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Ground Effect and Turbulence Simulation at the Pininfarina Wind Tunnel

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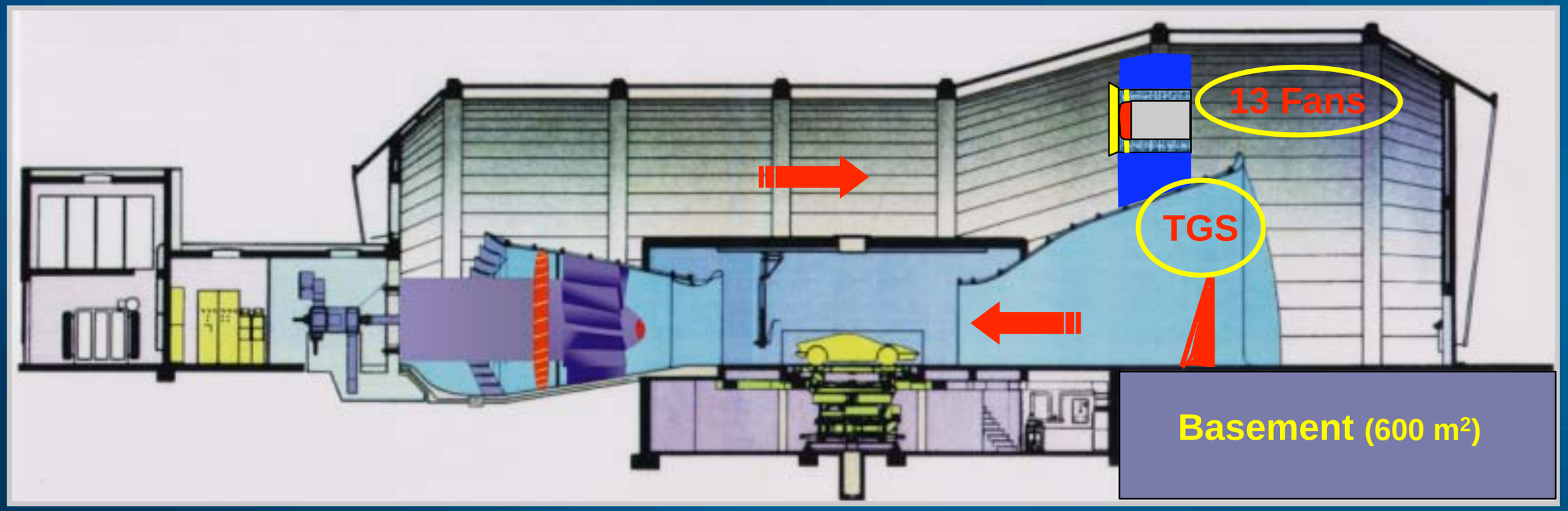
The Aerodynamic and Aeroacoustic Research Center




The **Full Scale Automotive Wind Tunnel** is the main facility of the Research Center.



Jet Section	:	11 m² (semi-circular)
Flow Max Velocity	:	260 Km/h (*)
Background Noise Level	:	68 dBA at V = 100 Km/h
Turbulence Intensity	:	0.3%
		up to 8% with TGS >>>

(*) in empty test section

The Aerodynamic and Aeroacoustic Research Center




The **Mission** of the Aerodynamic & Aeroacoustic Research Center is:

- To be a **center of excellence**
  in the field of **Aerodynamics and Aeroacoustics;**
- To work as an **independent Research Center**
  open to every Company, even to our competitors.

To achieve these targets:

- Pininfarina is **investing money** every year
  to upgrade the Center to keep it at the highest possible level;
- **25-35 %** of **Wind Tunnel time** is spent every year to improve the facility
  and to setup new measurement techniques.

The Center is certified ISO 9001 (1997) and then ISO/TS 16949 (2002).

Main upgrades of the facility in recent years

2003: **Turbulence Generation System (TGS)**
to produce on demand
a flow of **controlled turbulence**
similar to that on the road.

2005: A new low noise **high speed Fan-Drive System (13 fans)**

- to increase Wind Speed up to 260 km/h;
- to reduce background noise level to 68 dBA at 100 km/h.

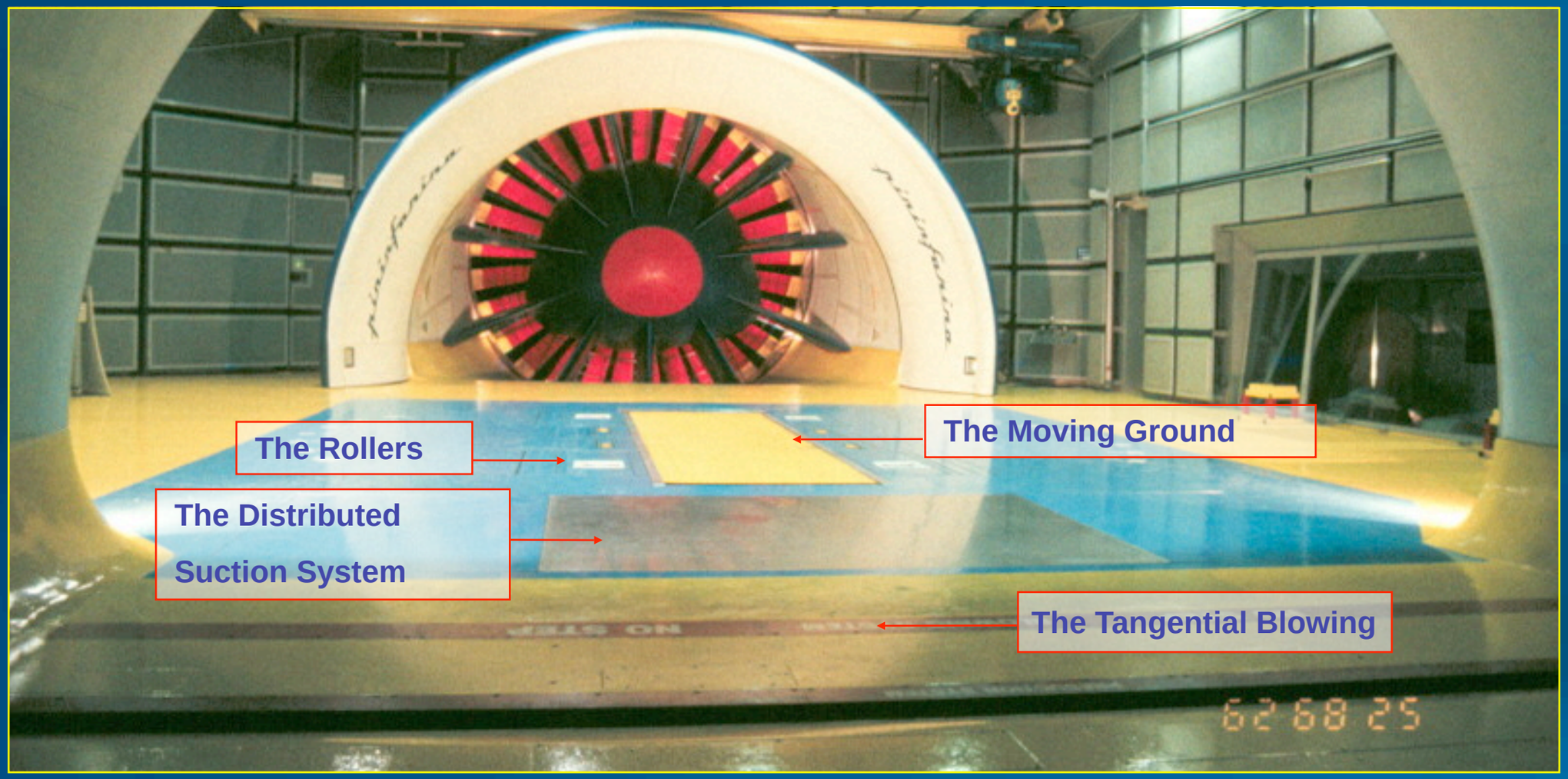
2006: A new system for the
simulation of the 'Car to Ground' relative motion.

