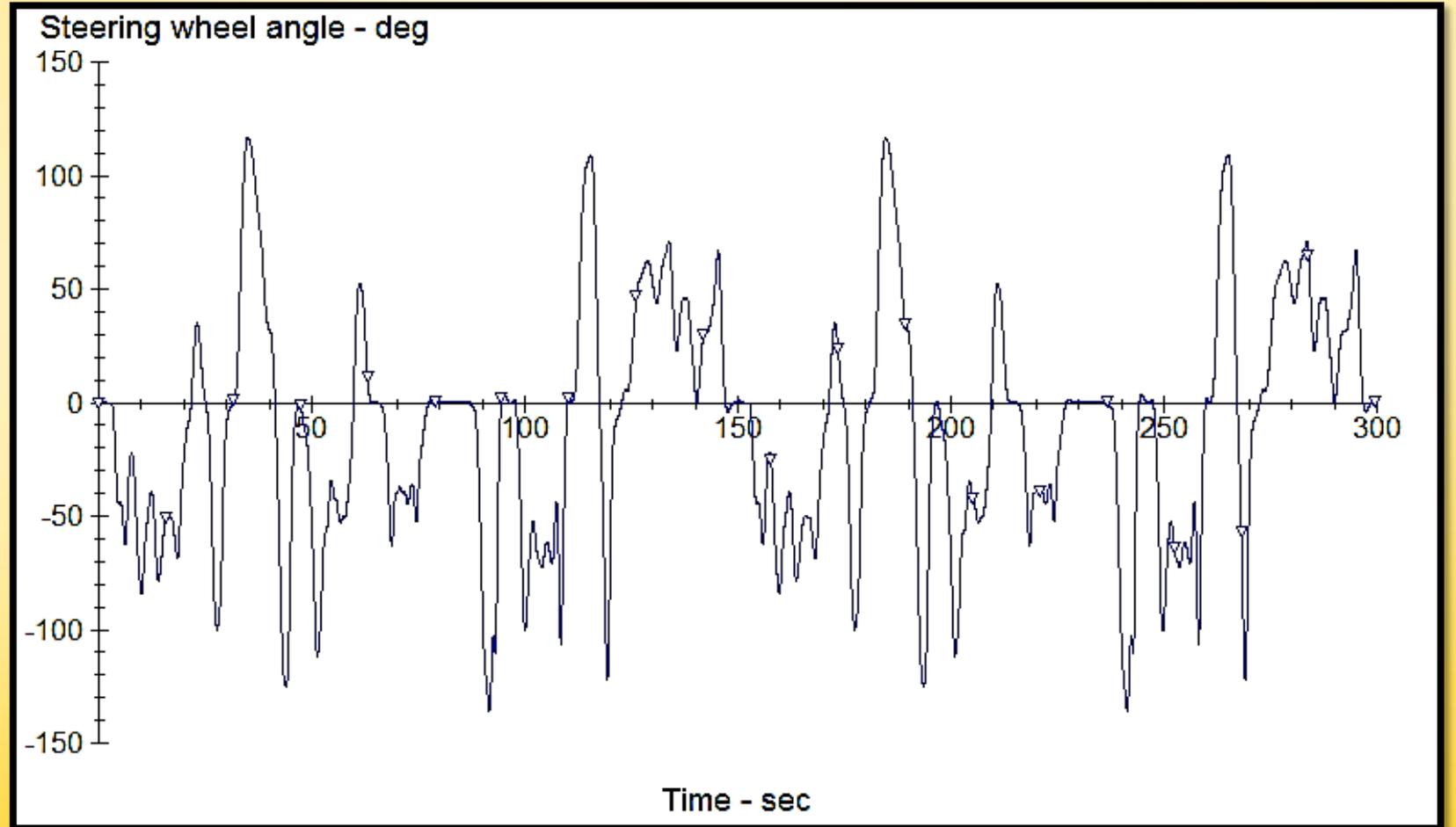
# CARSIM RESULTS [Without PI]

