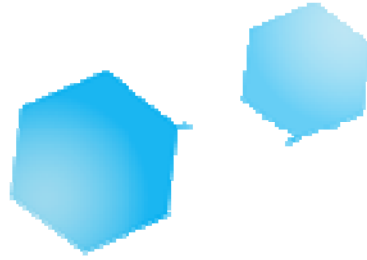


2016 MathWorks
中国汽车年会
6月23-24日 | 上海



Modeling and Simulation Technologies on Vehicle Intelligence

汽车智能化的模拟仿真技术

ASCL of Jilin University
吉林大学汽车仿真与控制国家重点实验室

Confidential

Background & Motivation

Challenges
on Vehicle
Intelligence

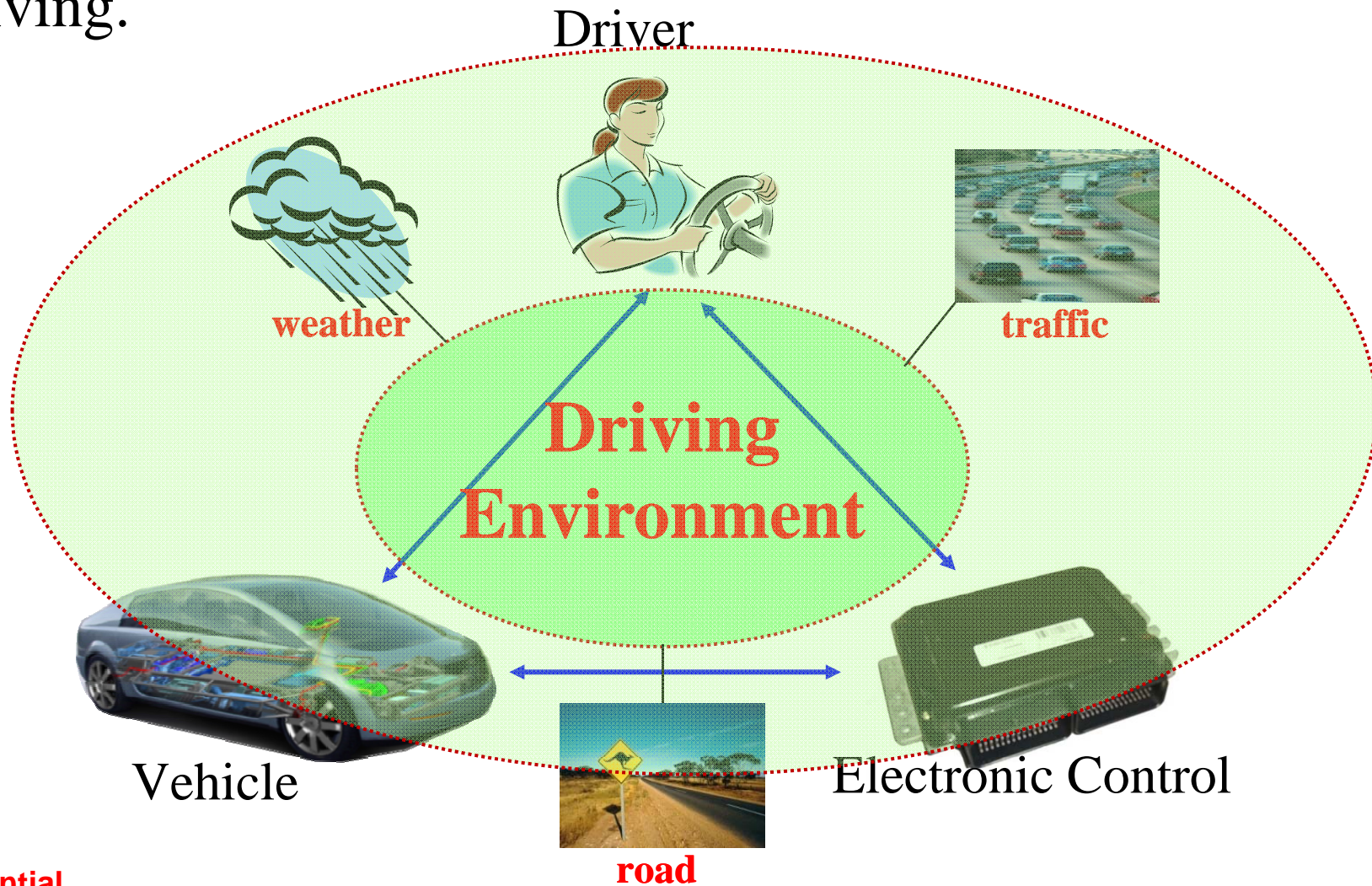
**Technological
Advancement**

**Modeling
Simulation**



Background & Motivation

Driving environment now plays an important or even critical role on the safety and performance of intelligent driving.



Motivation: Challenges on Testing & Validation



Setting up field testing for many features can be of **long-cycle and high-cost**, and even impossible.



Avoidance

Some **safety** critical features can be difficult, if not impossible, to test in the field, especially during the early development stages!



V2V Coordination

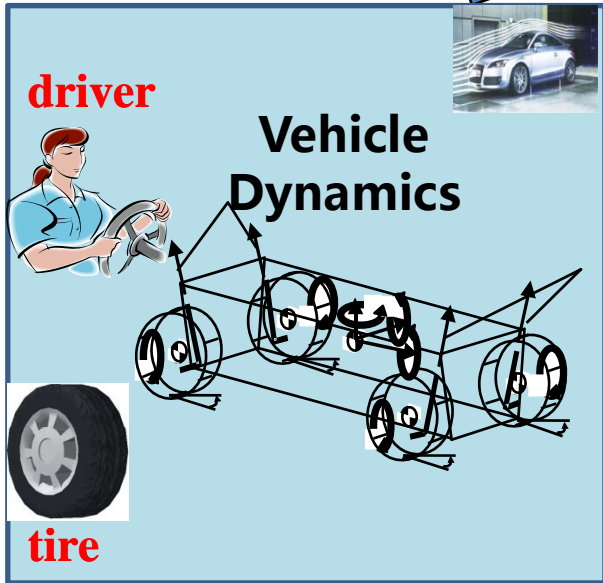
Intelligent Vehicle



Pedestrian Collision

Technological Advancement

Electrification



Intelligence

Modeling on **Battery** and **Electric Motors**, on-board **communication**



road



weather



traffic



camera



wireless



radar

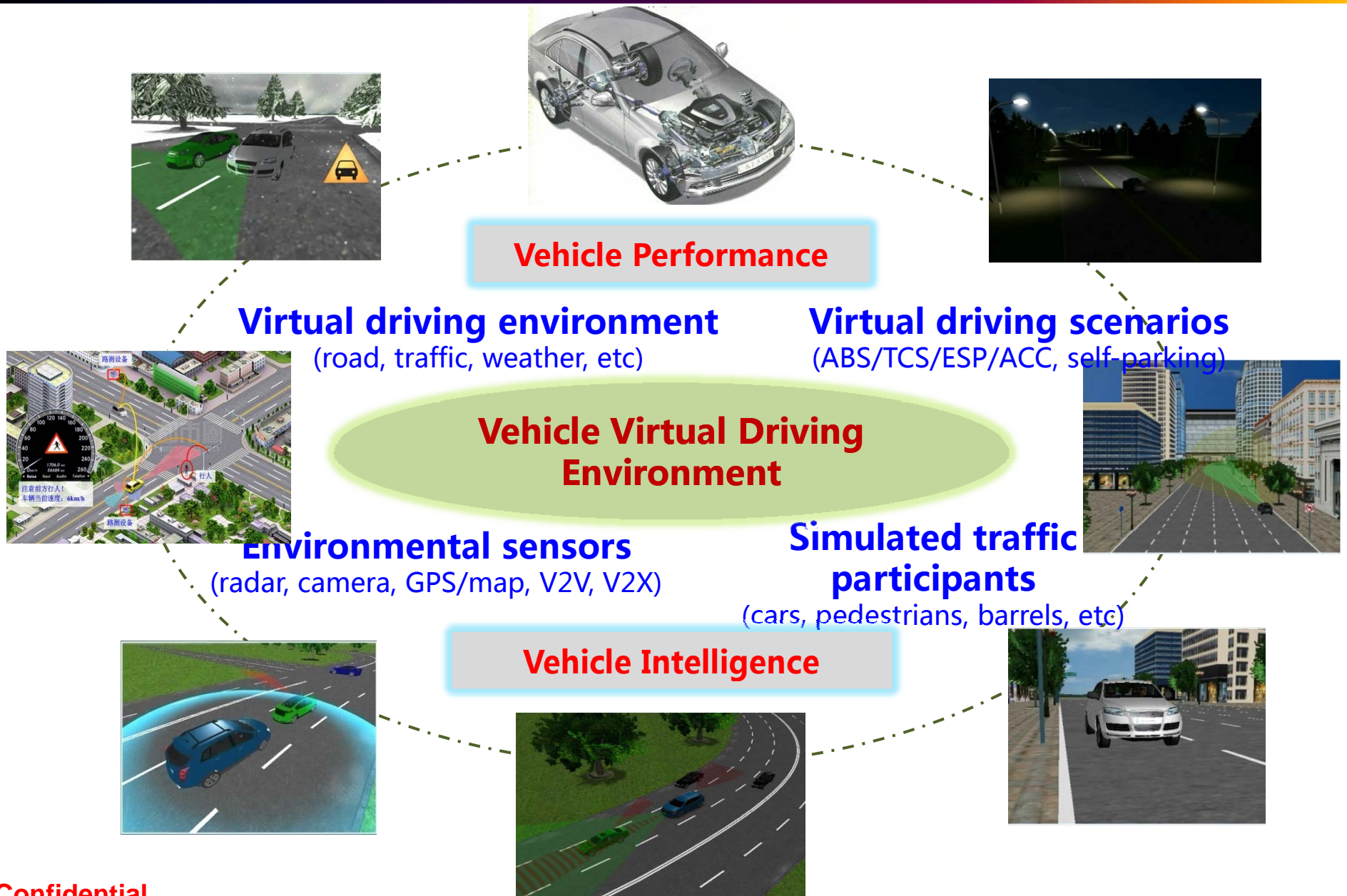
Modeling on **Driving Environment** and **Environmental Sensing**

