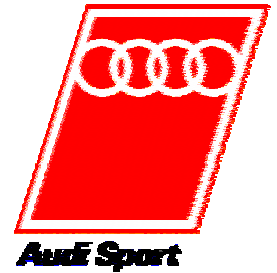


# ADAMS Simulation of a Prototype Car for Le Mans Race



Dr. Martin  
Mühlmeier,  
Audi Sport

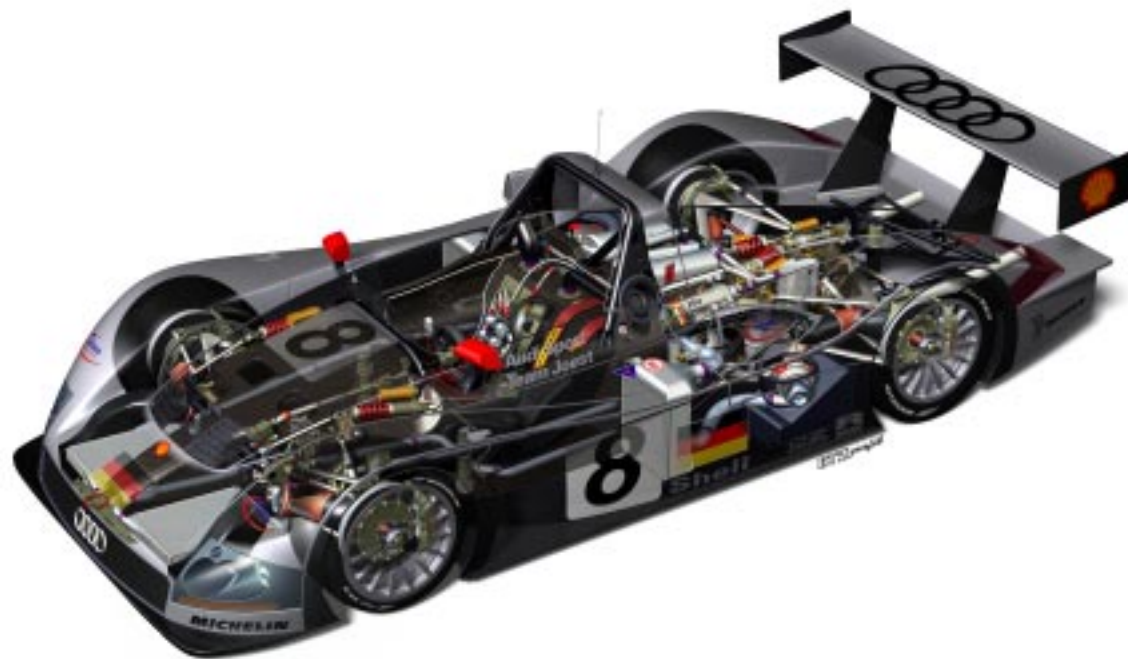
&

Diego  
Minen,  
Mechanical  
Dynamics

# R8 Model

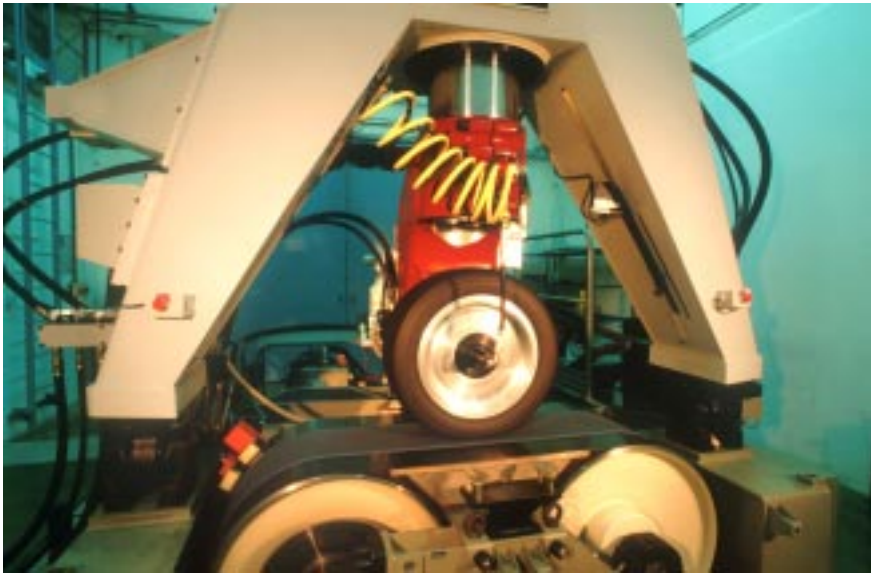
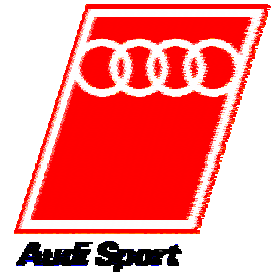