- Steering Angle



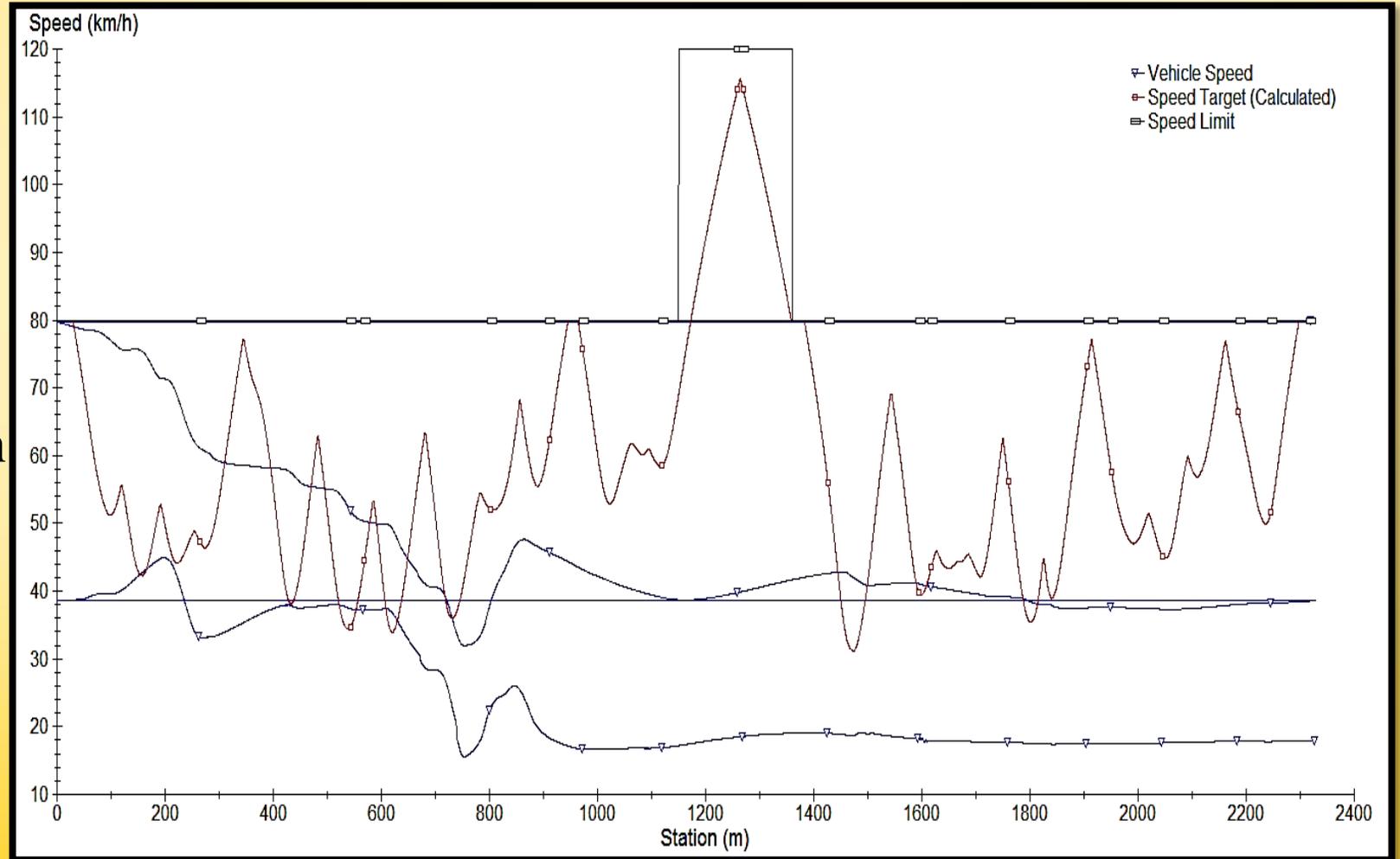
# CARSIM RESULTS [With PI]