Modeling & Simulation Plays Key Roles

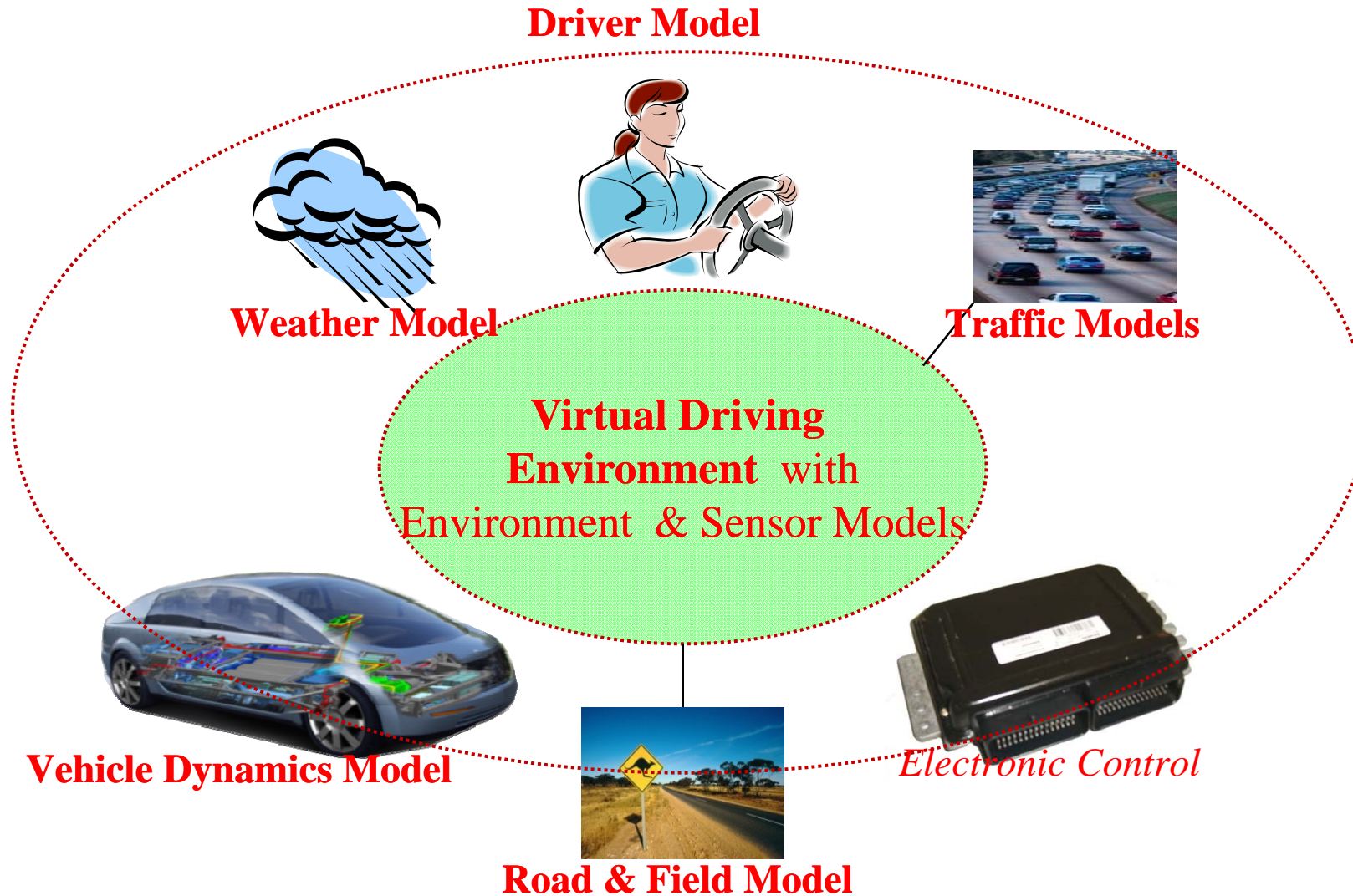
Advanced Development Platform



Tools & Method on Vehicle Intelligence



Tools & Method on Vehicle Intelligence

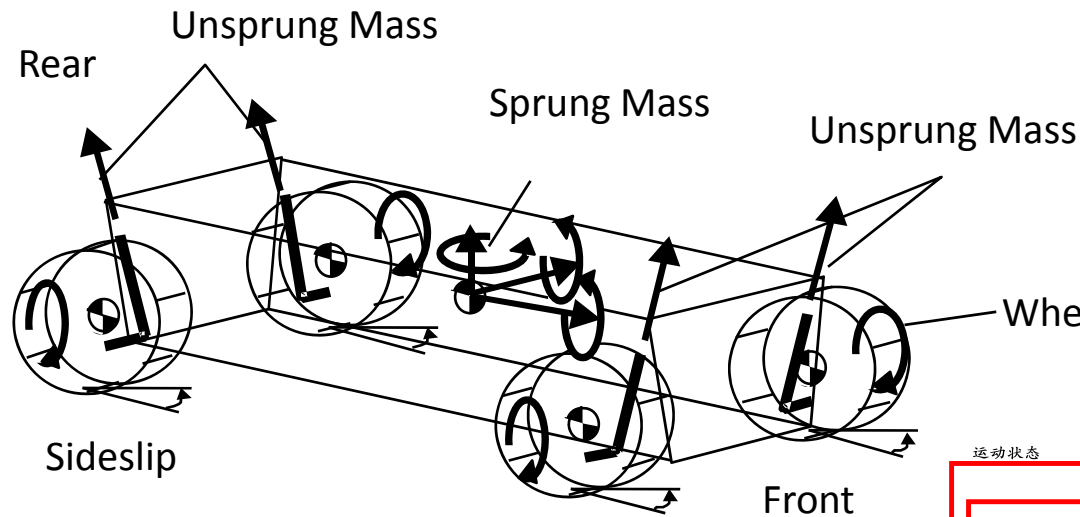




**Vehicle Dynamics Modeling:
*with High-Order, Large-Nonlinearity
and High Efficiency***

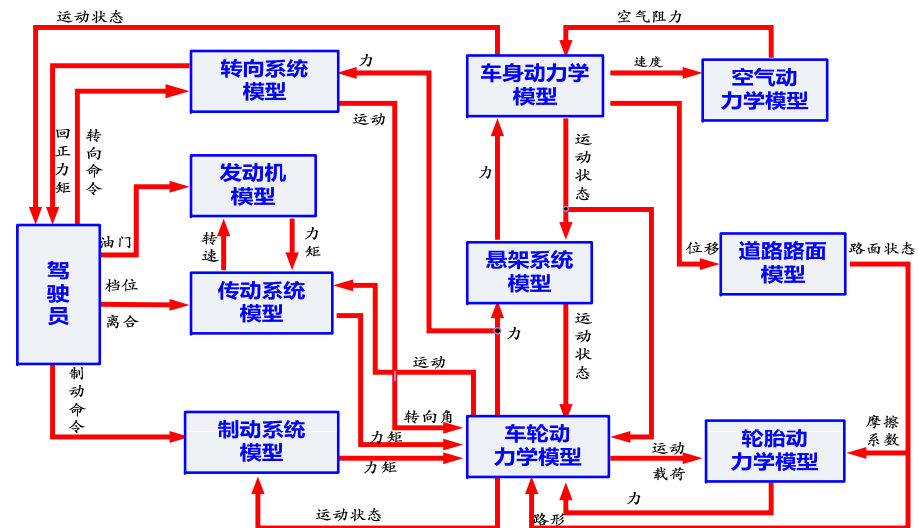
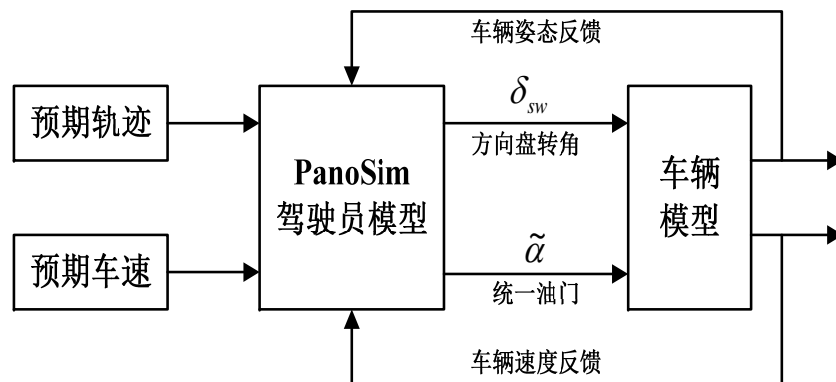


Vehicle Dynamics Model

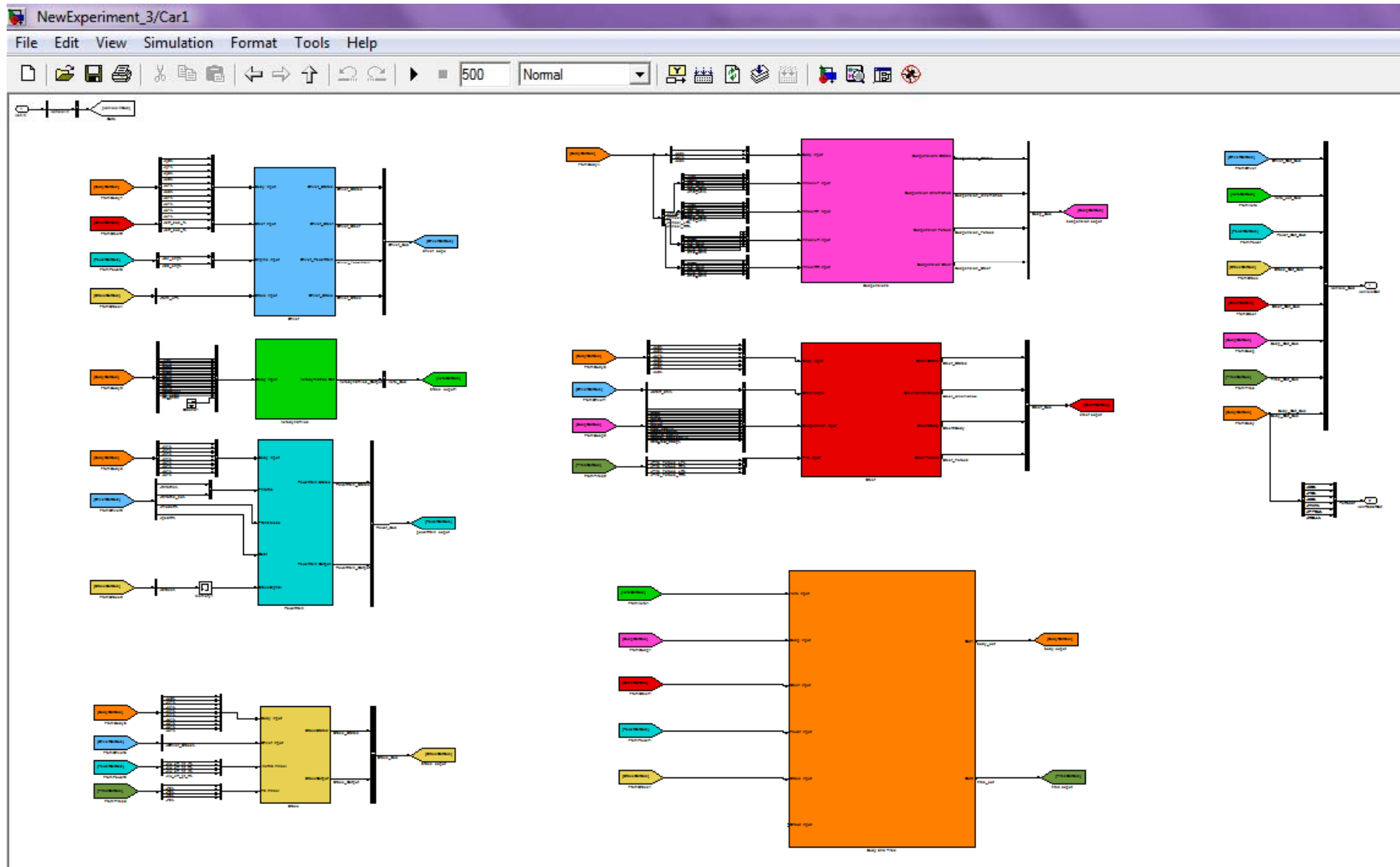


System-based modeling approach with:

- **high-order and large-nonlinearity**
- **high efficiency for real-time**
- **high fidelity**



Vehicle Dynamics Model (*under Simulink*)



