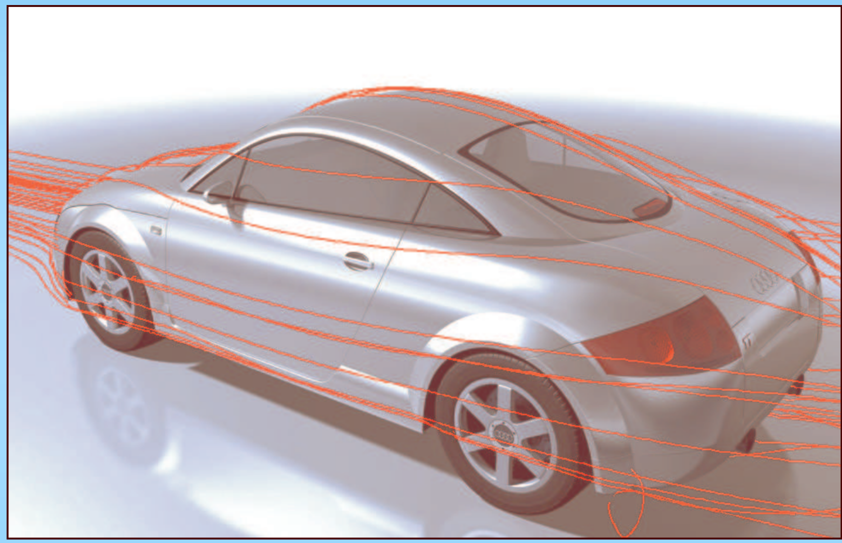
VEHICLE AERODYNAMICS

Introduction



Alessandro Talamelli

Johan Westin

Mekanik/KTH

- Course layout
- Importance of vehicle aerodynamics
- Historical review
- Aerodynamics as part of the design process

Why Vehicle Aerodynamics ?

Course schedule I

Week	Date	Day	Time	Room	Lecturer	
12	03-03-16	Tuesday	15-17	D2	AT	
12	03-03-17	Wednesday	13-15	V2	AT	
12	03-03-19	Friday	13-15	D3	GB	Ext. lecture
13	03-03-23	Tuesday	15-17		AT	
13	03-03-24	Wednesday	13-15		AT	
14	03-03-30	Tuesday	15-17		AT	

Course schedule II

Week	Date	Day	Time	Room	Lecturer	
18	03-04-27	Tuesday	15-17	D2	AT	
18	03-04-28	Wednesday	13-15		AT	
18	03-04-30	Friday	13-15	D3	SS	Ext. lecture
19	03-05-04	Tuesday	15-17		AT	
19	03-05-05	Wednesday	13-15		AT	
19	03-05-07	Thursday	8-18	MTL	AT	
19	03-05-07	Friday	13-15	D3	PE	Ext. lecture
20	03-05-11	Tuesday	15-17		AT	Hand in Projects
20	03-05-14	Friday	13-15	D3	ML	Ext. lecture
21	03-05-18	Tuesday	15-17	E36	AT	
21	03-05-21	Friday	13-15	D3	LM	Ext. lecture
22	03-05-25	Tuesday	9-17	???		Project Presentation

Contents

- **Introduction and general overview**
- **Kinematics and dynamics of fluids and fundamental Equations.**
- **Aerodynamic Forces – Lift and Drag**
- **Bluff body aerodynamics**
- **The Aerodynamic of a passenger car**
- **Directional Stability, Aerodynamic Forces and Moments**
- **Air Conditioning and Noise**
- **High performance vehicles**

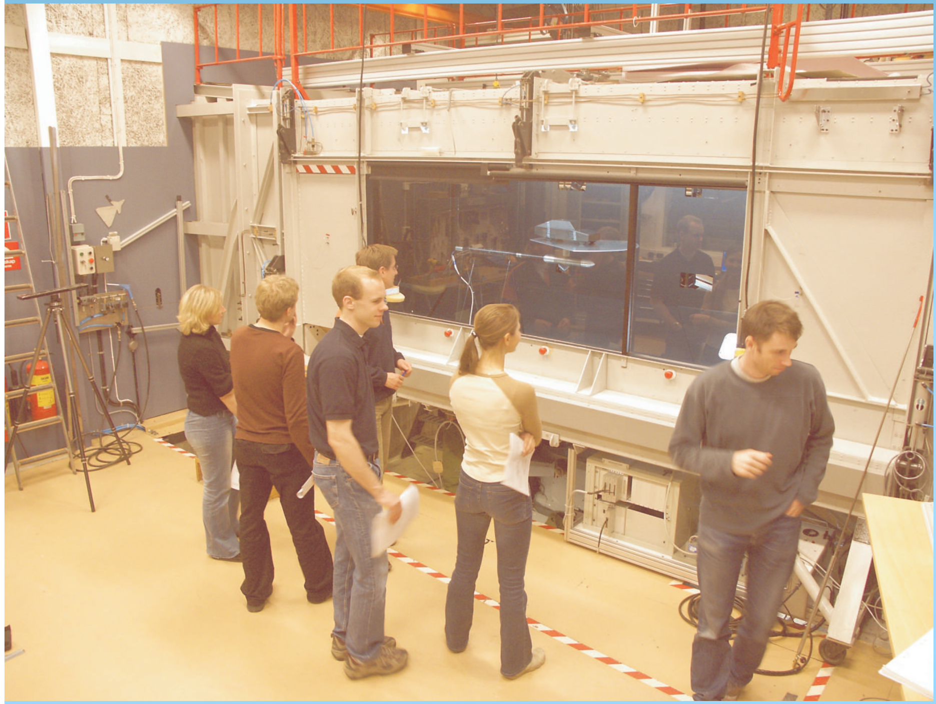
Lecturer

Alessandro Talamelli, Mekanik
Phone: 790 7582
E-mail: talamelli@mech.kth.se

TUESDAY – THURSDAY from 3 p.m. to 5 p.m.

Johan Westin, Mekanik
Phone: 790 7582
E-mail:johan.westin@vattenfall.com

Laboration



External lecturers I

March, the 19st

The Influence of Aerodynamics on the Design of High-Performance Road Vehicles

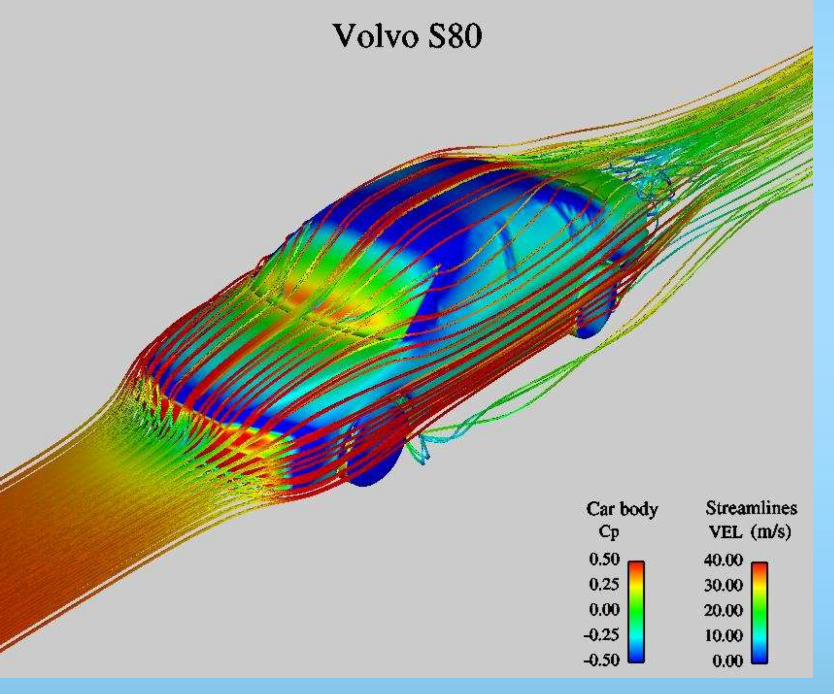
Prof. Guido Buresti

Professor in Fluid Mechanics at the Department of Aerospace Engineering
Università di Pisa (ITALY)

External lecturers II

April, the 30th

CFD at Volvo Car Corporation



Simone Sebben

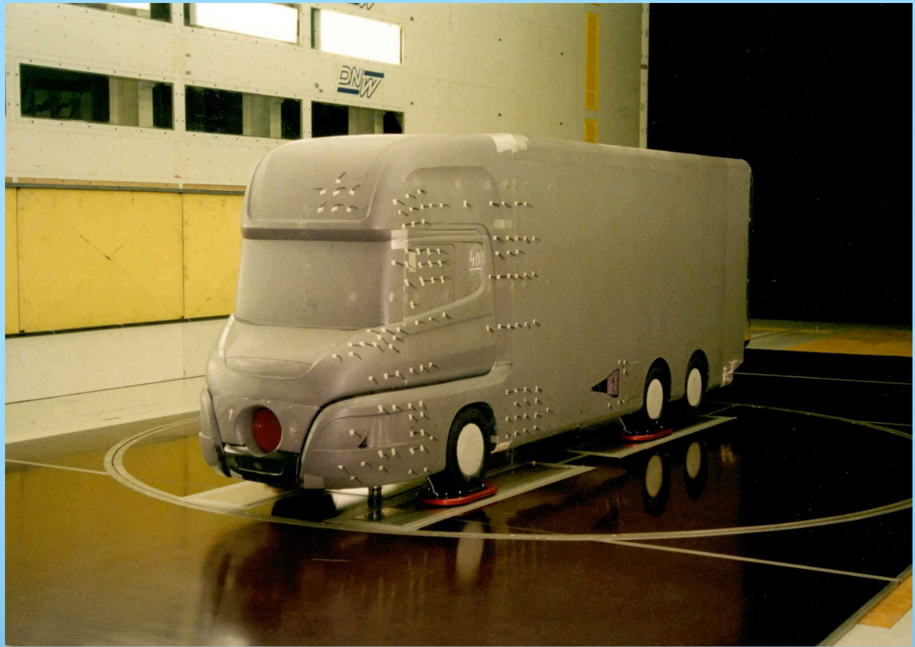
CFD Engineer Aerodynamics

Volvo CC.