- Steering Angle



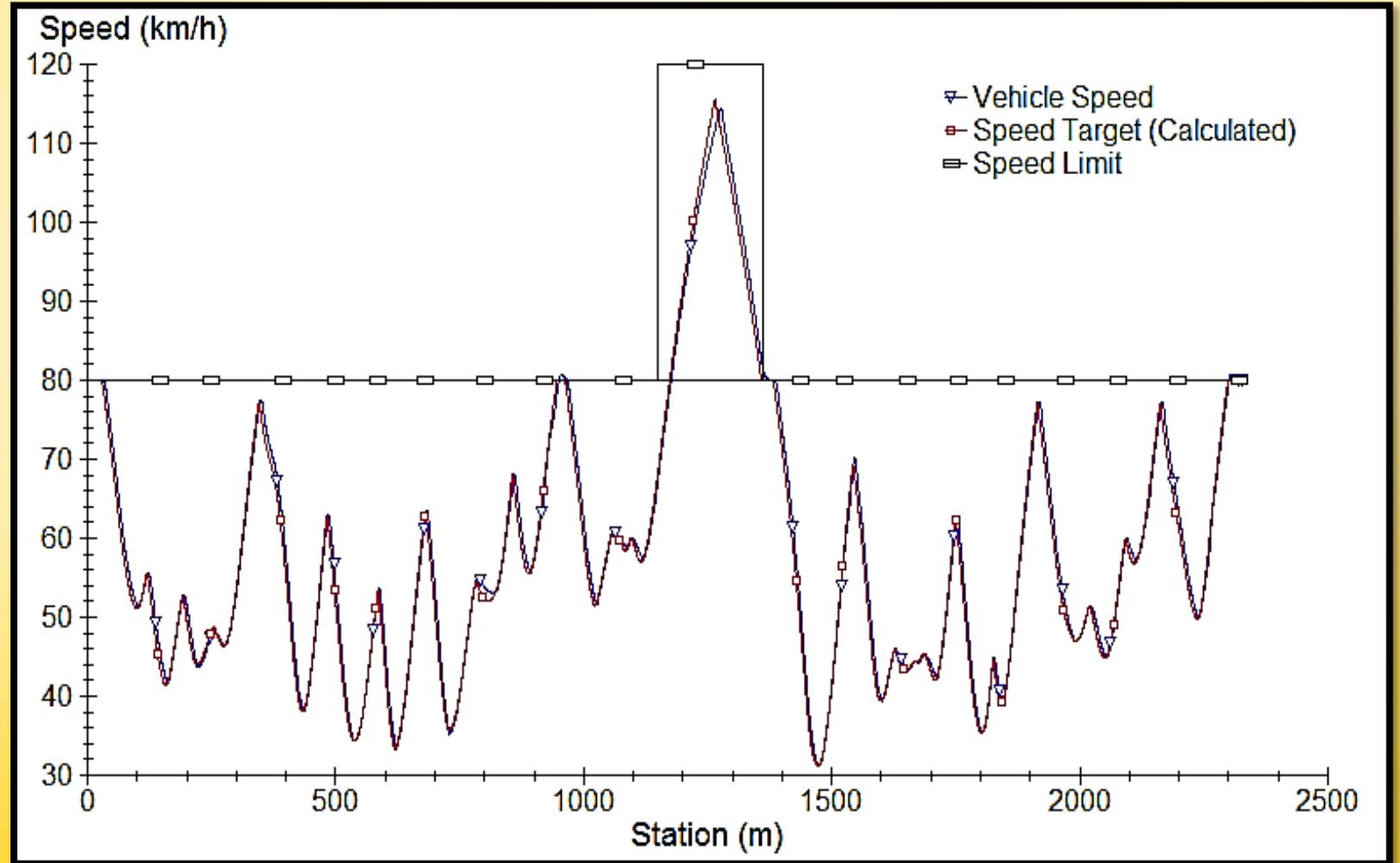
# CARSIM RESULTS [Without PI]