## Components



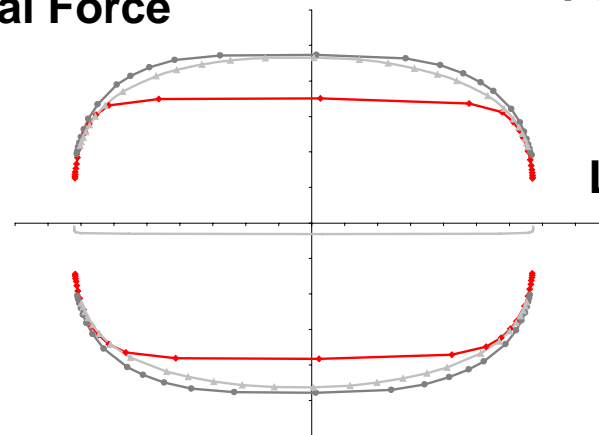
- Tyres
- Suspension systems
- Aerodynamics
- Drive Train
- Driver
- Road

# Tyres



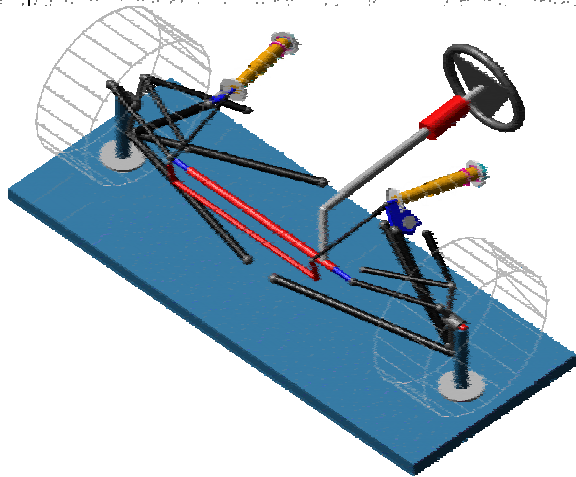
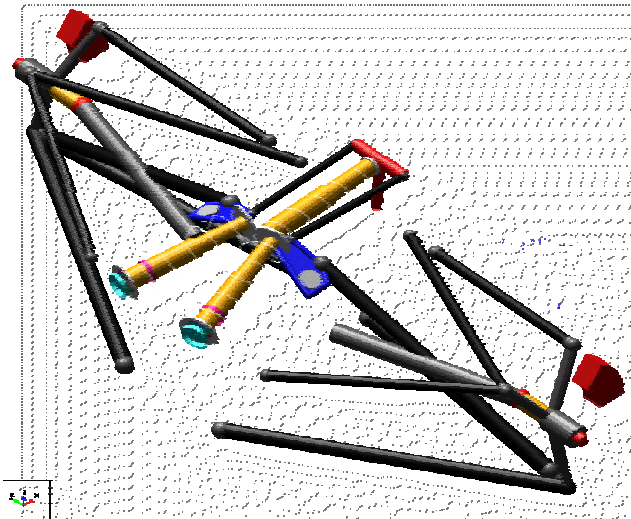
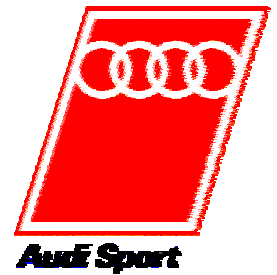
- Magic Formula  
(Michelin Extension)
- 1. Order Dynamics
- Non Constant  
Relaxation Length
- Variable Speed Rolling  
Resistance

