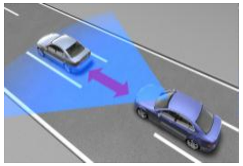
# Role of Hybrid Simulation in Vehicle Development

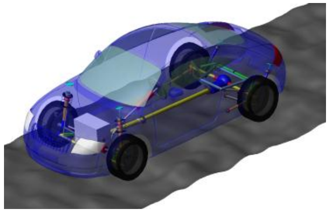
diego minen

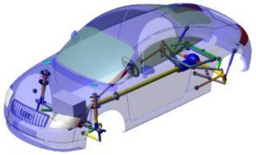
# VI-grade
## The Digital Car

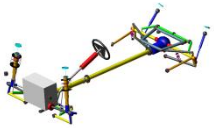
VI-DriveSim

Driver Assistance







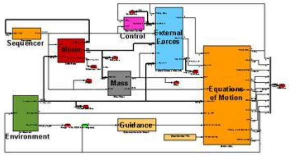


VI-SportsCar

VI-CarRealtime

Hardware-in-the-loop

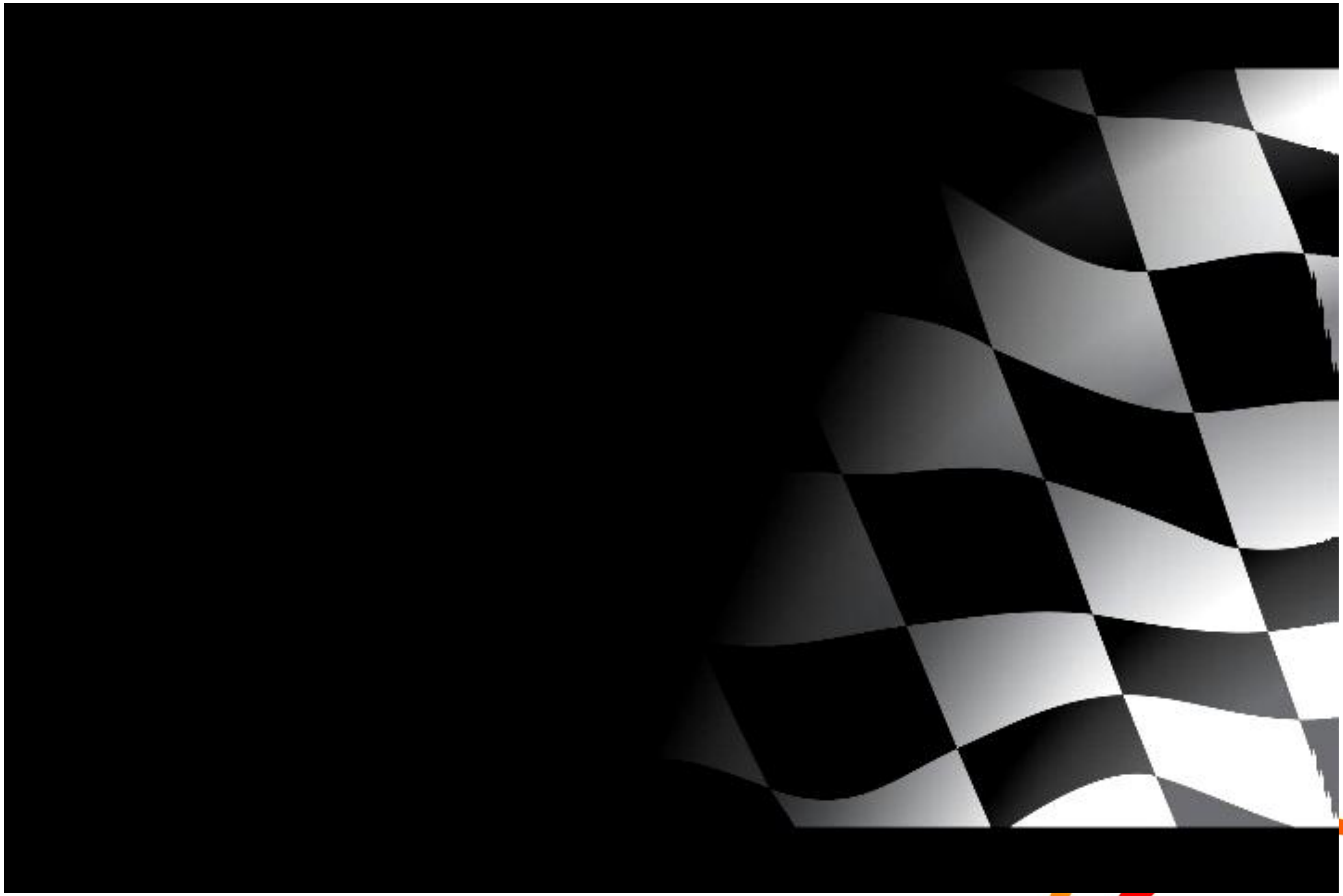
Software-in-the-Loop




Simulation performance rate

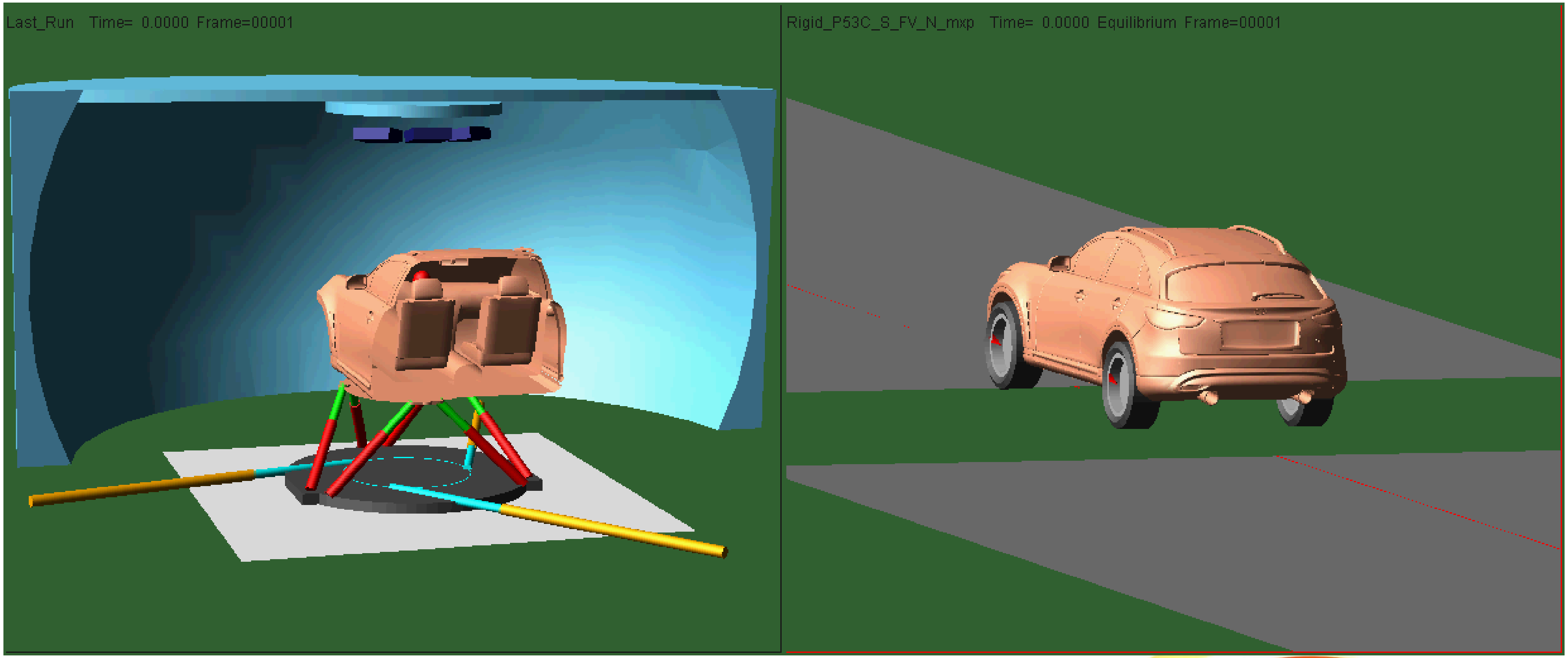
Model complexity

# Vehicle simulation
2011…



# Vehicle simulation
2012

# Vehicle simulation
## And beyond…



# Vehicle Development
## Physical Prototypes

- Essence of **<u>Product</u>** Innovation
- Need product construction
- Can be tested by humans
- **but**…
  - Cannot be modified easily