External lecturers III

May, the 7th

Experimental methods in vehicles aerodynamics



Per ELOFSSON

SCANIA, Fluid Dynamics Centre

Function & Attribute leader, Aerodynamics

External lecturers IV

May, the 14th

Race-Car Aerodynamics

Matthew John LAIGHT

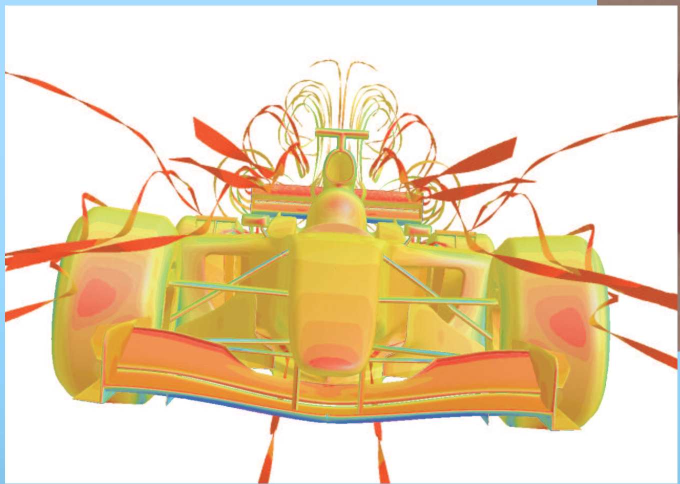
Renault F1 (formerly Benetton Formula Ltd)

Senior Aerodynamicist and Head of CFD

External lecturers V

May, the 21st

The role of CFD in the aerodynamic design of a Ferrari Formula 1 car

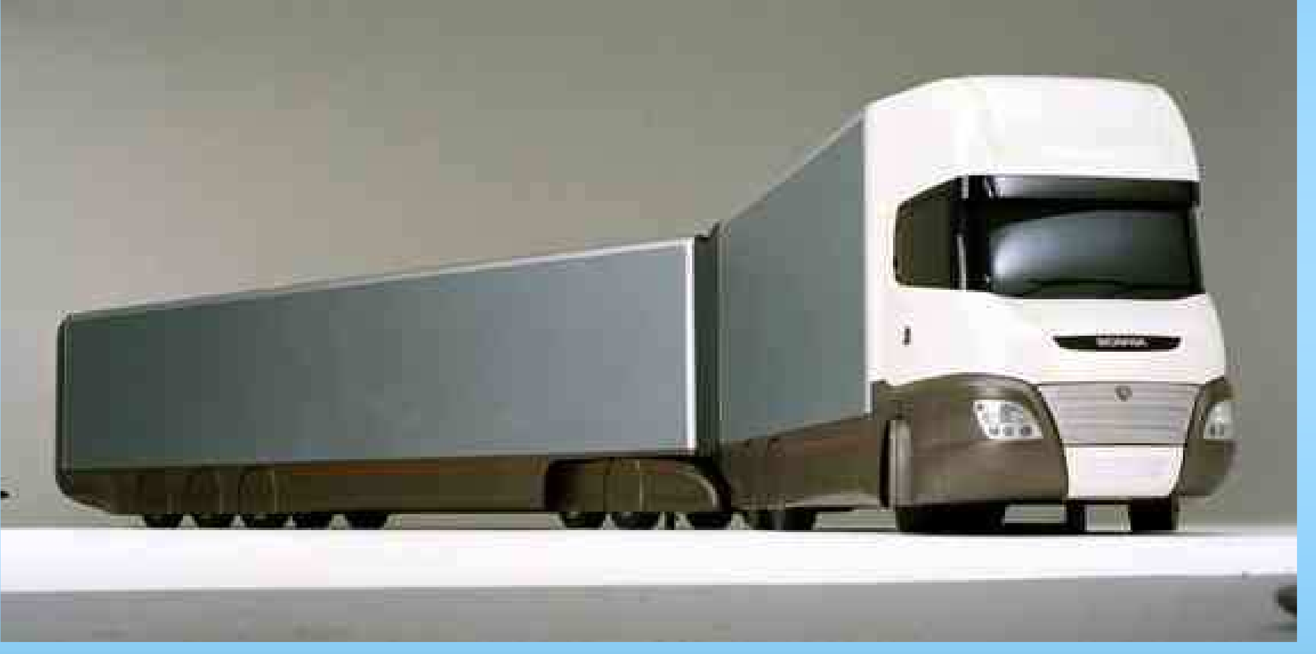


Luciano MARIELLA

FERRARI F1 GeS

External lecturers

Aerodynamics of Commercial Vehicles - Trains



Books

R.H. Barnard (2001):"Road Vehicle Aerodynamic Design, 2nd edition". MechAero Publishing, 2001. ISBN 0954073401

Hucho, Wolf-Henrich (1998) “Aerodynamics of road vehicles, 4th edition” SAE International. (can be ordered at http://www.sae.org/products/books/R-177.htm)

Additional material will be given out during the course.

Importance of vehicle aerodynamics

Both internal and external flow
(influence each other)

Importance of drag

Drag coefficient :

$$c_D = \frac{D}{\frac{1}{2}\rho V^2 A}$$

$D =$ drag force

$A =$ front area

$\rho =$ air density

$V =$ vehicle speed

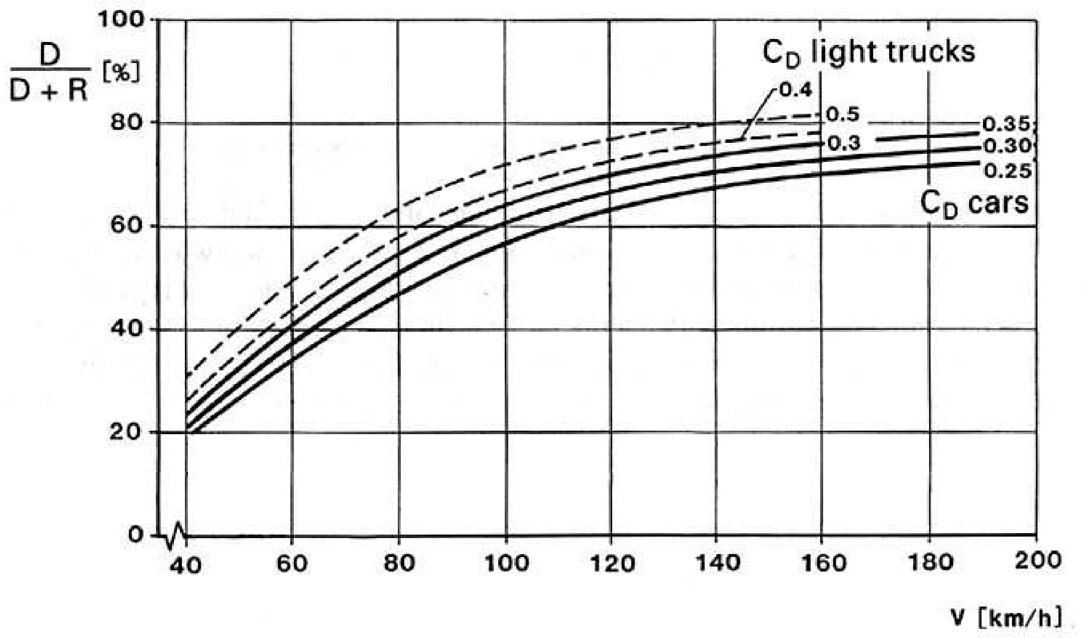
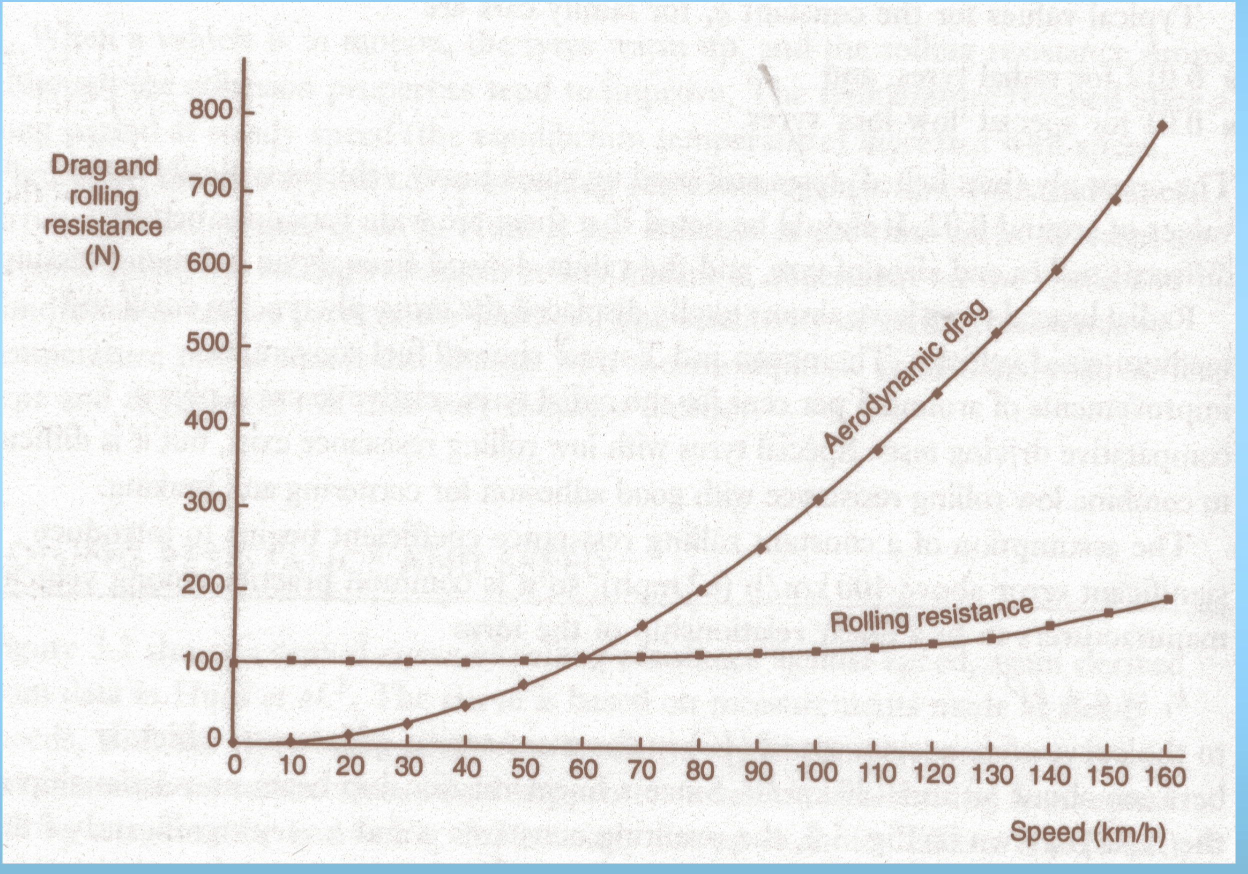


Fig. 3.6 Fraction of aerodynamic drag D in total drag D + R.

