Aerodynamic Development of a 2017 F1 Car: Performance Improvement in Freestream and Wake Flows

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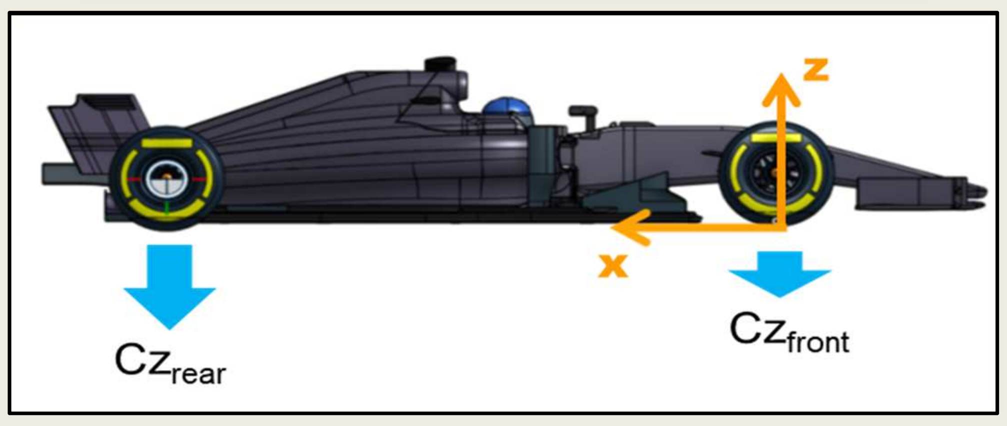
Abstract

Despite several attempts to solve the aerodynamic issues affecting high-downforce cars operating in slipstream, overtaking in F1 is still a challenge. Recent studies have demonstrated that 2017 F1 cars suffer a huge performance loss when working in wake flows. When approaching the leading car, the following driver experiences a dramatic decrease in downforce and a significant change in the aerodynamic load distribution between the front and rear axle: this could lead to safety problems in high-speed corners and during braking. Starting from a 2017 F1 car designed by the British constructor ©PERRINN, different devices have been conceived and numerically tested, with the aim of improving aerodynamic performance both in freestream and wake flows. Steady-state numerical simulations (RANS) have been performed by means of the open-source software OpenFOAM®.

Background



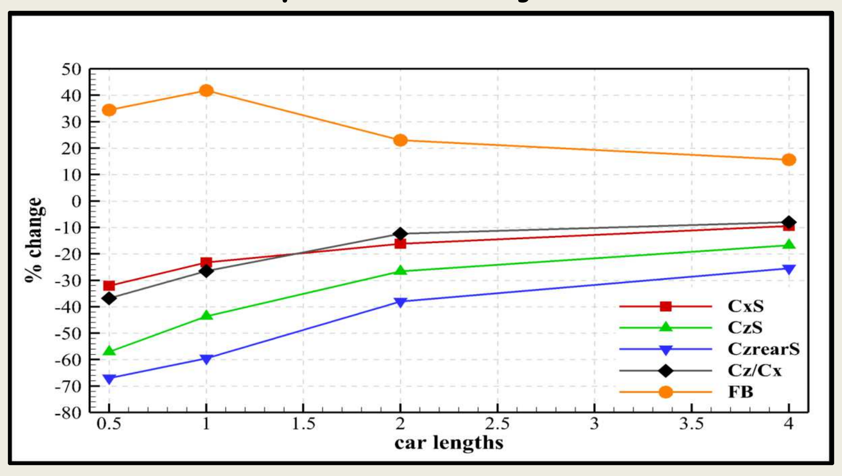
Object of the research: ©PERRINN 2017 F1 Car

Performance Coefficients:
- SCx → drag
- SCz → downforce
- Cz/Cx → efficiency
- FB = Cz_{front}/Cz → front balance

Freestream analysis: AEROMAP

FRH [mm]	RRH [mm] SCx [m²] 45	SCx 50	SCx 55	SCz [m²] 45	SCz 50	SCz 55	Cz/Cx 45	Cz/Cx 50	Cz/Cx 55	FB [%] 45	FB 50	FB 55
10	1.17	1.15	1.18	3.24	3.23	3.48	2.77	2.81	2.95	41.4	43.3	41.4
15	1.14	1.17	1.18	3.17	3.27	3.46	2.78	2.79	2.93	42.0	40.1	40.5
20	1.16	1.16	1.17	3.27	3.35	3.46	2.82	2.89	2.96	40.1	40.3	39.9
25	1.14	1.15	1.16	3.14	3.22	3.37	2.75	2.91	2.91	39.2	39.1	38.9