Simulation of the ‘Car to Ground’ motion

A **Moving Ground System** of new design was built in **1995**
to easily carry out tests on **full scale** vehicles.

Target: to improve aerodynamics of car **underbody** and **wheel-housings**.

GESS = Ground Effect Simulation System



Simulation of the ‘Car to Ground’ motion




In 10 years of experience,
some critical points emerged:

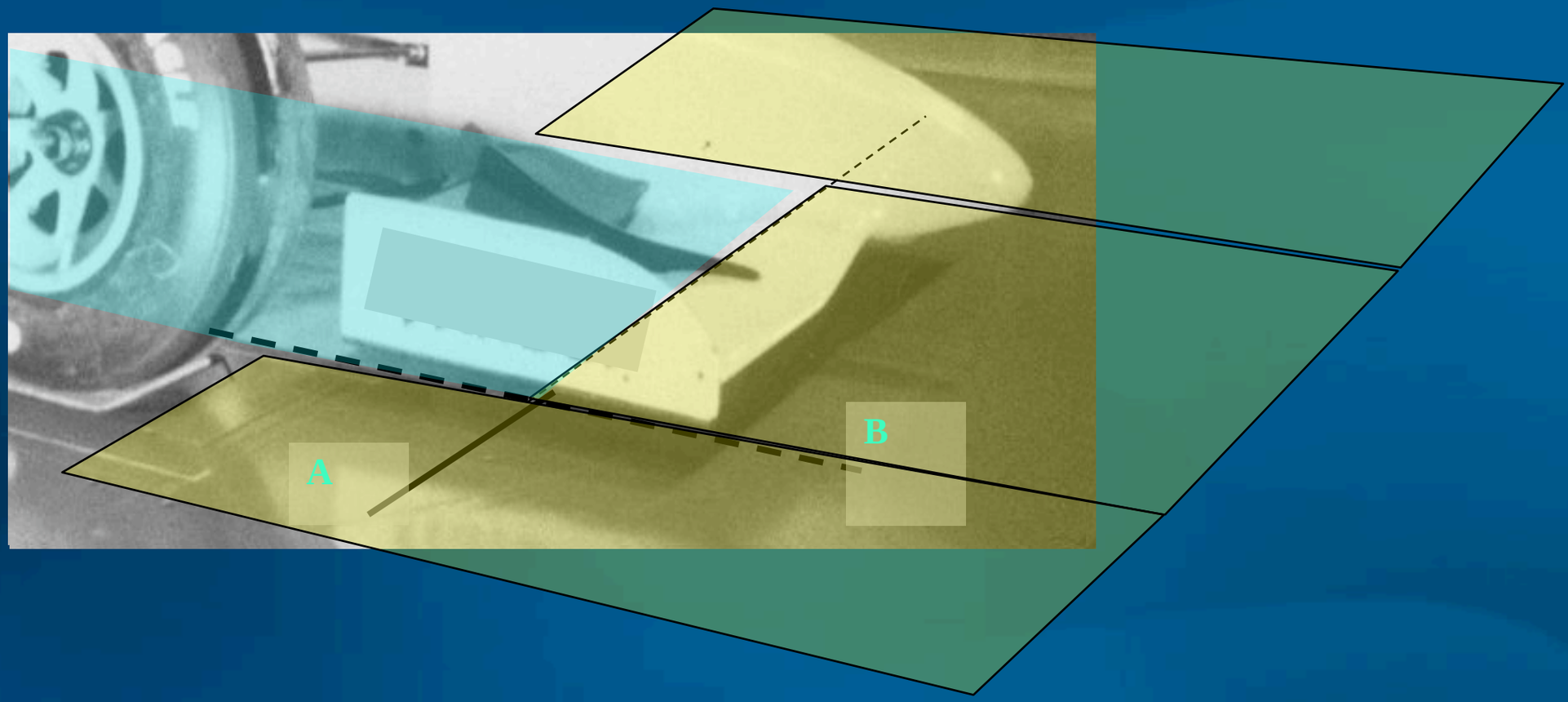
- **The belt was too short**
  for a good simulation of the flow
  under the front wing central part;

- **The wing tip flow and its interaction with**
  the front wheels were probably
  not well simulated;

- **The Tangential Blowing (TB) System and**
  the Distributed Suction System
  used to take care of these limitations,
  were not able
  to completely fix these criticalities.

Simulation of the ‘Car to Ground’ motion

In 2004 Pininfarina decided to build a new Moving Ground System



Main purpose is to improve the testing of full-scale Racing Cars by using:

- **A much longer Central Belt;**
- **Two additional Front Side Belts** that extend the system under the wing tips.