Importance of drag



Impact of drag on fuel consumption

- Reduced drag more efficient than reduced mass or installed power
- Which parameter is easiest to change?
- Important with relevant driving cycles!

Car Category	Mass [kg]	Power [KW]	Fr. Area [m^2]	C_D
A	800	40	1.76	0.36
E	1550	135	2.15	0.33

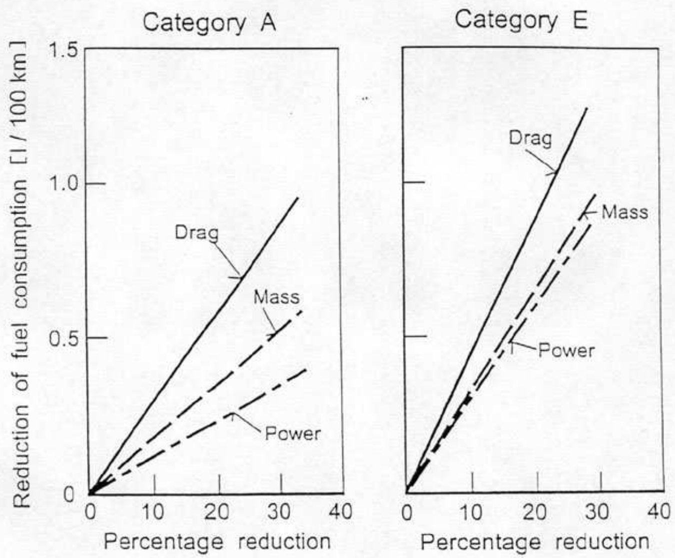
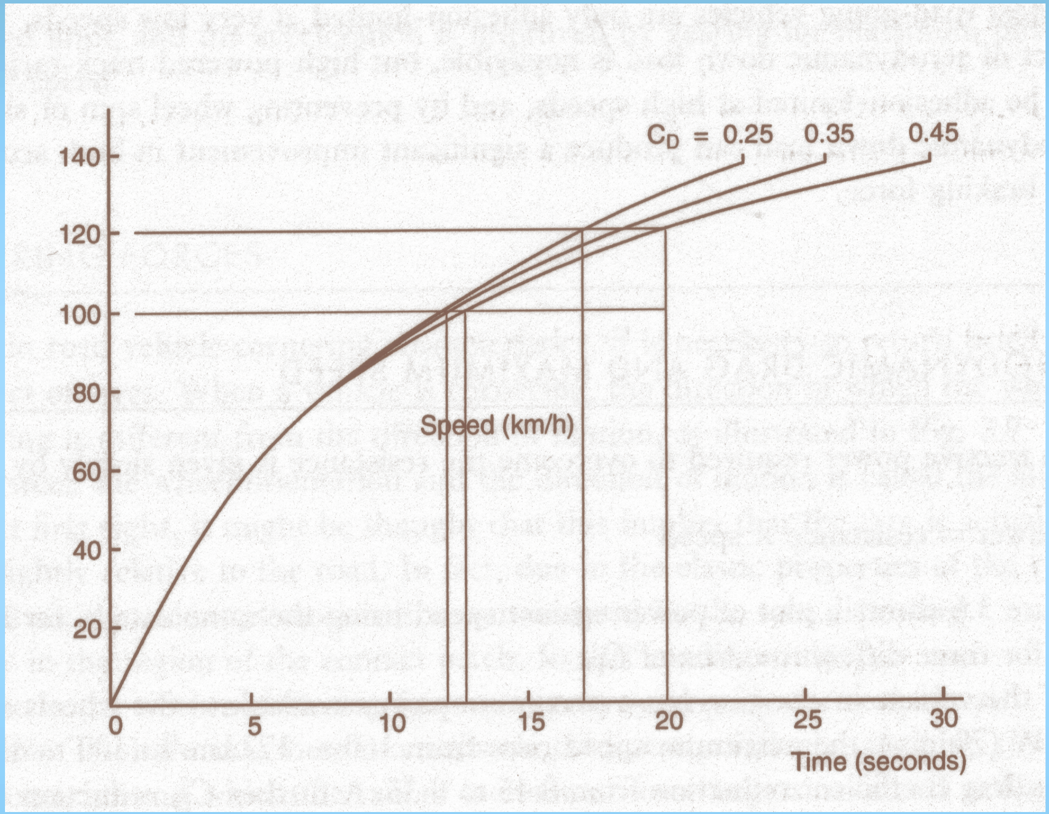


Fig. 2 Impact of Drag, Mass and Power Reduction on Fuel Consumption

From Ahmed (1999)

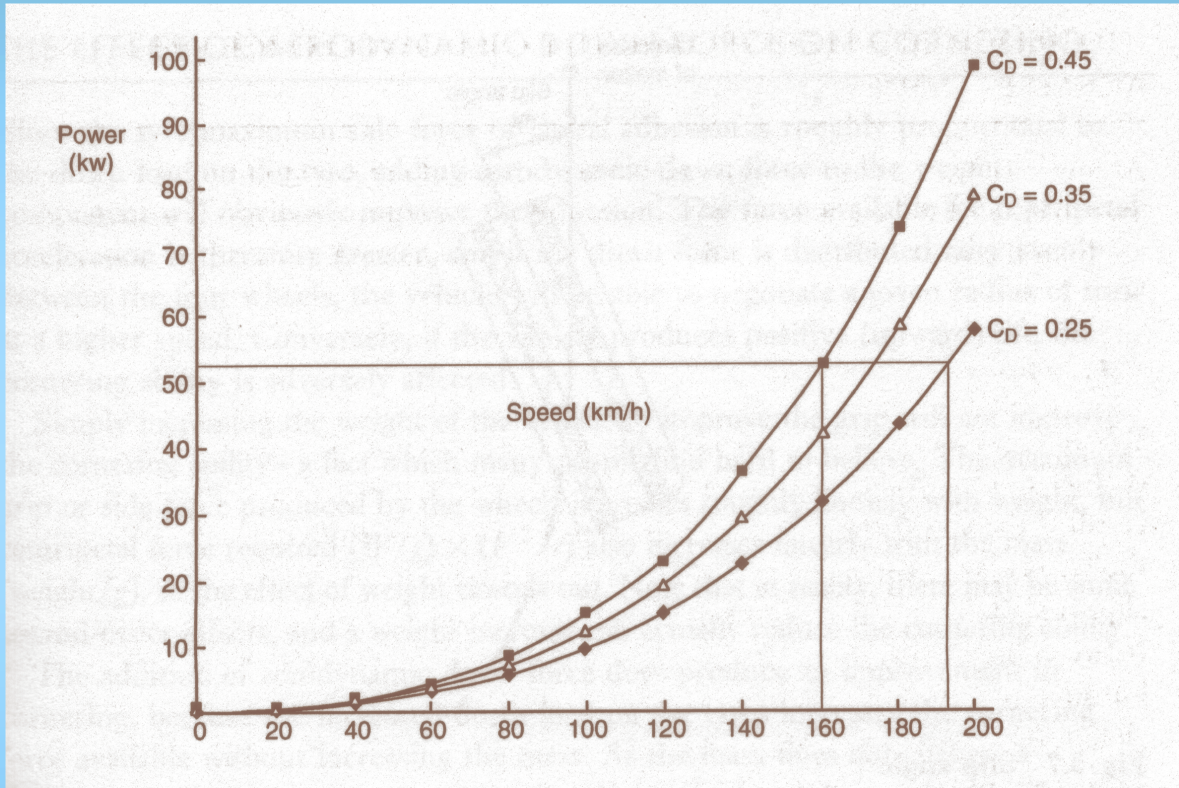
Impact of drag on acceleration



From Barnard (2001)

- Need high speed to be significant !!!!
- Ex: for 0-100 from 0.45 to 0.35 only 0.5 sec
  for 0-120 km/h 1.5 sec