Lateral Force

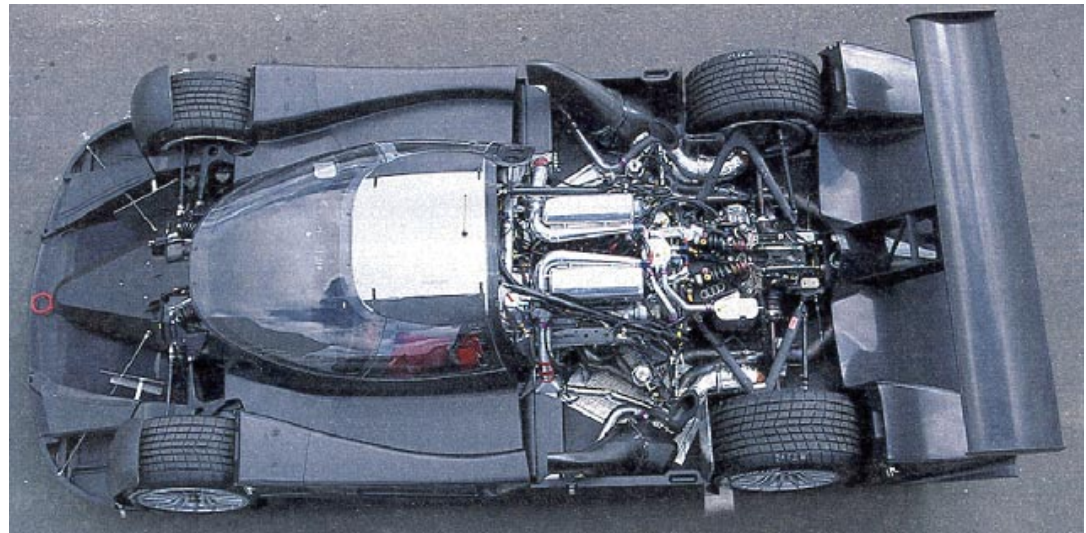


Longitudinal Force

# Suspension



- Rockerarms
- Nonlinear Springs
- Nonlinear Dampers
- Anti Roll Bars
- Power Steering

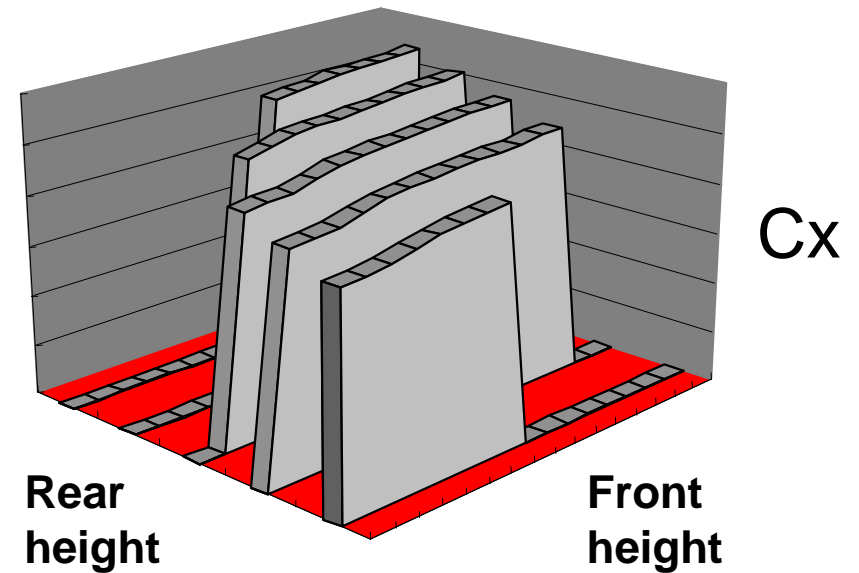
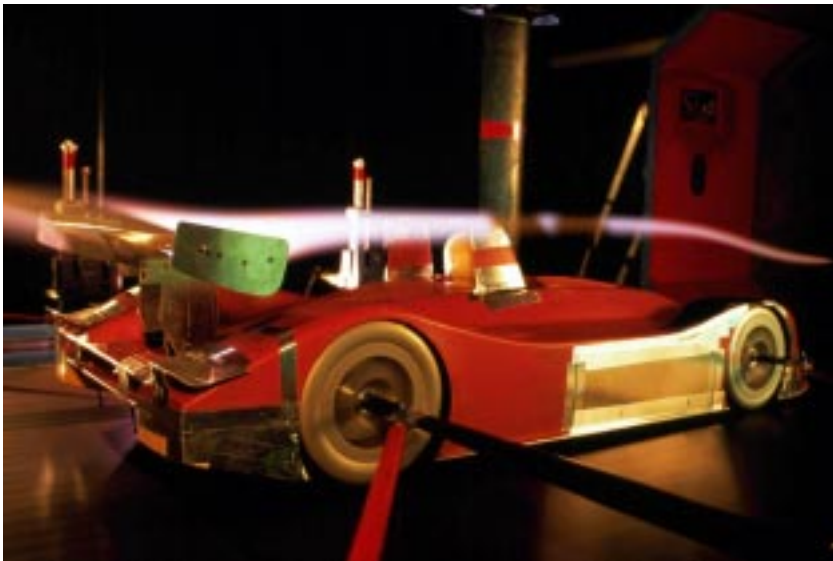