[Patent Pending]

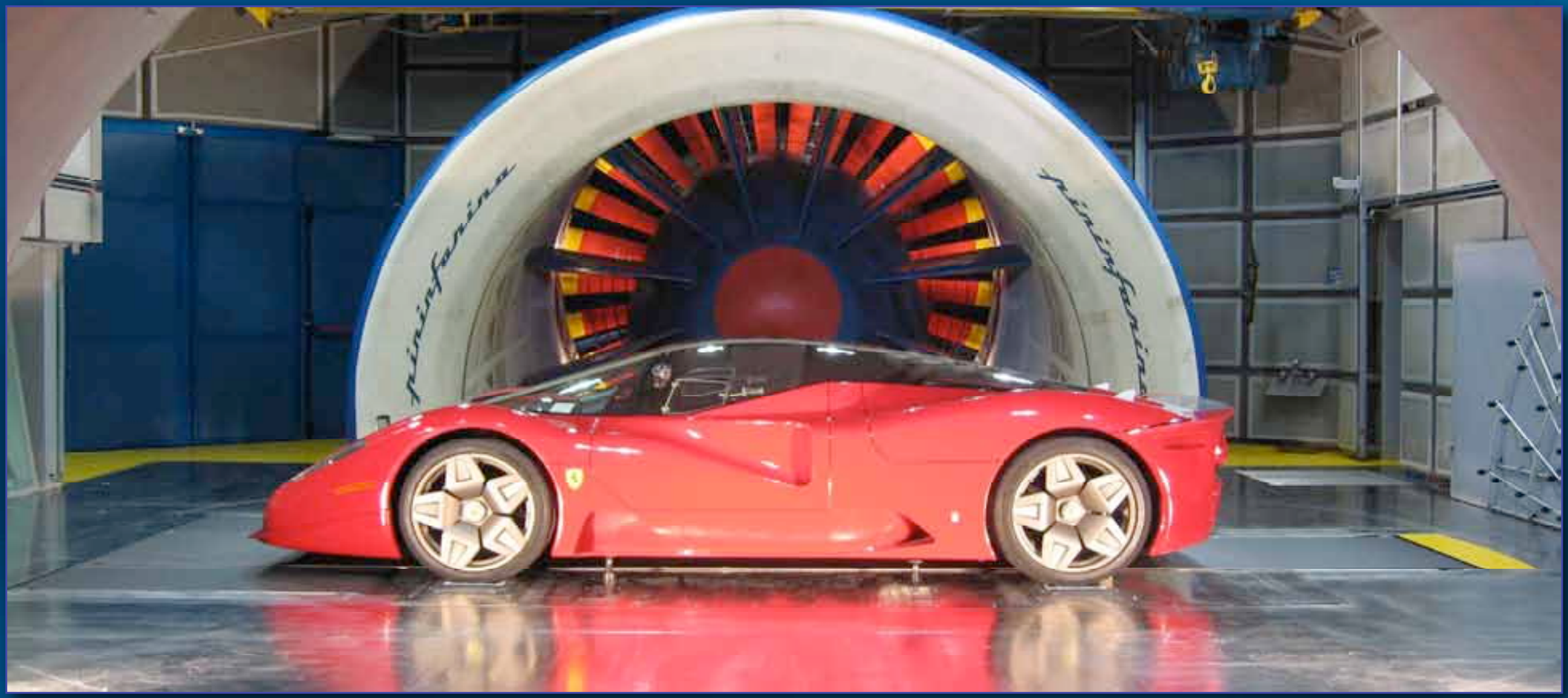
Simulation of the ‘Car to Ground’ motion




T-Belt Specifications

- **Max Speed: 250 Km/h;**
- A quite **long Central Belt:**
  6.7 m long 1.1 m wide;
- **2 front side belts:**
  1.5 m long
  0.7 m wide
  Total Width = 2.5 m;
- **4 Rollers**
  supporting the car full weight,
  without introducing lift errors;
- **Car supports** computer controlled:
  Car standing heights can be
  fixed or floating;
- **Lifters** to lift the car up to 400 mm;
- **Motorbikes** ready.