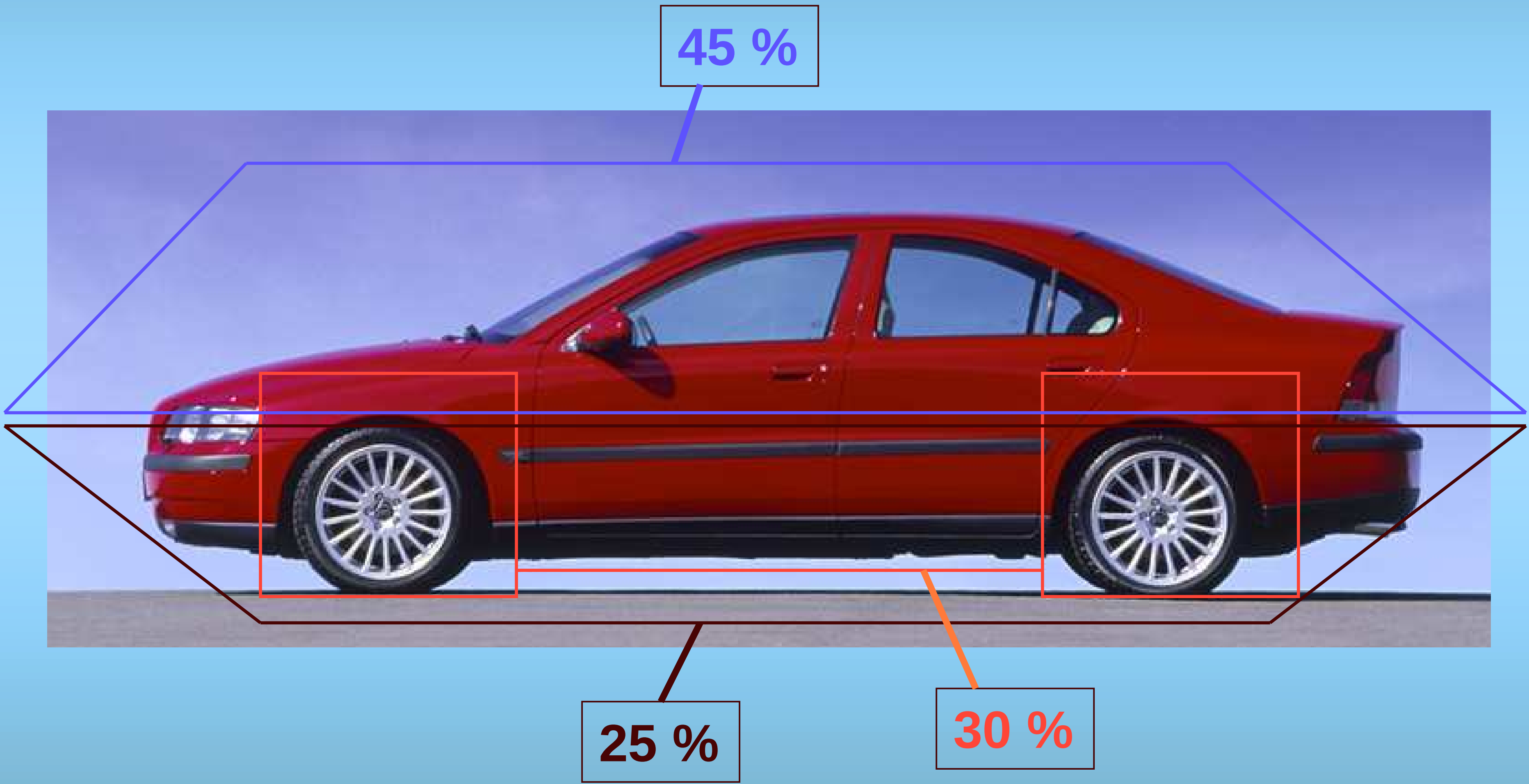
Impact of drag on maximum speed



From Barnard (2001)

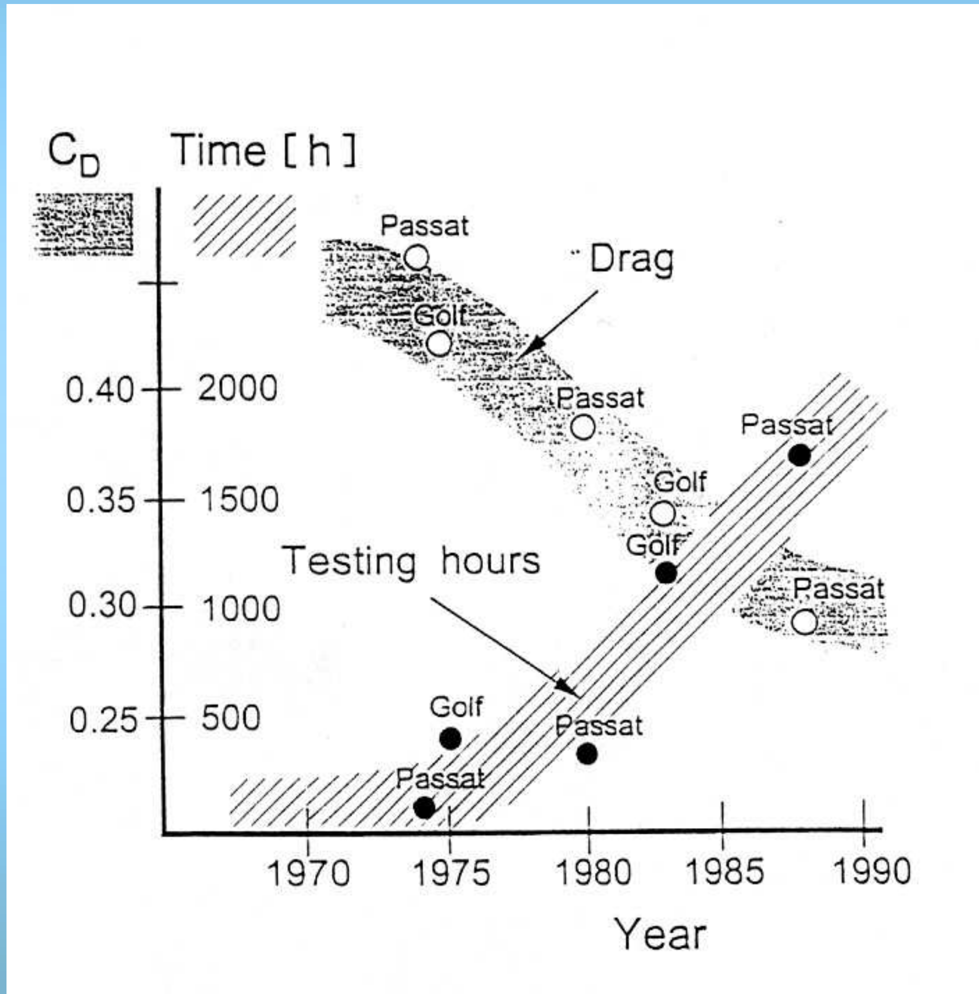
- Possible only if maximum power is developed at maximum speed

Source of drag on a modern car



Wind tunnel testing hours at VW

- More effort to achieve modest drag reduction
- Limited by economy?