Ready

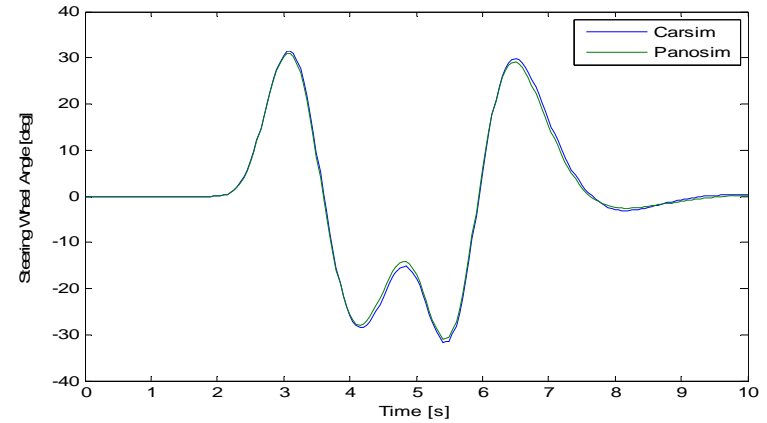
Confidential

33%

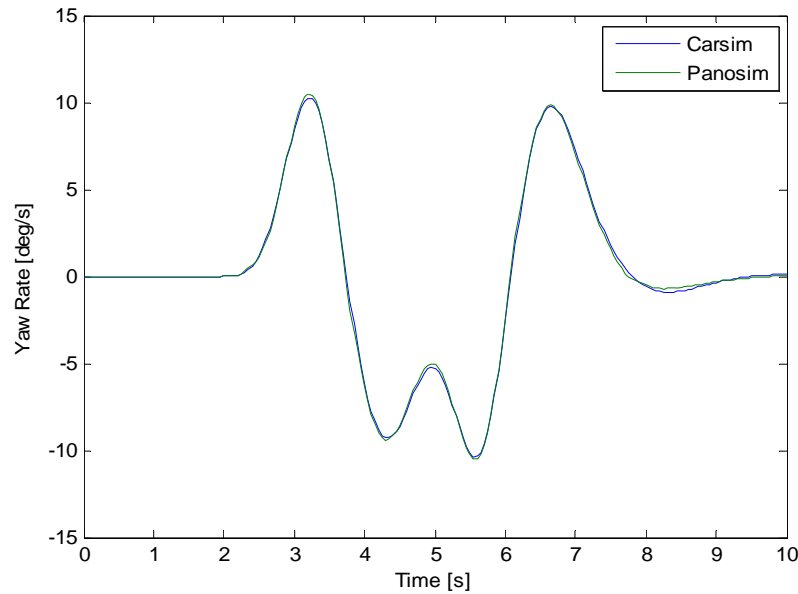
Vehicle Dynamics Model: *verification*

Double-Lane Change

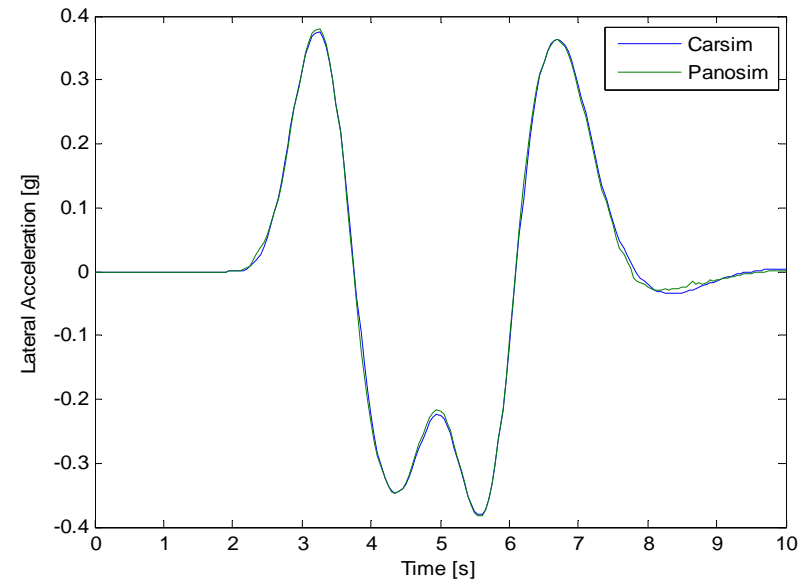
Simulated speed at 80kp



Steering Angle



Yaw Rate

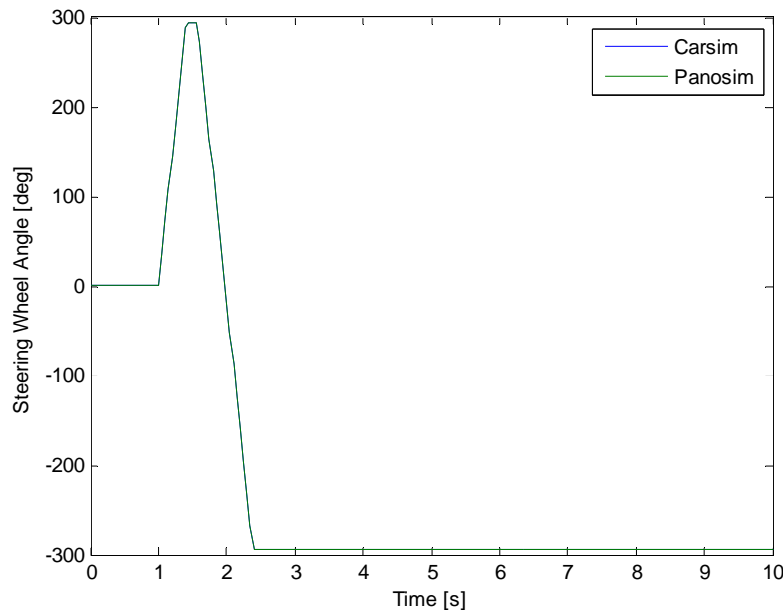


Lateral G

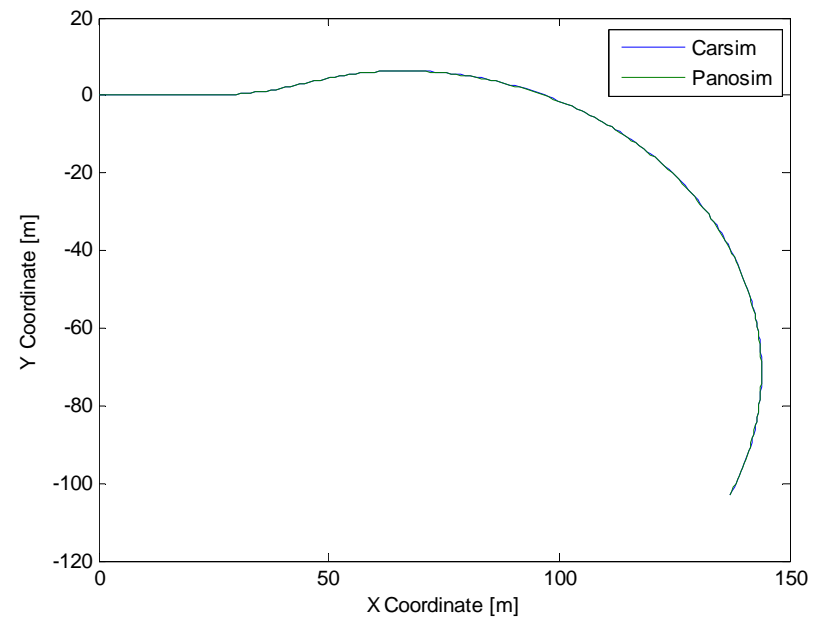
Vehicle Dynamics Model: *verification*

Fishhook Simulation

Simulated speed at 80kph, with steering and path shown below



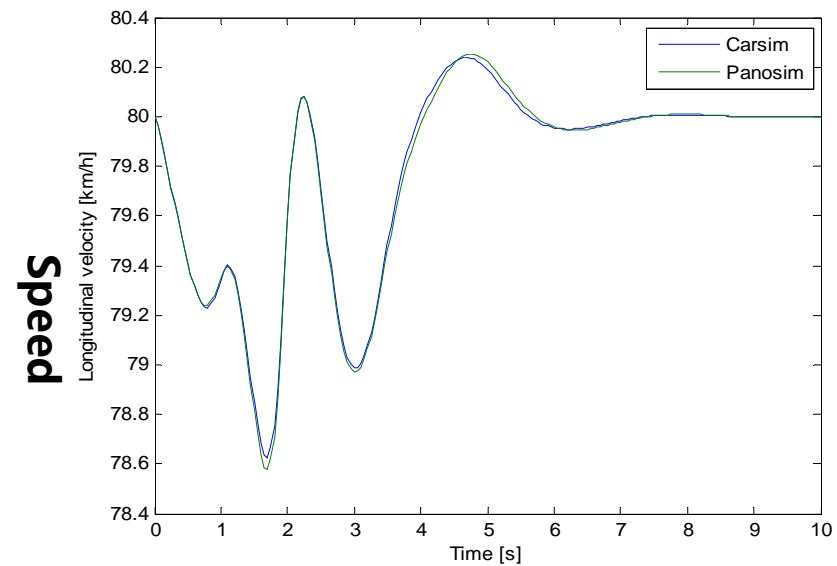
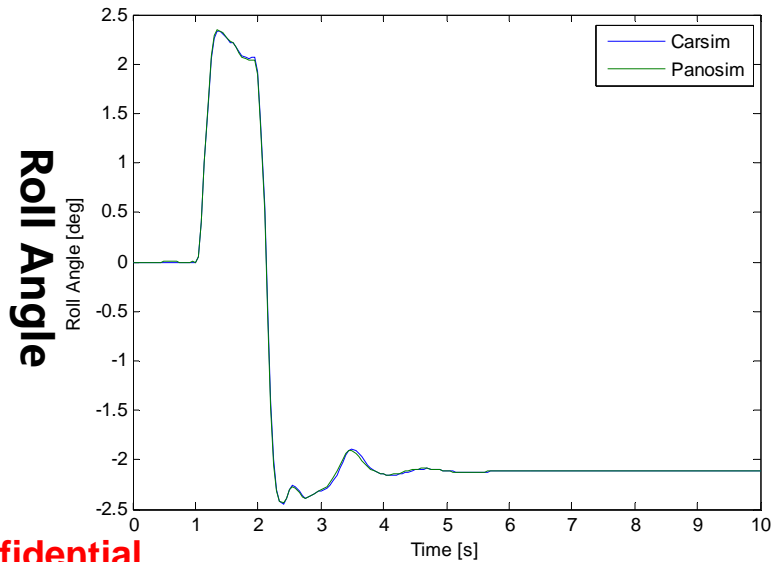
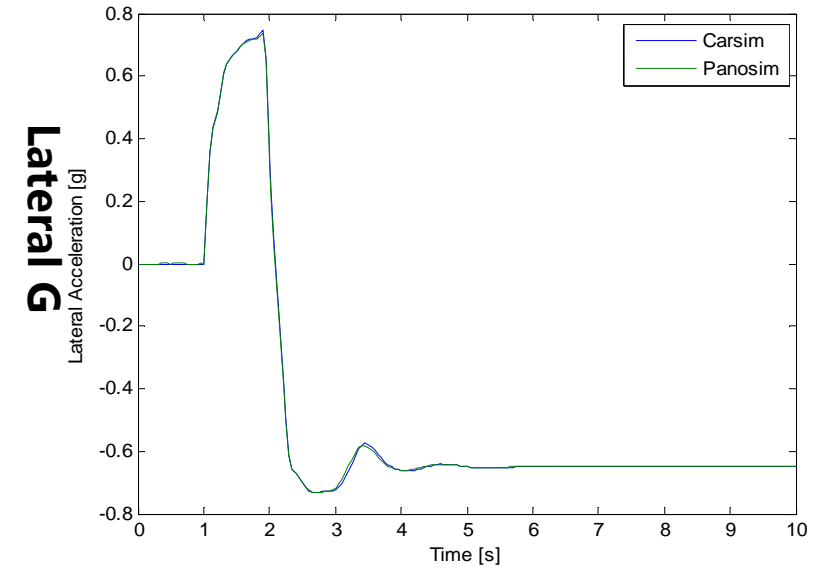
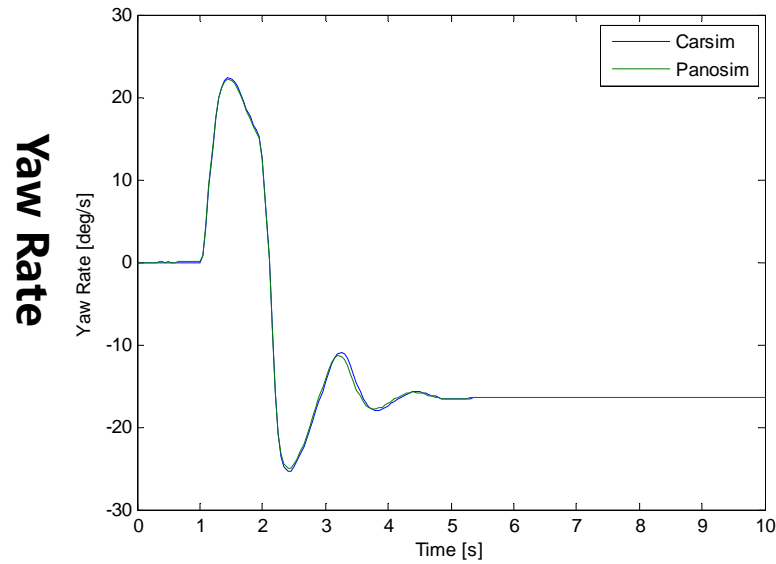
Steering Angle



