Aerodynamics at Volvo Car Corporation KTH 2008

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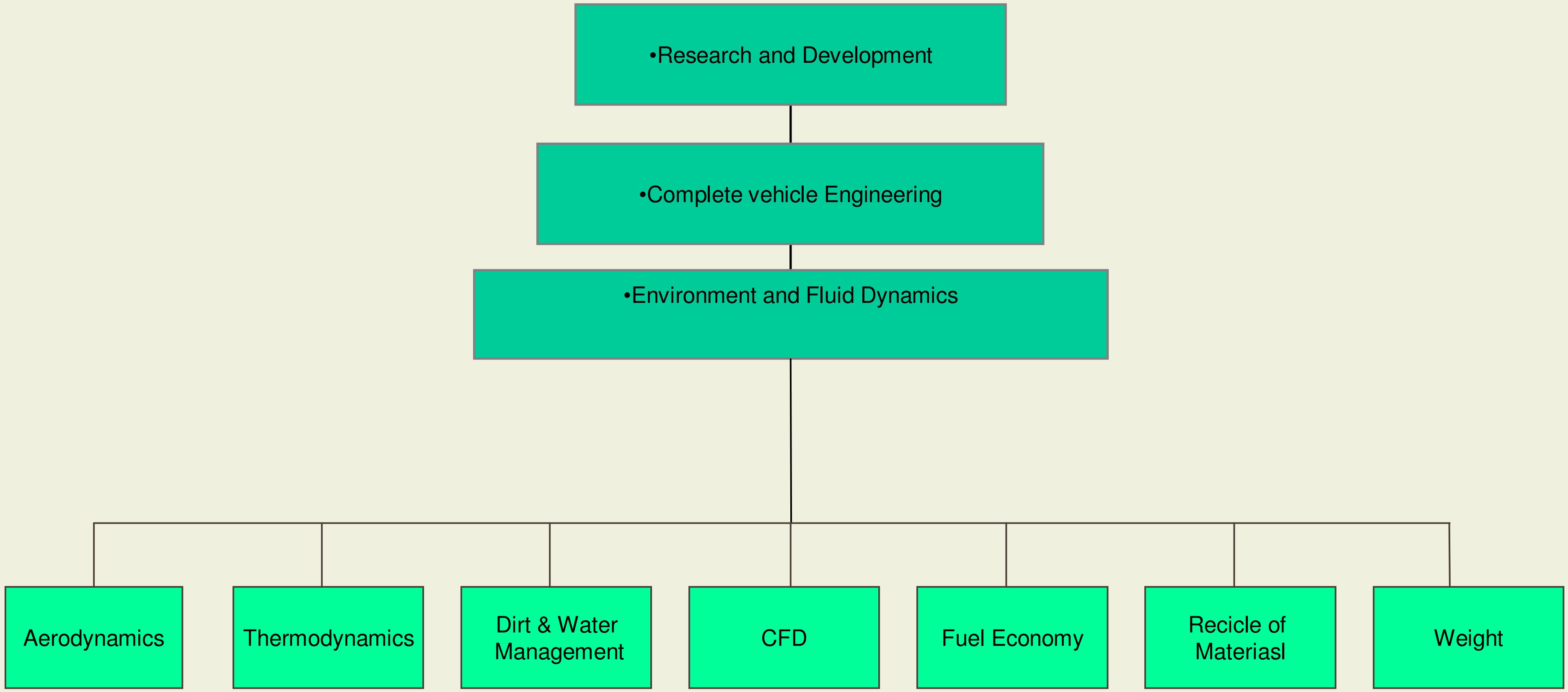
Volvo Car Corporation

Overview

- Organisation
- Influence of Aerodynamics on Passenger Cars
    - Why is aerodynamics important
- Development
- Facilities
    - Test Techniques
    - Moving Ground

VCC Environmental & Fluid Dynamics Centre



VCC Environmental & Fluid Dynamics Centre

Thermodynamics	Aerodynamics	CFD	Dirt & Water.
Cooling Performance Thermal Environment: Engine bay Floor Air Intake / Intercooler	Drag Stability	Aerodynamics Climatic Comfort Thermodynamics Aeroacoustics Water/Dirt Manag.	Dirt Deposition Water Tightness
13 People: 3 Mechanics 2 B.Sc. 7 M.Sc. 1 Lic.	11 People: 1 Mechanics 7 M.Sc. 1 Lic. 1 Ph.D	15 People: 5 M.Sc. 2 Lic. 8 Ph.D	13 People: 5 B.Sc. 7 M.Sc. 1 Lic.

Requirement specification, Customer requirements, Project management
Testing / System simulations, R&D / method development

•Plus 1 Aerodynamicist resident at the Design Studio

Influence of Aerodynamics

- Drag (fuel consumption, top speed, acceleration)
- High-speed stability (lift)
- Cross-wind stability (side force and yawing moment)
- Passenger comfort (cabriolets)
- Dirt deposition (visibility)
- Aero acoustics (limiting the strength of sources)
- Body deformation (Door frames etc)

Calculated effect of changed CDxA on fuel consumption and performance

SI6, M66														
		delta CDxA		Performance Unchanged Final Drive changed			Performance Changed Final drive unchanged							
		[m2]	[%]		[g CO2 / km]	Equiv. [kg]	[l/100 km]	[mpg]	[g CO2 / km]	V max [km/h]	80 - 120 km/h [s]	90 km/h [l/100km]	150 km/h [l/100km]	Equiv. [kg]
S80	2WD	0,05	6,7%	0,14	3,3	25	0,084	0,30	2,0	7,0	0,2	0,16	0,51	58
		0,1	13,3%	0,28	6,7	50	0,178	0,59	4,2	13,1	0,3	0,32	1,02	122
SUV	AWD	0,05	5,3%				0,086	0,22	2,0	4,4	0,4	0,18	0,49	56
		0,1	10,5%				0,172	0,44	4,1	8,3	0,7	0,36	0,99	112

Rule of thumb:
A 10% reduction of CdxA will reduce the NEDC fuel consumption by 3%


RENAULT
VOLKSWAGEN
EUROPE'S TWO BIGGEST CAR BRANDS.
ONE BIG DIFFERENCE.
In 1998, Europe's carmakers committed themselves to cut CO_2 emissions from new vehicles to an average of 140 grammes per kilometre by 2008. That commitment is a cornerstone of European climate policy and should have also reduced our dependence on imported oil.
The EU agreed to keep quiet about how each car brand has been doing. But we think the public has a right to know.
Research commissioned by T&E shows that just a quarter of major brands have lived up to their commitment.
In 2005, only Fiat, Citroen, Renault, Ford and Peugeot were on track to reach the target.
75% of big brands are failing; some miserably. Volkswagen, Europe's biggest brand, is way off track, having cut emissions at less than half the rate of Renault, the second biggest.
Eight years ago the EU trusted carmakers to regulate themselves. That trust has been betrayed by the majority of the industry as a whole. It is now time for legally-binding standards to ensure the fuel efficiency of new cars is doubled within the next decade.
Find out more at www.transportenvironment.org
T&E is Europe's principal environmental organisation campaigning specifically on transport. Together with our 44 member organisations in 20 European countries, we work to promote an environmentally-sound approach to transport and mobility.
T&E
European Federation for TRANSPORT and ENVIRONMENT