# Vehicle Development
## Virtual Prototypes

- Essence of **<u>Design</u>** Innovation
- Need digital model construction
- Can be modified easily
- **but**...
  - Cannot be tested by humans

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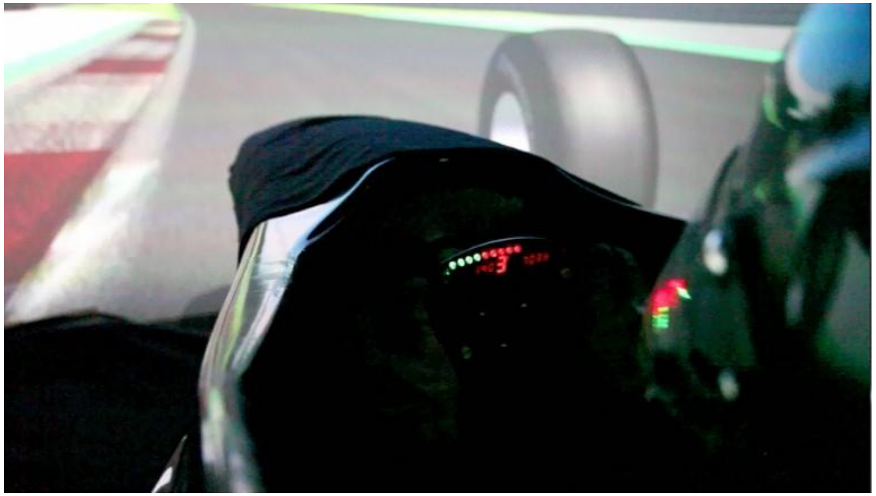
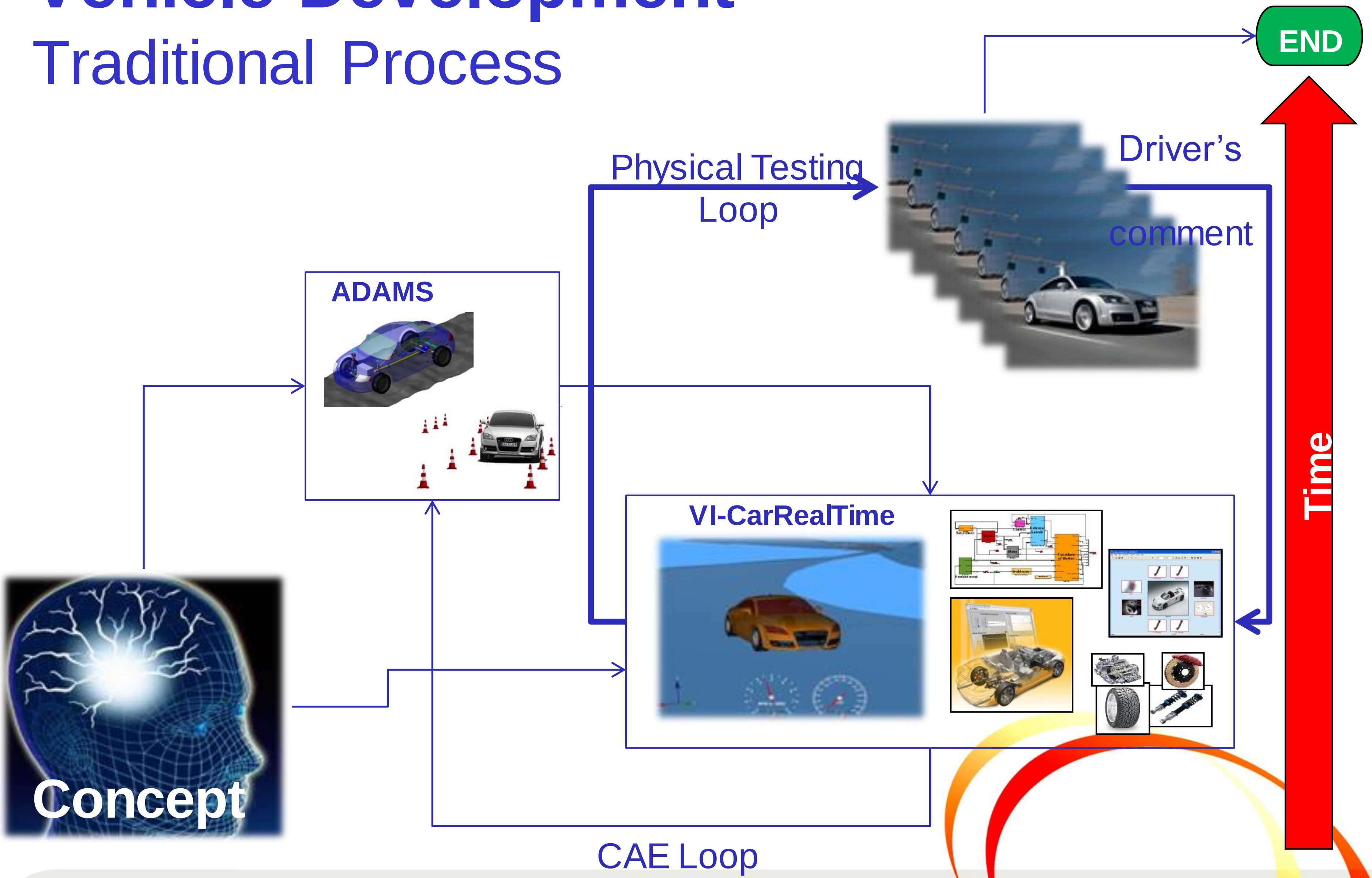
# Vehicle Development
## Hybrid Prototypes