Path

Vehicle Dynamics Model: *verification*

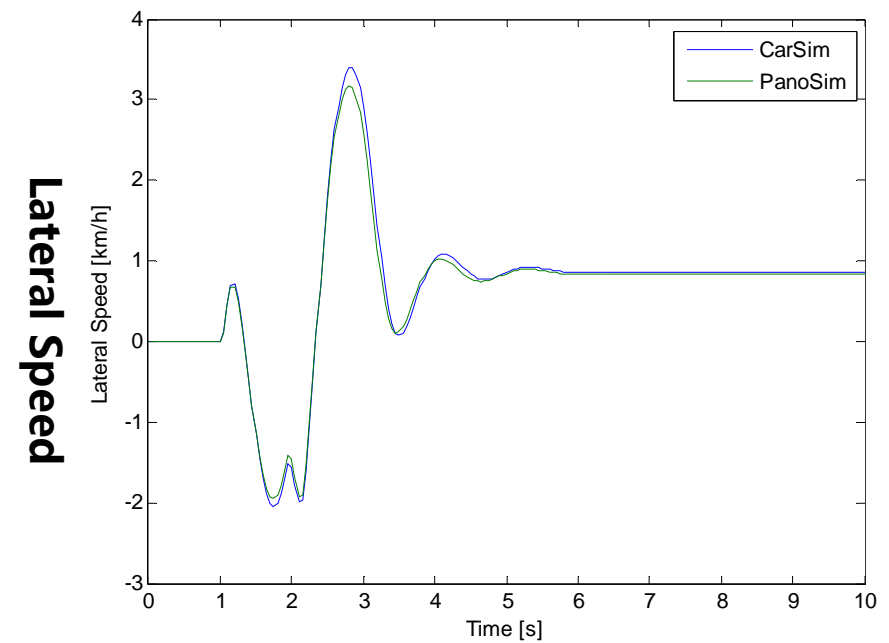
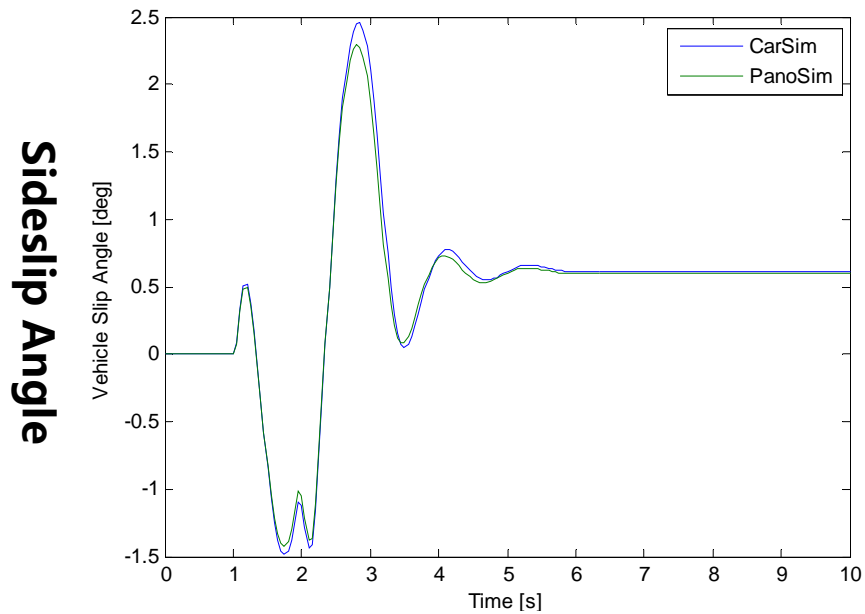
Fishhook Simulation



Confidential

Vehicle Dynamics Model: *verification*

Fishhook Simulation



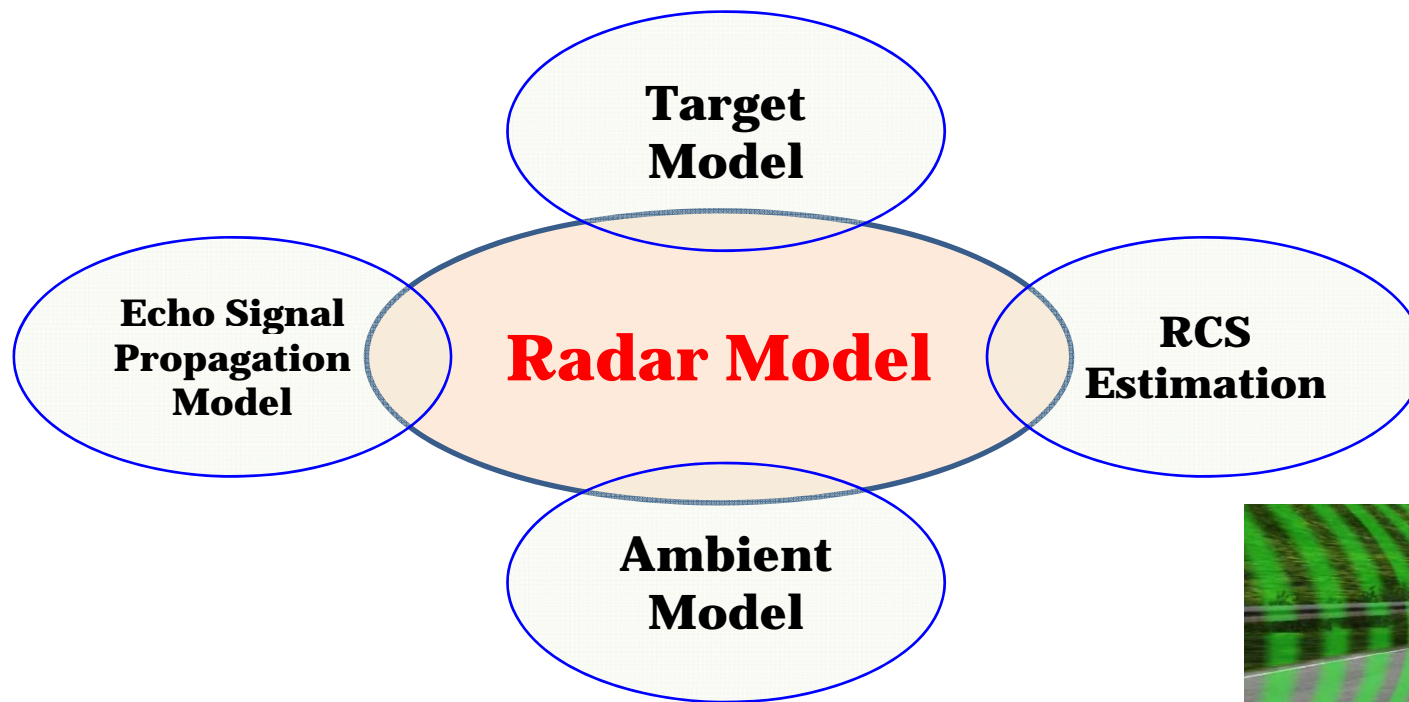


Radar Modeling: *with Combined Geometric and Physical Approaches*

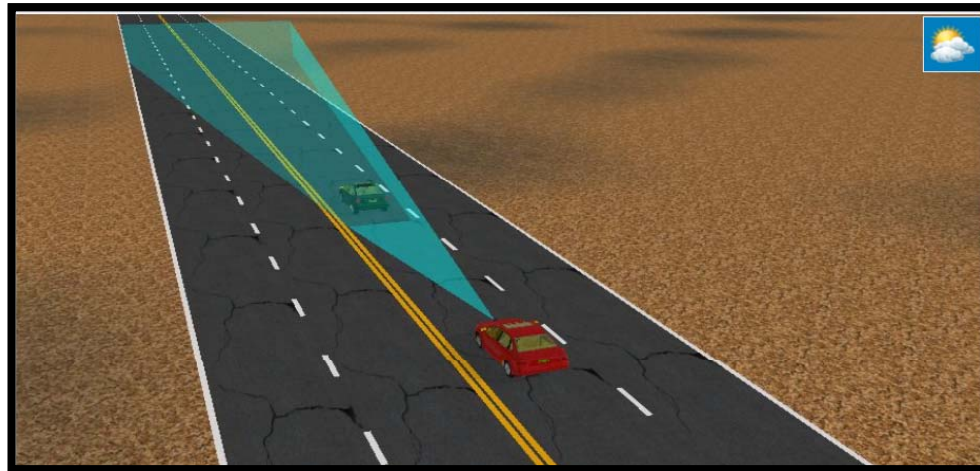


Radar Modeling

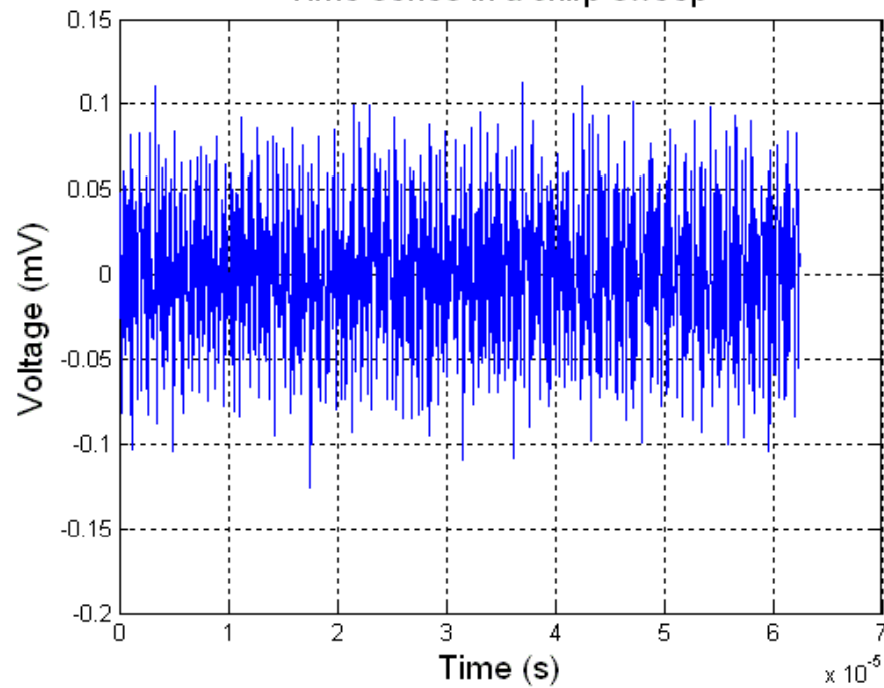
- Take into consideration of major physical factors, such as electromagnetic wave propagation (echo signals), target and its RCS estimation, and ambient noise
- Combined geometric and physical modeling approaches to achieve **high fidelity** while maintaining real-time computational **efficiency**