Influenced by fashion

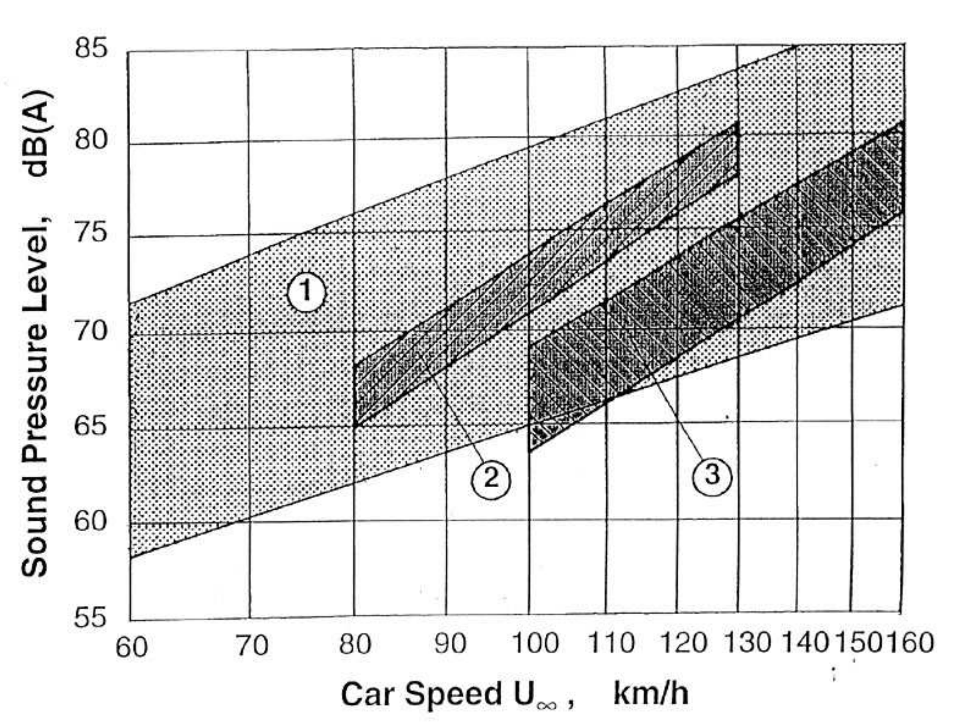
Chrysler PT Cruiser

BMW X5

Aerodynamically induced stability problems

Aerodynamical noise

Exterior noise



1 = tire noise
2 = airflow noise of pick-ups
3 = airflow noise of cars

Sources for fluctuating pressure

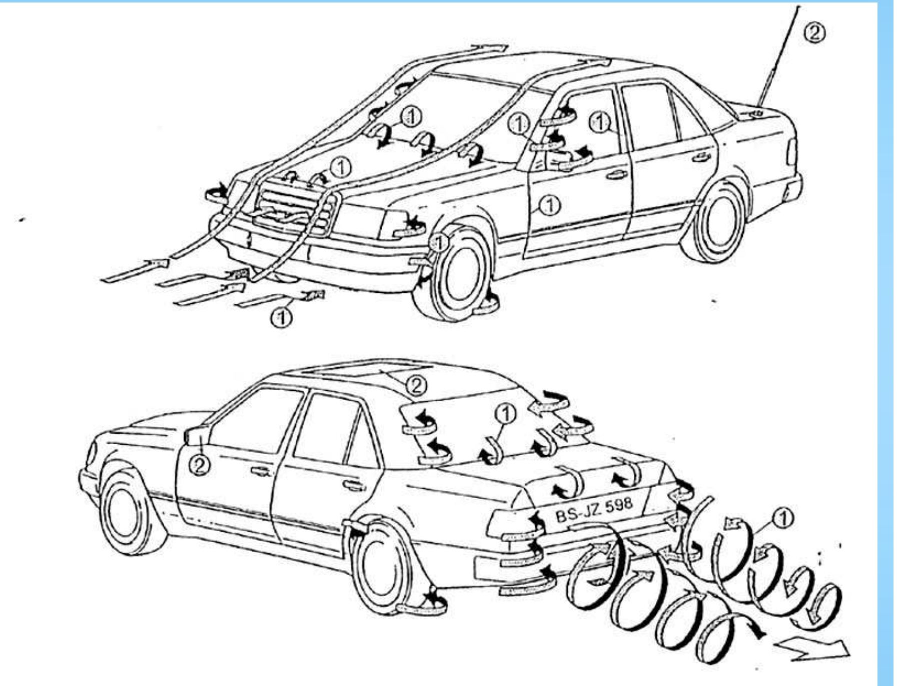


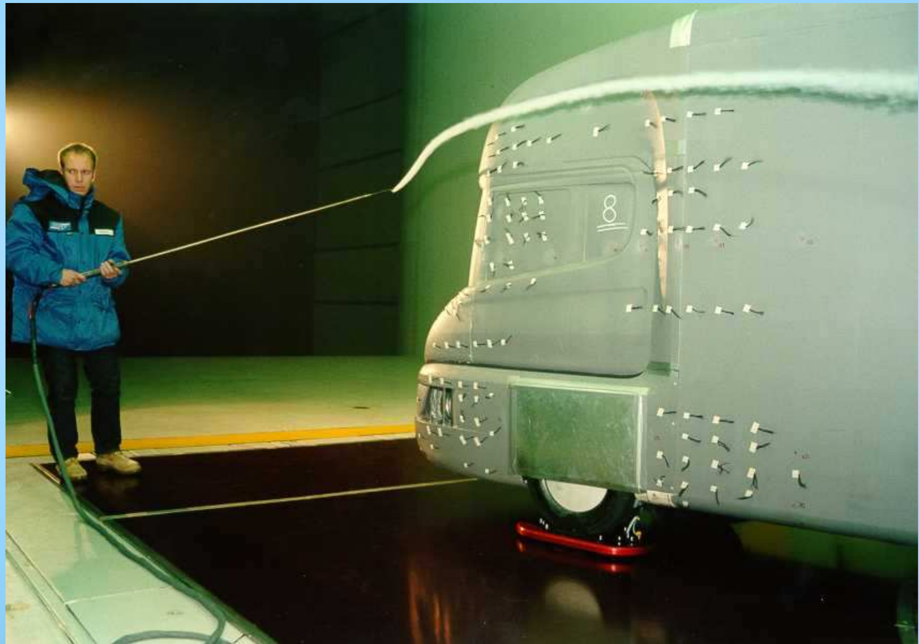
Fig. 18 : Fluctuating pressure locations on a car body

Aerodynamics crucial for race cars

Teknikens Värld 19/99

Aerodynamics of commercial vehicles

Scania press release
14/10-99



"Wind-tunnel tests have shown that the boattail on the trailer alone reduces air drag for the whole combination by more than 10 percent, an improvement that corre- sponds to fuel savings from perhaps a decade of engine research and development."

Aerodynamics of motorbikes

Aerodynamical differences

Cars

- Bluff bodies
- Large viscous regions
- Low aspect ratio (3D)
- Strong interaction between body parts
- Ground effects

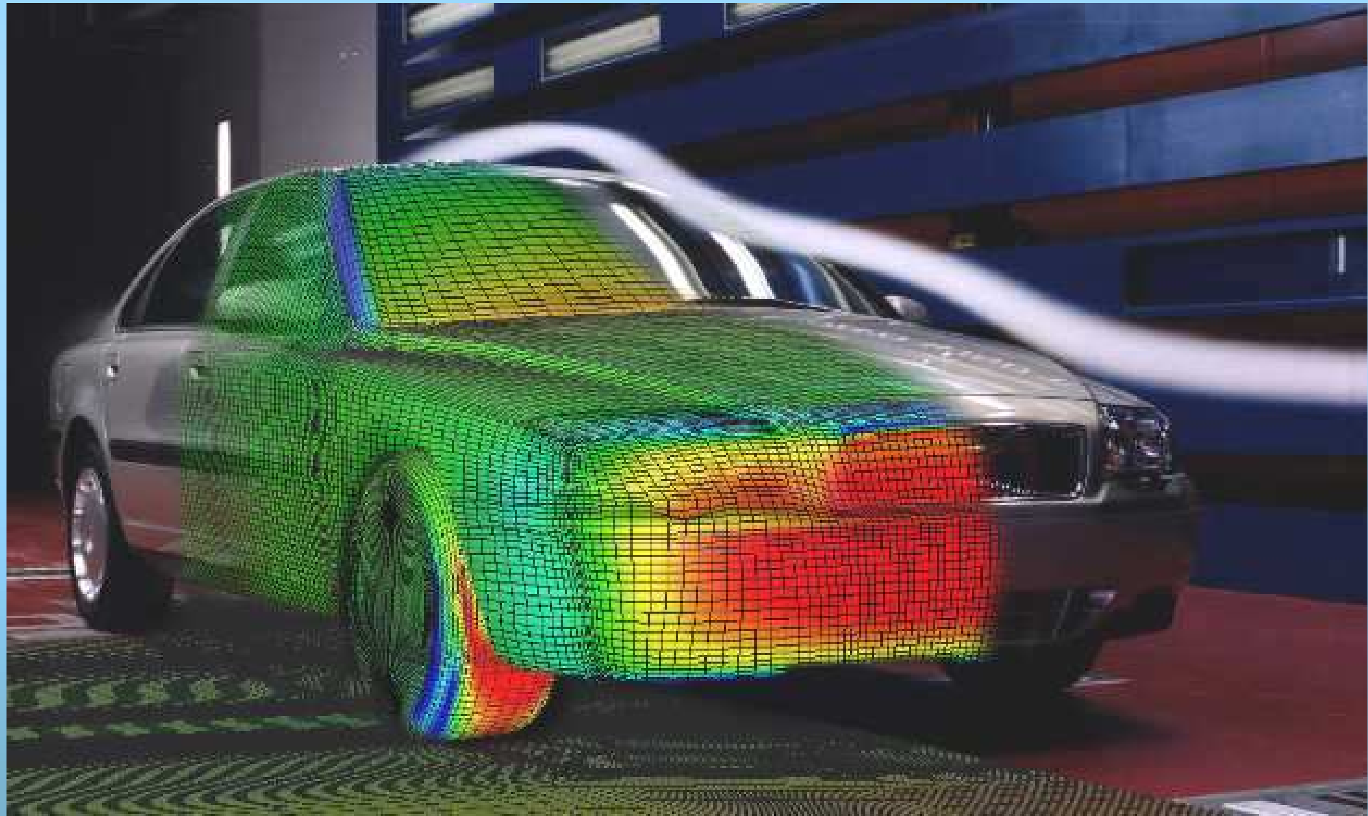
Airplanes

- Streamlined
- Inviscid flow dominates
- High aspect ratio (partly 2D)
- Step-by step optimization

Car aerodynamics still dominated by empiricism!

Advanced analysis methods required

- Computational Fluid Dynamics (CFD)
- Wind-tunnel test



Historical review: 1900-1925

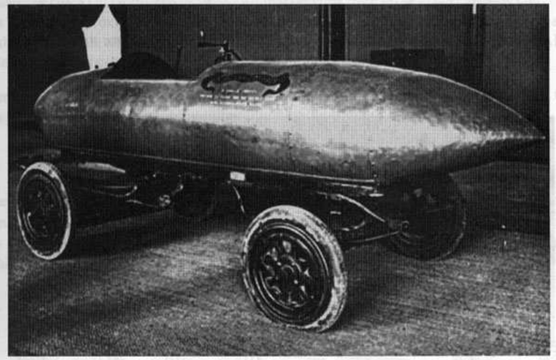


Fig. 1.11 Record-breaking car from CAMILLE JENATZY, 1899.
(Photo by Chambre Syndicale des Constructeurs Automobiles Francais)

Jenatzy
1899

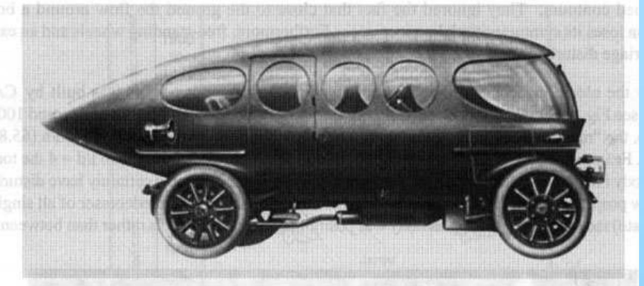


Fig. 1.12 Alfa Romeo of COUNT RICOTTI, 1914. (Photo and exposure Alfa Romeo)

Alfa Romeo
1914

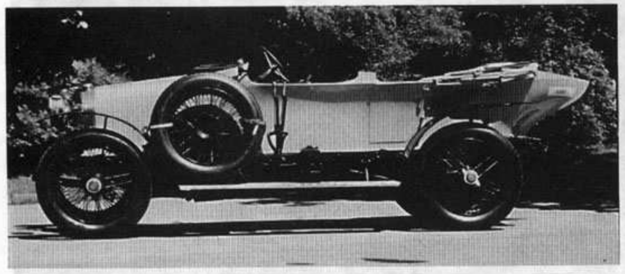


Fig. 1.13 Boat-tailed "Audi Alpensieger," 1913. (Photo and exposure Deutsches Museum, Munich)

Boat-tail
1913

- Borrowed shapes from aeronautics & ships
- Did not consider ground effects
- Free standing wheels gives disturbances