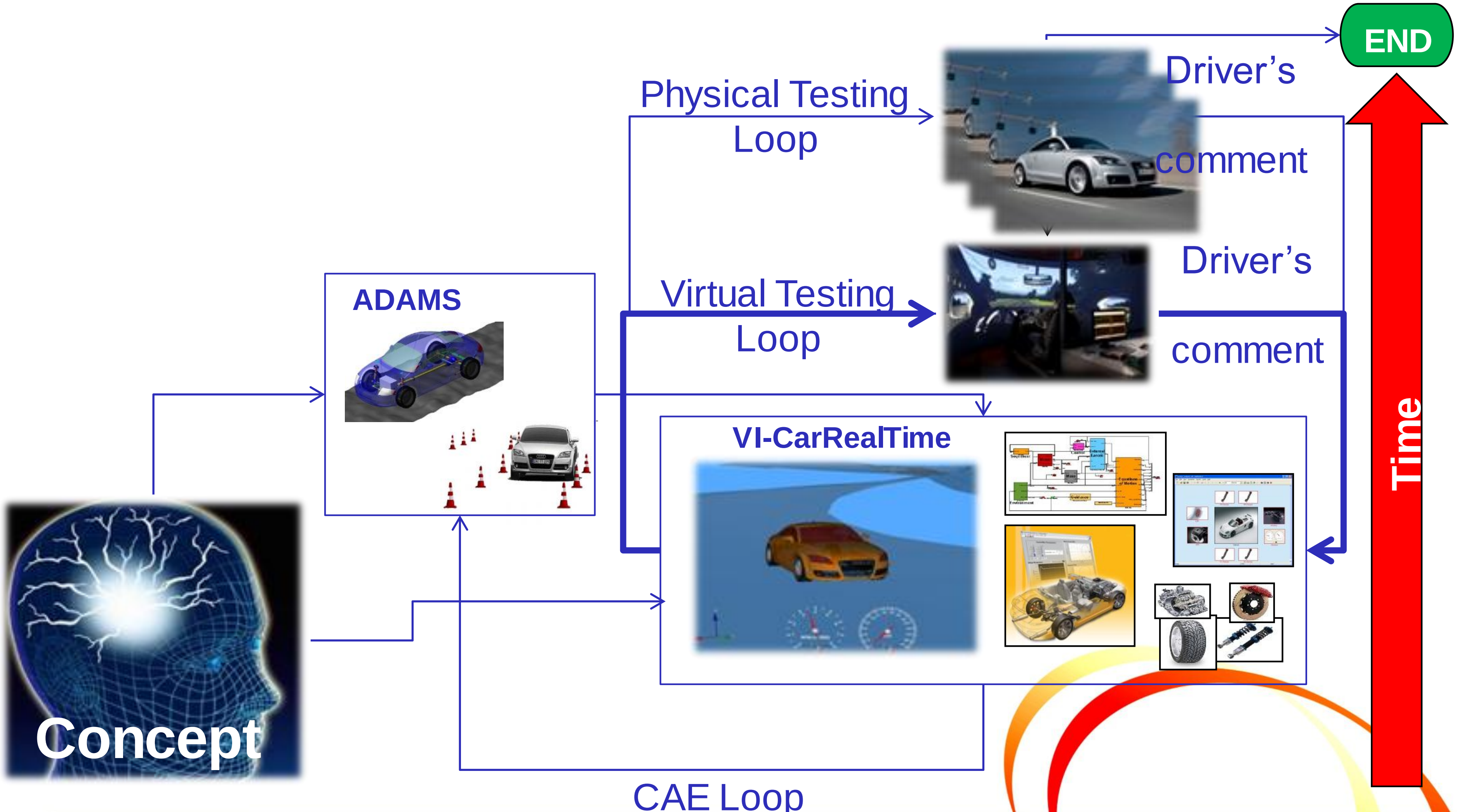


- **Engineering** Revolution
- Use the virtual prototype same digital model
- Can be modified easily
- **and**...
  - Can be tested by humans

# Vehicle Development
## Traditional Process

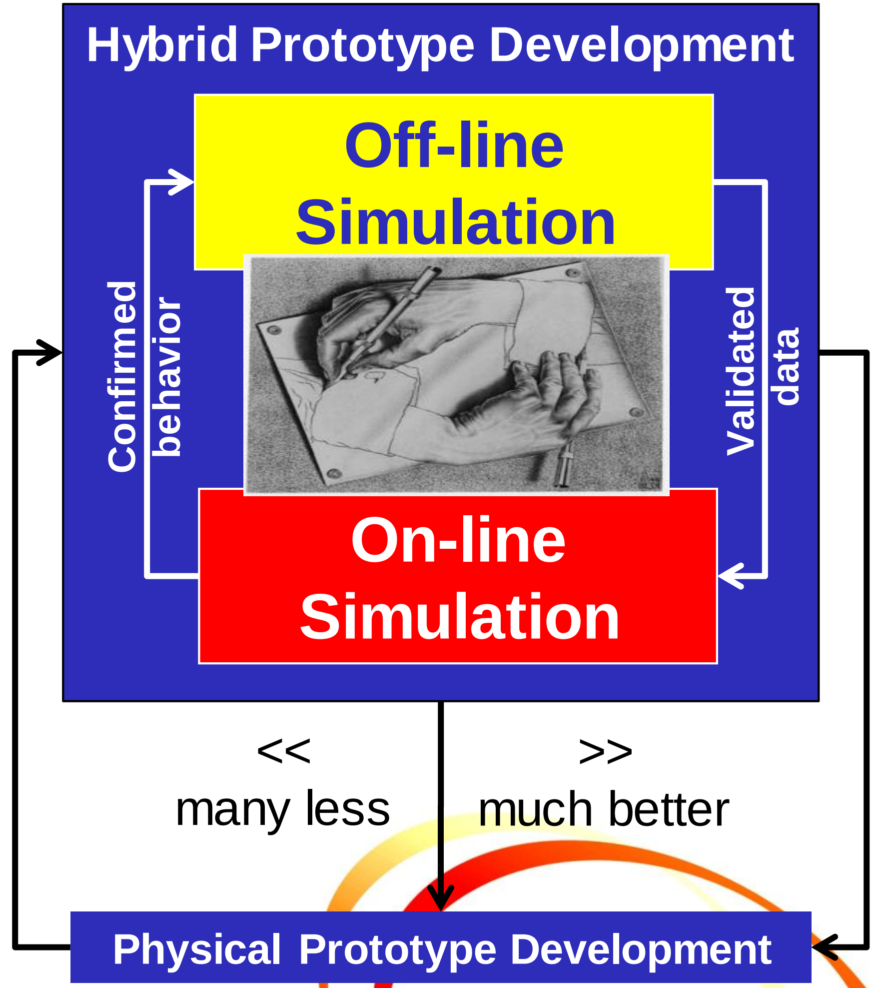


# Vehicle Development
## VI-DriveSim Development Process



# Vehicle Development
## Real-time Hybrid Simulation

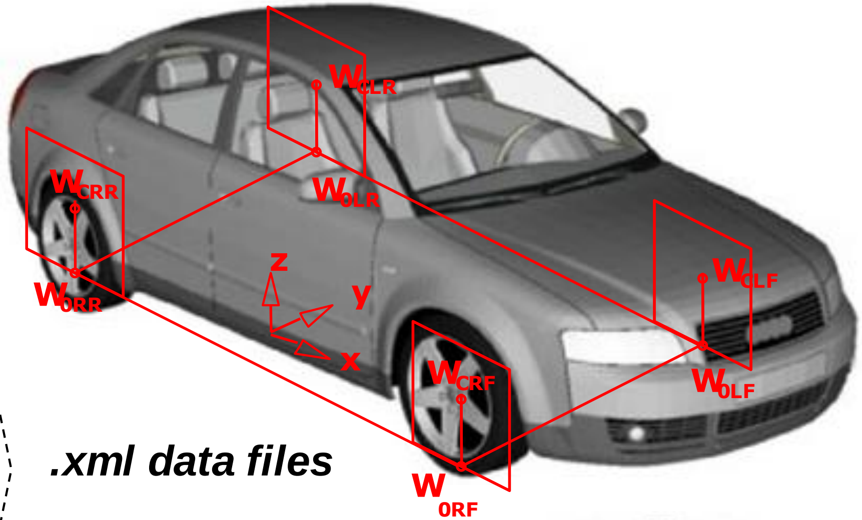
- **Off-line:** on computer
- **On-line:** on VI-DriveSim
  - share the same model
  - mutually validate and complement each other