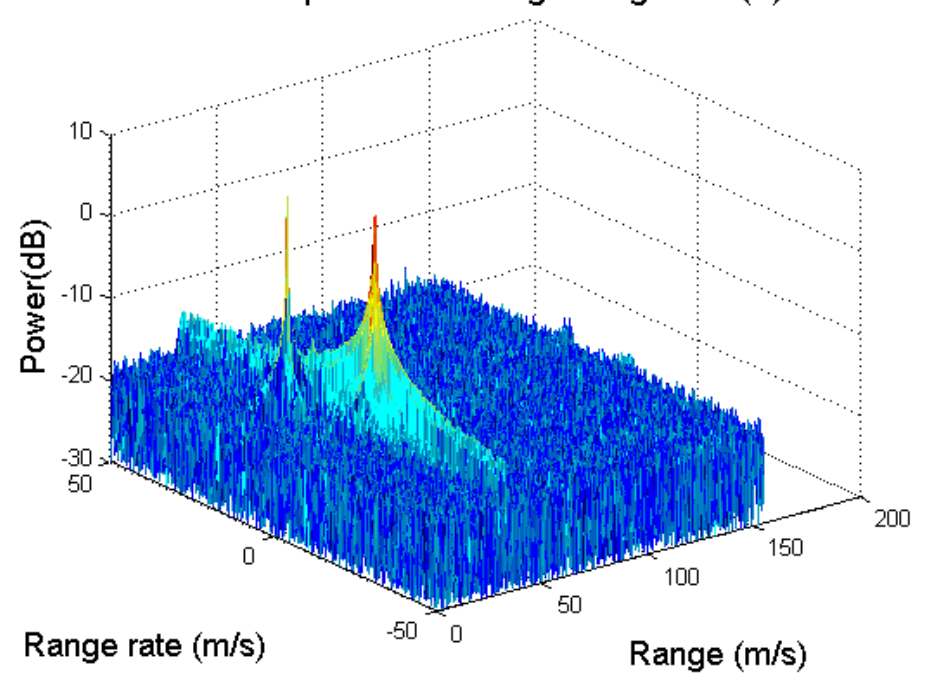
Radar Modeling



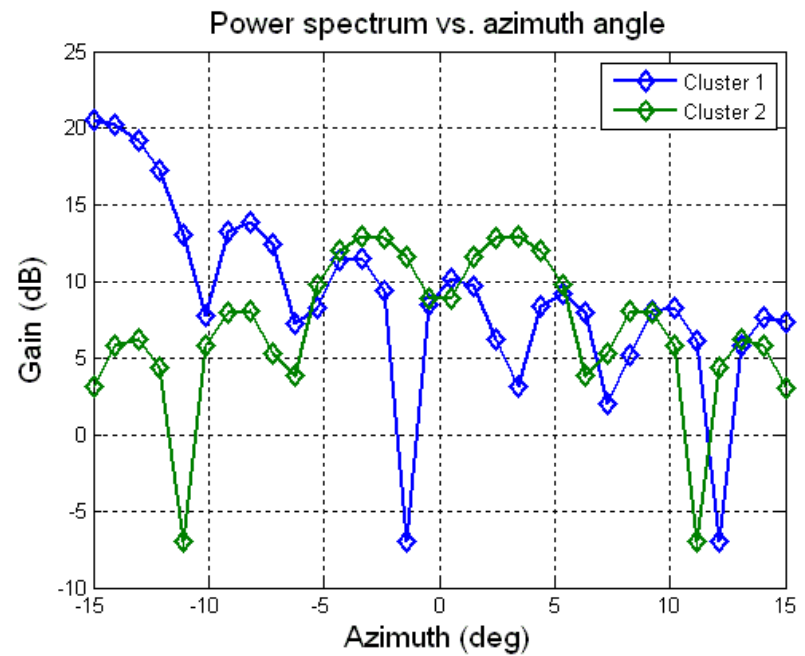
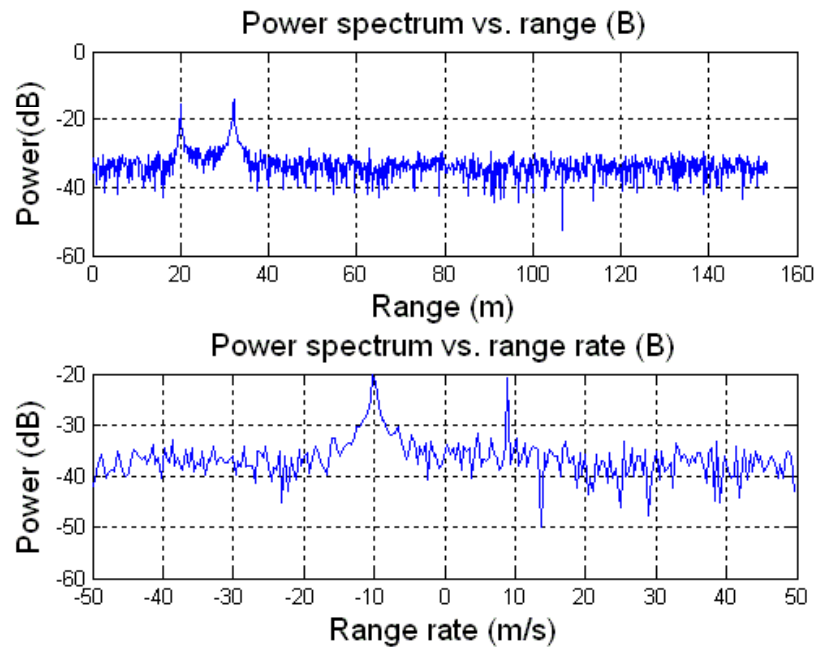
Time series in a chirp sweep



Power spectrum vs. range+range rate (B)