# Aerodynamics



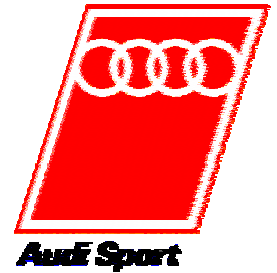
- Lookup Tables for

Drag & Downforce depending on ride height





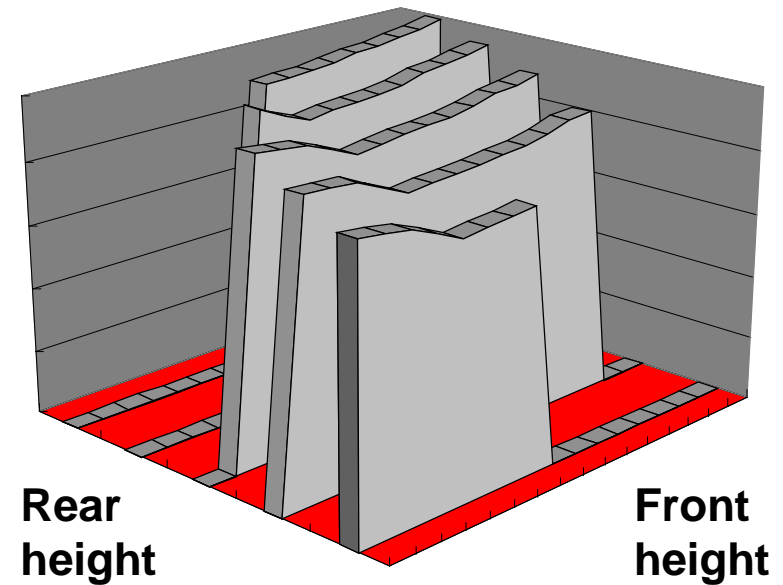
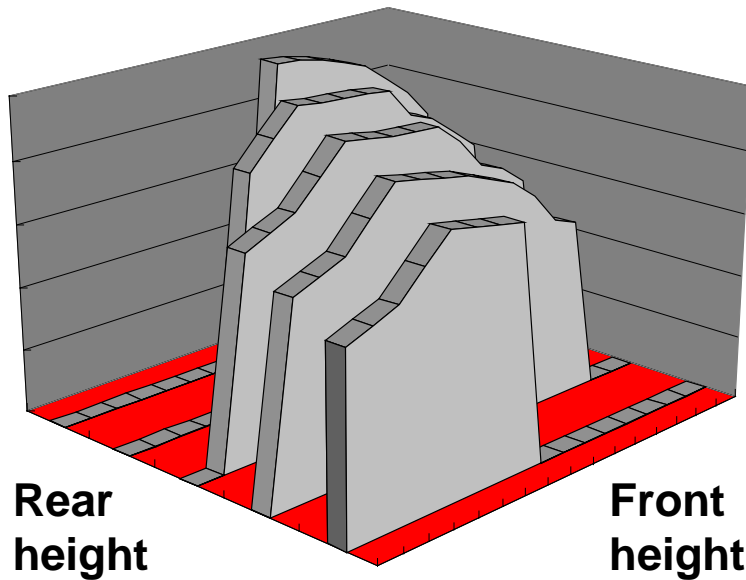
# Aerodynamics



Downforce  
front ( $C_z$ )



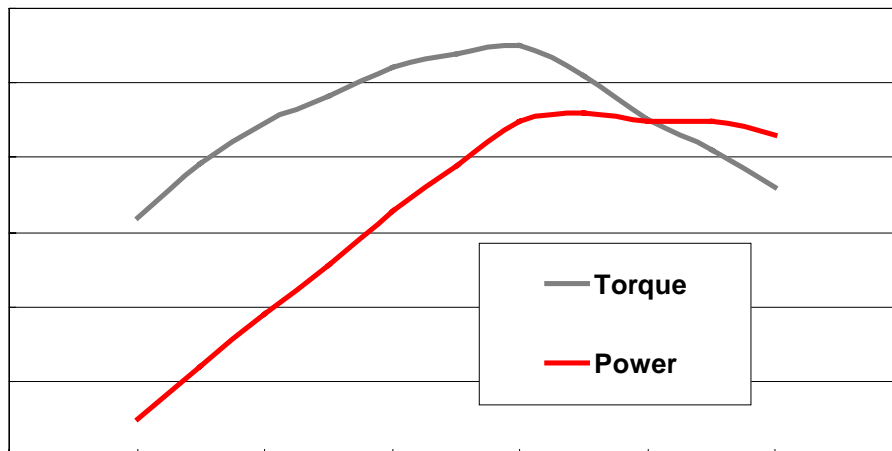
Downforce  
rear ( $C_z$ )