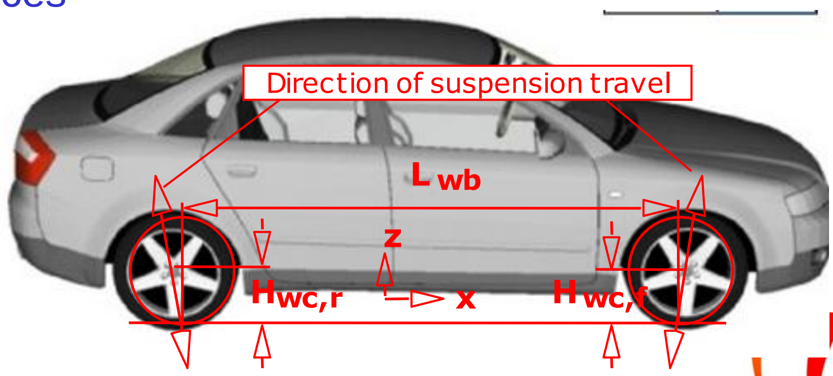


# VI-DriveSim
## Vehicle Model

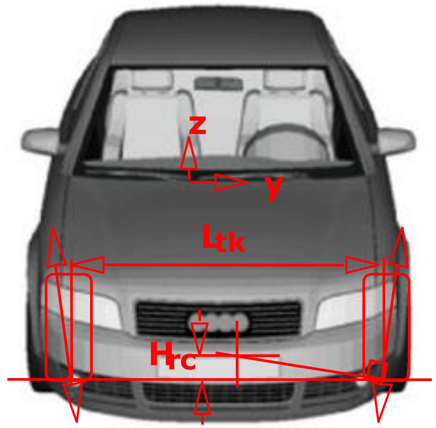
- Vehicle Sprung Mass
  - Rigid or compliant body
  - Independent/Dependent Front/Rear Suspension
  - Suspension Installation Stiffness
  - Steering
  - Brakes
  - Powertrain, Gearbox, Differentials
  - Tires (Pacejika Formulas)
  - Full aerodynamic Forces
  - User Sensors

***.xml data files***



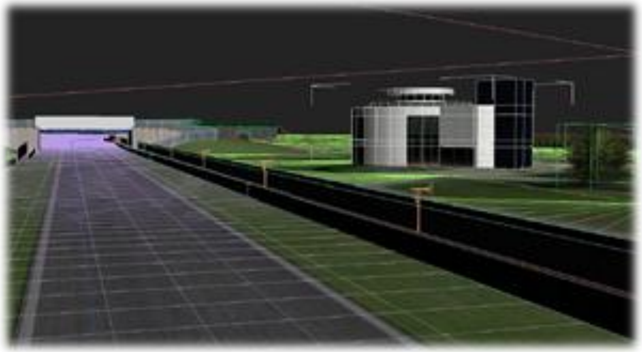

Side view




Front view

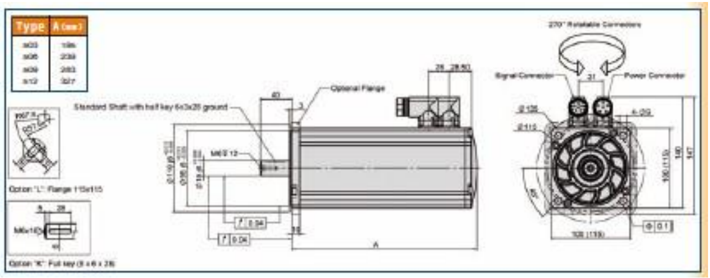
# VI-DriveSim
## Graphic Environment

- Features
  - 3D Track models (based on LiDaR and other methods)
  - Skid marks and smoke effects
  - Light conditions based on location, date and time of the day
  - Modeling of surroundings around the track
  - Rain, snow and fog effects
  - Handling of hundreds of lights (for night races)
  - Accurate vehicle modeling and shading
  - Widgets for speed, gear, RPM, G-G diagram
  - Real-time reflections on car
  - Real-time mirrors
  - Real-time shadows



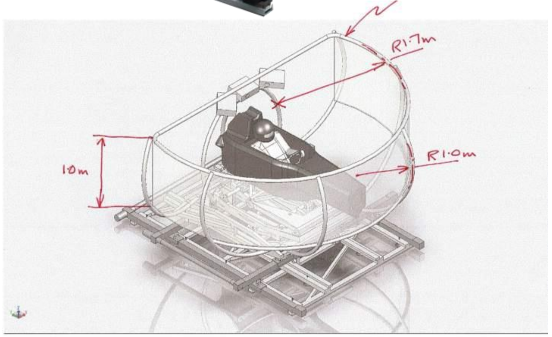
# VI-DriveSim
## Human Interface

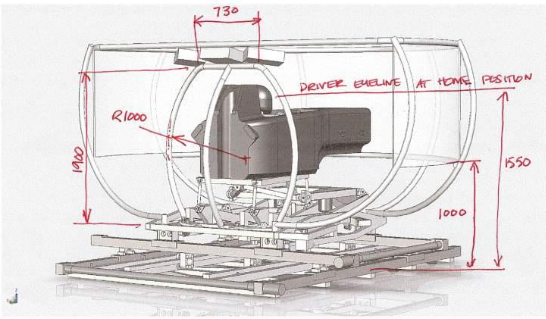
- Electric Motor (220/380 voltage supply)
- Receives data from VI-CarRealTime
- CANBUS Interface
- Programmable PLC interface
- Analog signal for throttle and brake pedals converted to CANBUS
- Analog signal for gear shifting (converted to USB)
- No clutch (neutral gear available)



# VI-DriveSim
## Motion Platform

- VI-DriveSim runs on any motion platform
- The new Ansible Motion platform, couples motions similarly to a real car:
  - X,Y and Yaw degrees of freedom are decoupled
  - Roll, Pitch, Heave are coupled

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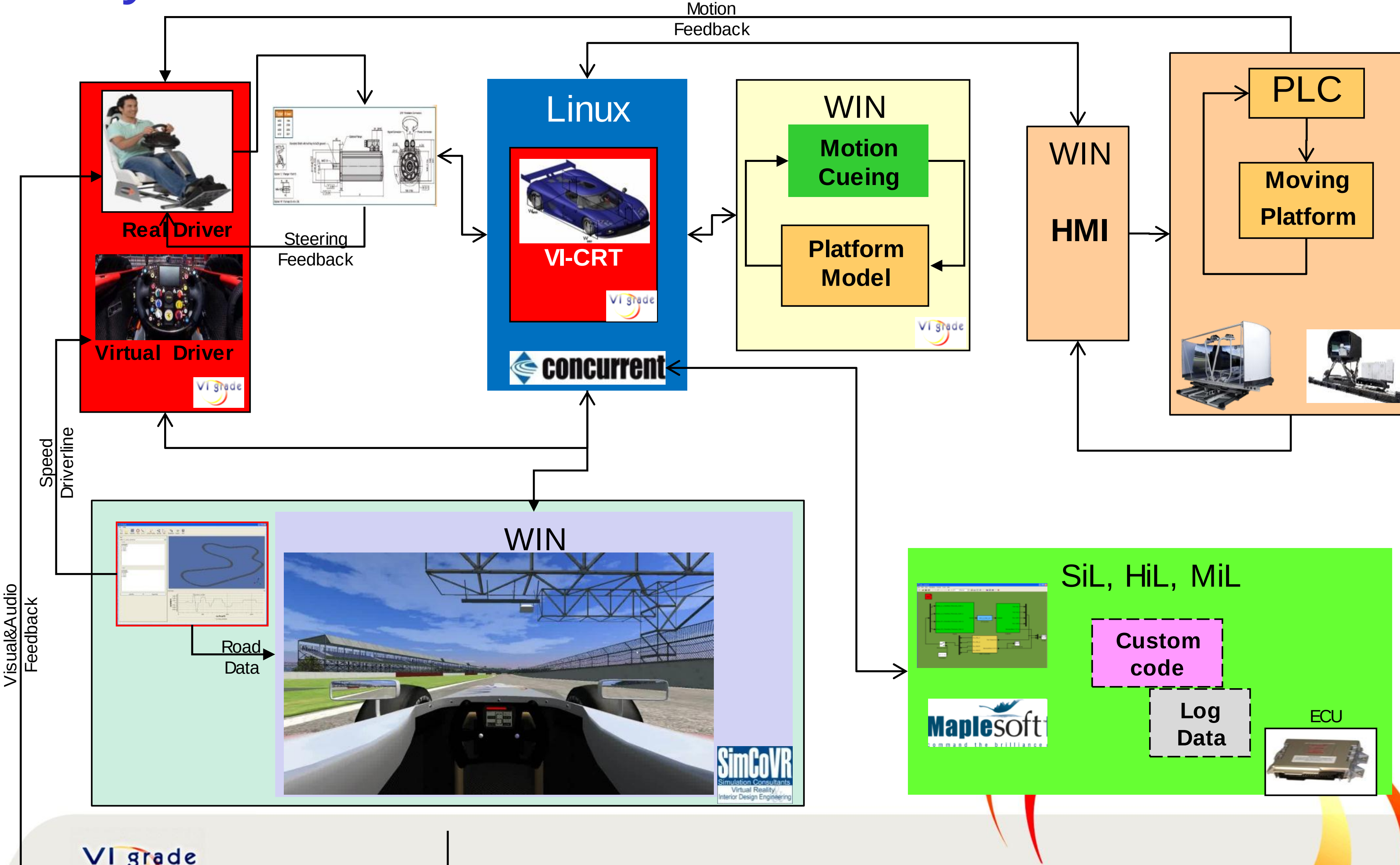
# VI-DriveSim