Streamlined cars 1920-

Rumpler's teardrop car (1922)

c_D=0.28

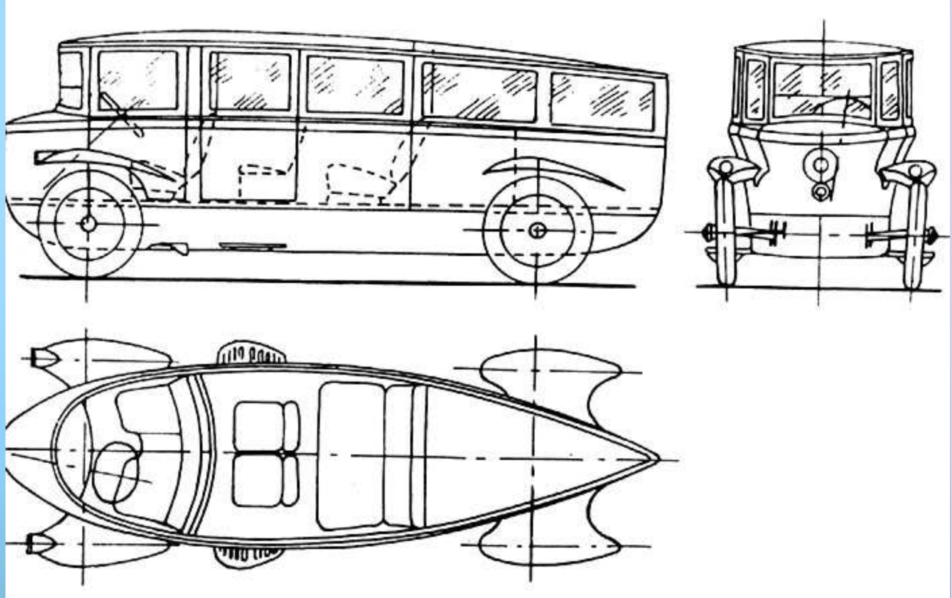
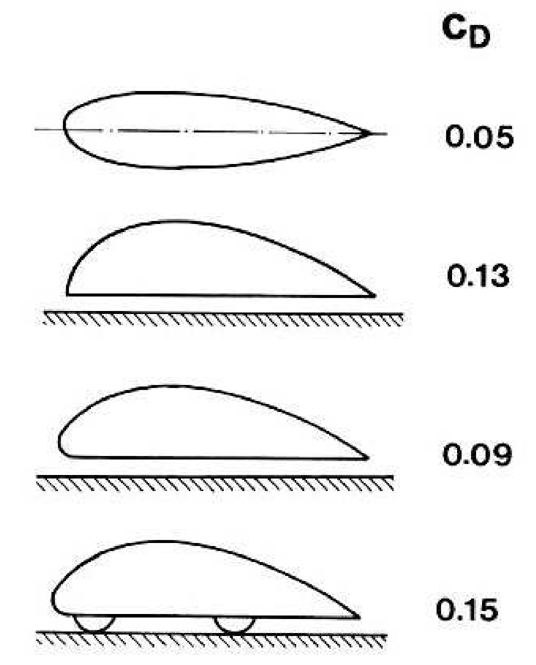


Fig. 1.14 RUMPLER's "teardrop" limousine, 1922.

- Body shaped as 2D wing profile
- Cambered roof and smooth underbody to avoid end-effects
- Low c_D despite open wheels

Streamlining based on aeronautical know-how

Klemperer & Jaray (ca 1922)



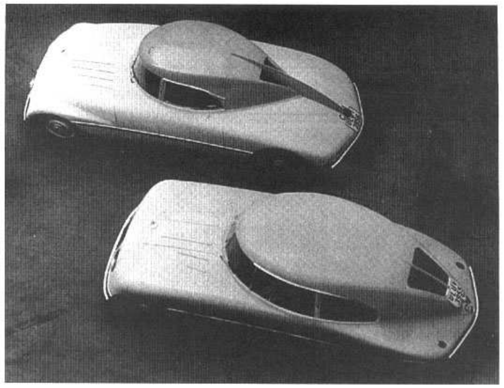


Fig. 1.27 Two typical Jaray cars, made by Huber & Brühwiler, Luzern, 1933-34. Top: 2L Audi; bottom: Daimler-Benz Type 200. (Courtesy R.F.J. Kieselbach)

Jaray cars
1933-34

- Study ground effect on a body of revolution
- Started to develop cars based on combinations of streamlined bodies
- Revolutionary shapes for that time
- Low c_D (ca 0.30, instead of typically 0.7, without cooling flow)
- Too long tails (Jaray-back) (separation)
- Difficult to find byers!!

Lange-car (1937)

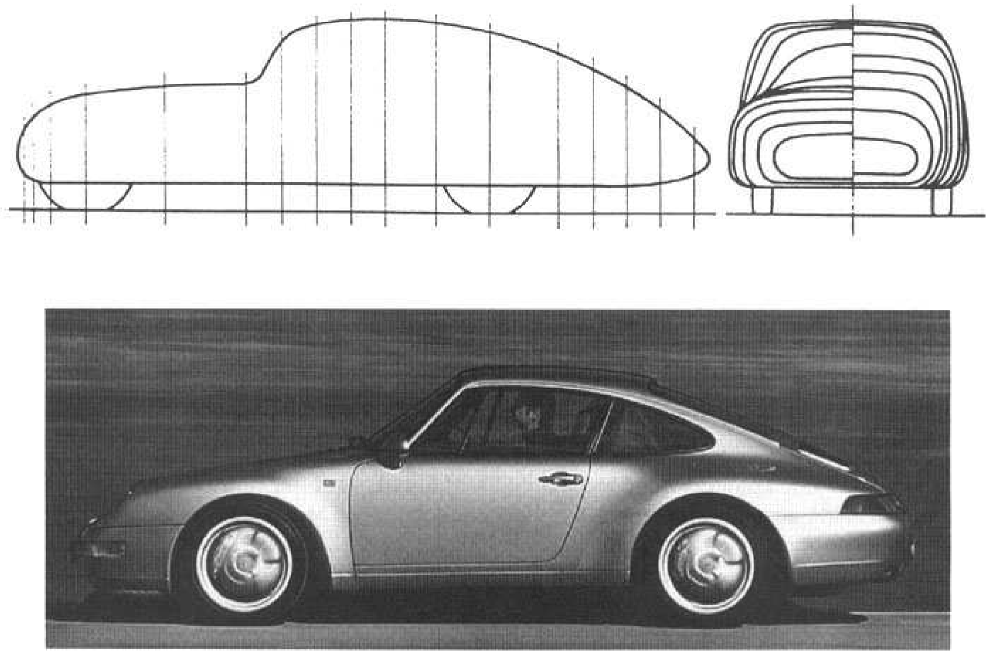


Fig. 1.32 a) Lines of the "Lange-car," $c_D = 0.14$, completely smooth model; b) Porsche 911 Carrera, MY 1995, $c_D = 0.33$, $A = 1.86\ m^2$. (Courtesy Porsche AG)

- Based on two horizontal wing profiles
- c_D=0.16 of smooth model

Kamm-back (ca 1939)

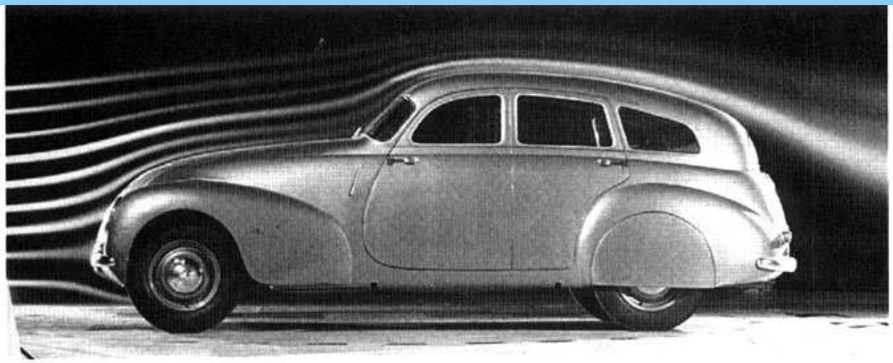
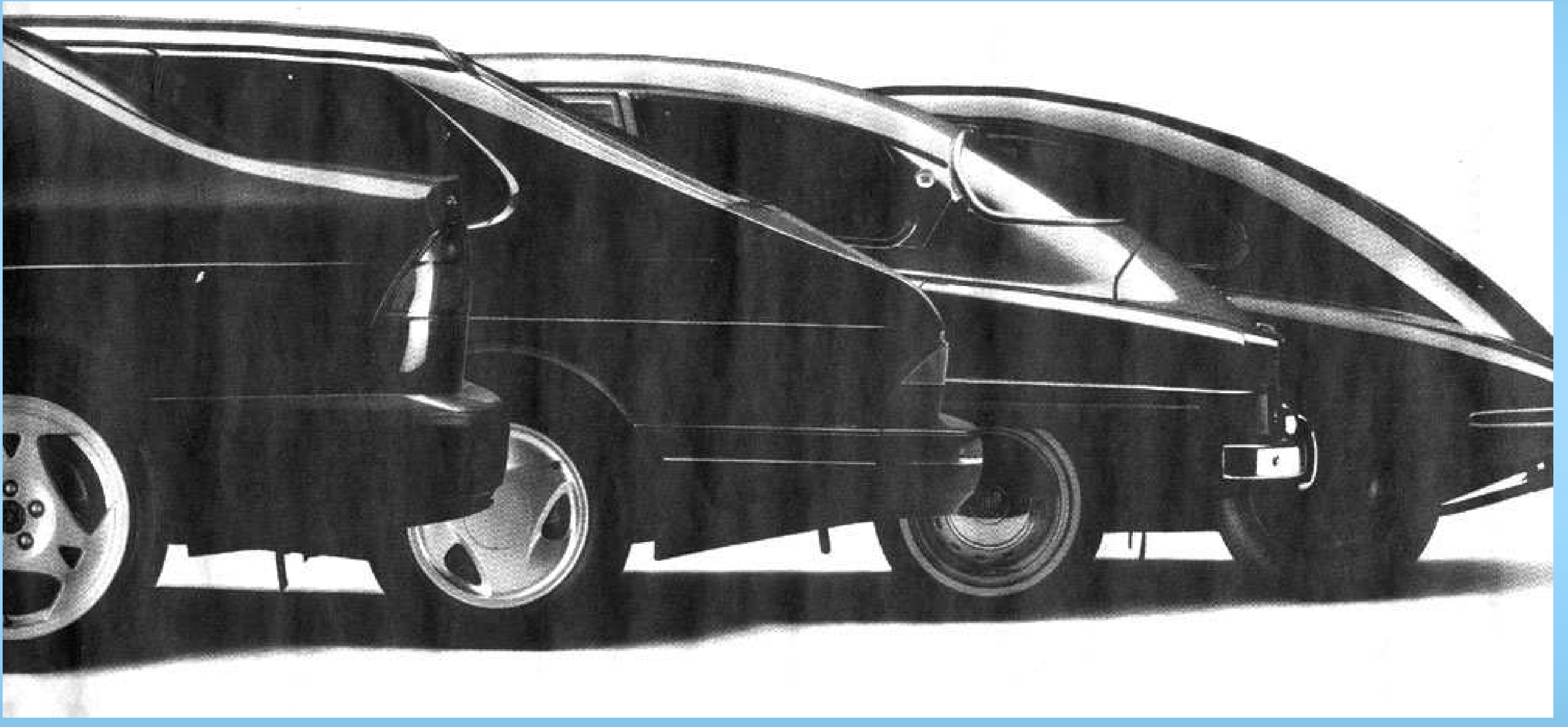