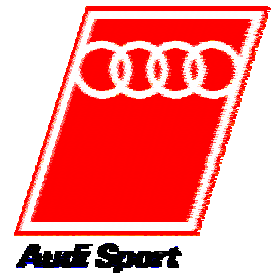
# Drive train



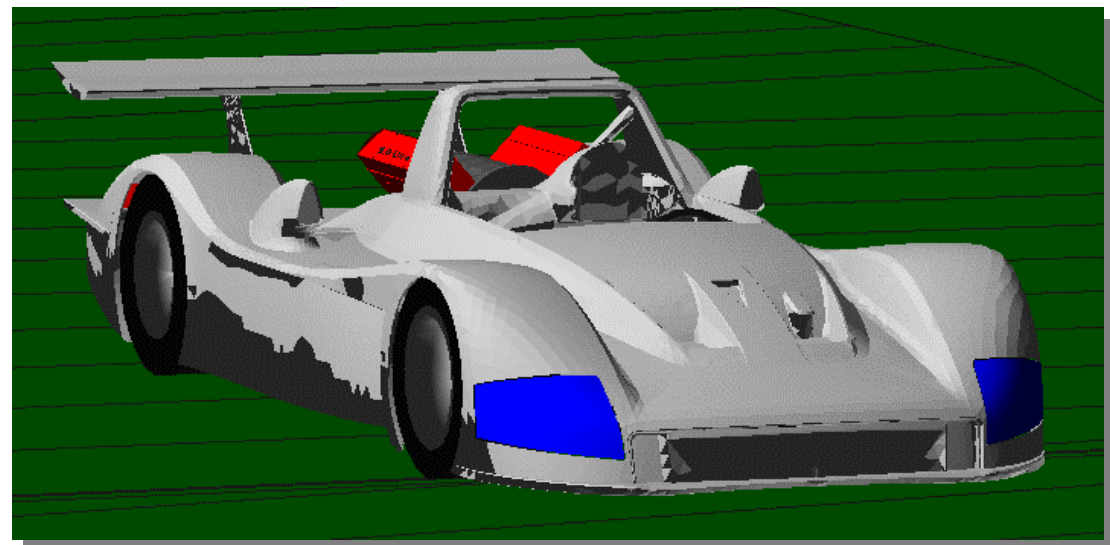
- Engine Map
- Enhanced Clutch
- Limited Slip Differential
  - Coulomb and Nonlinear Viscous Friction
- Flexible Driveshafts



# Vehicle Adjustments

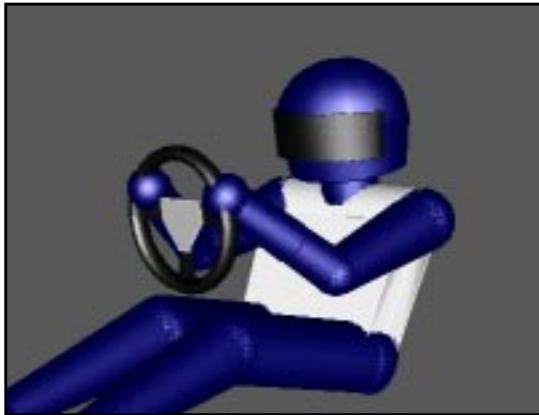


- Suspension Alignment (toe, camber)
- Driver CG and Mass
- Fuel CG and Mass
- Skidplates stiffness and heights
- Ride Heights
- AntiRollBars
- Spring Rates and Pre-Loads
- Damper Lengths
- Pushrod Rates
- Torsional Body Stiffness
- Body CG and Mass
- Aero Forces



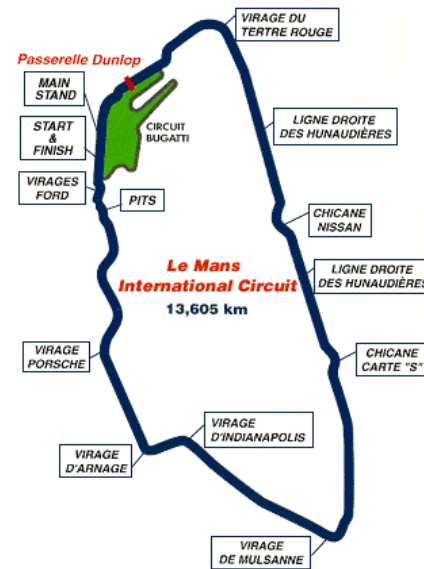
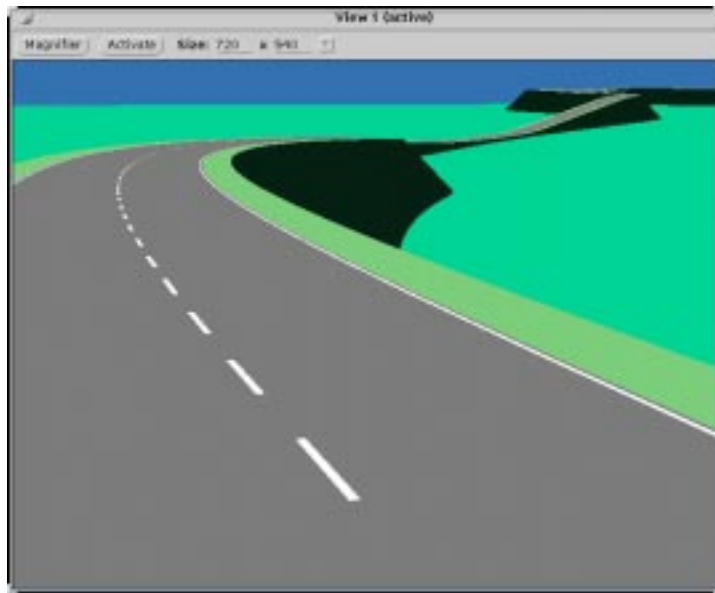