1. FIAT
2. CITROEN
3. RENAULT
4. FORD
5. PEUGEOT
EUROPE'S BIGGEST CAR BRANDS.
SPOT THE DIFFERENCE.
6. OPEL/VAUXHALL
7. TOYOTA
8. KIA
9. SKODA
10. SEAT
11. HONDA
12. MERCEDES-BENZ
13. HYUNDAI
14. VOLKSWAGEN
15. BMW
16. VOLVO
17. AUDI
18. MAZDA
19. SUZUKI
20. NISSAN
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Research commissioned by T&E shows that by 2005 only a quarter of major brands were on track to meet the target. Fiat came top of our ranking, the only brand to have already achieved the target. 75% of big brands are failing; some miserably. Nissan came bottom, having made only a fifth of the necessary reductions. Volkswagen, Europe's biggest brand, cut emissions at less than half the rate of Renault, the second biggest.
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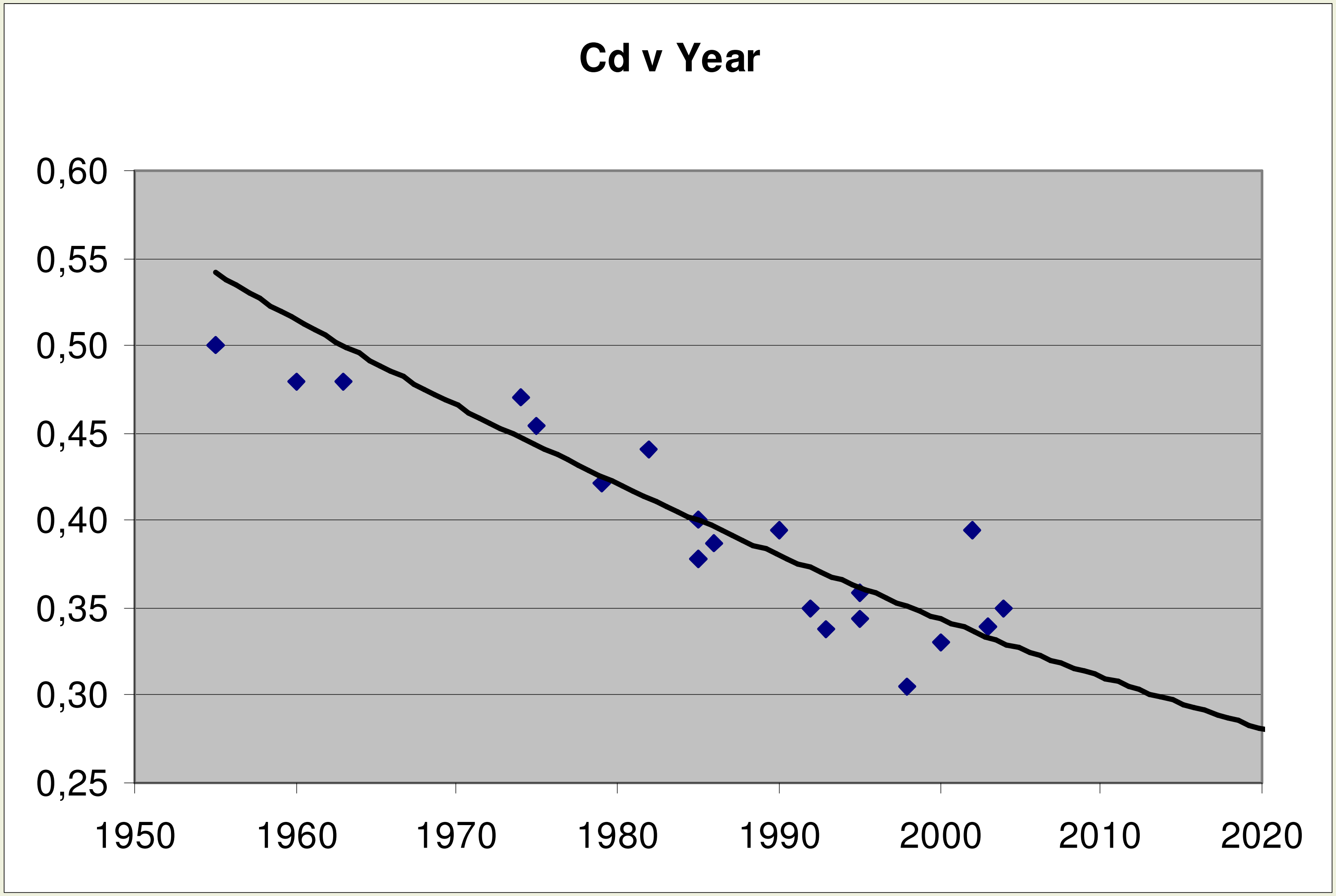
Ranking	Brand	2005 sales	CO_2 emissions in g/km			
			1997 average	2005 average	reduction 1997 - 2005	reduction target
1	Fiat	681,613	169	139	-30	-21
2	Citroen	875,389	172	144	-28	-24
3	Renault	1,361,607	173	149	-25	-25
4	Ford	1,167,602	180	151	-29	-30
5	Peugeot	1,049,819	177	151	-26	-28
6	Opel/Vauxhall	1,262,798	180	156	-24	-30
7	Toyota	704,723	189	163	-26	-35
8	Kia	231,434	202	170	-32	-44
9	Skoda	265,486	165	152	-13	-19
10	Seat	344,693	158	150	-8	-13
11	Honda	224,258	184	166	-18	-31
12	Mercedes-Benz	626,824	223	185	-38	-64
13	Hyundai	294,468	189	170	-19	-34
14	Volkswagen	1,387,628	170	159	-11	-22
15	BMW	575,087	216	192	-23	-58
16	Volvo	224,415	219	195	-24	-61
17	Audi	582,220	190	177	-13	-38
18	Mazda	214,105	186	177	-9	-32
19	Suzuki	172,941	169	165	-4	-20
20	Nissan	332,742	177	172	-5	-26

Challenges facing Aerodynamicists

- Styling
- Manufacturing
  - Parts
  - Assembly
- Packaging
- Visibility
- Other attributes (eg Thermo, dirt, handling ……)
- ”Carry-over” content
- Cost!!!

Aerodynamics through the ages

	Year	Cd
PV 544	1955	0,50
Amazon	1960	0,48
P1800	1963	0,48
P1800ES	1968	0,61
240	1974	0,47
245	1975	0,45
343	1979	0,42
760	1982	0,44
765	1985	0,40
960	1990	0,40
854	1992	0,35
855	1993	0,34
S80	1998	0,31
V70	2000	0,33
XC90	2002	0,40
V50	2004	0,35
S40N	2003	0,34
460	1986	0,39
480ES	1985	0,38
S40	1995	0,34
V40	1995	0,36



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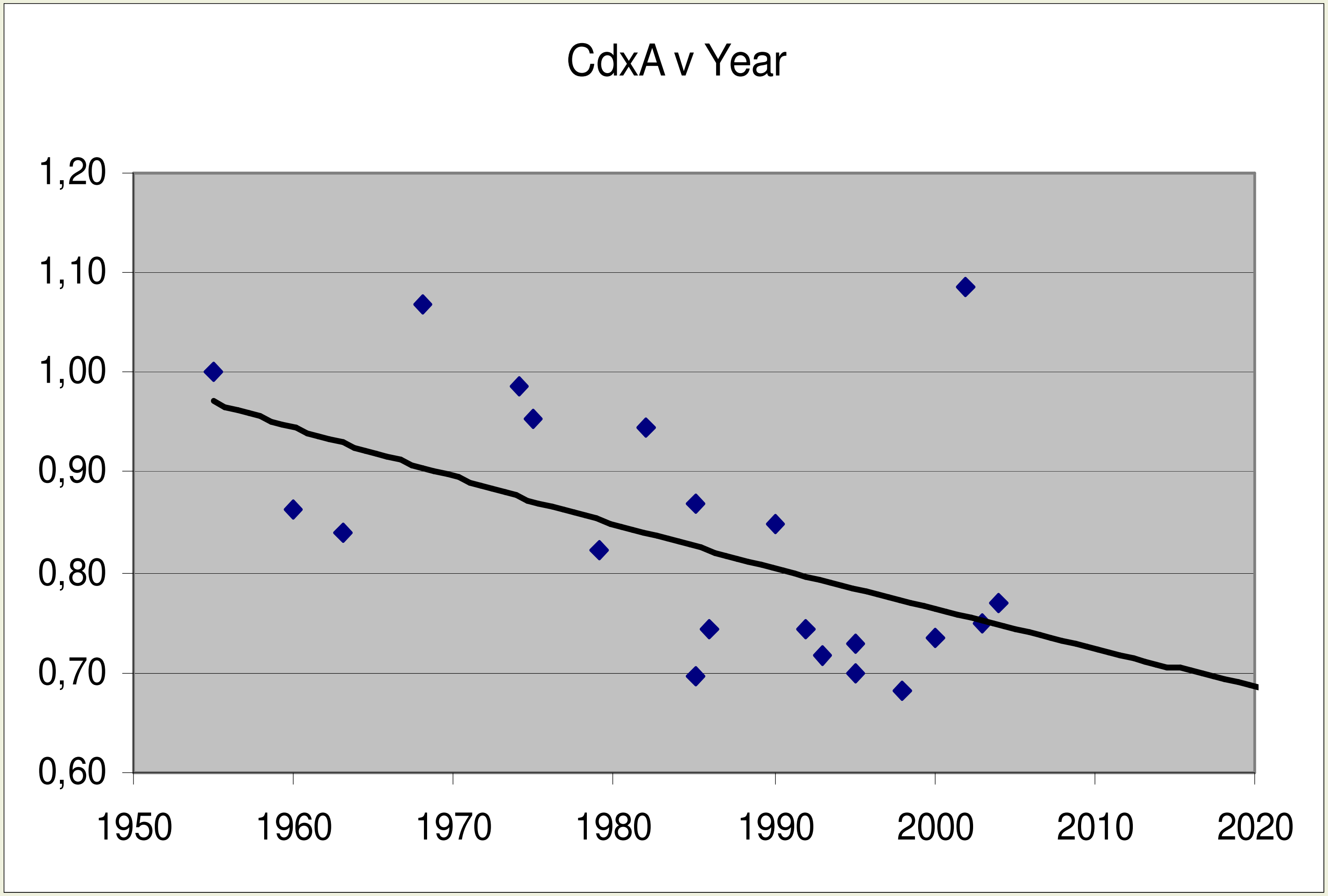