- Speed Variation



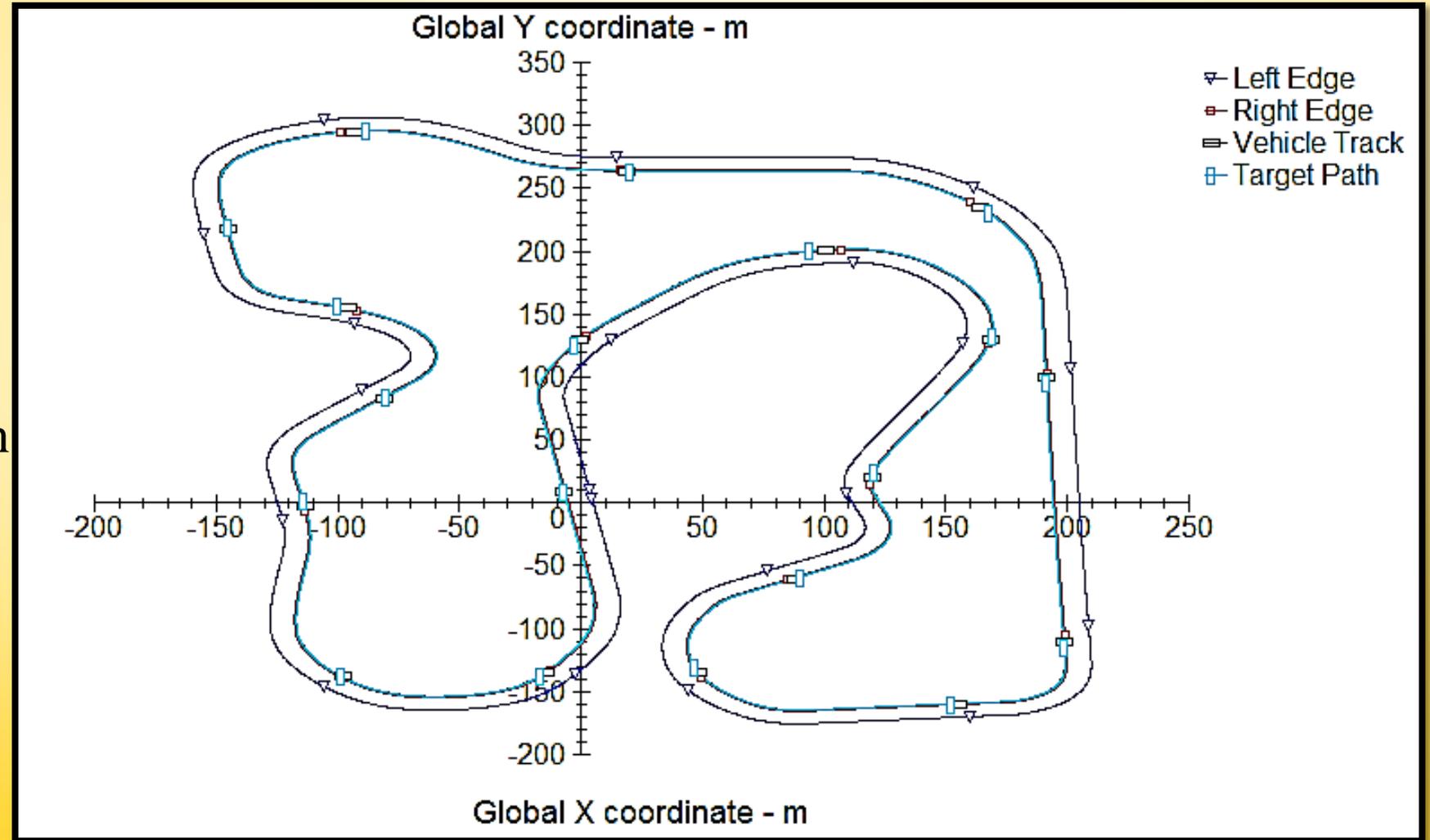
# CARSIM RESULTS [With PI]