## Dynamic Simulator

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# Driving Simulator Correlation Factors

- In order of importance for perception:
  1. **Visual**
  2. Vehicle Physics
  3. Steering Torque Feedback
  4. Acustics
  5. Pedal Feedbacks
  6. Motion Cueing

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# Driving Simulator Correlation Factors

- In order of R&D for perception:
  1. **Motion Cueing**
  2. Acustics
  3. Steering Torque Feedback
  4. Pedal Feedbacks
  5. Vehicle Physics
  6. Visual

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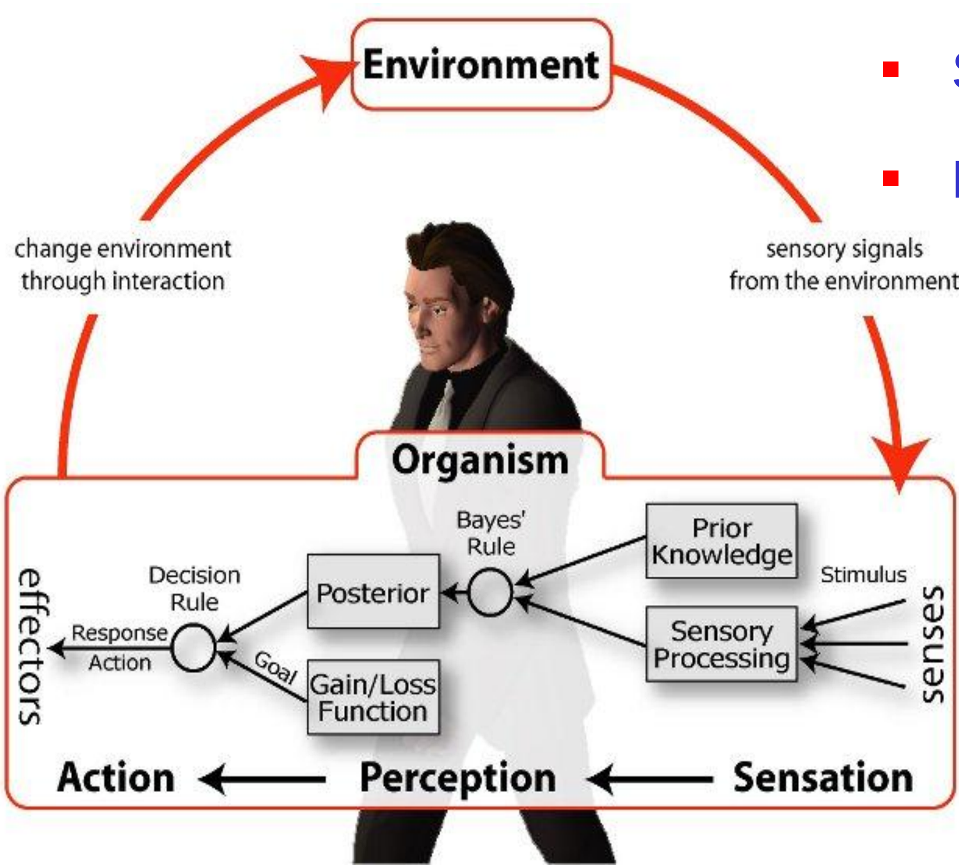
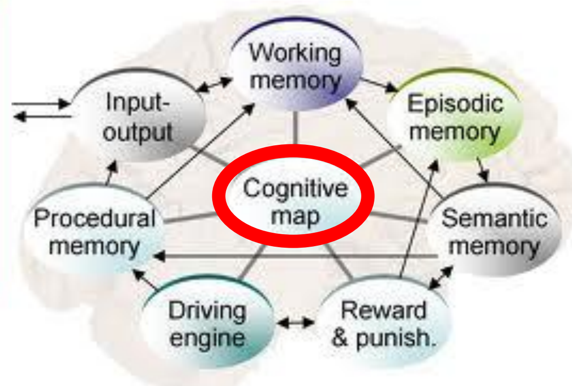
# Perception

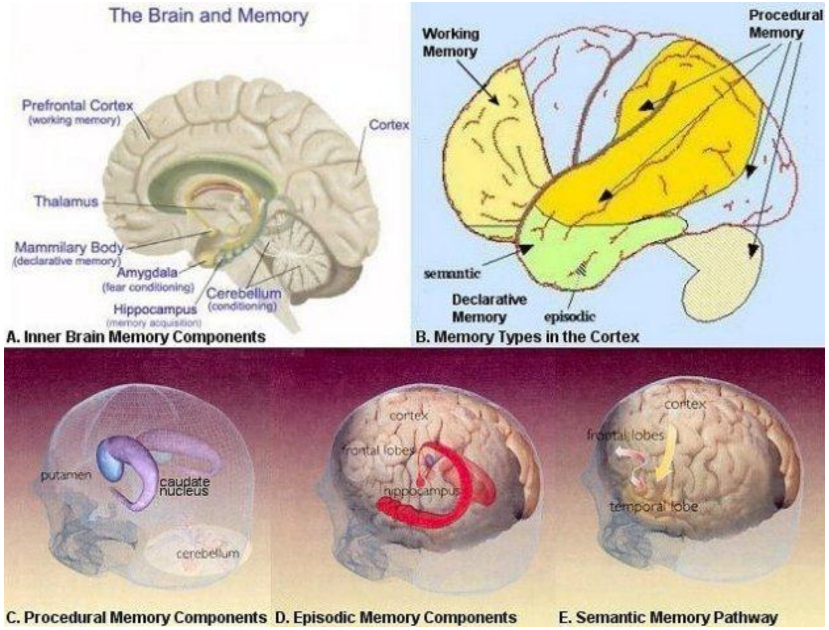
- Multi-sensory process
- Spatial-temporal window of integration
- Bayes' rule:
  - relates the odds on probability models A, B before and after evidence is observed