Radar Modeling

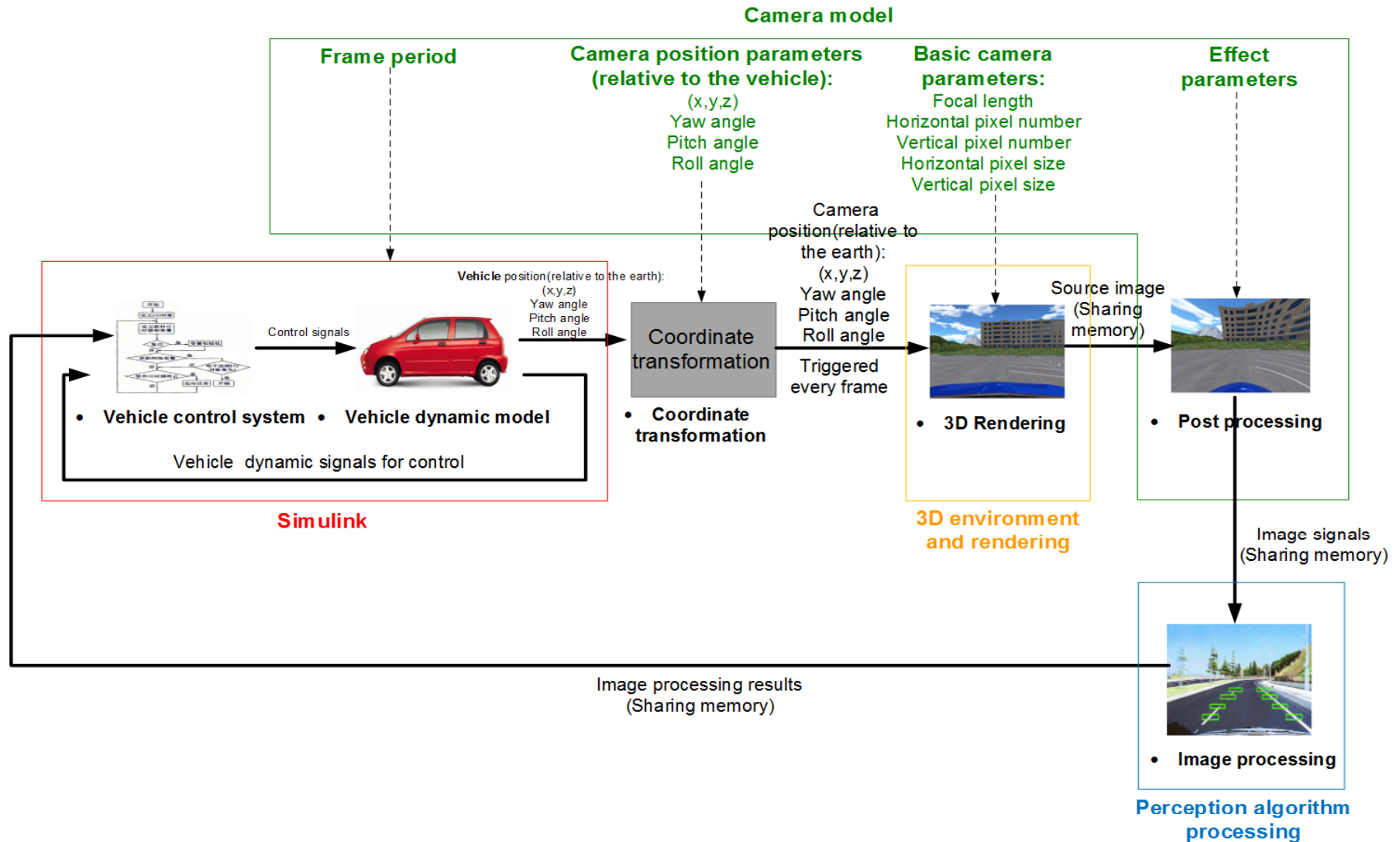




Camera Modeling



PanoSim : Camera Modeling



Basic Camera Modeling

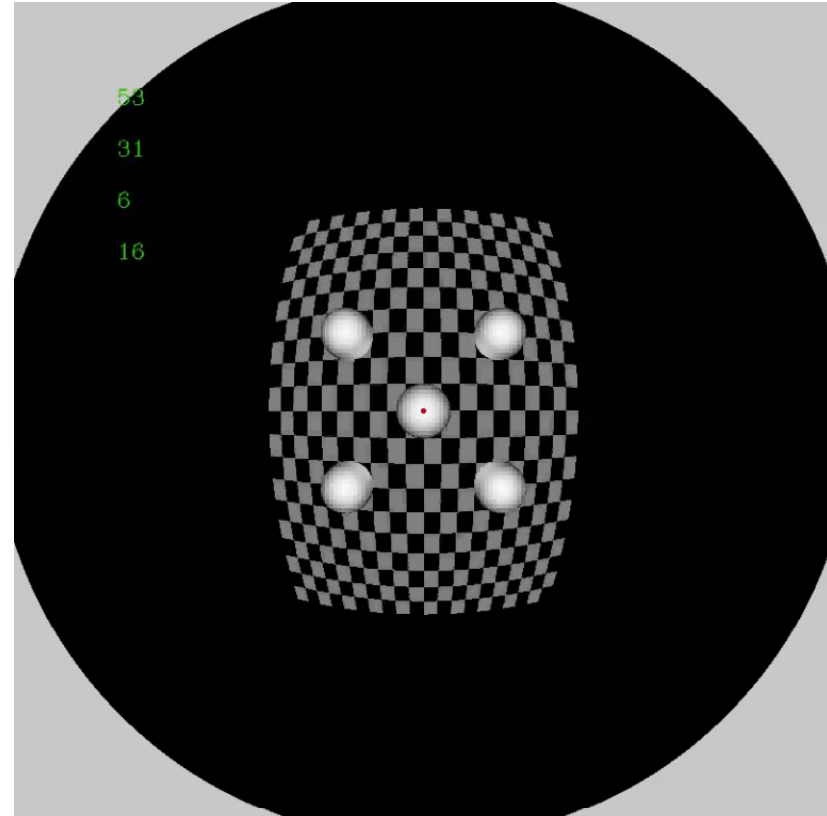
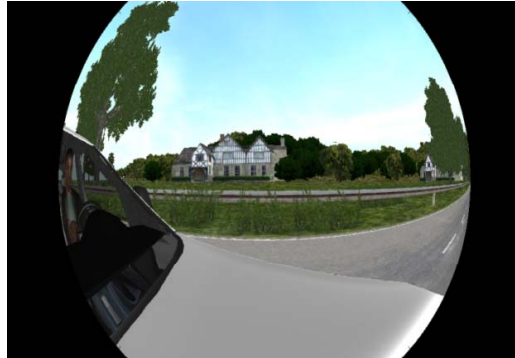
PanoSim : Camera Modeling

$$r = f \cdot \theta$$

$$r = 2f \tan(\theta/2)$$

$$r = f \sin(\theta)$$

$$r = 2f \sin(\theta/2)$$



**Fisheye & Wide Angle
Camera Modeling and Validation**

Fisheye Camera Modeling

PanoSim : Camera Mounting & Calibration



Take Pictures

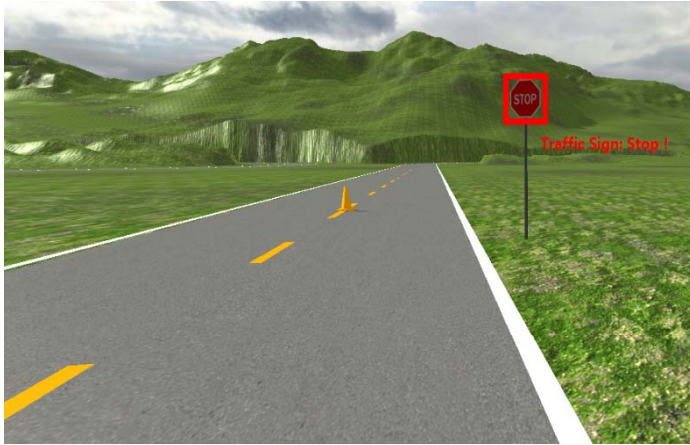


Record Video



Video Playback

PanoSim : Camera Model Applications



Traffic Sign Recognition



Distance/Speed Measurement



Object Detection



Lane Marker Detection

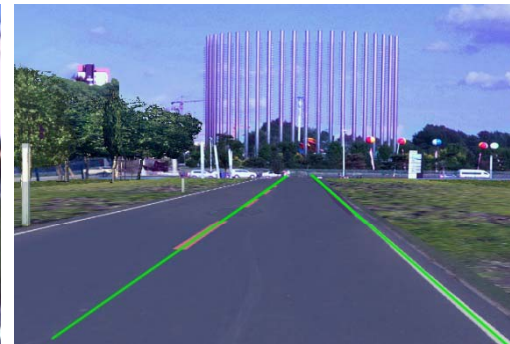
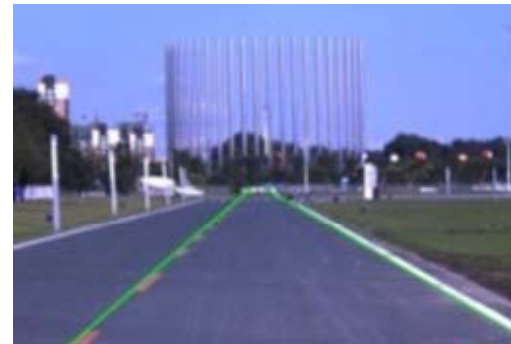
Highly Correlated with the Results from Real Image

Real Image

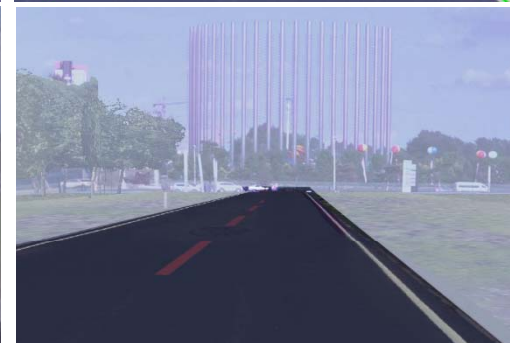
Simulated Image



**Lane detection using
Hough transform**



**Road detection using
watershed algorithm**





An Integrated Software Tool



***PanoSim* : Six Modules with Many Functions**

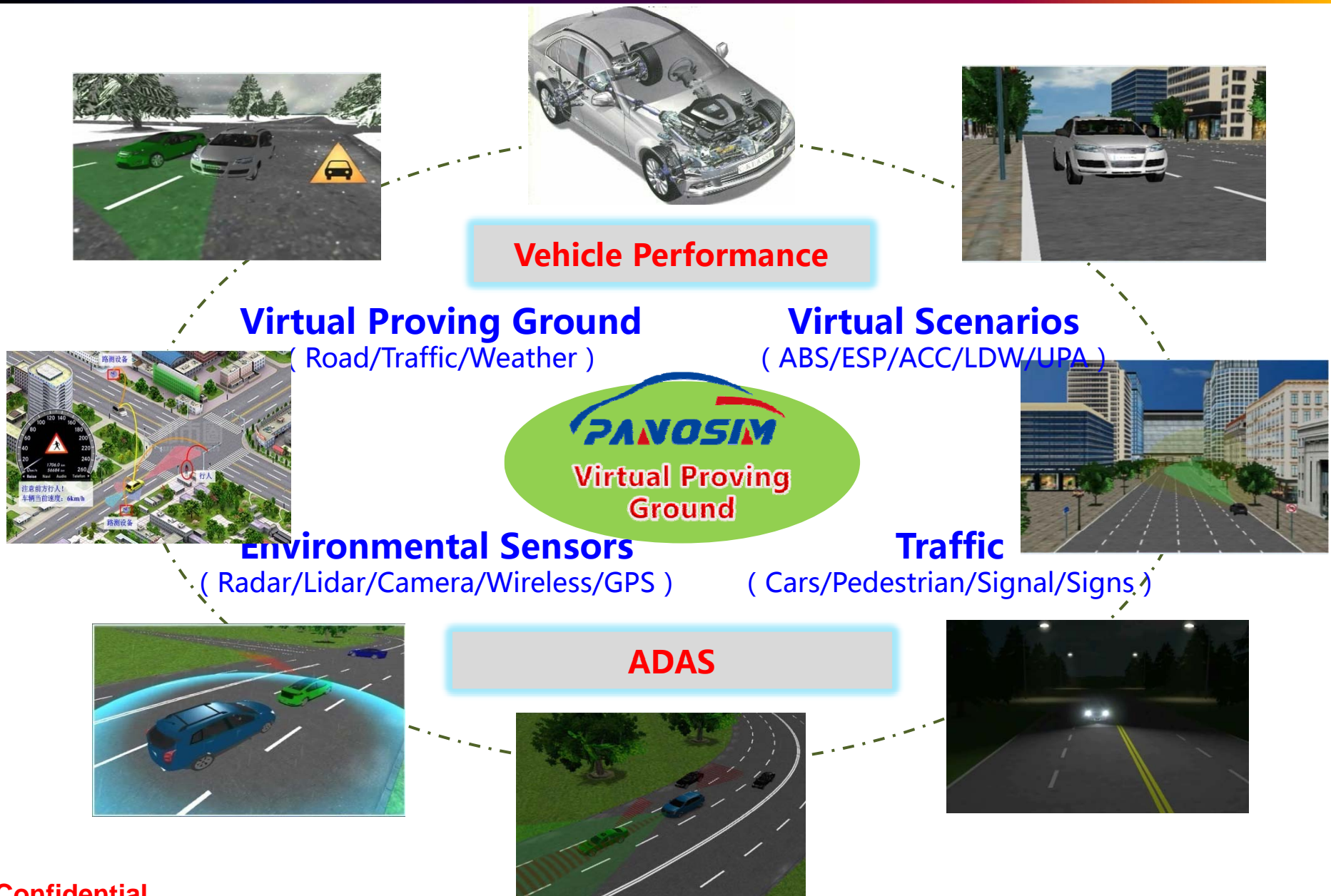
- **Main GUIs**
- **FieldBuilder**
- **PanoPlot/PanoAnim**
- **VehicleBuilder**
- **PanoCam**
- **MDL Generator**