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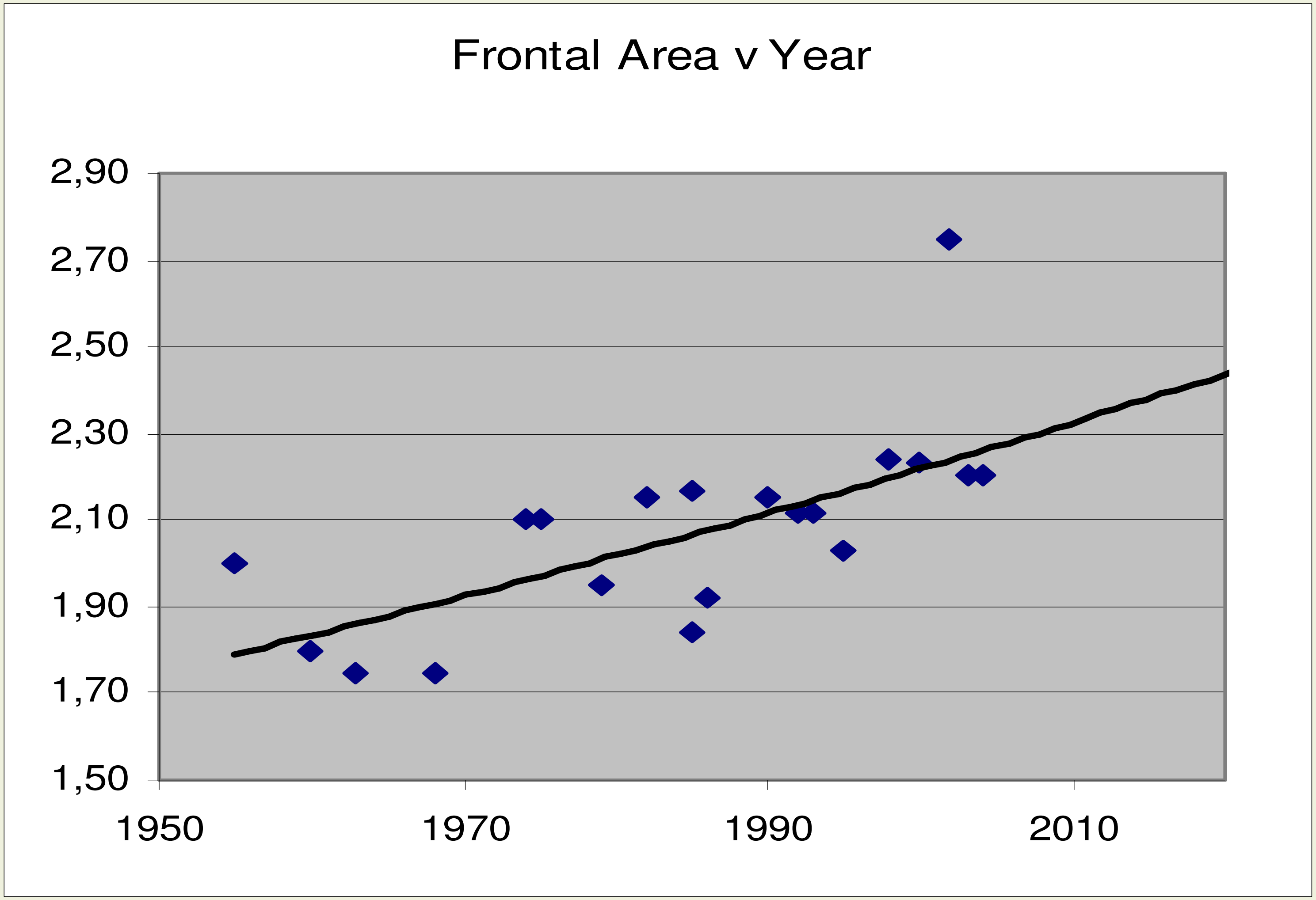


Development process

Concept study

- Generic shape studies
- Evaluate styling proposals
- Define underfloor concepts

•Analysis and research of previous models and competitors
•Simple scale model tests (parameter studies)
•Semi-detailed CFD (parameter studies)
•Create guidelines to design and engineering
•Create aerodynamic ”hard points”

Development process

Prestudy

- Develop frozen design
- Develop underfloor solutions

•Analyse and suggest improvements to many designs (CFD and models)
•Give recommendations when choosing design
•Develop and improve chosen design using full-scale clay model and fully detailed CFD modelling
•Confirm and approve the chosen design's predicted characteristics

Development process

•Fine tuning of pre-production prototypes
•Confirm and approve all characteristics
•Follow up any late design changes
•Confirm production car

Project

- Detail optimization
- Verification

36-48 months

Concept study

- Generic shape studies
- Evaluate styling proposals
- Define underfloor concepts

Prestudy

- Develop frozen design
- Develop underfloor solutions

Project

- Detail optimization
- Verification

Wind tunnel facilities at Volvo

In-house testing in three wind tunnels, Gothenburg

PVT	MWT	Climatic
Test section 27m^2 (6.6mx4.1m , length 15.8m) Max speed 250 kph Temp. +20 to 60° C Chassi dyn. load 150 kW Sun sim. max 1200 W/m^2	1:5 scale of PVT Test section 1.1m^2 Max. speed 200 kph	Test section/nozzle 11.2m^2 Max. speed 200 kph Temp range -40 to +50° C Chassi dyn. load 280 kW Sun sim. max 1200 W/m^2

Full-scale wind tunnel (PVT)