# Driver

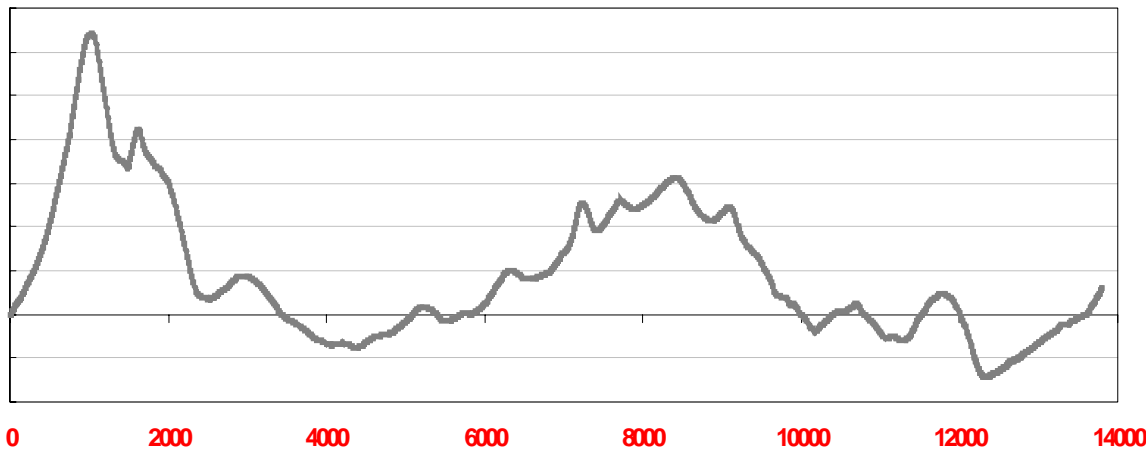


- Learns Basic Dynamics  
(less than 1 lap)
- Learns Max speed on 2D track (2-3 laps)
- Adapts to „racing“ style
- Adjustable Max Accs to compensate 3D irregularities
- Normal Tire Force Control Feed to throttle
- Max Speed Control on selected sections

# Road



- On road 3D measured data
- 2DCAD-mapped data
- Data compared and adjusted to match