Simulation of the ‘Car to Ground’ motion



Simulation of the ‘Car to Ground’ motion

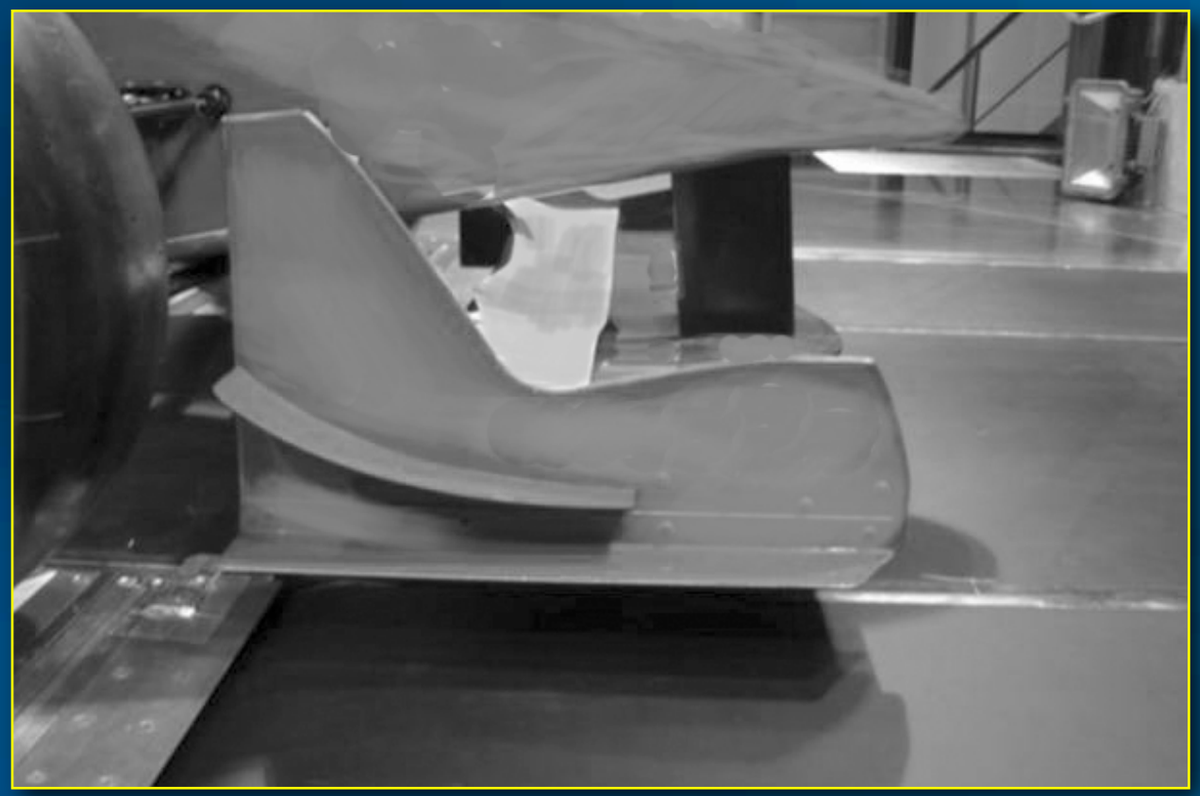
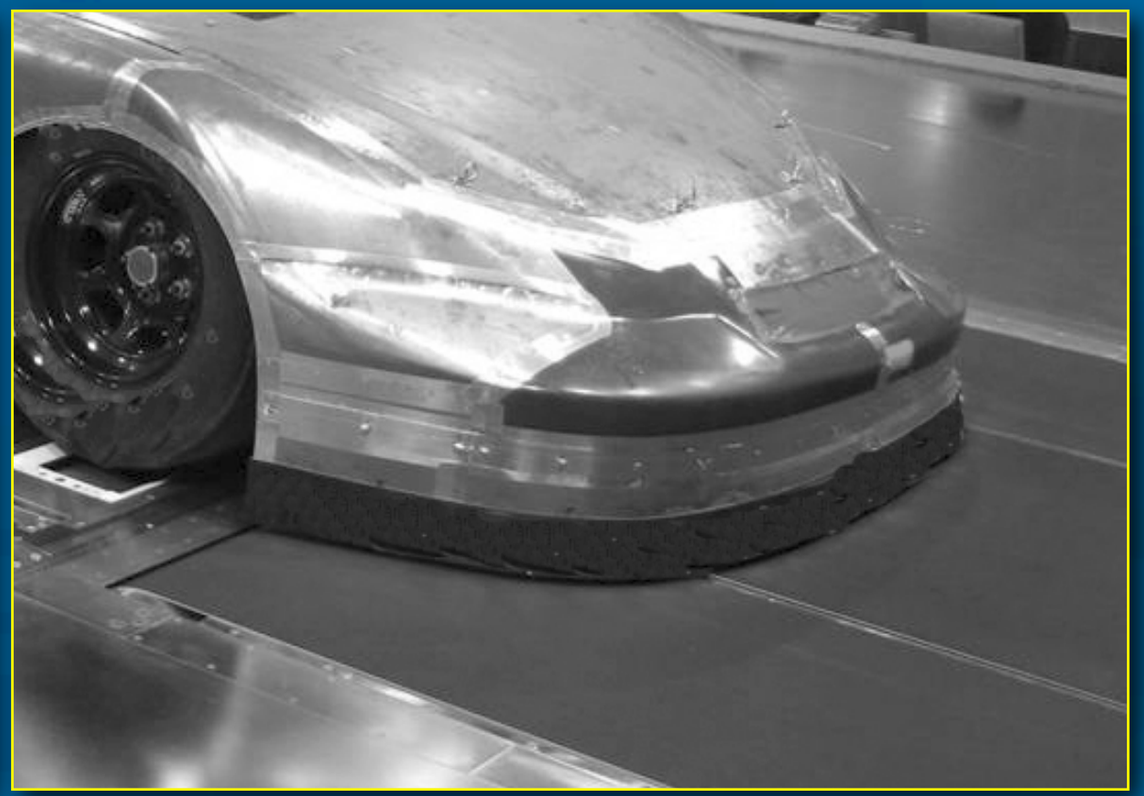
Simulation of the ‘Car to Ground’ motion




The **full width** of the 3 belts under the car front end is **2.5 m**.

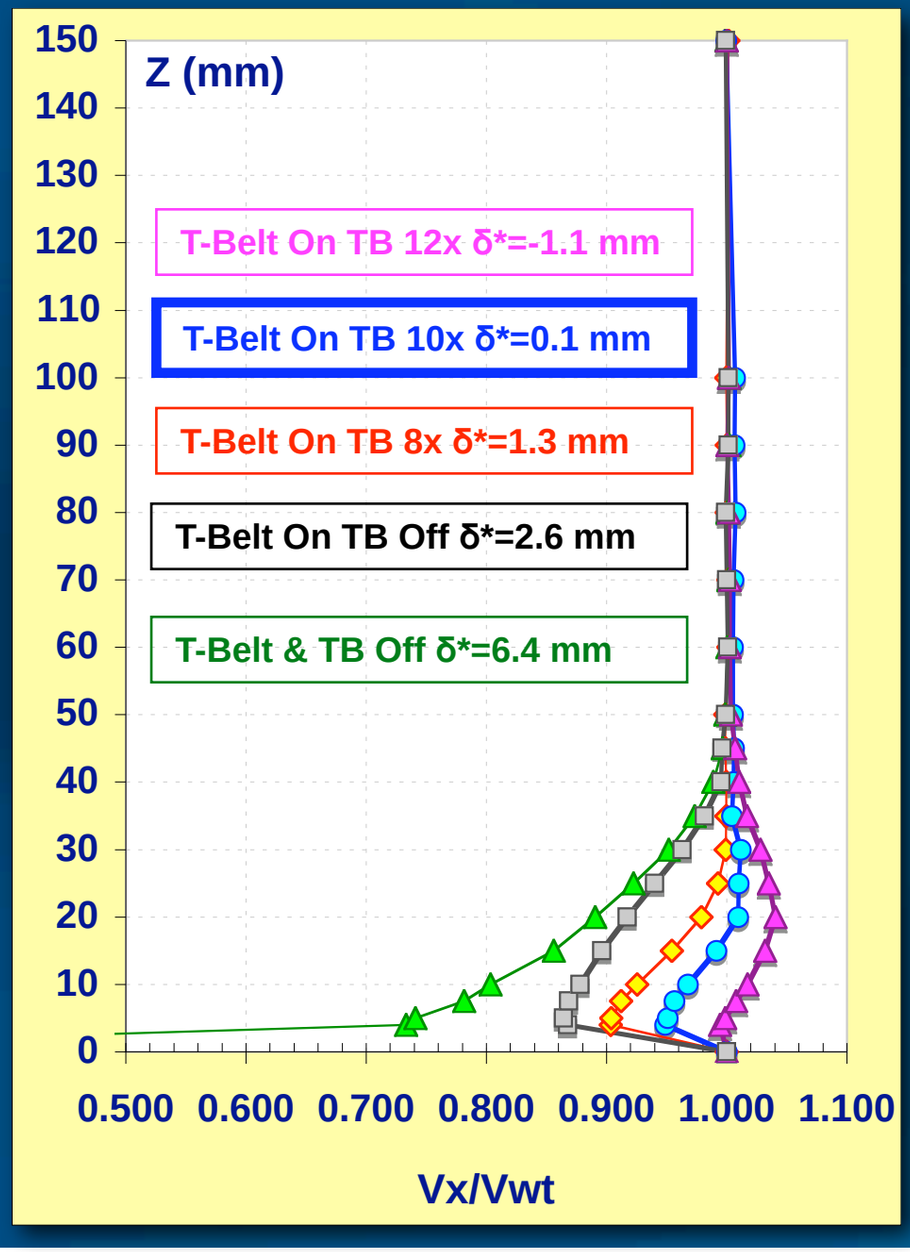
It is **optimised** to achieve a good simulation of the approaching flow:

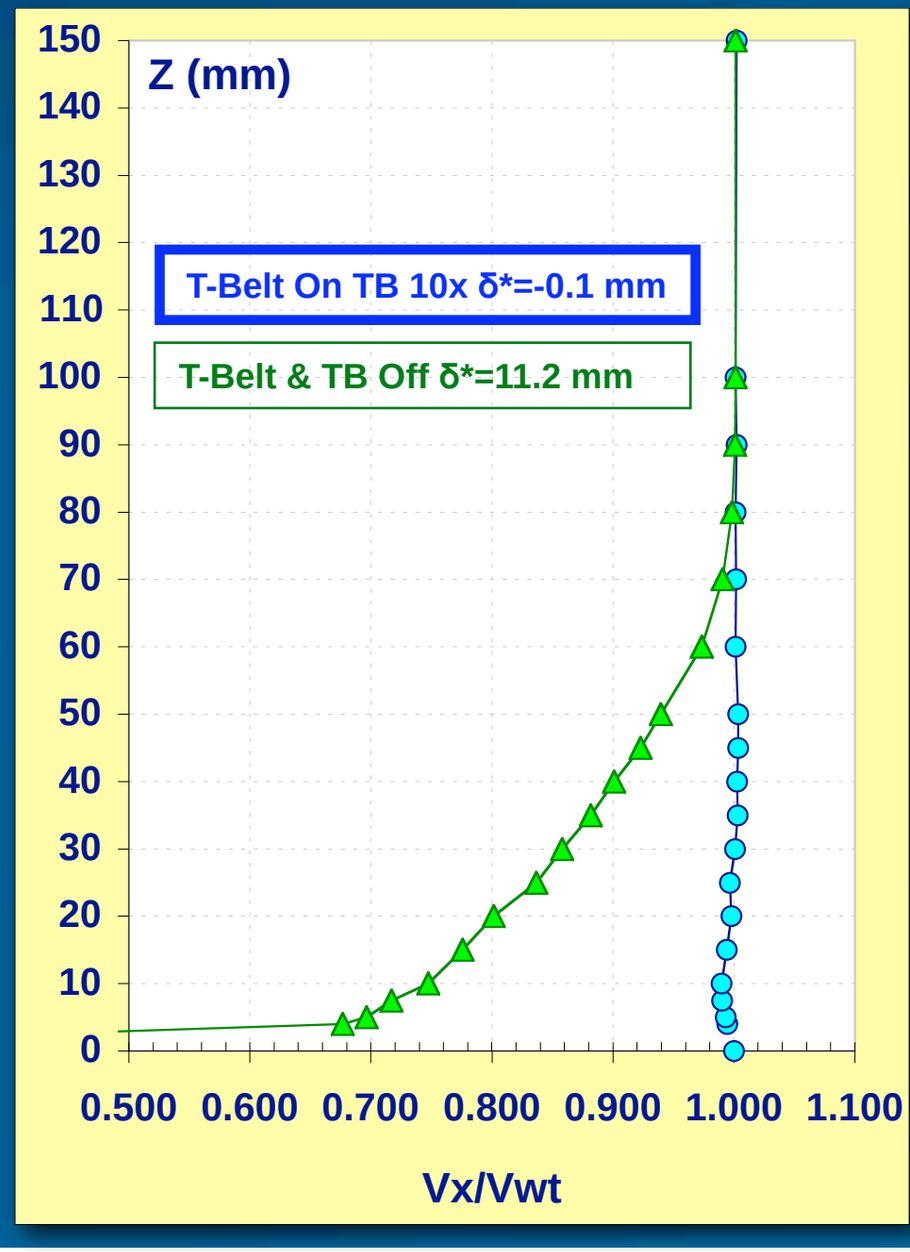
- under the **car front end**;
- under the **front wing** of a **racing car**;
- ahead of the **front wheels**.

Simulation of the ‘Car to Ground’ motion

Boundary Layer on the T-Belt (meas by LDV)
along the Test Section Centerline Y=0 mm, at V = 38.9 m/s