Slipstream analysis: PERFORMANCE LOSS CALCULATION



Serious performance worsening:

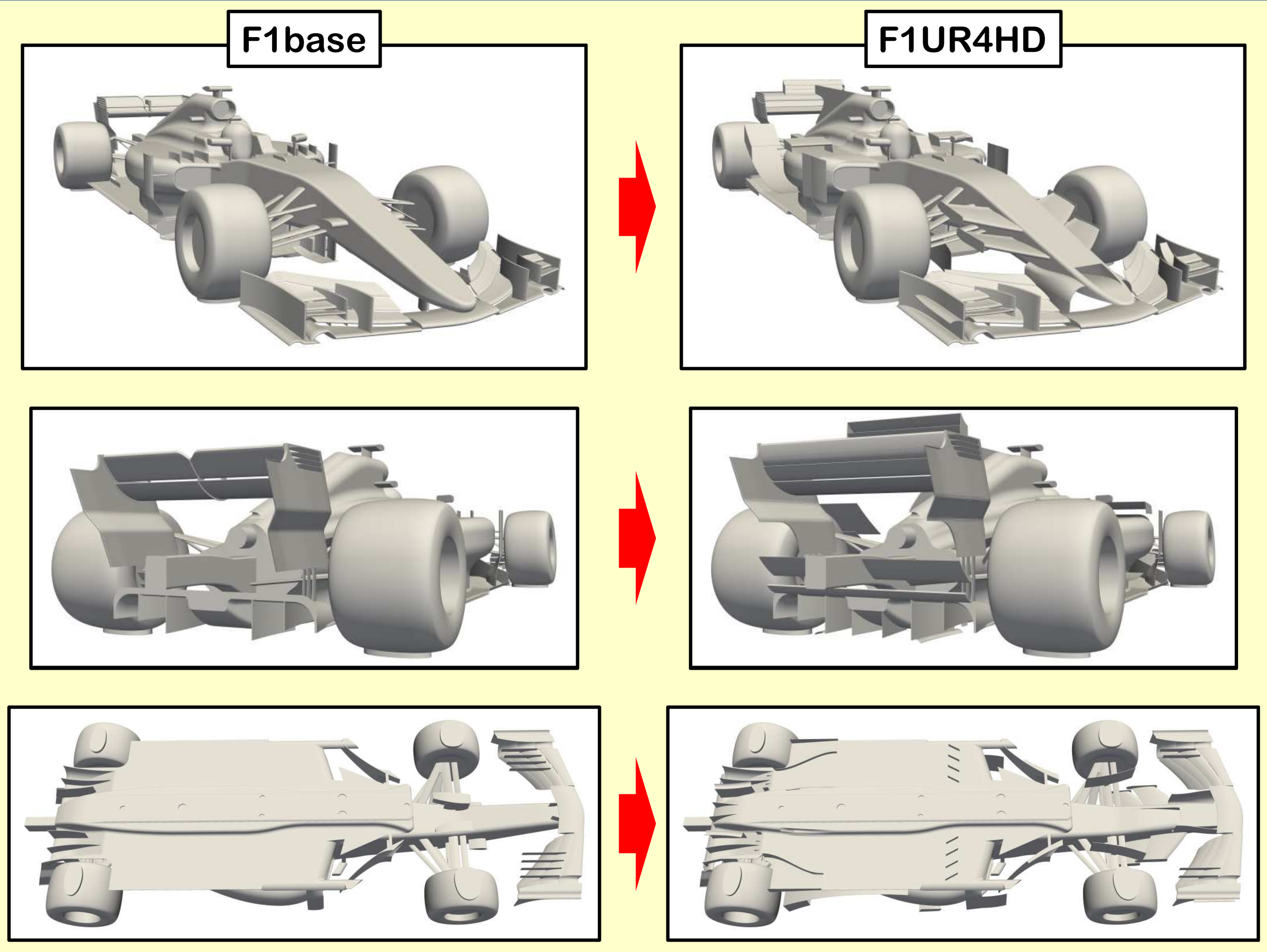
Total Performance loss:
- > 50% SCz (↓)
- > 30% Cz/Cx (↓)
- > 30% FB (↑)

SCz loss of single components:
- Front wing: > 25 %
- Rear Wing: > 50 %
- Underfloor: >55 %

Targets of the research

Improve aerodynamic performance of the baseline car in freestream, in order to reach realistic levels of downforce
Improve aerodynamic performance in slipstream by means of simple and effective solutions for better and safer overtaking

1. Aerodynamic Development



Description of the new components mounted on the F1UR4HD car:

Front-end of the vehicle:
- Removal of two inboard fences mounted on the first flap of the wing
- Span of the cascade winglets extended by 60 mm
- Turning vane mounted on the main plane translated by 40 mm spanwise
- Angle of incidence of the cascade endplate and the turning vane increased up to 25°
- Addition of a small high-cambered profile inside the endplate
- Doubling of the endplate foot
- Addition of the 4th flap
- Addition of Gurney flap on the 4th flap and the wing tunnel
- Convergent-shaped nose pylons
- Thinned down nosecone
- New nosecone duct
- Removal of the front bodywork turning vanes
- Addition of double element canards on the front bodywork
- Turning vane mounted on the lower wishbone of the front suspension

Middle region of the vehicle:
- Lengthened sidepod panels
- New guide vanes at the leading edge of the sidepods
- Addition of a shark fin on the engine cover
- Winglets on the side of the cockpit
- Addition of three-element T-wing
- Double-deck tyre ramps

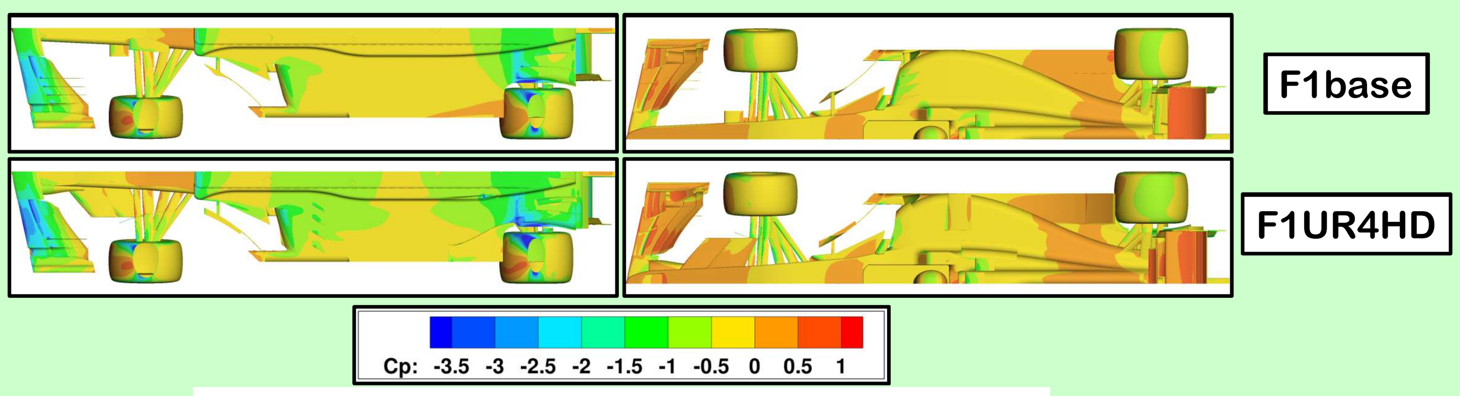
Underfloor:
- Horizontal lip in front of the rear tyres
- Two additional expansion areas in front of the rear tyres
- Enhanced diffuser strakes and diffuser channels
- Underbody duct blowing the diffuser nolder
- Vortex generators at the diffuser inlet
- Array of vortex generators at the step plane inlet (25° incidence)
- Convergent guide vane at the diffuser inlet
- New diffuser nolder

Rear-end of the vehicle:
- Small wing profile on the toe link of the rear suspension
- Three-element rear wing compound with 25° AOA (Be 112-205, 122-125, 152-105)
- Wing position raised by 50 mm in Z-direction
- Beam wing mounted on the rear crash

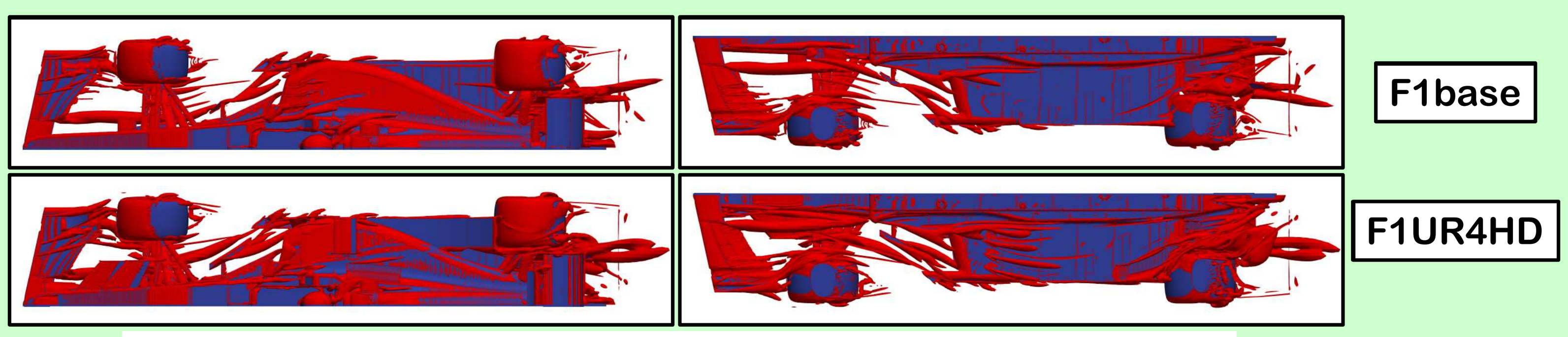
2. F1base vs F1UR4HD: Freestream analysis