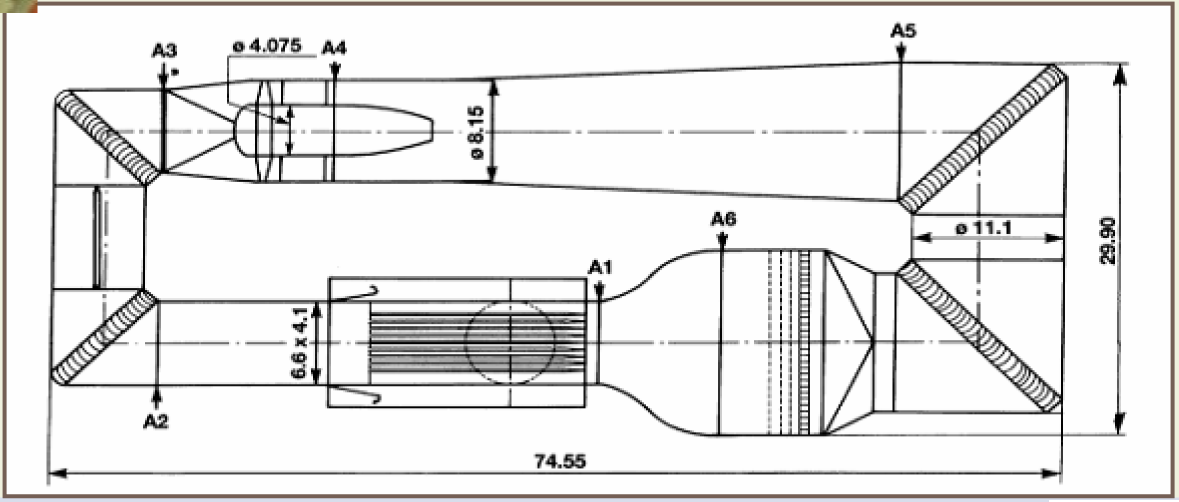
Test capabilities:

Aerodynamics

Hot Climate/Thermo

Soiling

Wind Noise



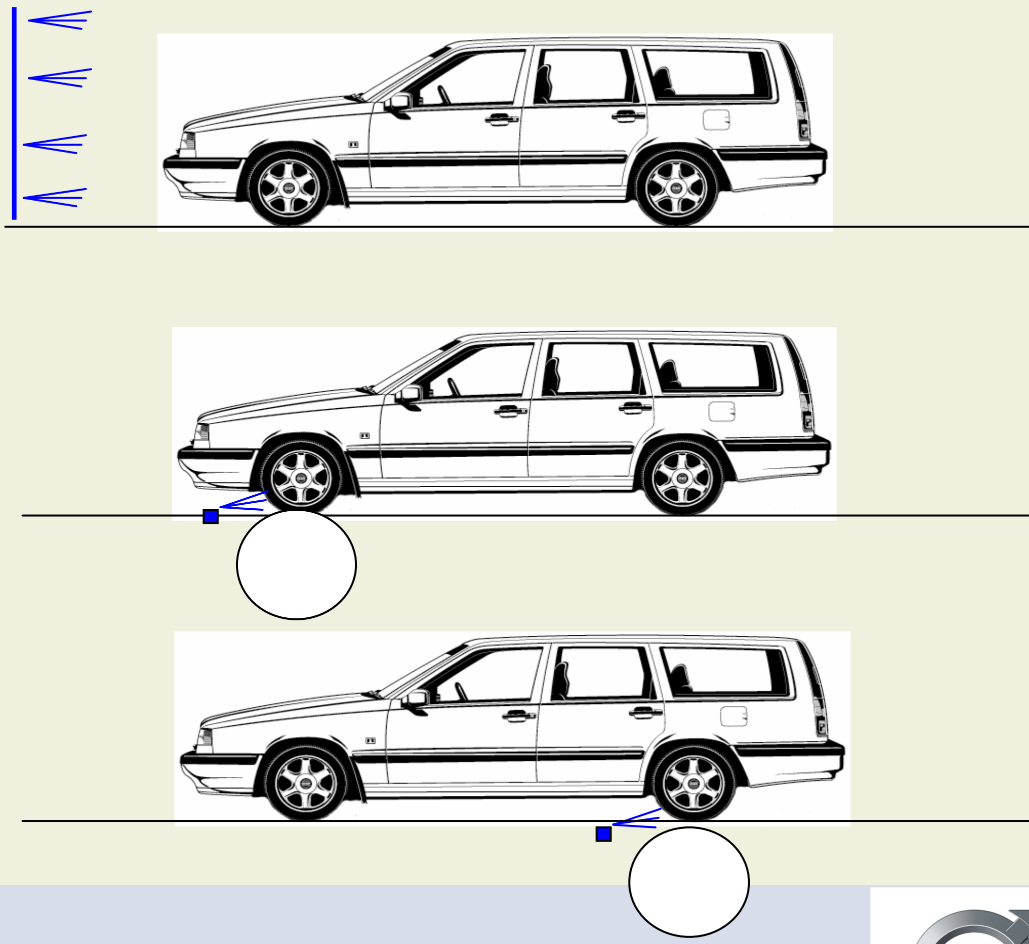
Road Testing

Road testing (soiling, snow deposition)

- Dirt deposition tests in Sweden and USA
- Snow deposition in Jokkmokk

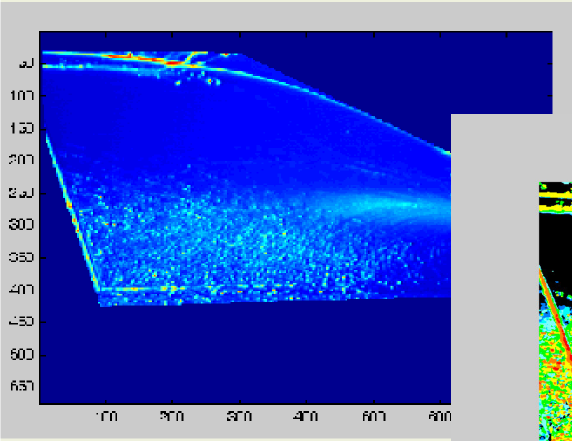
Dirt deposition testing in the Volvo wind tunnel

- Detection of emitted light from an UV sensitive chemical dissolved in water
- The signal from a set of UV sensitive cameras are recorded by a frame grabber card in a PC
- Image processing is used to evaluate the dirt deposition