— z

- Used to generate 3D Road file and Driver file

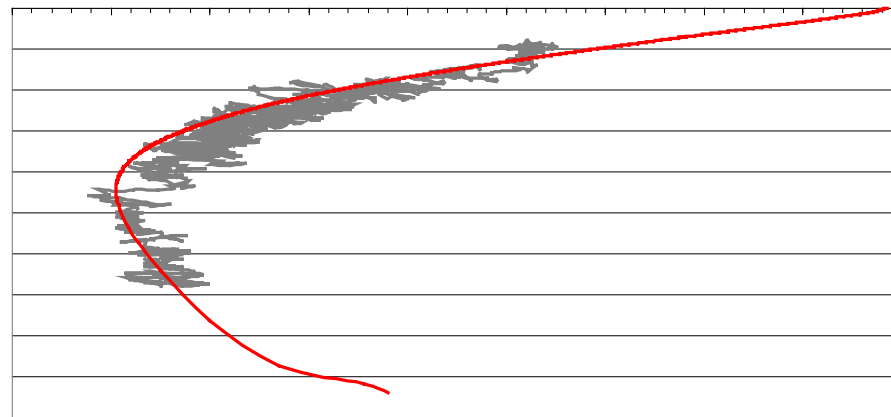
# Validation



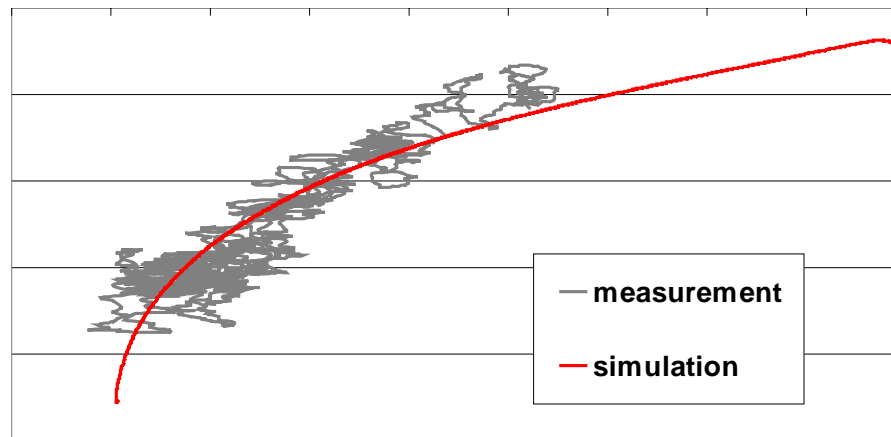
## Constant radius cornering



**lateral acceleration**

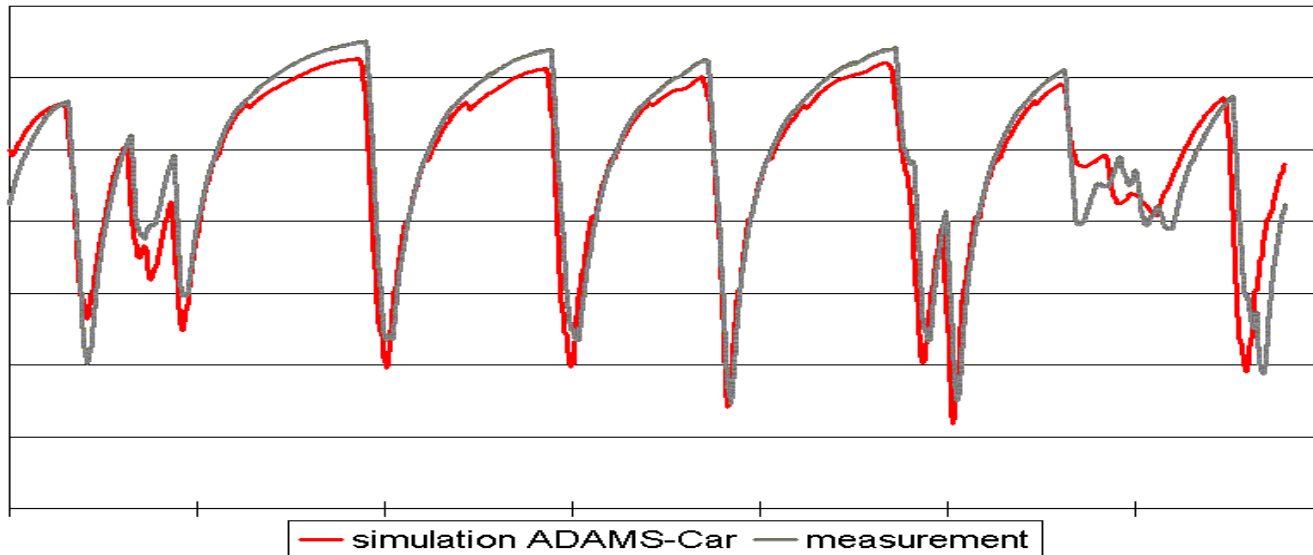


**slip angle front**

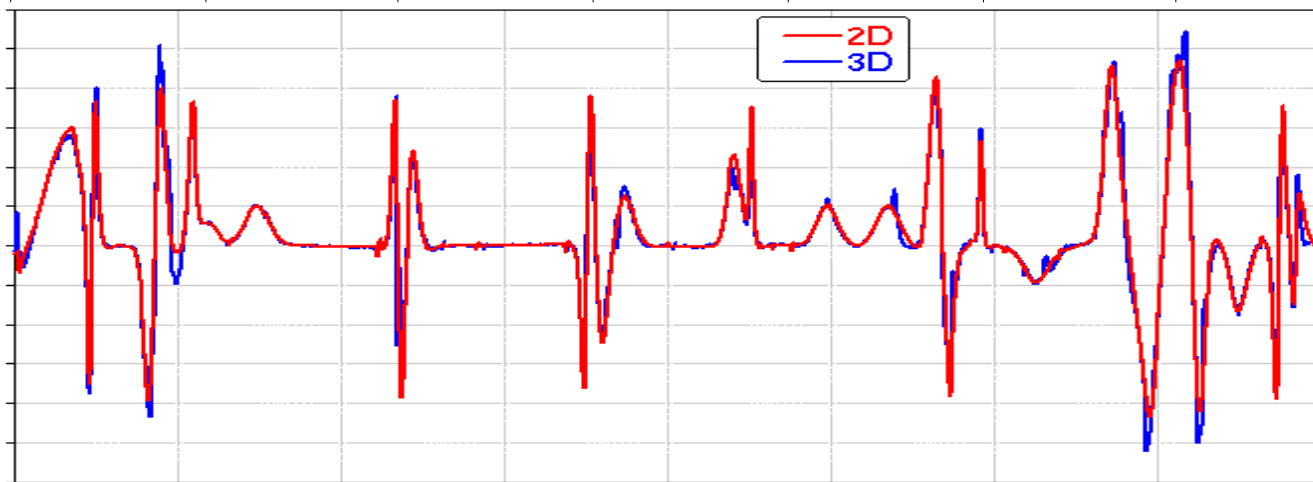


**slip angle rear**

# Simulation Results



velocity



acceleration

# Simulation Performance

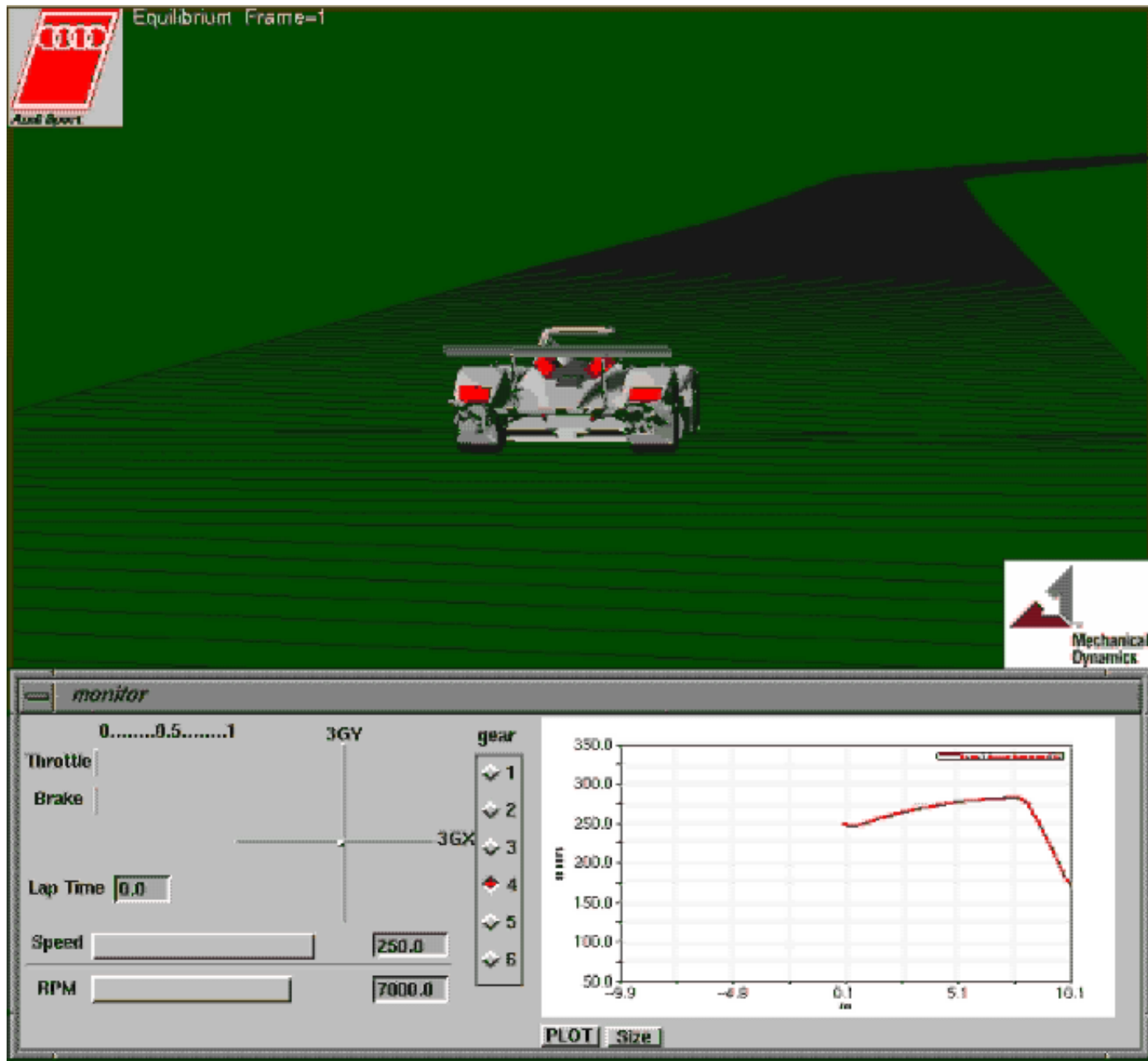
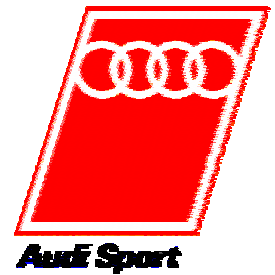
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- **Model runs both on 2D and 3D road**
- **Learning Max Speed process on 2D road**
- **Circuit Length: 13600 m**
- **CPU Time / Real Time = 40**
- **ADAMS/Driver Estimated Lap time: 220 sec. (close 1-2% to the real car on Le Mans Track)**



# Simulation Visualisation



# Conclusions

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- **Simulation helps to understand critical dynamic conditions on the 3D road surface**
- **Need more precise 3D road data measurements**
- **Driver learning process to take into account more complex vehicle-road parameters**
- **Tire model to take into account thermal influence on adhesion**
- **Simulation data will be used to improve the design of the vehicles for the years 2000, 2001**