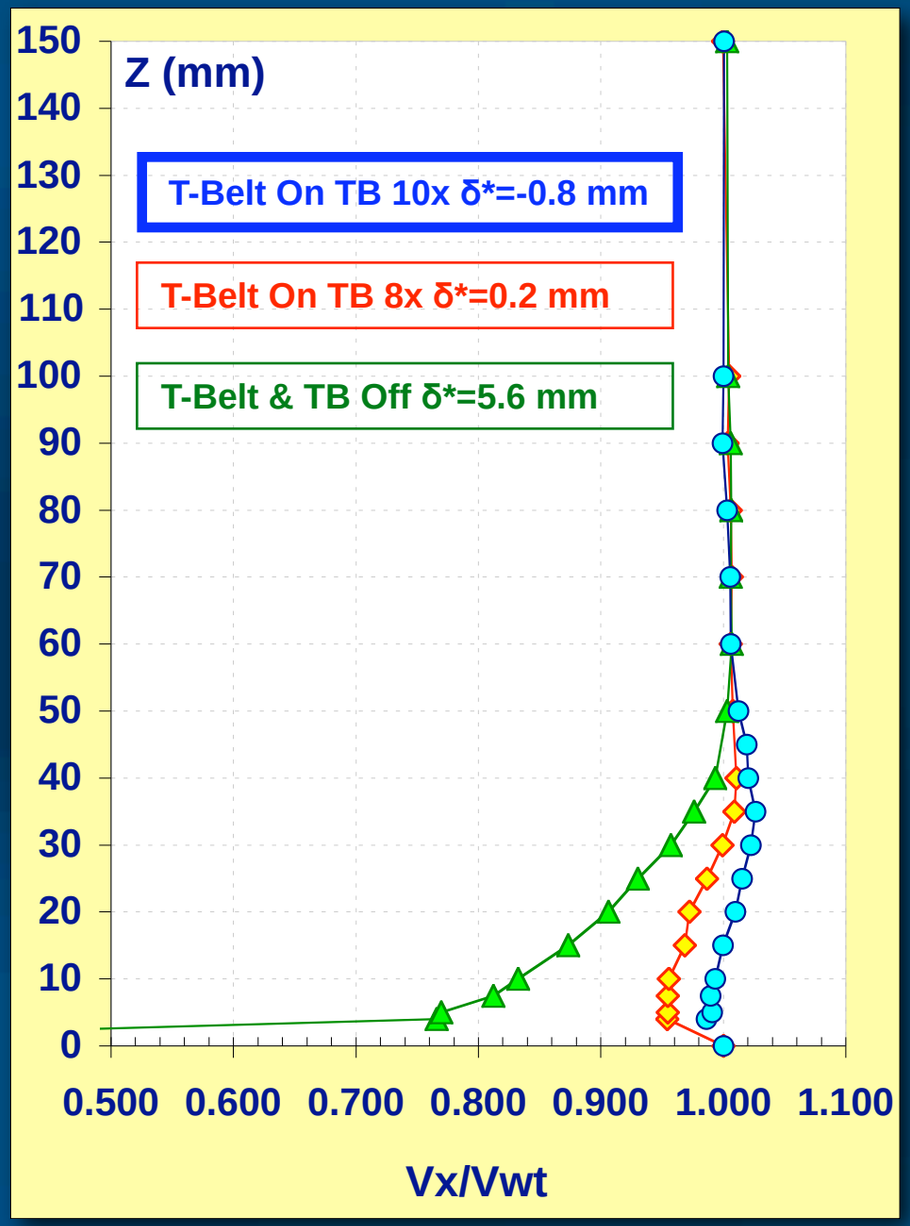


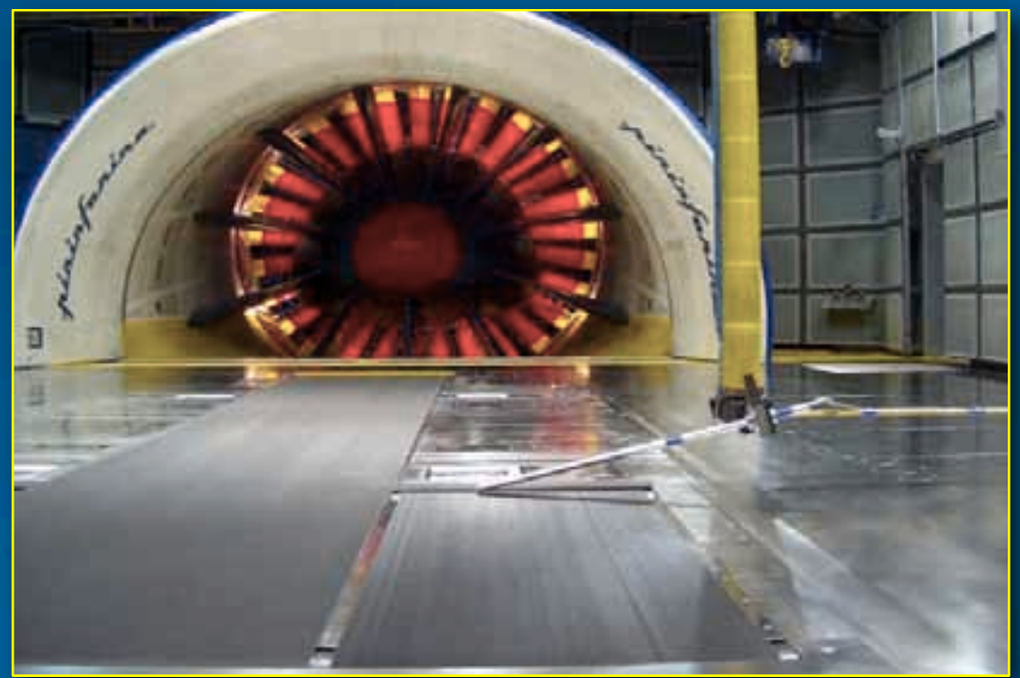
Simulation of the ‘Car to Ground’ motion




Boundary Layer ahead of the Front Wheel

X = -435 mm, Y = -750 mm, V= 38.9 m/s





	X (mm)	Y (mm)	δ* (mm) GESS Off	δ* (mm) GESS On
Center of Balance	3675	0	11.2	-0.1
X = -2.5 m form CoB	1175	0	6.4	0.1
Ahead of Front Wheel	1890	-750	5.6	-0.8

Simulation of the ‘Car to Ground’ motion

Example of Contributions of Side Belts to lift in a racing car

	ΔC_D	ΔC_L Front	ΔC_L Rear
T-Belt Off	-	-	-
T-Belt On & Side Belts Off	0.000	-0.059	0.027
T-Belt fully On (wrt T-Belt On & Side Belts Off)	0.001 (0.001)	- 0.071 (- 0.012)	0.020 (- 0.007)

- No relevant contribution to Drag
- Front Lift Reduction
- Rear Lift Increase
- Probably due to greater flow mass running below the vehicle.

Simulation of Turbulence




1. Road vehicles are moving in a **turbulent flow**.
2. **Turbulence on the road** is due to **2 main sources**:
   a) **Ambient wind**,
      often in the presence of roadside obstacles;
   b) **Other vehicles** running on the road;
   c) A **combination** of the sources **a)** and **b)**.

Item **a)** was the **key point** for **design and development** of the **Turbulence Generation System (TGS)**.

The TGS is operational **since 2003**.