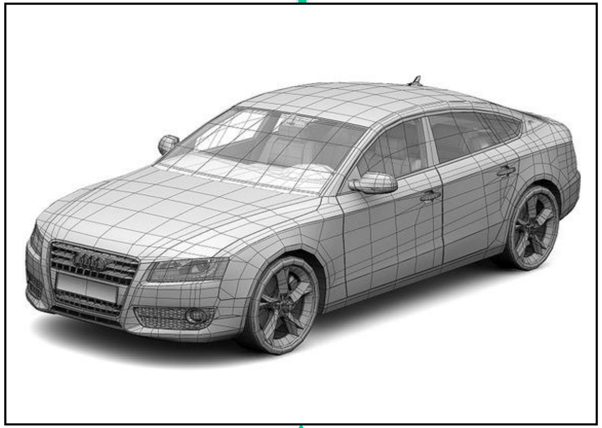
# Virtual-Real Correlation

- A good Driving Simulator:
  - Activates driver's automatic reaction
  - Easily allows to compare the virtual experience with the real
  - Does not overload driver's brain



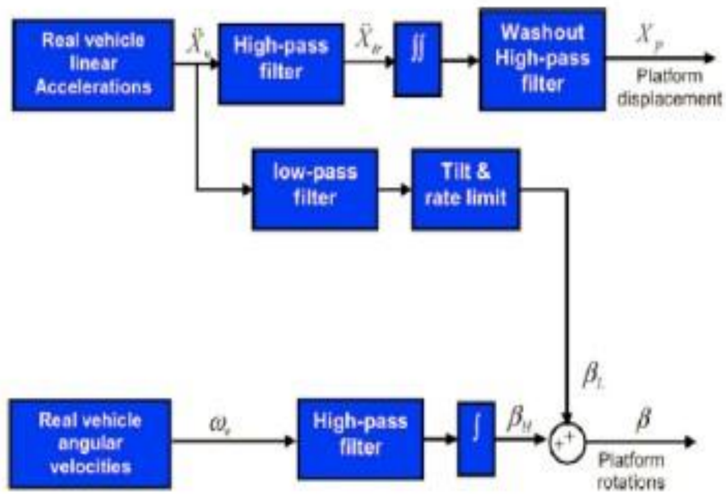
# Virtual-Real Correlation

- Virtual and real worlds are **correlated** but **not identical**
- Hybrid Simulation leads to a completely new engineering process



# Classical Motion Cueing

Scheme of the Classical Motion Cueing algorithm

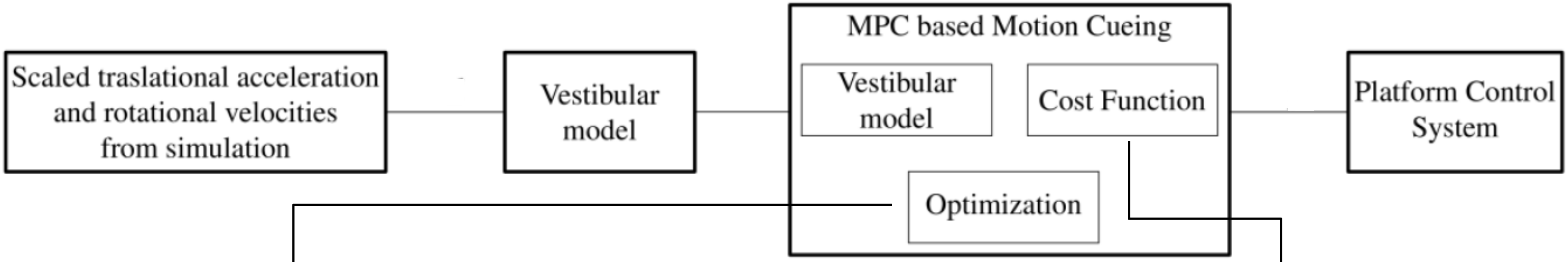


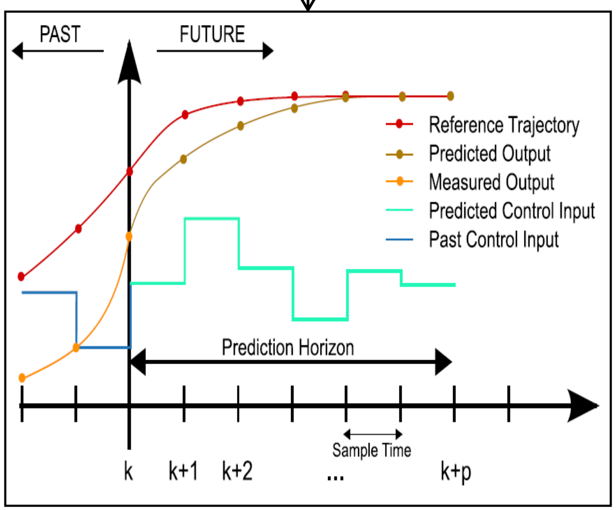

om Nehaoua et al, IEEE TRANS. ON VEHIC. TECH., VOL. 57, NO. 2, MARCH 2008

## Main drawbacks

- No possibility of including constraints $\Longrightarrow$ conservative design
- WFs often introduce accelerations "inversion"

# Model Base Prediction for Motion Cueing




*A cost function is minimized over a sequence of future input commands*

$$\min_u J = f_1\left(\|y-r\|^2_{Q_y}\right) + f_2\left(\|u\|^2_{Q_u}\right) + f_3\left(\|x\|^2_{Q_x}\right)$$

$$\text{subject to} \quad x \leq M \quad (\textit{platform} \quad \textit{limits})$$

*Parameters*

- *y are the perceived accelerations;*
- *r are the desired perceived accelerations;*
- *Qy ;Qu; Qx are the weights, M are the platform limits;*
- *x are the states;*
- *u are the reference for the platform control system*
- ***f1, f2, f3 are weight parameters***