- Speed Variation



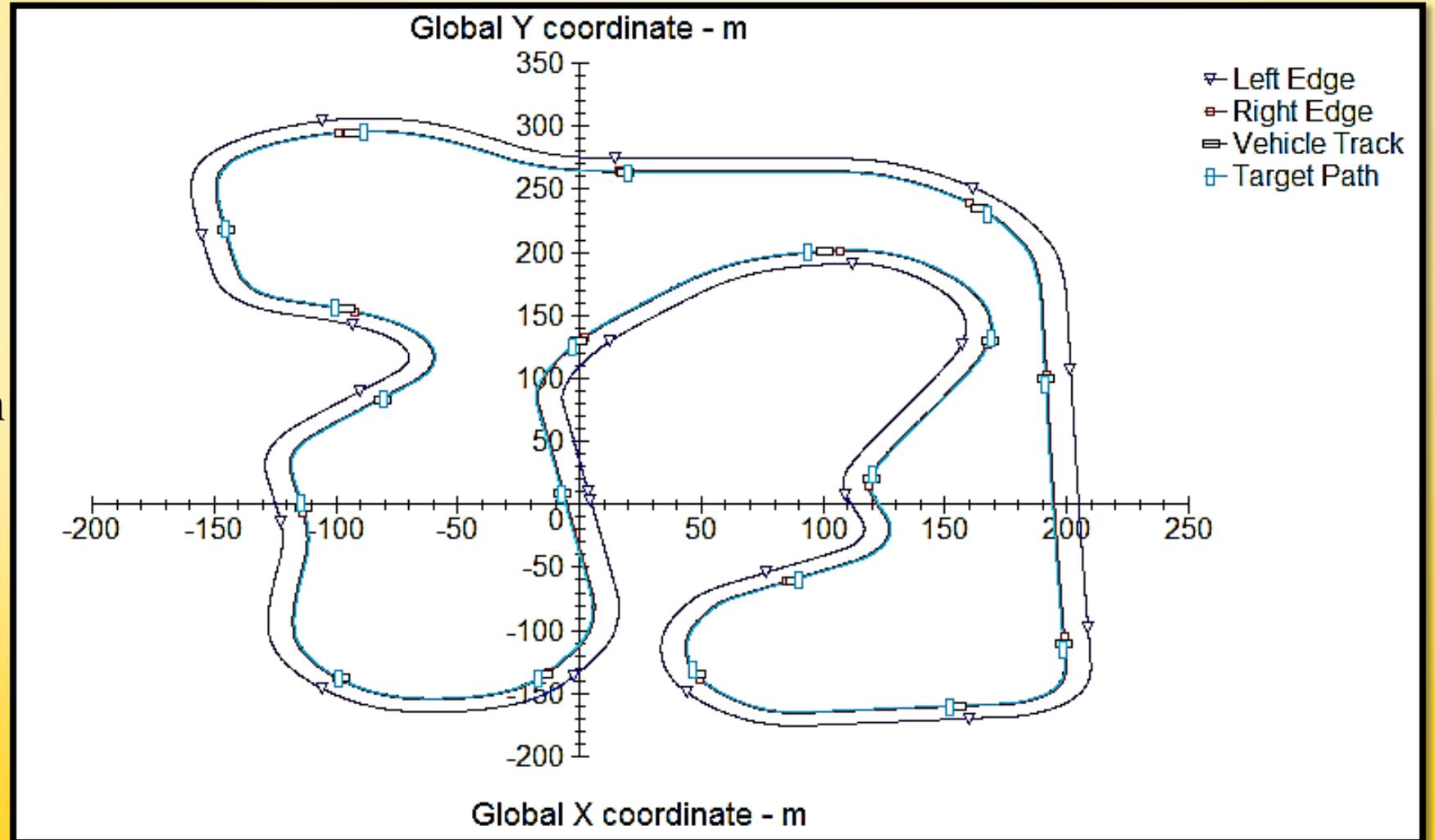
# CARSIM RESULTS [Without PI]