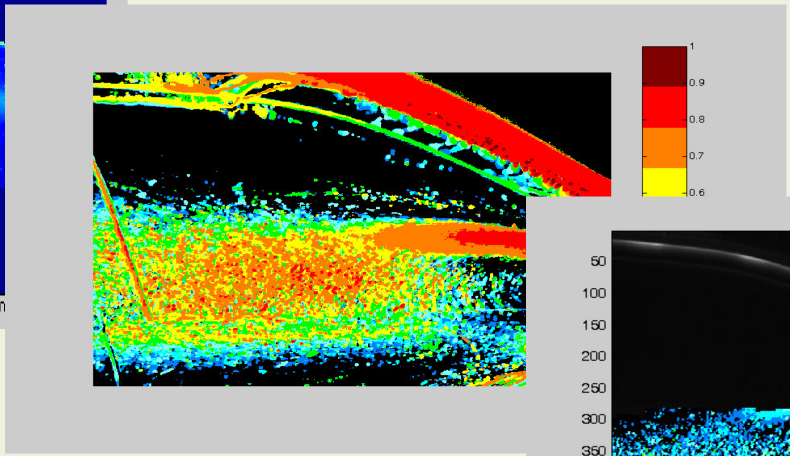


Side window dirt deposition

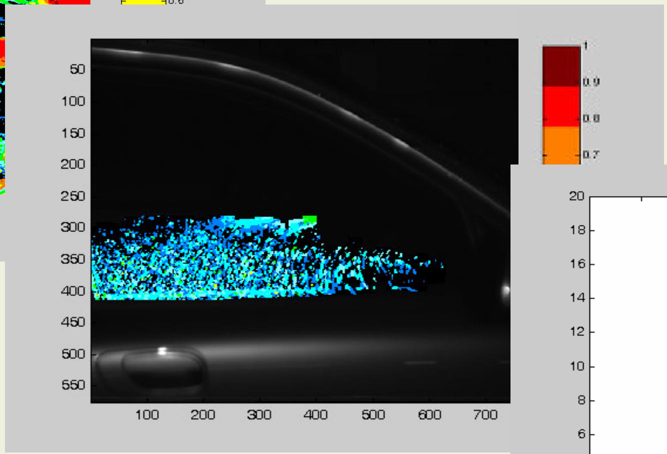
Image processing sequence



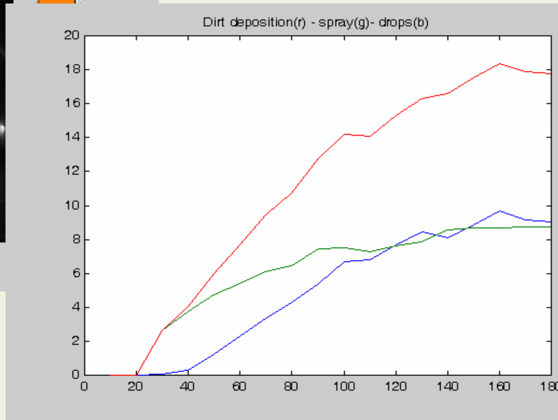
Video snapshot



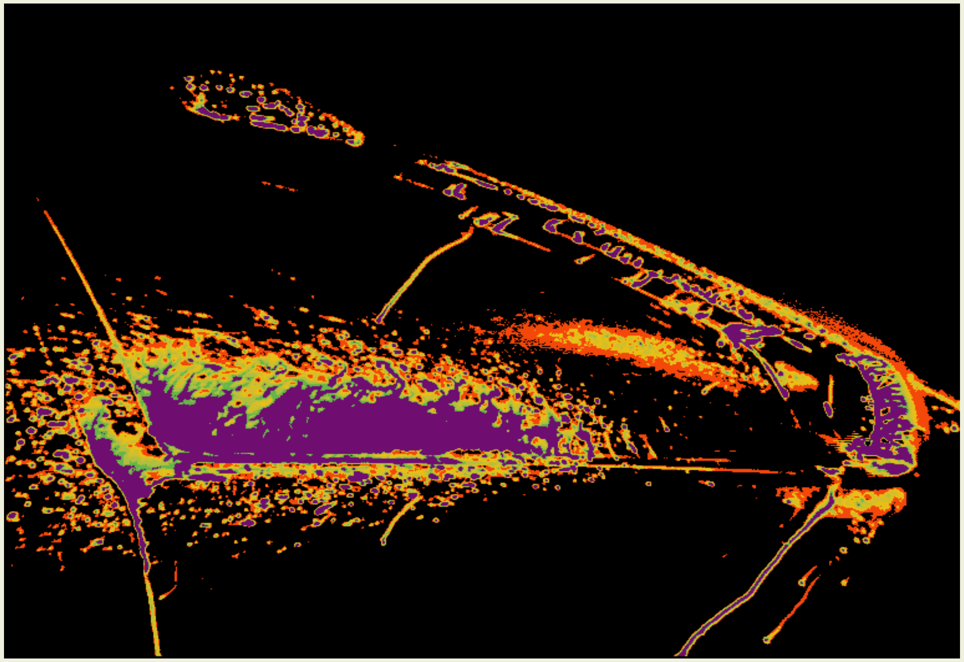
Picture of the dirt deposition build up



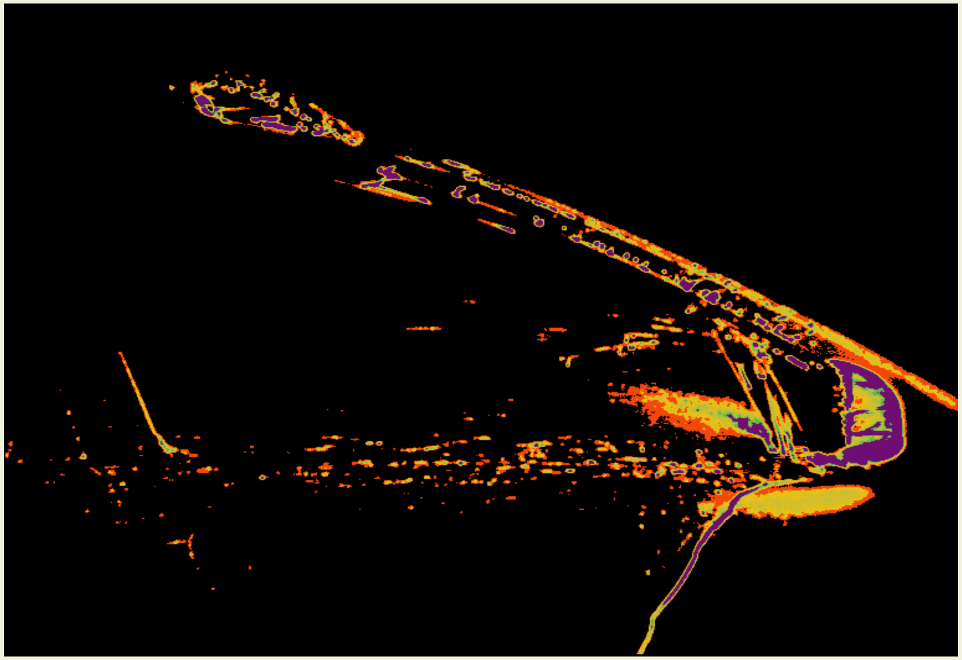
Separation of fine spray from droplets



Quantification of dirt deposition build up



Std 2001 Mirror



2003 Mirror

Physical Test objects

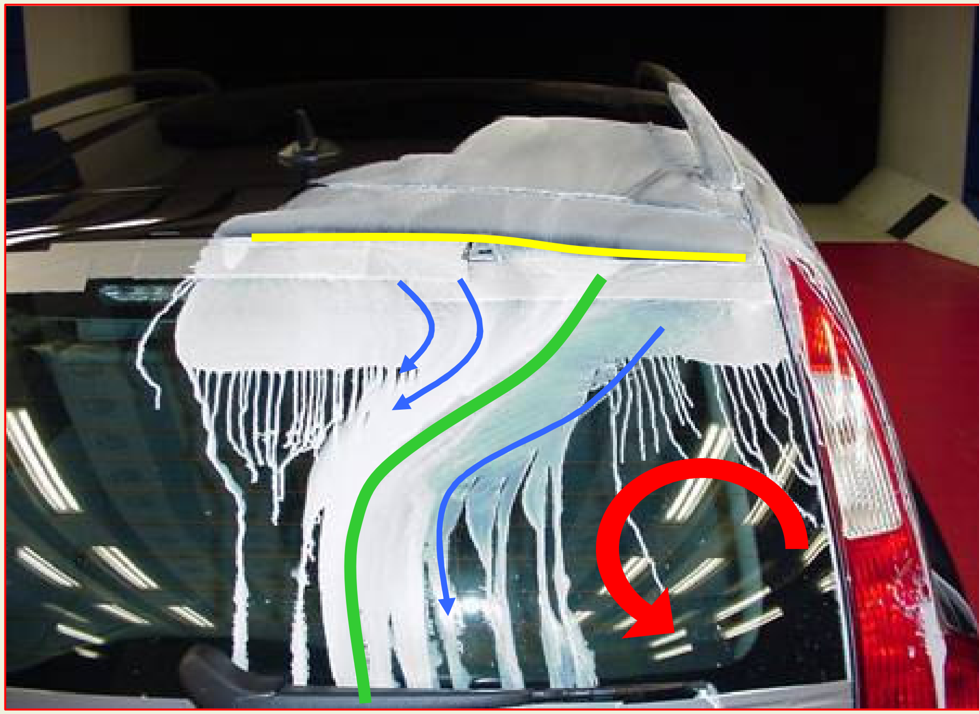
- Clay model (1:5 or 1:1 scale)
- Plastic model
- Mock-up (metal/plastic exterior)
- Prototype
- Production vehicle