The Turbulence Generation System (TGS)




The Turbulence Generation System (TGS)

Simulation of Turbulence

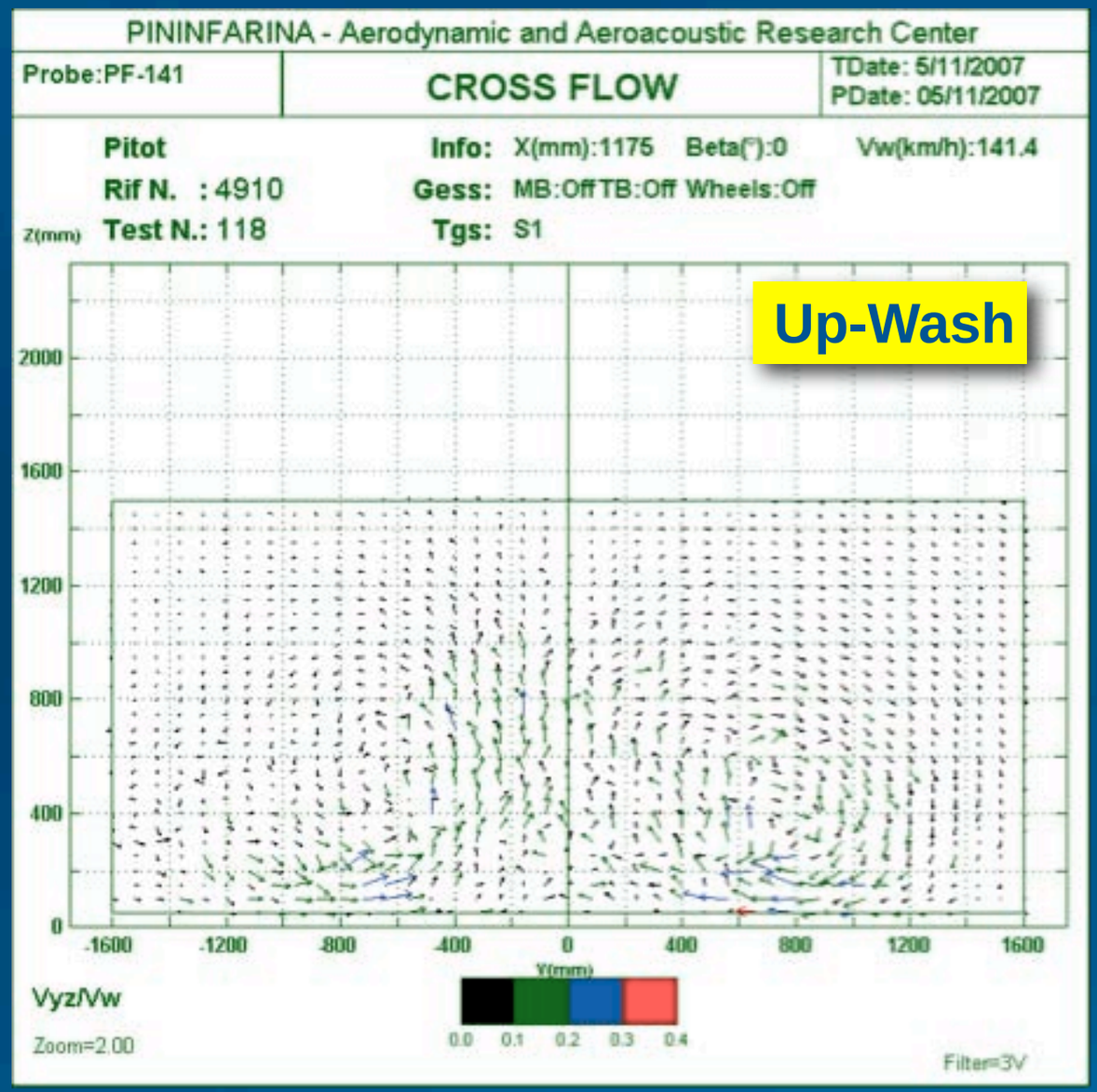
- The 5 Vortex Generators are **fully independent** and computer controlled.
- According to the selected **operational mode** it is possible to simulate:

1. Light average **ambient wind;**
2. **Upstream wakes** of:
   a) Down-lifting vehicles;
   b) Up-lifting vehicles;
3. **Transients** (see SAE 2006-01-1031):
   a) First phase of an overtaking manoeuvre;
   b) Sudden change of wind direction;
4. **Crosswind** with dynamic yawing of the oncoming flow (see SAE 2007-01-0902).