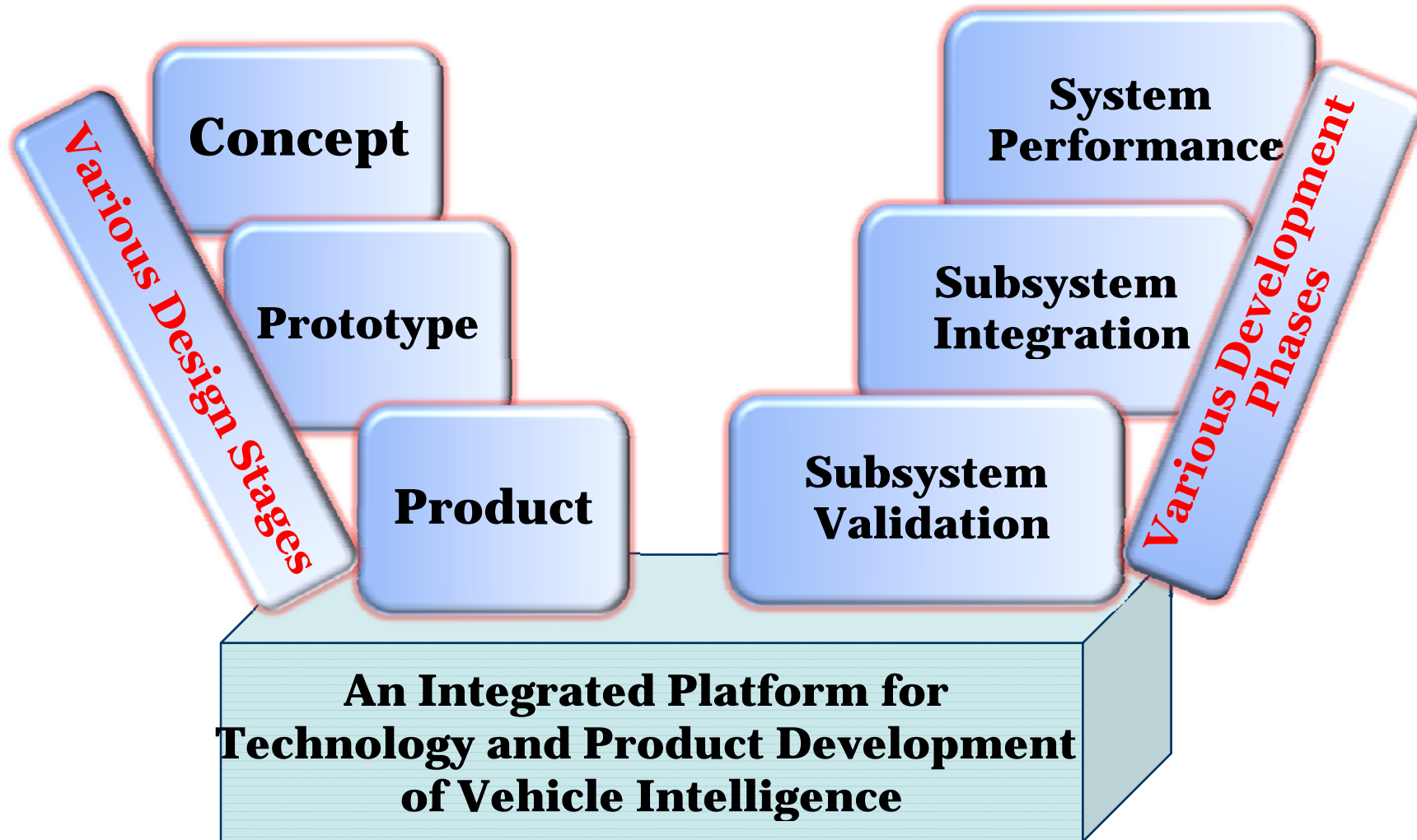
- ✓ **Vehicle Dynamics**
- ✓ **Wireless Comm**
- ✓ **Radar/Lidar/Camera**
- ✓ **Virtual Proving Ground**
- ✓ **Traffic**
- ✓ **Weather/Light**

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PanoSim : Applications



PanoSim : Applications



PanoSim : Applications

Vehicle Performance

- Brake/Steer/Suspension
- Handling & Stability

Powertrain System

- Engine/Transmission
- Driveline & Driveability

Electronic Controls

- ABS/TCS
- ESP

ADAS

- ACC/LDW/LKA/FCW
- Autonomous Parking

Environment Sensing

- Vision-based sensing & IP
- Radar Detection
- Sensor Fusion

Intelligent Driving

- Planning & Decision
- Positioning/Navigation

Intelligent Transportation

- V2V/V2I/V2X
- Autonomous Driving

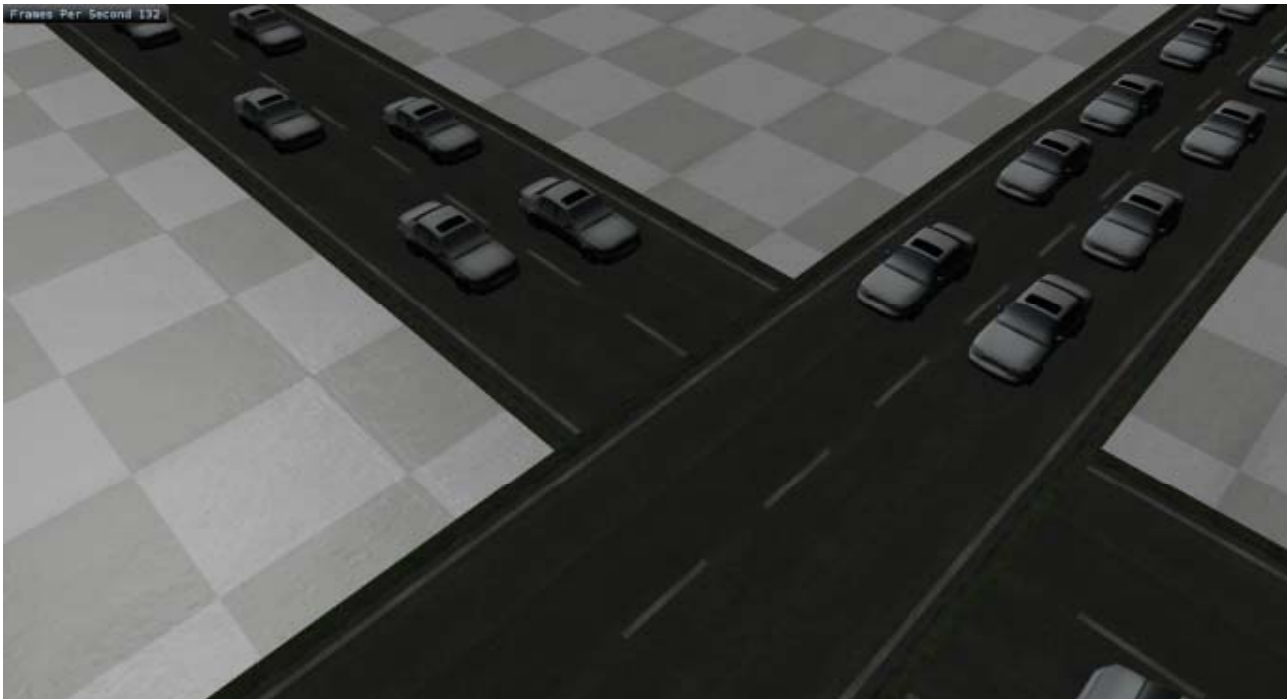
FieldBuilder : Building Testing Field



3D Virtual Proving Ground

Traffic : Traffic Modeling for ADAS

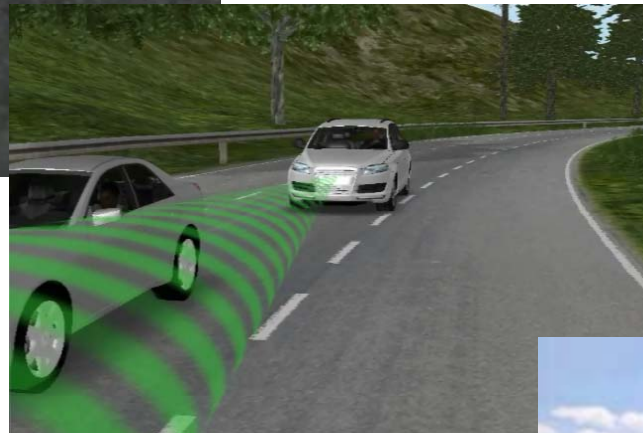
- Good **fidelity** in traffic dynamics, while maintaining sufficient computational **efficiency**
- Good **flexibility** in generating desired **disturbances** for ADAS feature development, while maintaining its nature of **randomness**



PanoSim : Virtual Testing & Verification



**Collision
Avoidance**



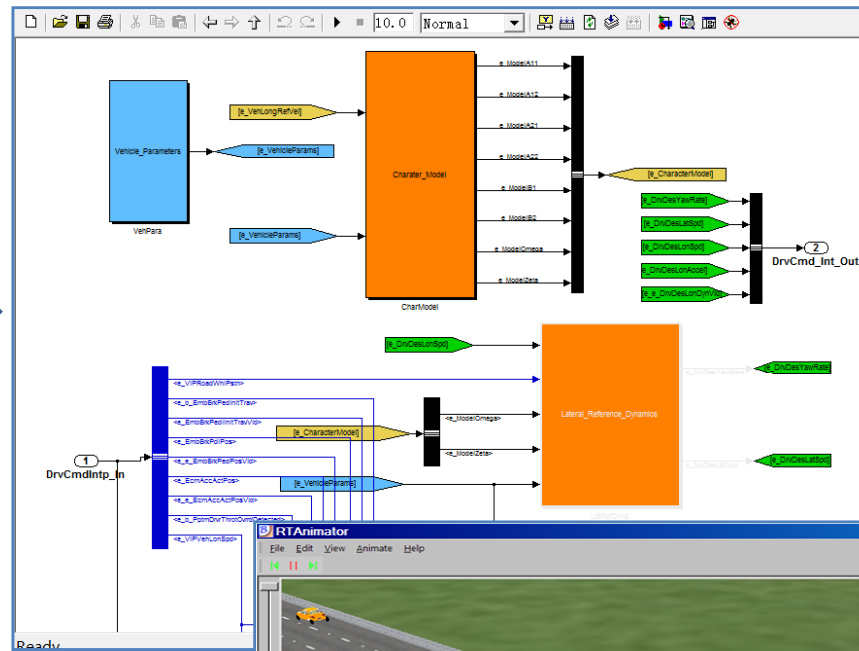
**Adaptive Cruise
Control**



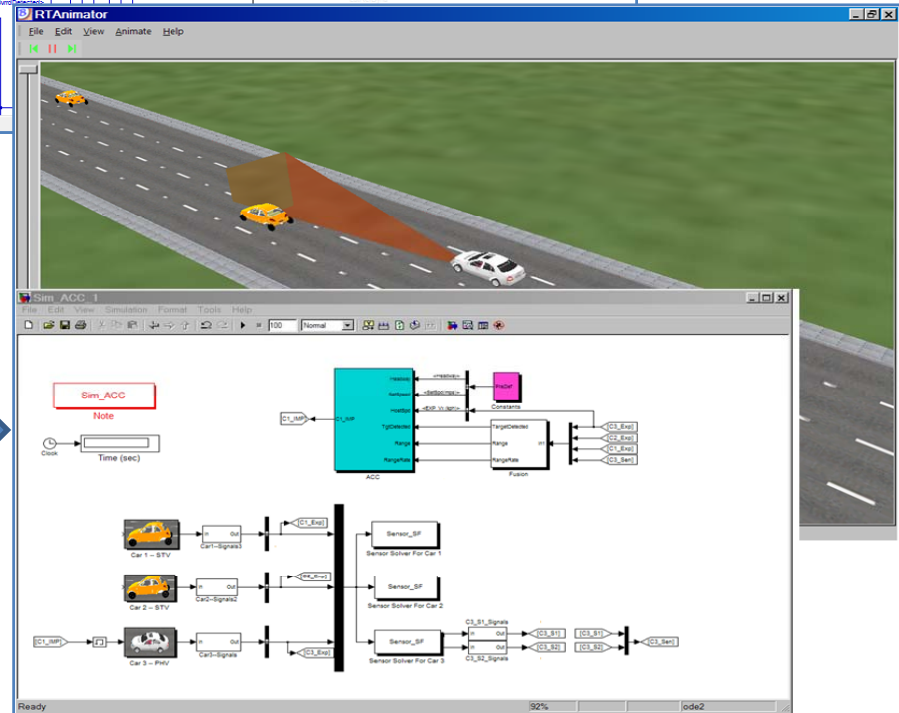
**Autonomous
Parking**

PanoSim : Seamless Connection to Simulink

**Auto Simulink
Model Generation**



**High Efficient
Numerical Simulation**





Real-Time HIL/DIL Simulation



Simulation on **Vehicle Intelligence Development**

Extend the functionality of driver simulator with
environmental sensing



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Camera Modeling: Applications