Conventional aerodynamic testing

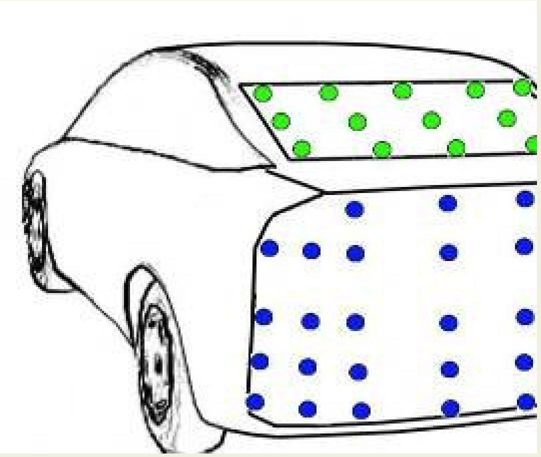
- Balance measurements
  - Effect of configuration changes on aero coefficients
  - Investigate sensitivity to flow angle, vehicle attitude and wind speed

Conventional aerodynamic testing

- Pressure measurements
- Flow visualization (smoke, surface paint, tufts)



Methods to increase the knowledge gained from aerodynamic testing



- Pressure Measurements
- Base pressure measurements
- Wake analysis (seven-hole pressure probe measurements)
- Image processing methods applied to soiling