- Track Motion

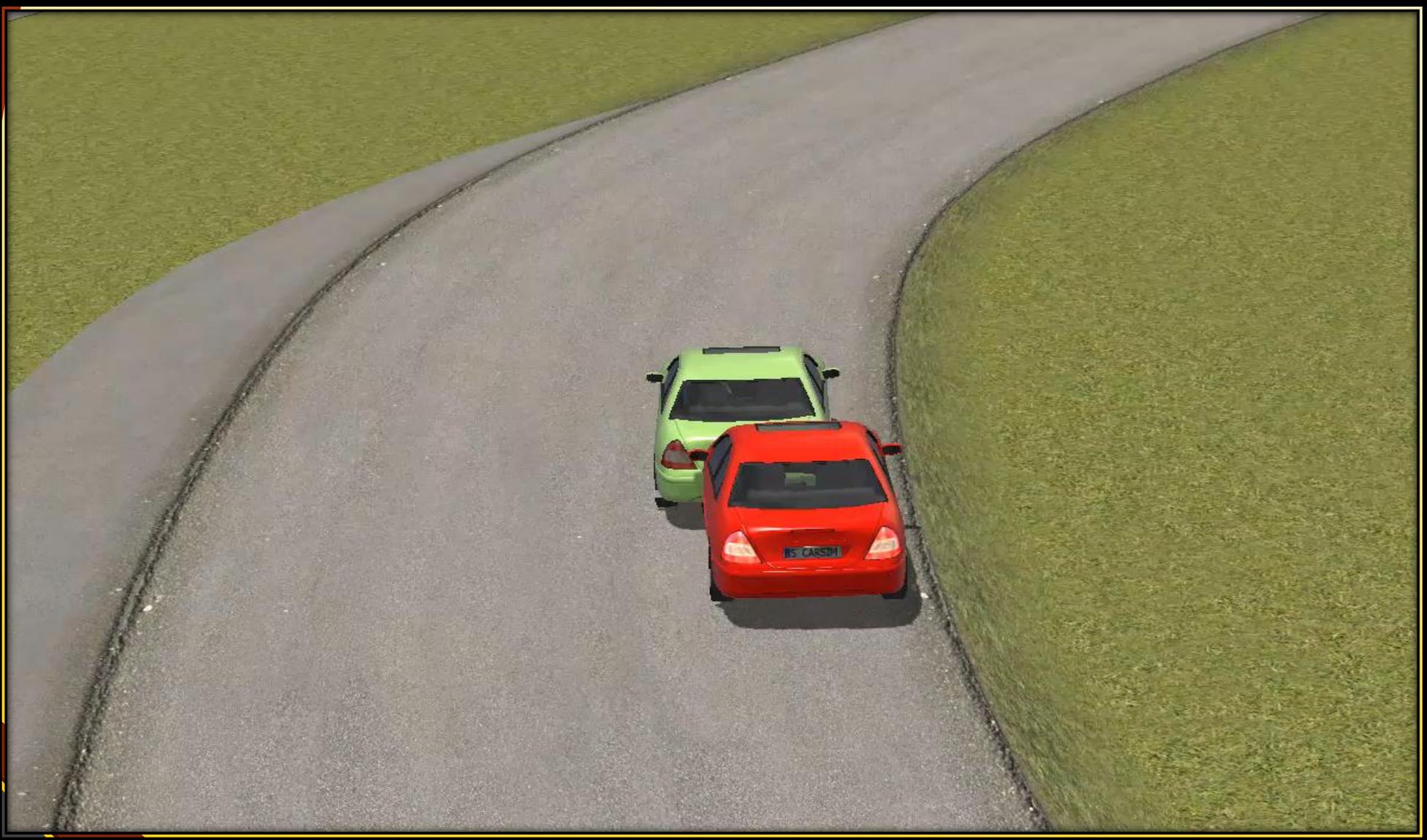


# CARSIM RESULTS [With PI]

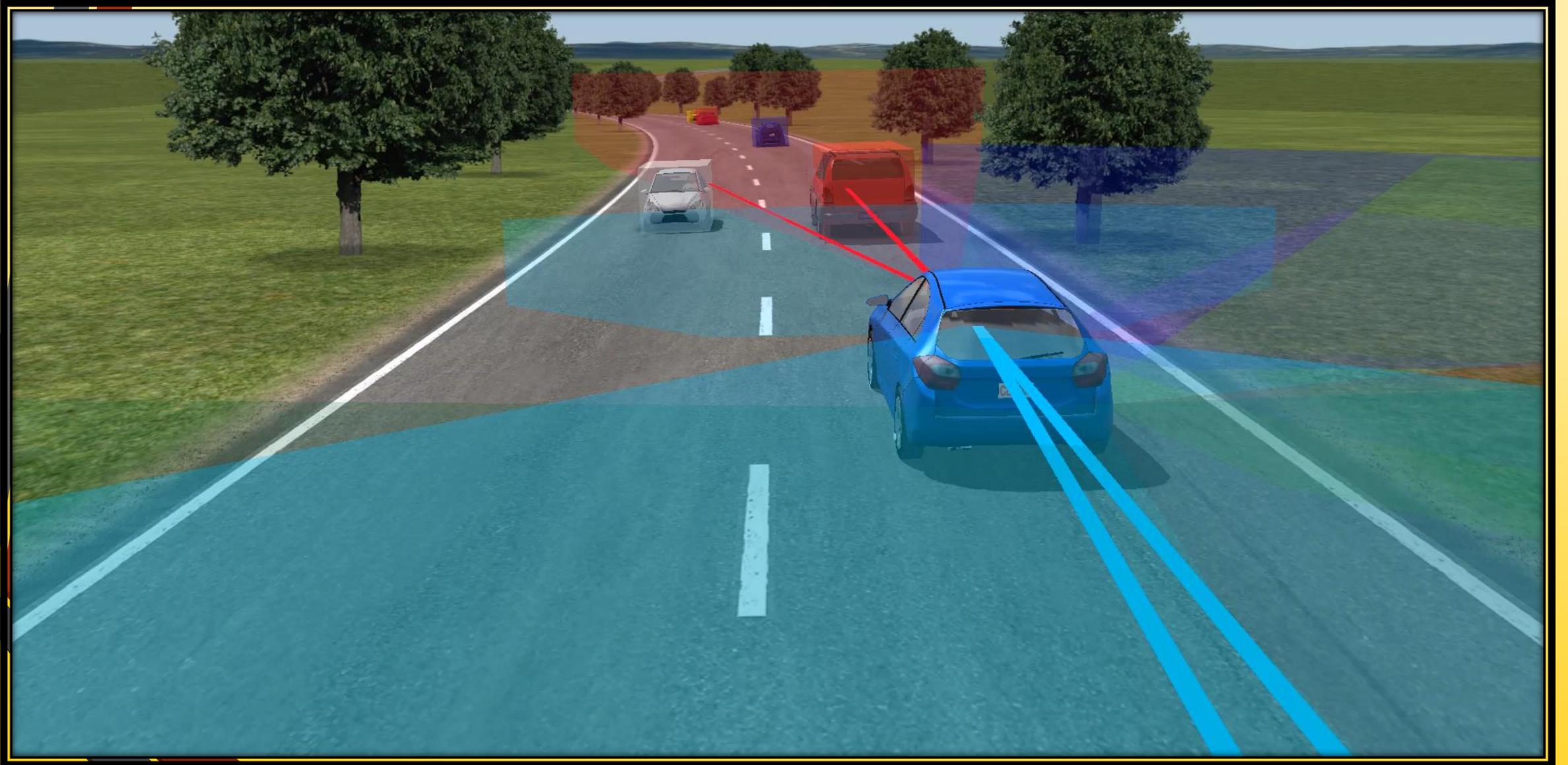
- Track Motion



# CARSIM Video Result [With PI& Without PI]



# Video on Automatic Steering Control

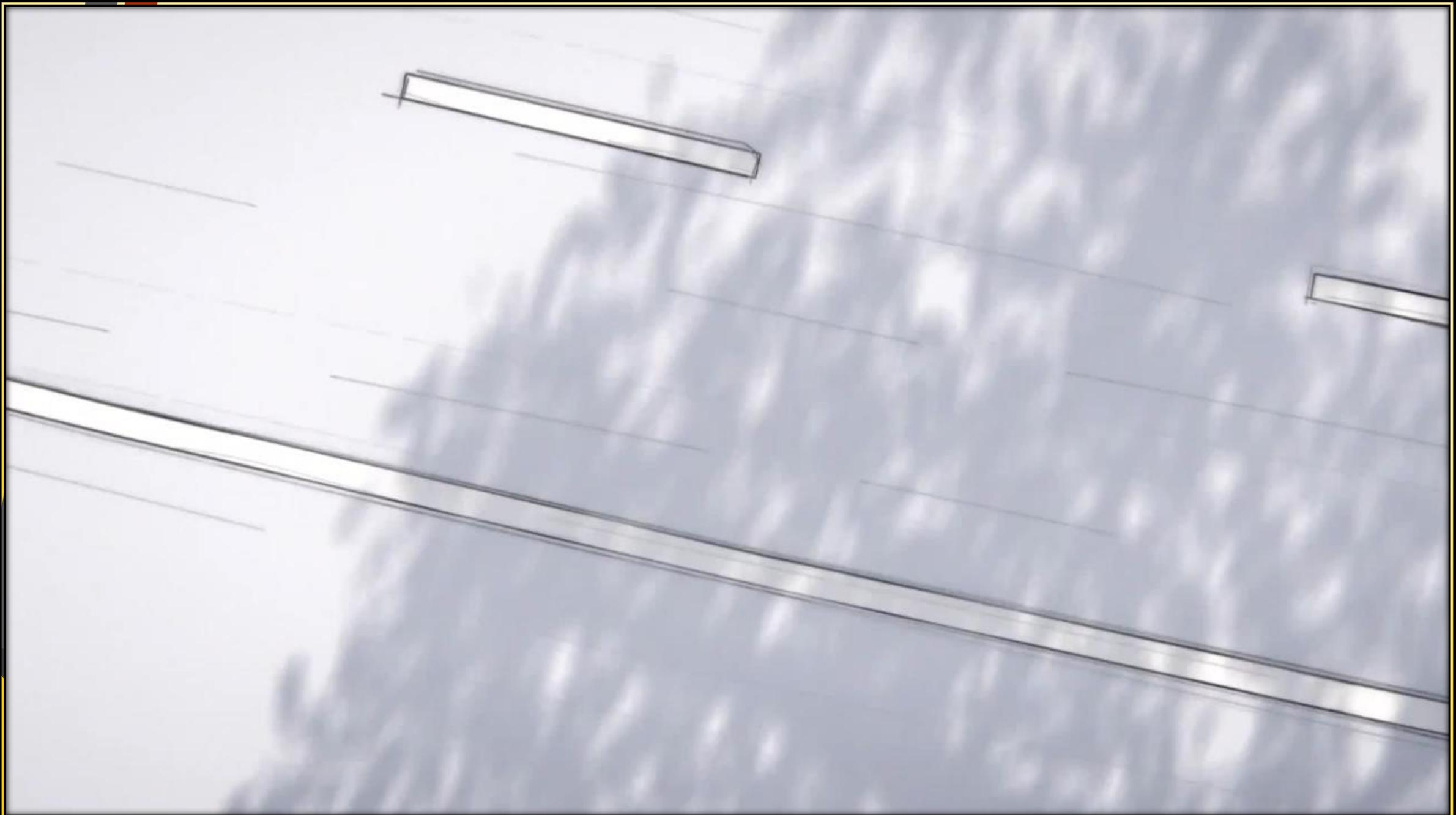


# CONCLUSIONS

Several simulations, carried out on a standard CarSim vehicle model, confirm the robustness of the proposed control system. The simulations show reduced path following errors and new stable manoeuvres in comparison with the CarSim model predictive steering controller in the case in which the driver does not perform any action on the steering wheel (autonomous control).

# REFERENCES

- [A] Riccardo Marino, Stefano Scalzi, Mariana Netto, Nested PID steering control for lane keeping in autonomous vehicles, Control Engineering Practice, Volume 19, Issue 12, December 2011, Pages 1459-1467.
- [B] Marino, Riccardo, Stefano Scalzi, and Mariana Netto. "Integrated driver and active steering control for vision-based lane keeping." European journal of control 18.5 (2012): 473-484.
- [C] Pacejka, H. B. (2004). Tire and vehicle dynamics. Elsevier, Butterworth Heinemann.
- [D] <https://www.carsim.com/downloads/videos.php>
- [E] [http://www.artc.org.tw/chinese/03\\_service/down.aspx?file\\_name=tw\\_knowledge\\_IA-97-0060.pdf&file\\_value=3](http://www.artc.org.tw/chinese/03_service/down.aspx?file_name=tw_knowledge_IA-97-0060.pdf&file_value=3)





Thank You ...