Real-time HIL/DIL simulation with camera model

Virtual Driving Environment



Driver Simulator



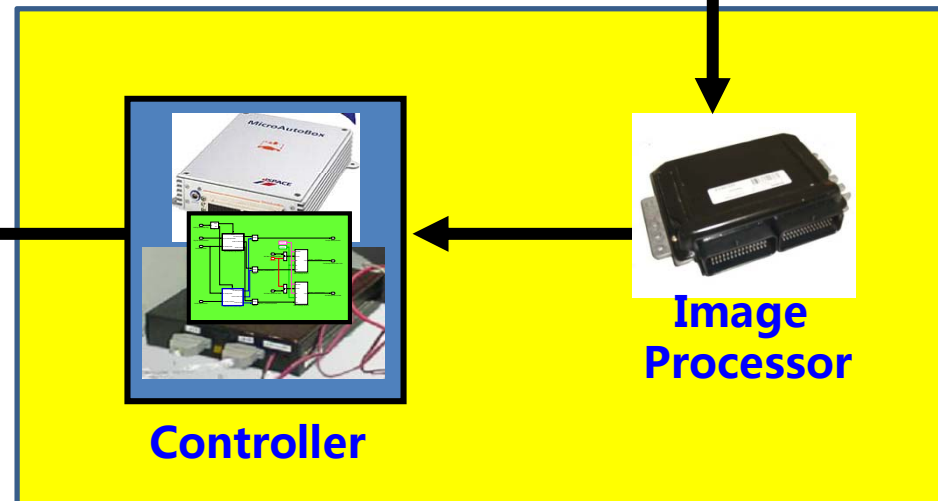
RT Vehicle Model



HIL

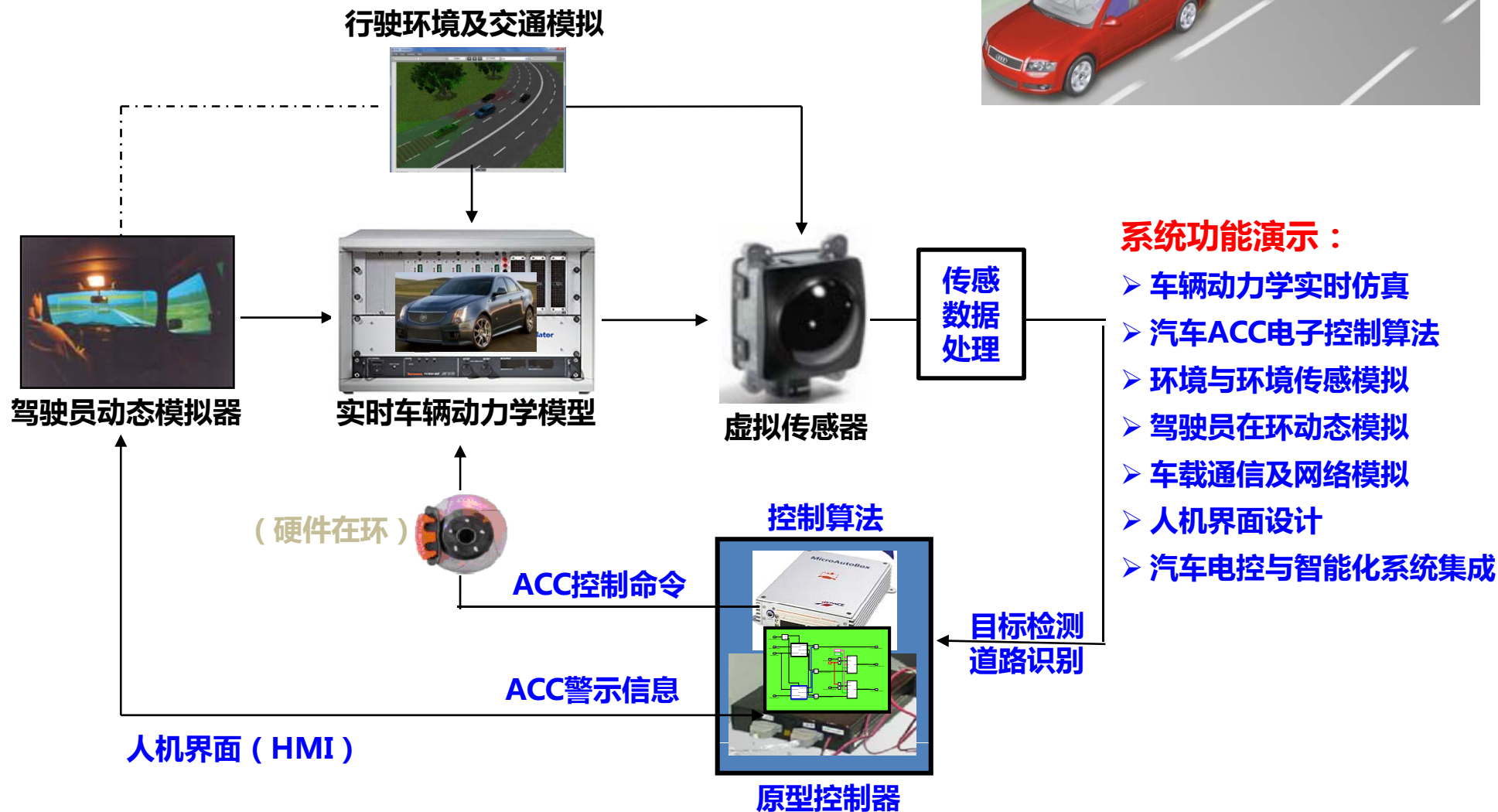


Camera Model

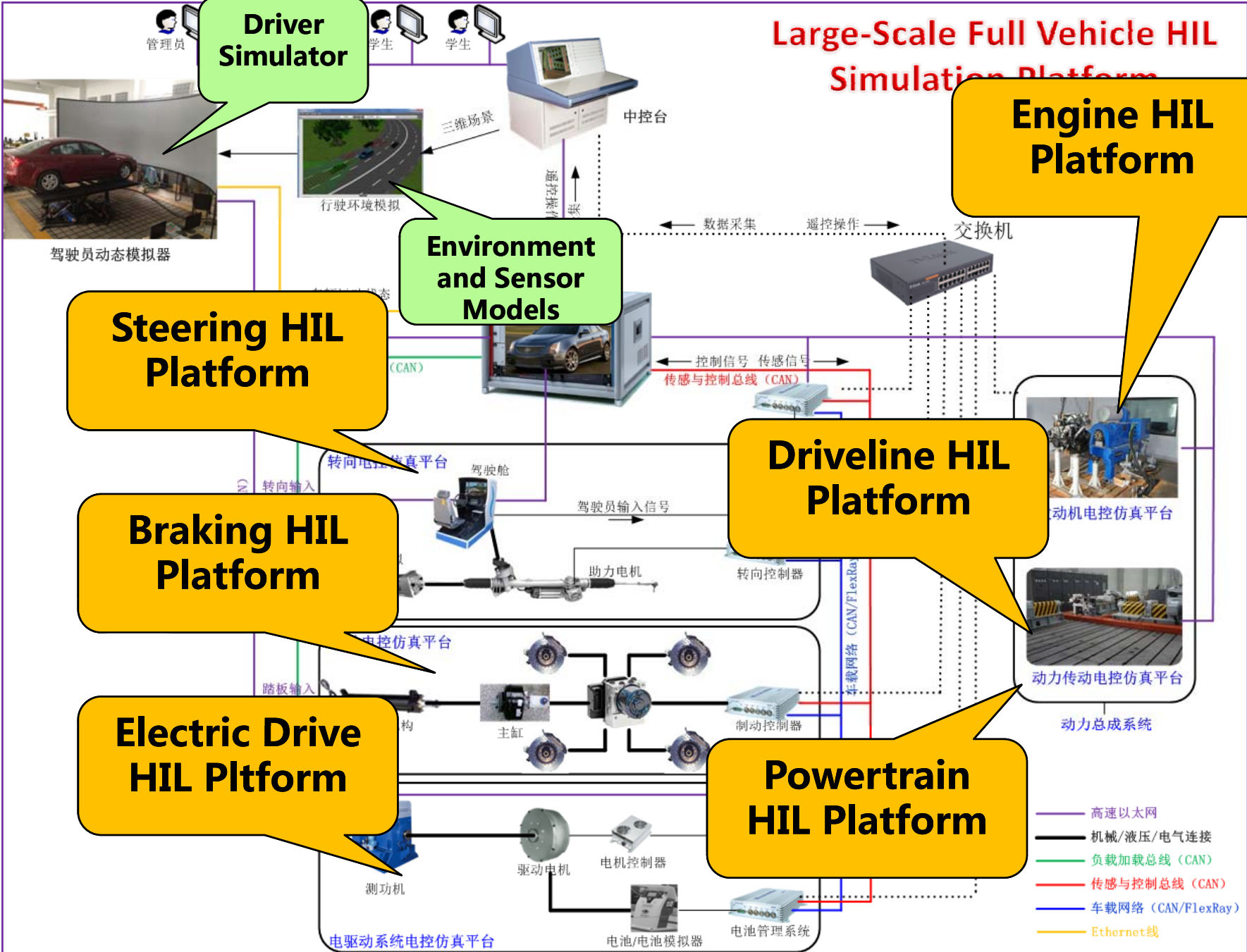


汽车自适应巡航控制系统 (ACC)

实时仿真 (演示)



Large-Scale Full Vehicle HIL Simulation Platform



Engine HIL Platform

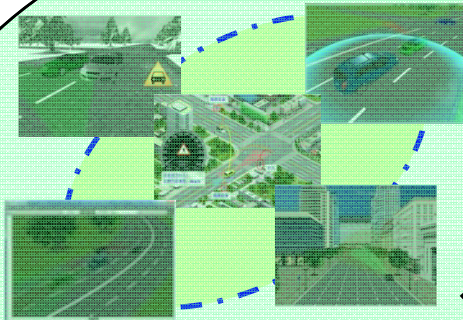
Steering HIL Platform

Braking HIL Platform

Electric Drive HIL Platform

Driveline HIL Platform

Powertrain HIL Platform

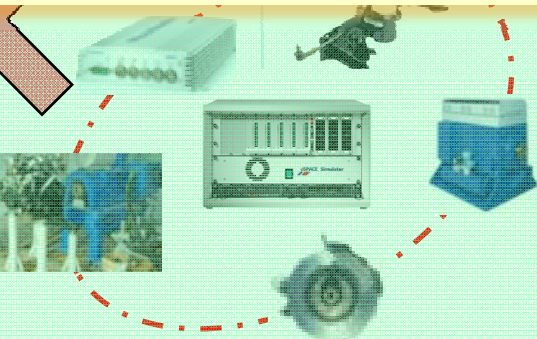


Virtual Driving Environment

Virtual camera, radar, V2V
Traffic and 3D environment

Integrated Real-Time HIL/DIL Platform with Virtual Environment

DIL Simulator
DIL simulation
HMI



RT Vehicle Controls

Prototype Controller
By-wire actuators
In-vehicle communications

Conclusions:

- Field testing can be very challenging on cost, time, and flexibility, and sometimes even impossible.
- Virtual driving environment can be in high fidelity with models of road, traffic and weather, and environmental sensors of radar and camera (and V2V next).
- It is proved to be very effective in the early design, test and verification of vehicle intelligence.