Fig. 1.37 Kamm car K3 from 1938-39 in the large climatic wind tunnel of Volkswagen AG. (Photo Volkswagen AG, exposure Langenburg Castle)

- Introduced blunt trailing edge
- Truncated the body just upstream separation point
- Kamm K3: c_D=0.37 (real car)
- More “useful” shapes than Jaray

Fiat Ecobasic c_D=0.28
(TV 1/2000)

Development of rear end shapes



Development of production cars

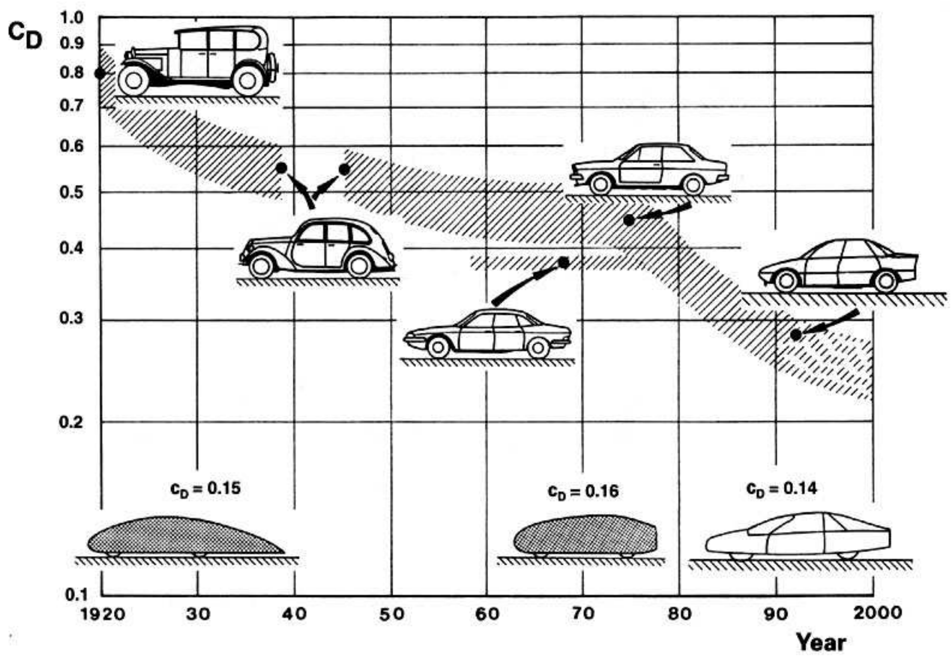


Fig. 1.58 History of drag coefficient c_D of European passenger cars in comparison to low drag configurations and a research car, the Ford Probe V.

- Despite all streamlined bodies cars looked like carriages during 20-30’s (c_D≈0.7-0.8)
- After WWII: three-volume body (cd≈0.45)
- Oil crisis 1973: Increased focus on aerodynamics (**Detail optimization**)

Alternative routes to low drag

1) Detail optimization
(basic shape from designers viewpoint)

2) Shape optimization
(start from a streamlined basic shape)

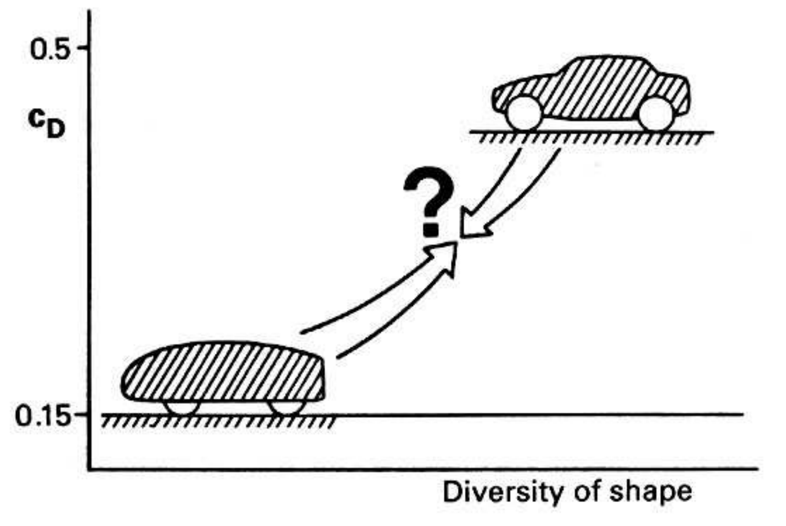


Fig. 1.65 Alternative routes to low-drag shapes.

Limitations how far you can reach with detail optimization
(Hucho: difficult to reduce c_D below 0.4)

Historical review

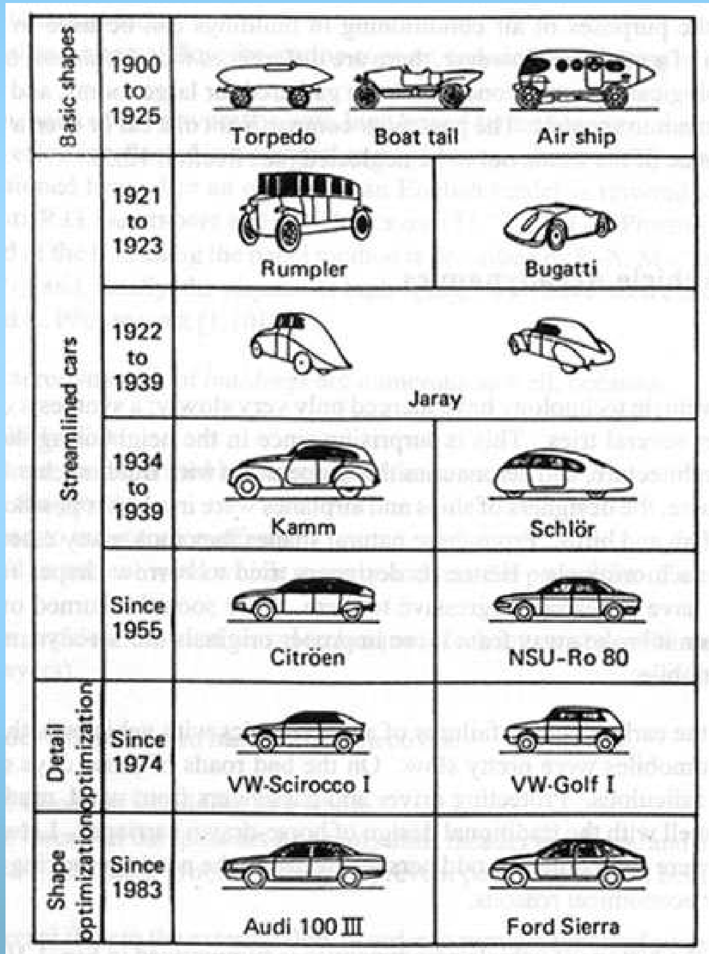


Fig. 1.10 History of vehicle aerodynamics in passenger cars.