Vehicle	SCz [m²]	SCz [m²]	Cz/Cx	FB
F1base	1.18	-3.48	3.0	0.41
F1UR4HD	1.61	-5.16	3.2	0.43

Performance Improvement:
- SCz → +48%
- Cz/Cx → +7%



F1base vs F1UR4HD: Pressure Coefficient – top and bottom view



F1base vs F1UR4HD: Iso-contour of the variable Q = 50000 1/s² – top and bottom view

The baseline vehicle was developed improving both downforce (+48%) and efficiency (+7%) in freestream, by means of simple aerodynamic components. Some of the new devices, such as the front wing add-ons, follow the 2017 F1 Technical Regulations; other elements were designed on the basis of past regulations or completely new approaches: particular attention was given to the underbody and the rear wing, whose performance deteriorates significantly by running in wake flows.

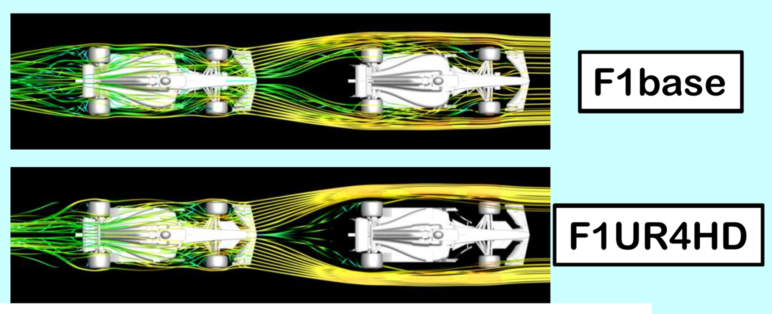
3. F1base vs F1UR4HD: Slipstream analysis

0.5L	SCx [m²]	SCz [m²]	Cz/Cx	FB
F1base	-32%	-53%	-30%	+20%
F1UR4HD	-22%	-39%	-22%	+14%

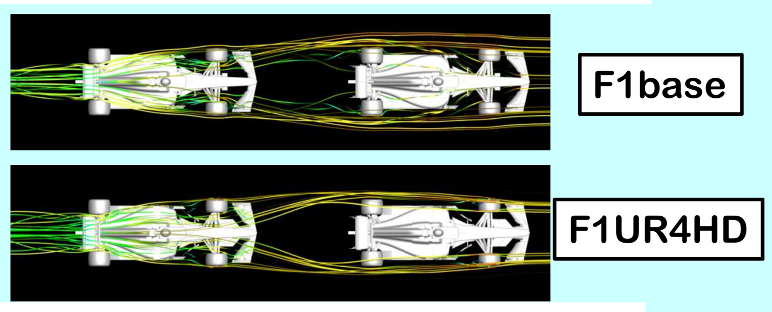
L	SCx [m²]	SCz [m²]	Cz/Cx	FB
F1base	-22%	-44%	-30%	+34%
F1UR4HD	-14%	-25%	-13%	+12%

2L	SCx [m²]	SCz [m²]	Cz/Cx	FB
F1base	-14%	-25%	-13%	+20%
F1UR4HD	-6%	-12%	-6%	+5%

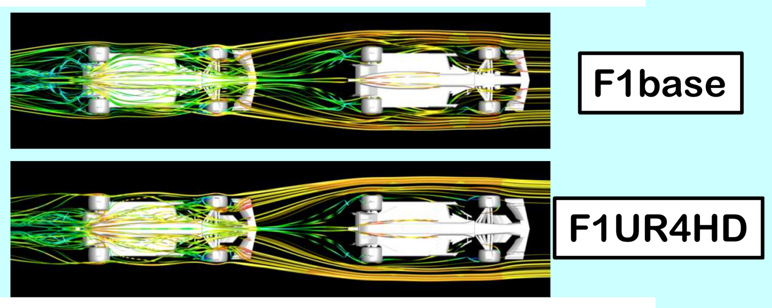
4L	SCx [m²]	SCz [m²]	Cz/Cx	FB
F1base	-8%	-10%	-3%	+7%
F1UR4HD	-2%	-7%	-3%	+2%