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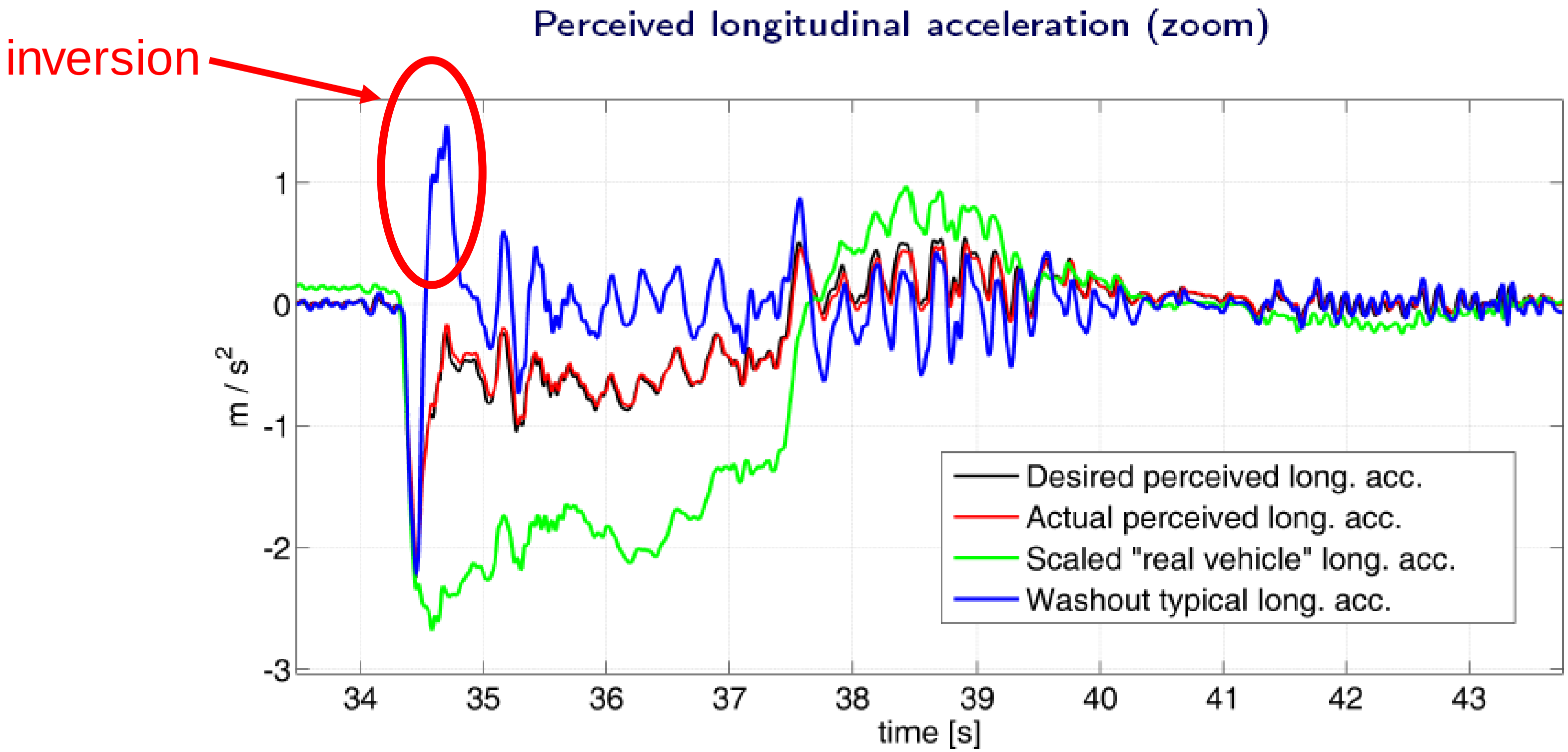
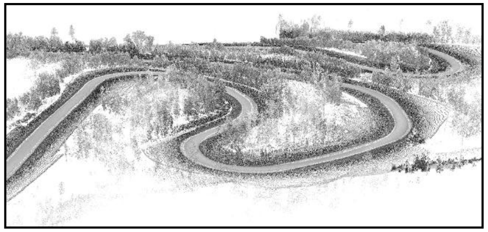
# Model Base Prediction for Motion Cueing

- The reference signal is well tracked within the platform limits
- No “inversion” can be perceived



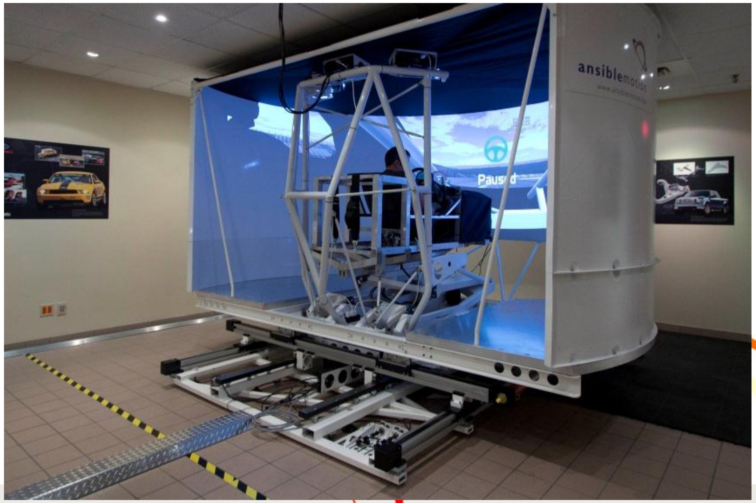
# Which Size Simulator?

- Big vs. Small Workspace
  - car model → sport productive car
  - track → 5km hilly proving ground
  - virtual driver (perf std-dev = 0)
  - Laptime = 150s

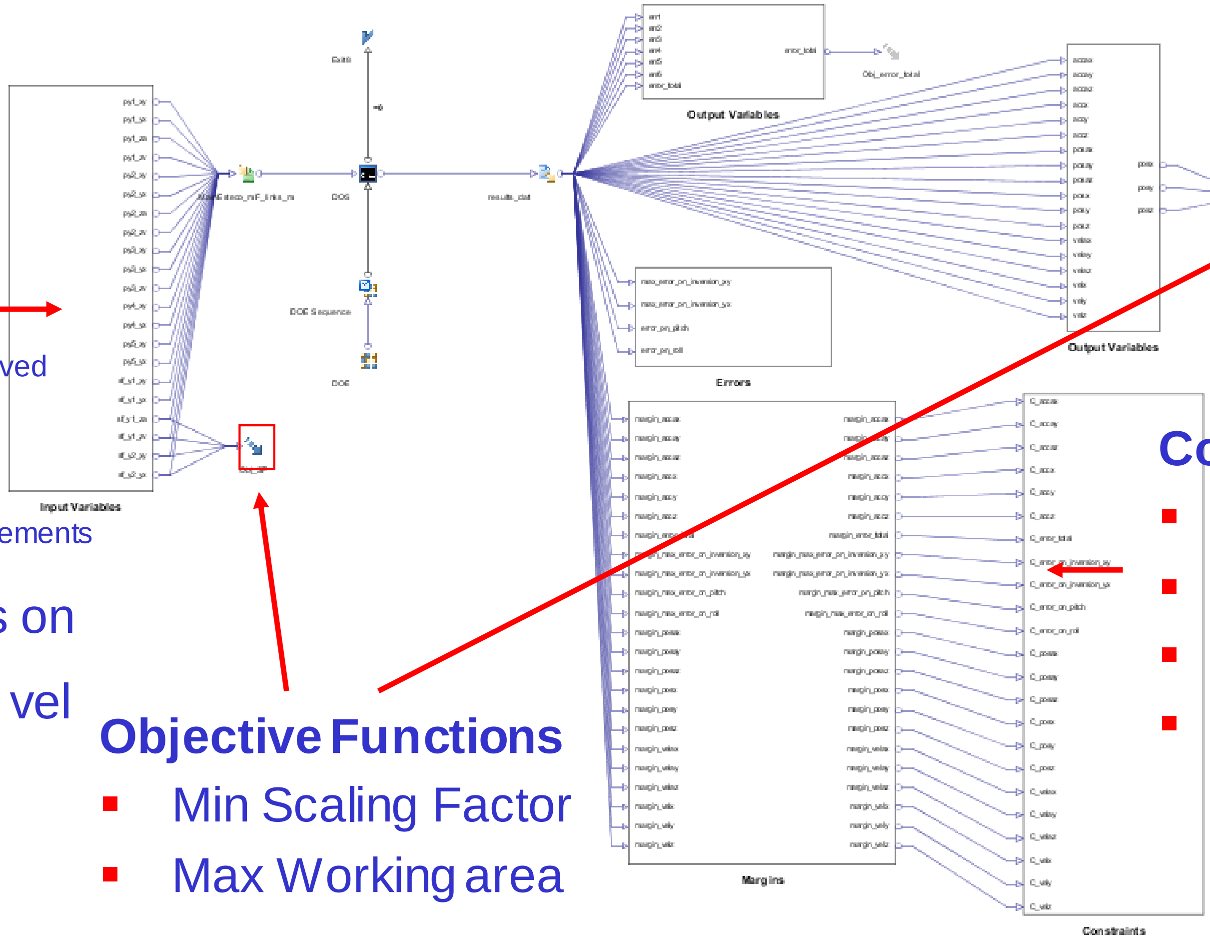


Big simulator

Small simulator



# Enhancing Motion Cueing using mFrontier




## Input variables

- Weights:
  - tracking of perceived acc, vel
  - Transational and rotational displacements
- Scaling factors on perceived acc, vel