Simulation of Turbulence



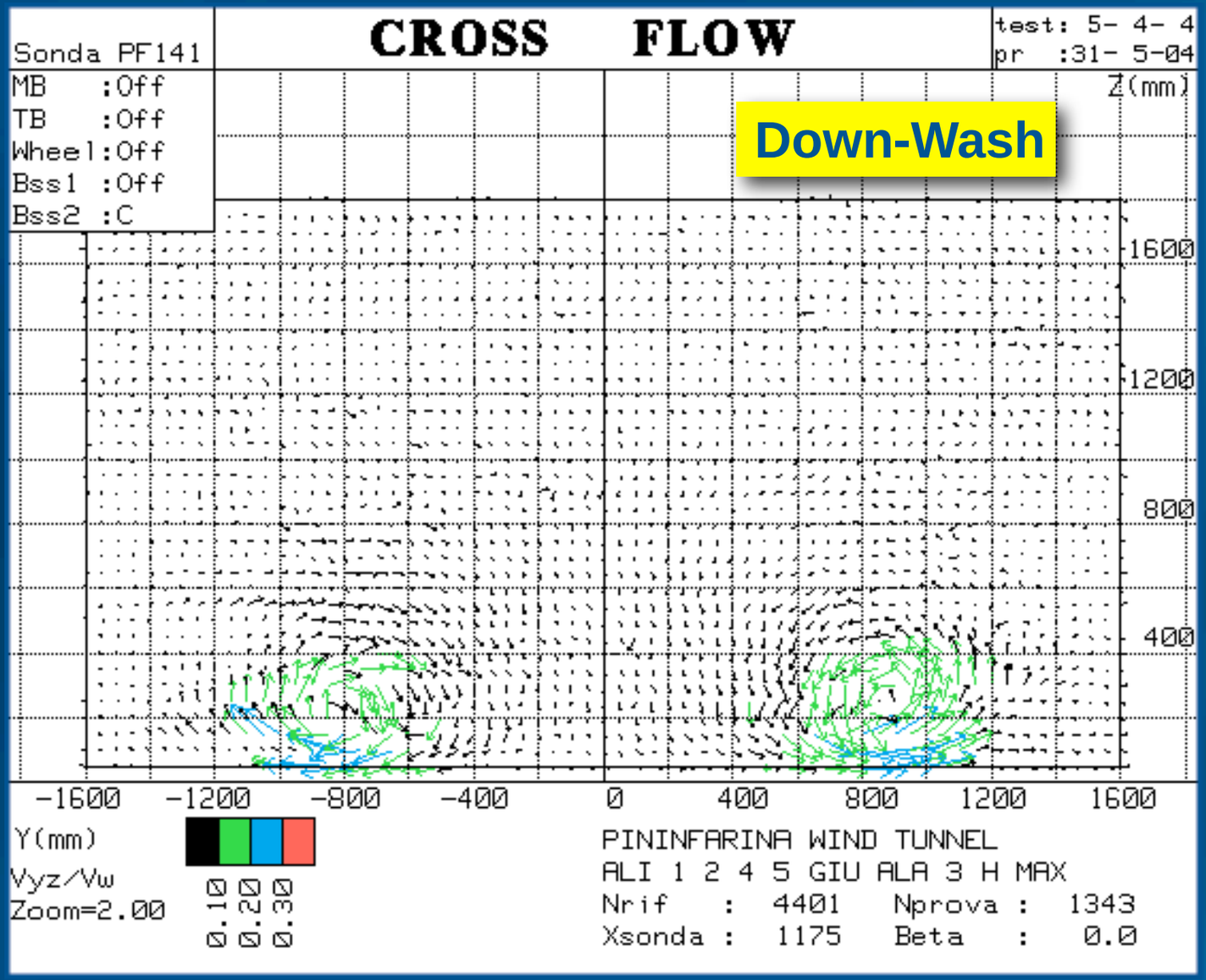

Example of simulation of an upstream down-lifting car (meas by PF 14-hole probe)



Simulation of Turbulence




Example of simulation of an upstream up-lifting car (meas by PF 14-hole probe)

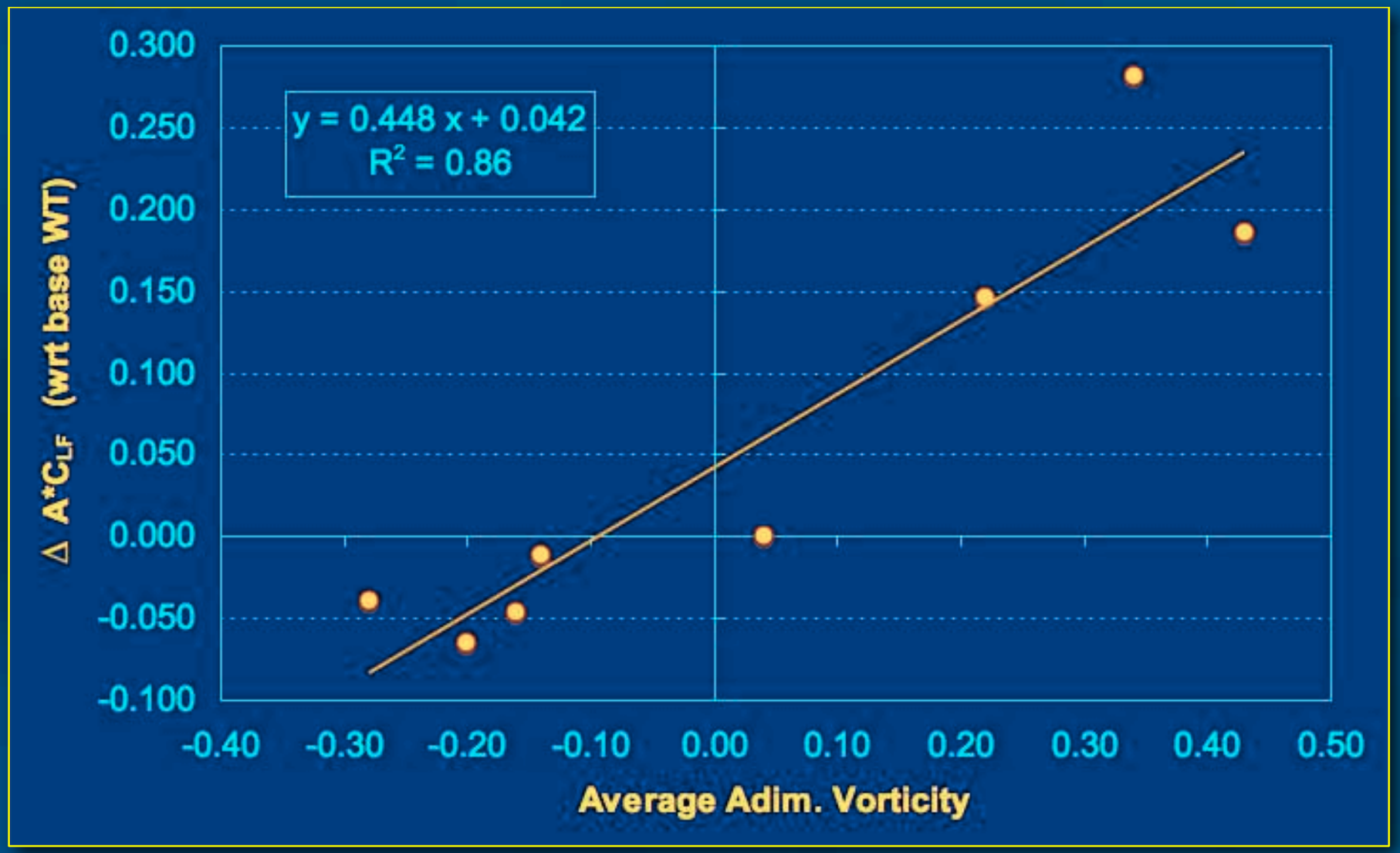


Simulation of Turbulence




Example: Single-Seater

Front Lift change vs. vorticity coming from the upstream car



Quantitative assessment of **front lift sensitivity** to upstream wakes:

$\partial C_{LF} / \partial Vor = 0.448$

Reference: SAE 2005-01-1455

Conclusion




- The new moving ground **“T-Belt”** is now in operation since **Sep. 1st 2006**;
- Thanks to the **2.5 m wide belt**, better **flow simulation** of:
  - **Car front end** (wing, splitter, etc.)
  - **Front wheels** and **wheel-housing**
- With respect to traditional narrow belt, tests with T-Belt show:
  - **Reduced Front Lift**
  - **Increased Rear Lift**
  - **Slightly higher Drag**
- The **Turbulence Generation System** (TGS) is used to simulate:
  - Average ambient wind
  - Upstream wakes
  - Transients
  - Dynamic Crosswind

Conclusion




- For racing cars TGS can be used to simulate
  the presence of an upstream car and its effects on lift.

- The contemporary use of
  the Turbulence Generation System (TGS) and
  the “T-Belt” Ground Effect Simulation System (GESS)
  can help to improve the simulation of the aerodynamic conditions
  existing on the road and on track.

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More information on our measurement techniques at **www.pinifarina.it/arc**

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