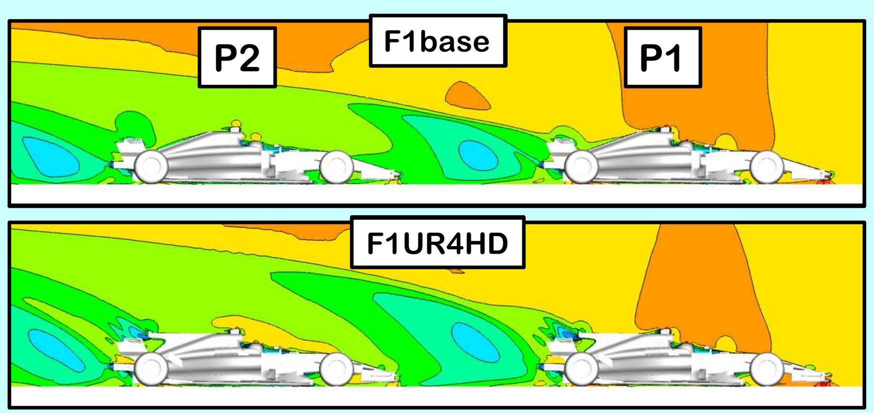
F1base vs F1UR4HD: streamlines feeding the front wing



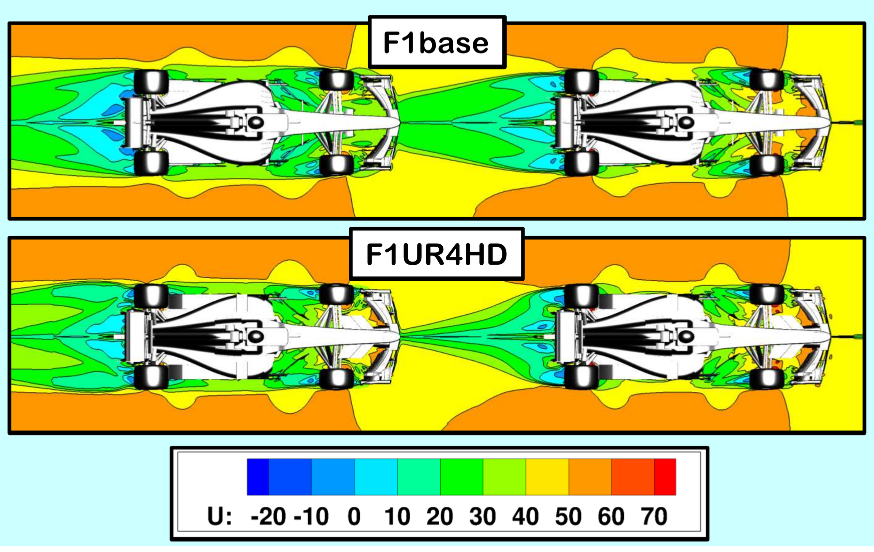
F1base vs F1UR4HD: streamlines feeding the rear wing



F1base vs F1UR4HD: streamlines feeding the underfloor



F1base vs F1UR4HD: Streamwise velocity (U) on XZ plane (Y = 0 m)



F1base vs F1UR4HD: Streamwise velocity (U) on XY plane (Z = 0.1 m)

The F1UR4HD car resulted to be much more robust than the baseline in wake flows, because of the following features:
- Uniform distribution of downforce on the entire vehicle bodywork by means of numerous and different kinds of aero appendices
- The P2 car can re-energize the flow feeding the underfloor and restore the local low-pressure cores by means of dedicated aero devices; the design of the new rear wing assembly is suitable for managing chaotic flow and its interaction with the bottom of the car prevents flow separation in the diffuser.
- The P1 car ensures favourable flow conditions for the P2 car: the underfloor devices make the lower wake very narrow in spanwise direction; the new rear-end assembly gives the streamlines underneath the car a strong upward deviation and shields the P2 car against the incoming low-energy flow.

To sum up, the features of the new wake in terms of width (XY plane) and height (XZ plane) allow high-energy flow to fill the gap between the two vehicles from the outside, thus improving the aerodynamic performance of the car in slipstream.

Acknowledgements

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