Wake measurements

Seven-hole probe rake

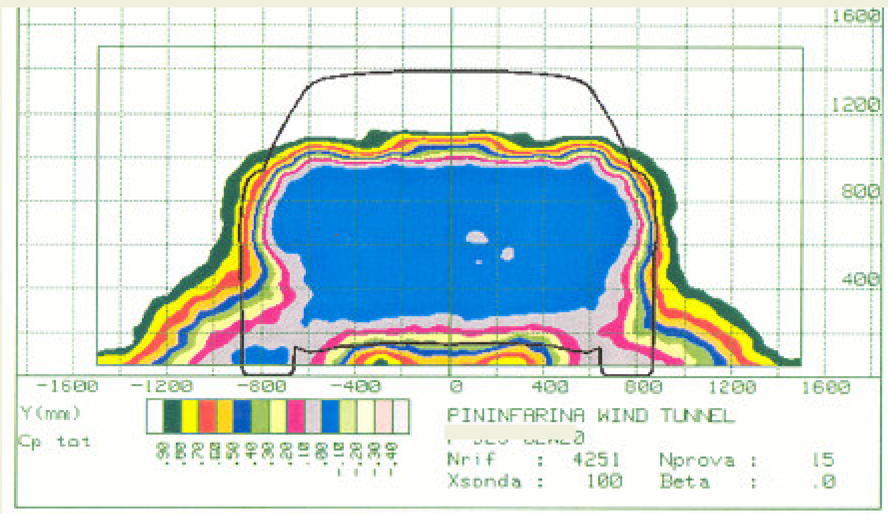
Floor traverse

$$D = \iint (P_1 + \rho U_1^2 - P_2 - \rho U_2^2)\,dydz$$

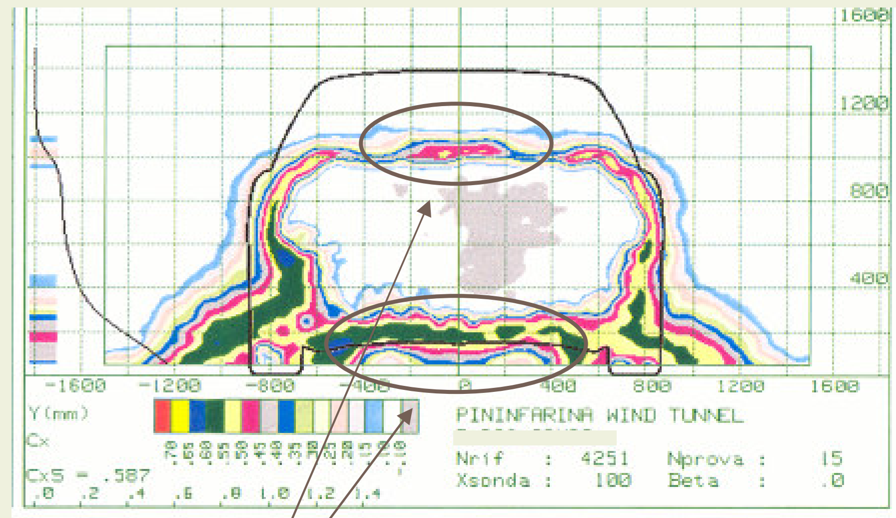
Wake analysis

Wake measured 100 mm downstream of a notchback

Total pressure

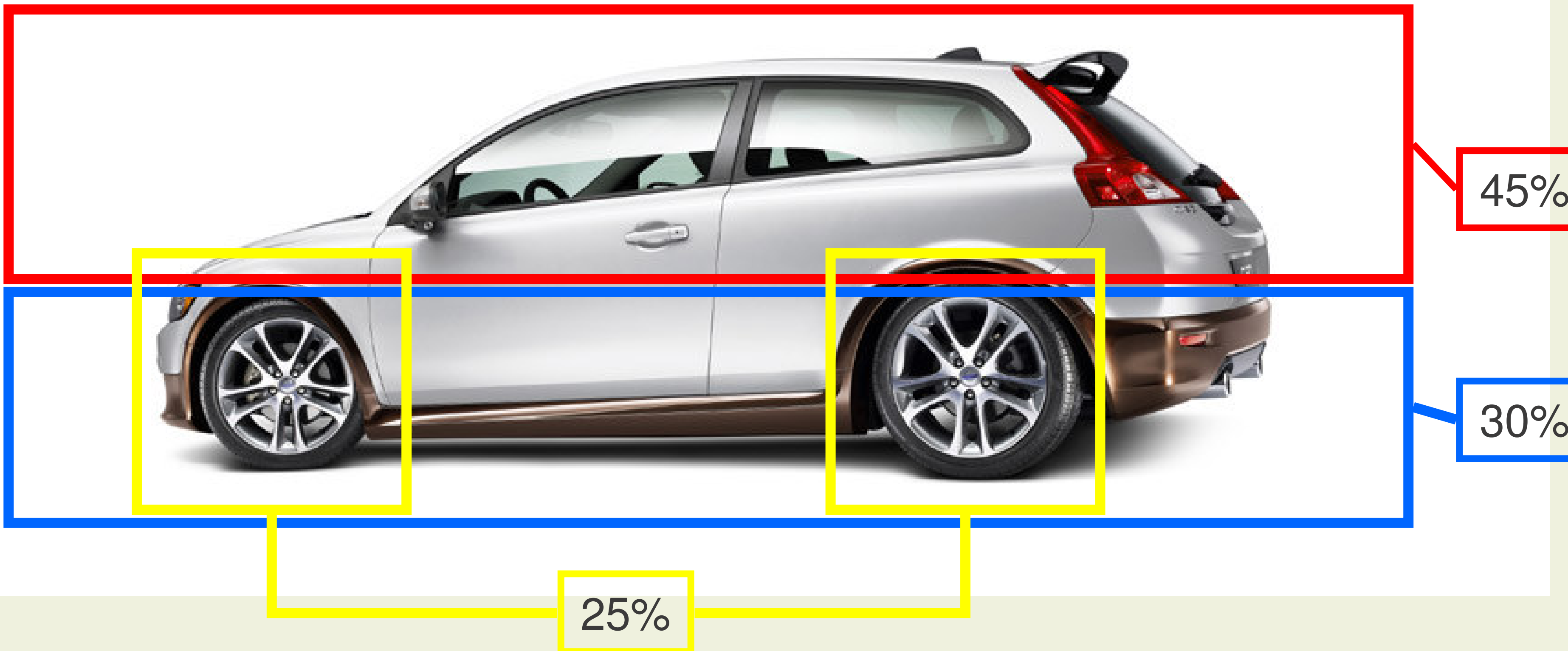


Microdrag



Identify regions that can be improved

Sources of drag on a modern car



Why Moving Ground is Neccessary

Provides correct relative movement between the car body and tunnel floor

Provides correct relative movement between the car body and wheels

} Influences flow under and around car

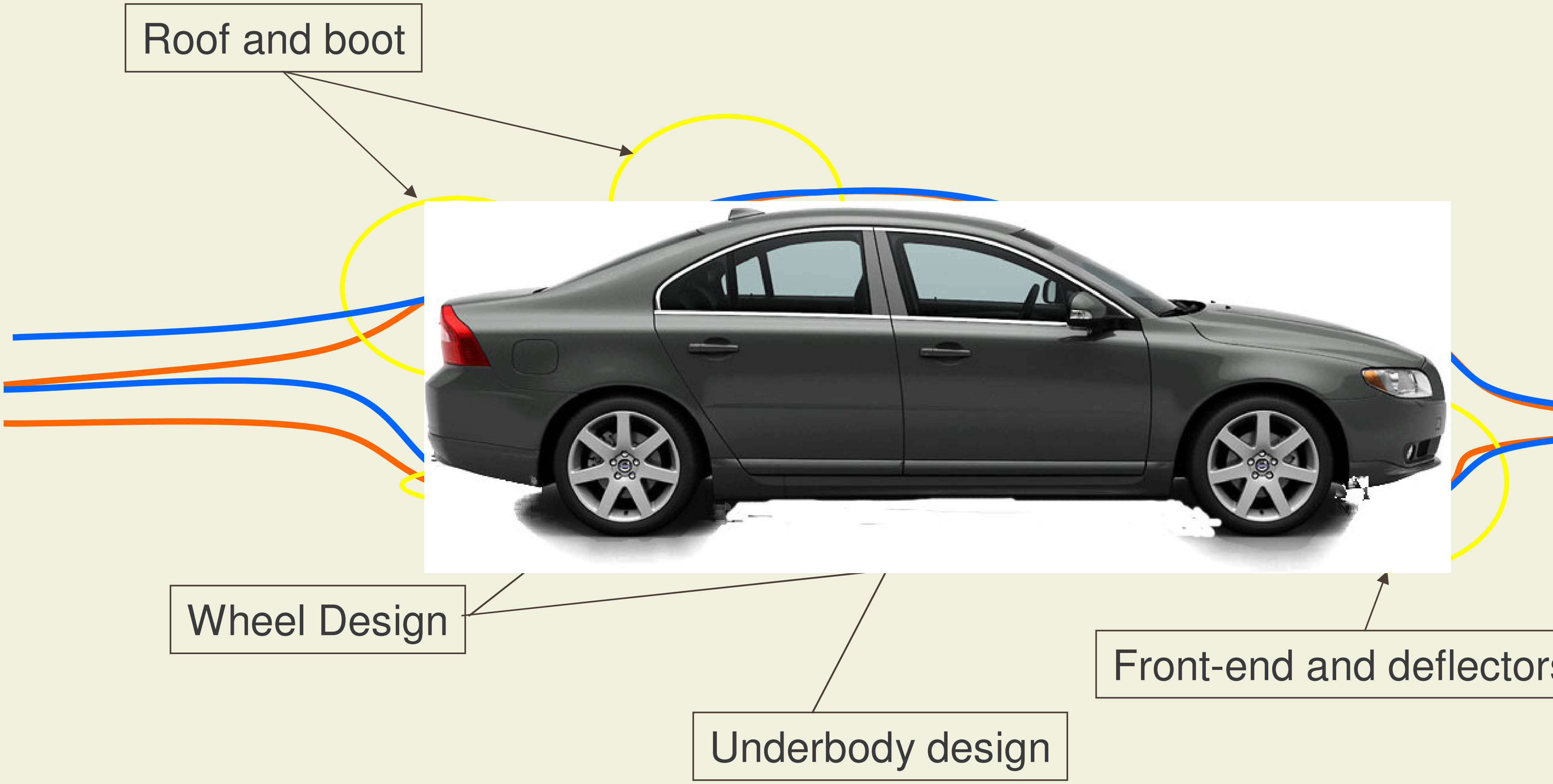
Correct simulation of the flow influences:

- Under body optimisation
- Upper body optimisation

How: Stationary Floor and Wheels

How: Moving Ground and Rotating Wheels

Optimisation affected



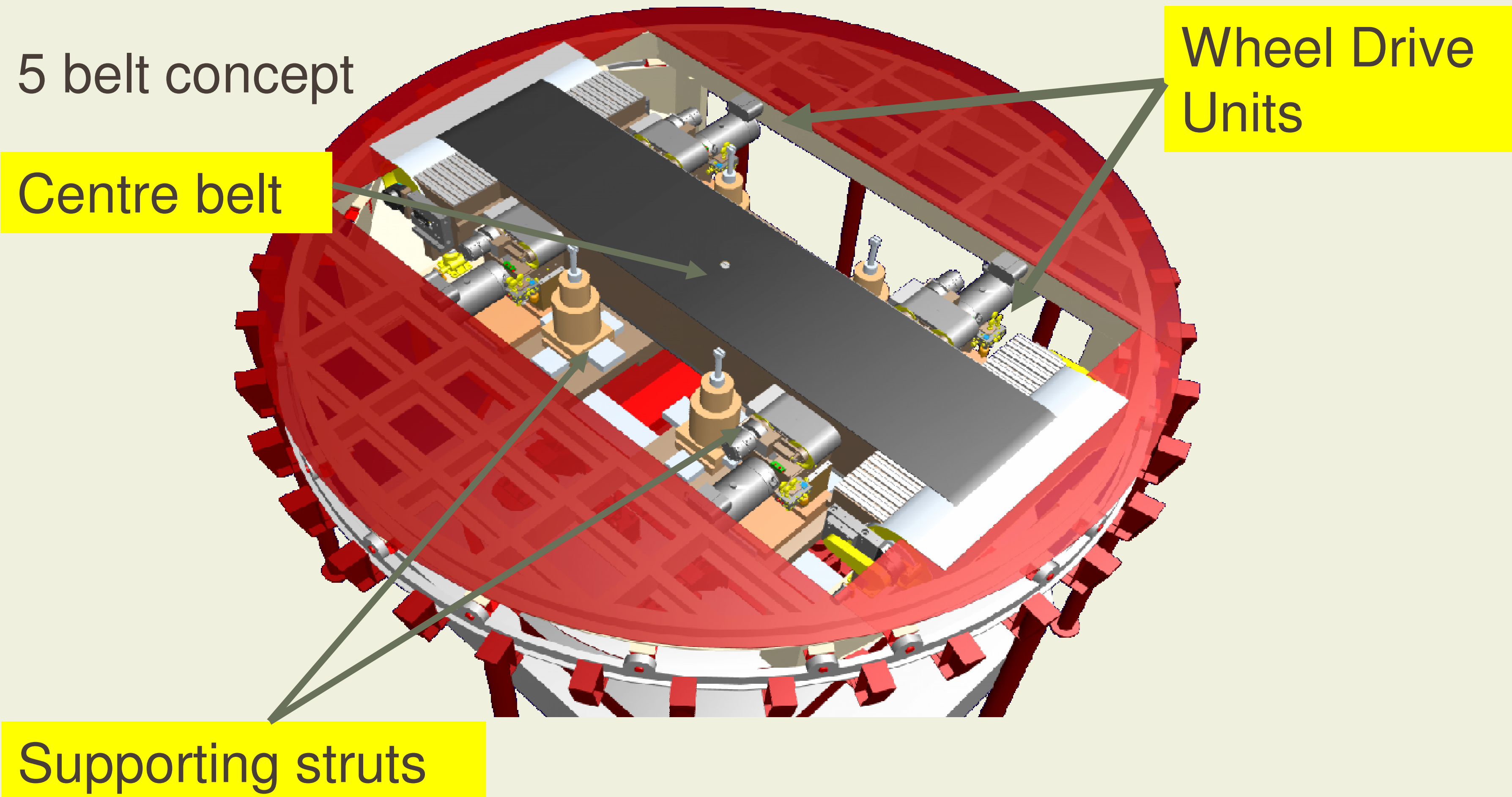
Volvo Full Scale Moving Ground

Wind Tunnel Uppgrade

- Installation of 5-belt moving ground
- Steel belts
- Improved Boundary Layer control
- Wind speed increased to 250km/h
- Work started July 2005
- Work completed January 2007