- Reached the limit of detail optimization
- Old ideas of Jaray and Kamm re-evaluated today (shape optimization)

Present status

Histogram of c_D of production cars (1995)

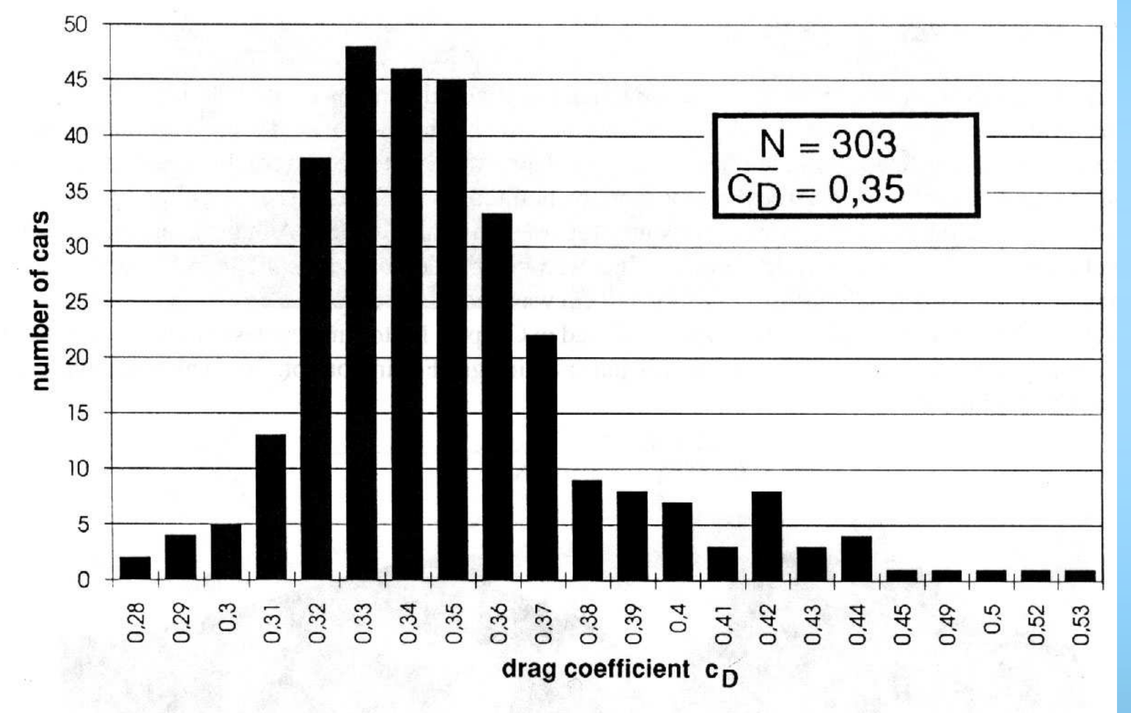


Fig. 1.56 c_D-histogram of cars for sale in Europe 1995. (Courtesy B. Leie, Volkswagen AG)

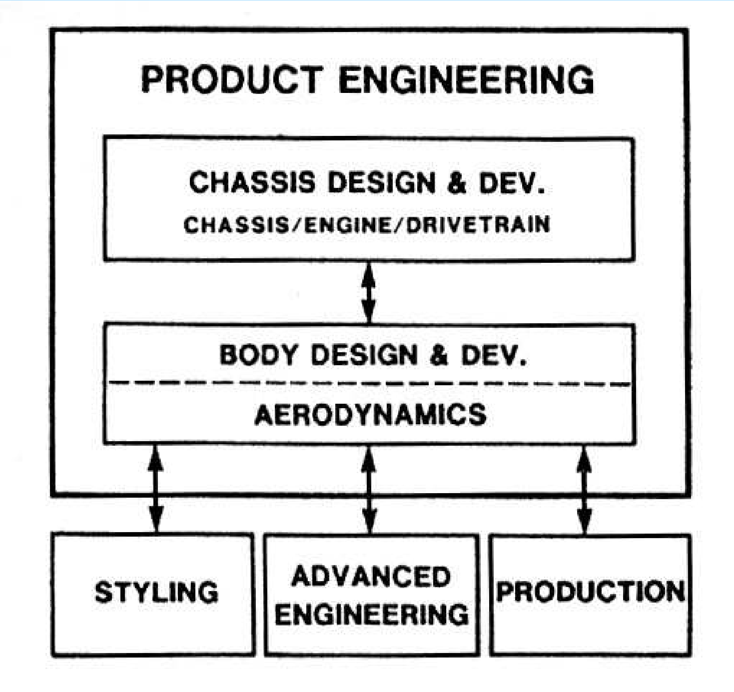
Today: average c_D close to 0.30 (?)

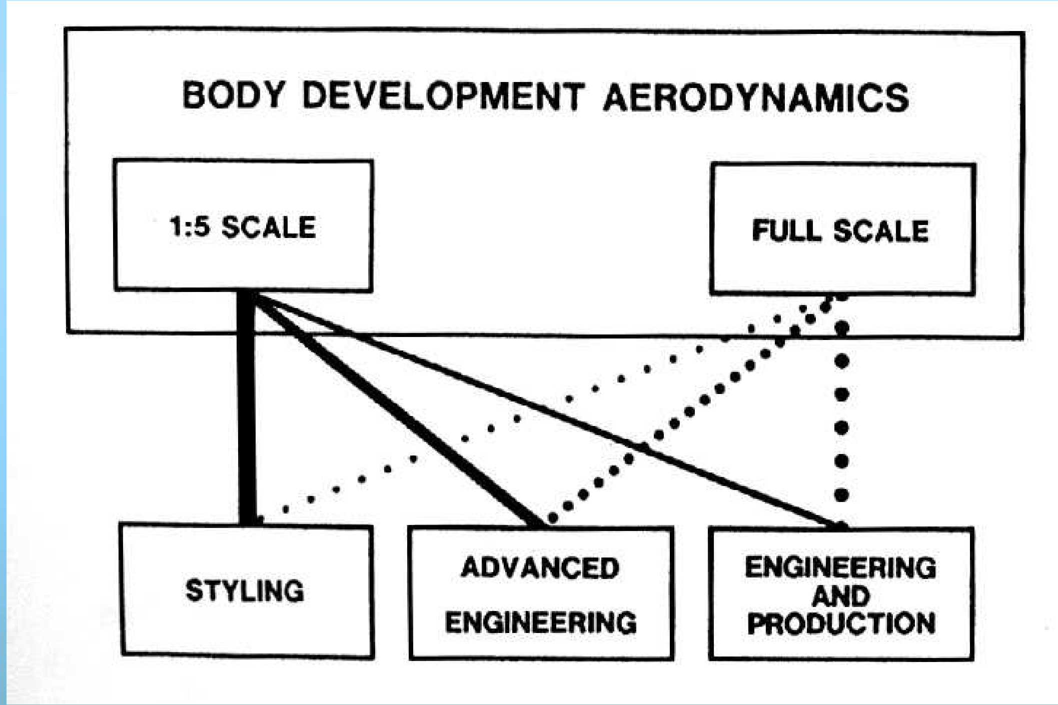
Aerodynamics as part of the design process

The development of Opel Calibra (c_D=0.26)

Organisation

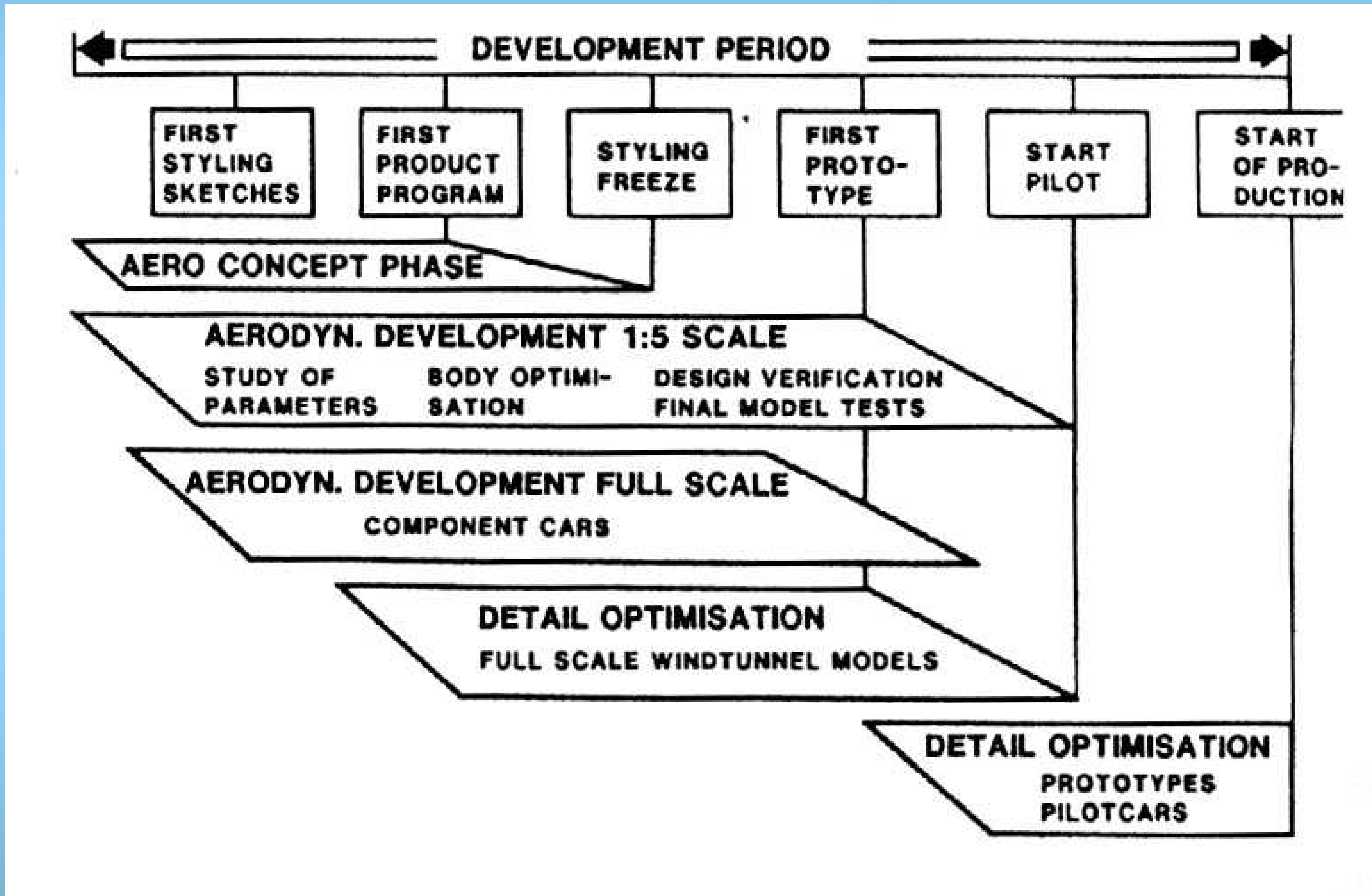
Interaction within the organisation





From Emmelman, Berneburg & Schulze (1990)

Aerodynamic timing (Opel Calibra)



From Emmelman, Berneburg & Schulze (1990)

General remarks

- Write down unanswered questions during the course!
- Suggest a subject which you find interesting (literature study)
- Suggestions/criticism on how to improve the course