## Objective Functions

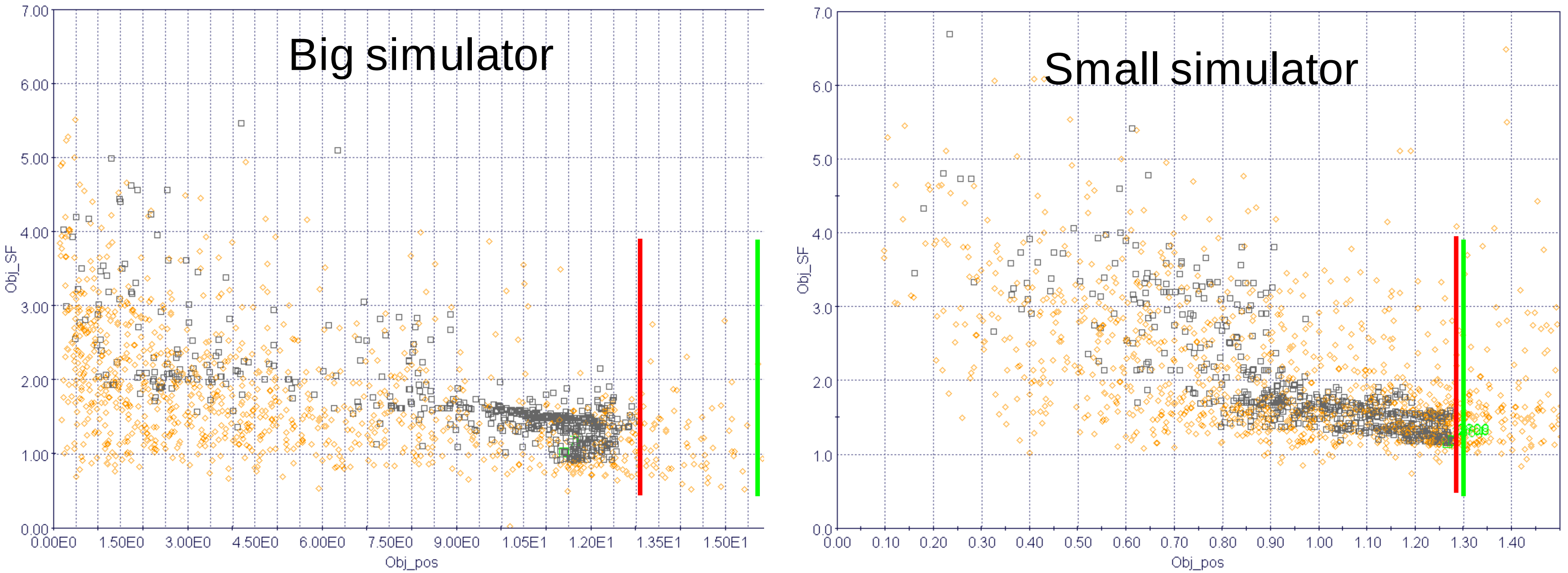
- Min Scaling Factor
- Max Working area

## Constraints:

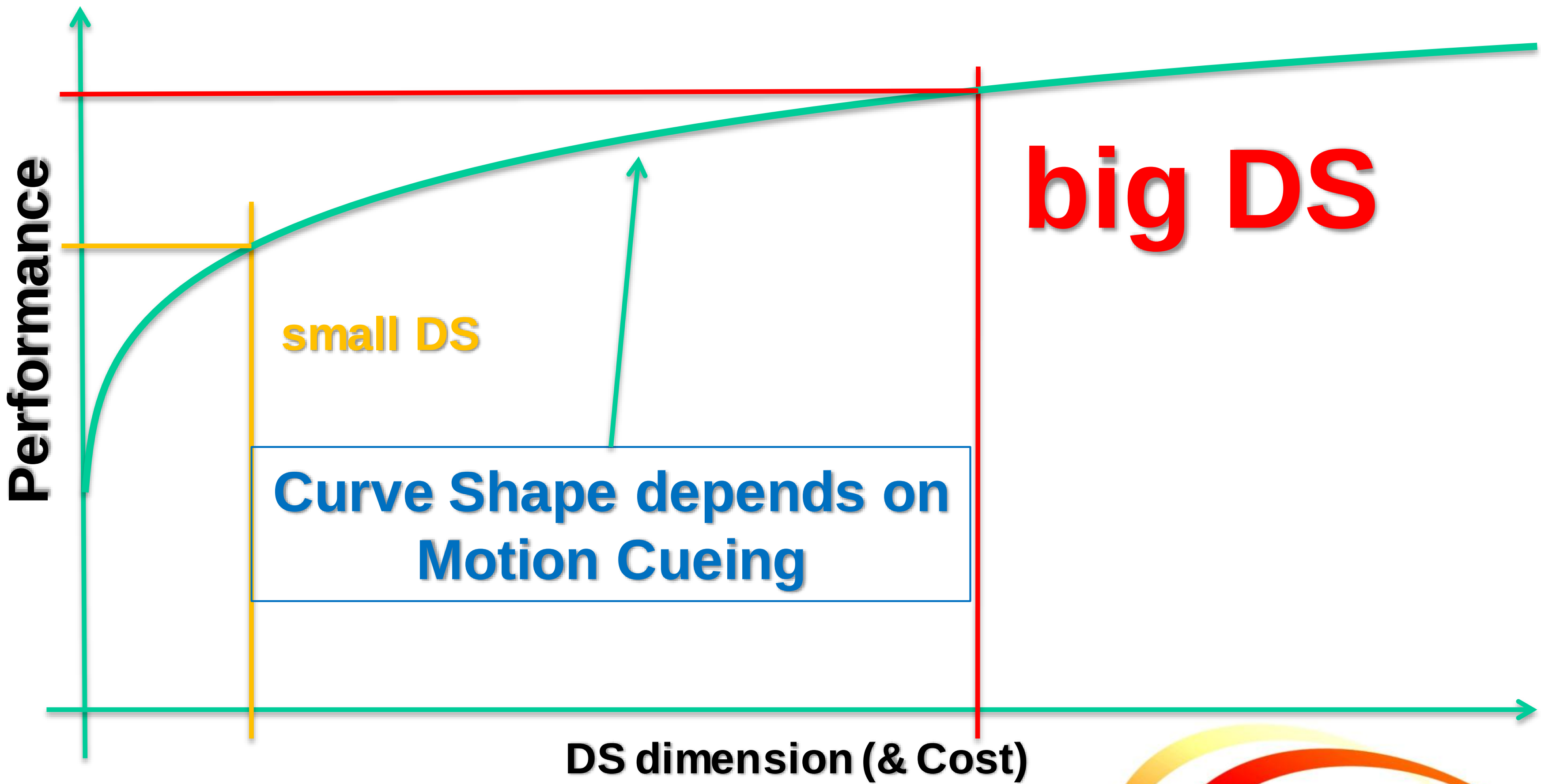
- 6 pos
- 6 vel
- 6 acc
- Acc inversion

# Which Size Simulator?

- Multi-Objective plots as function of f1, f2, f3 weight pars:
  - SF=scaling factor of real peak accelerations (X,Y) vs. virtual
  - POS: total platform workspace usage



# Which Size Simulator?



# VI-DriveSim
## Teamwork

- We provide a turnkey solution:
  - Industry Validated real-time model
  - High Performance Real Time Computing
  - Quality Graphics and Sound
  - Professional Vehicle Engineering
  - R&D Motion Cueing Algorithms
  - Desk-Side Motion Platform

# VI-grade Technology

Q&A