Volvo Full Scale Moving Ground

5 belt concept



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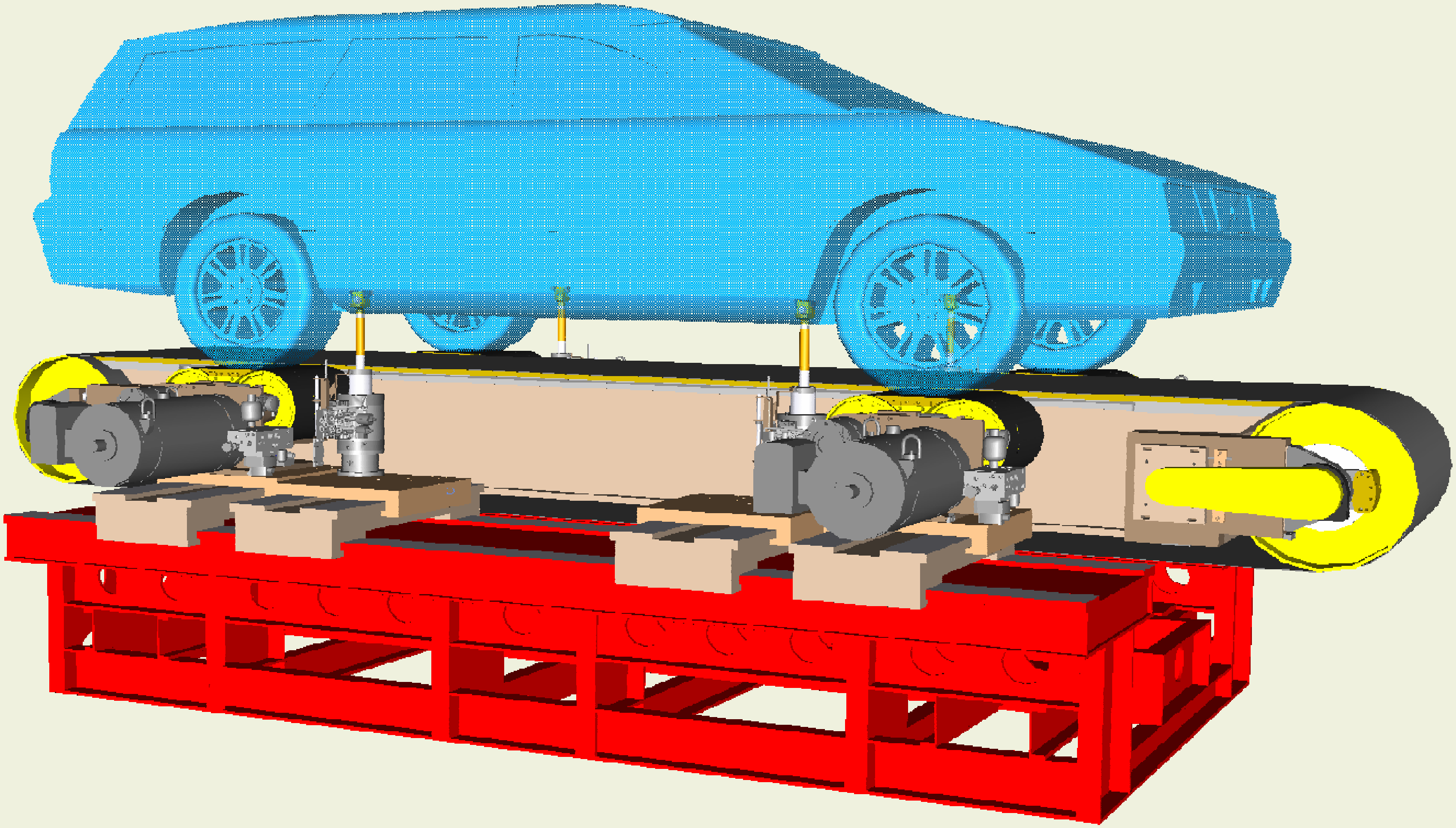
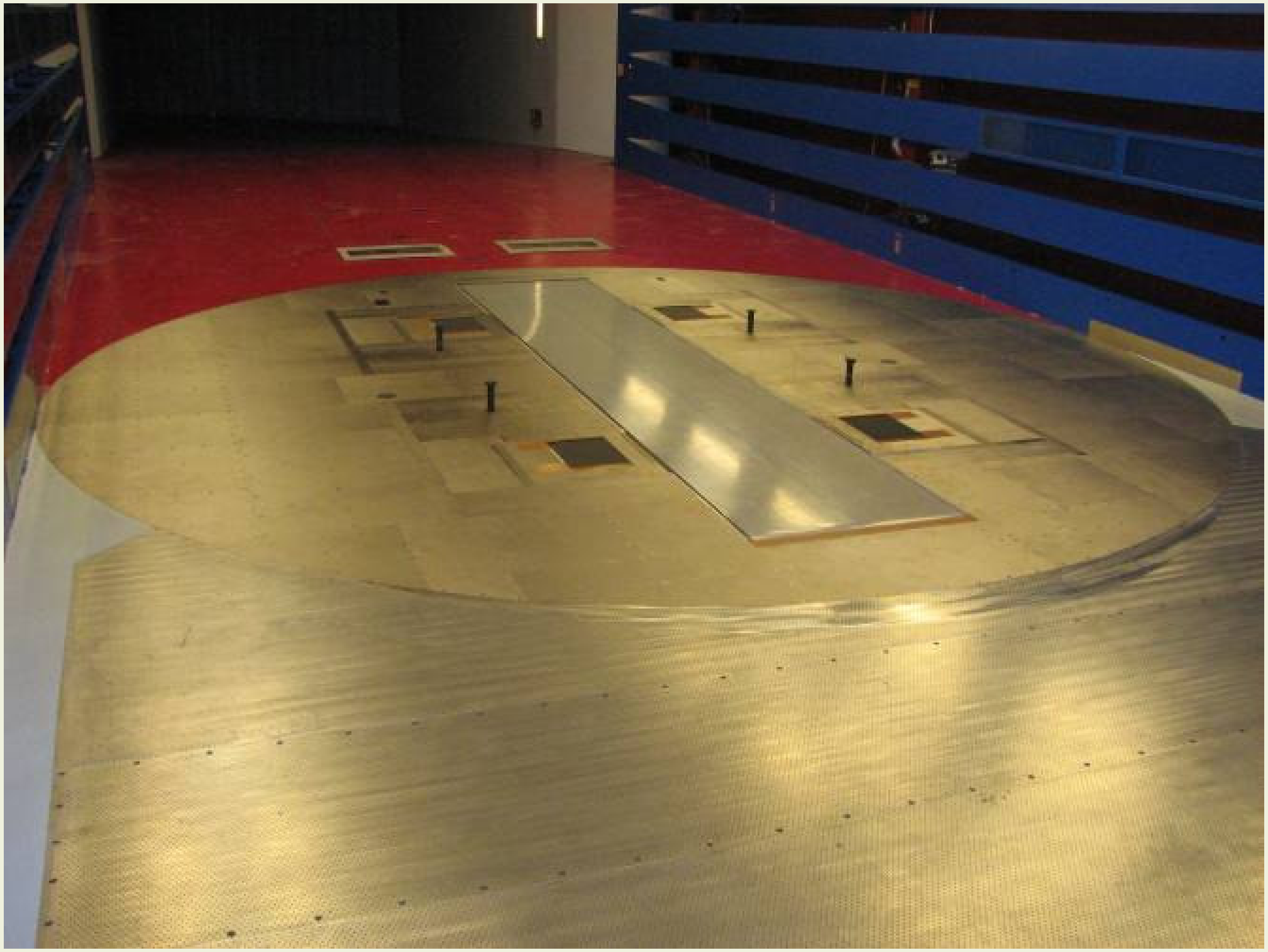


Measuring Frame for WDU's and struts

Moving Ground Installation



Moving Ground Installation

Moving Ground F1 Installation

Aero Concept Car

Volvo 3C Concept Car 2004