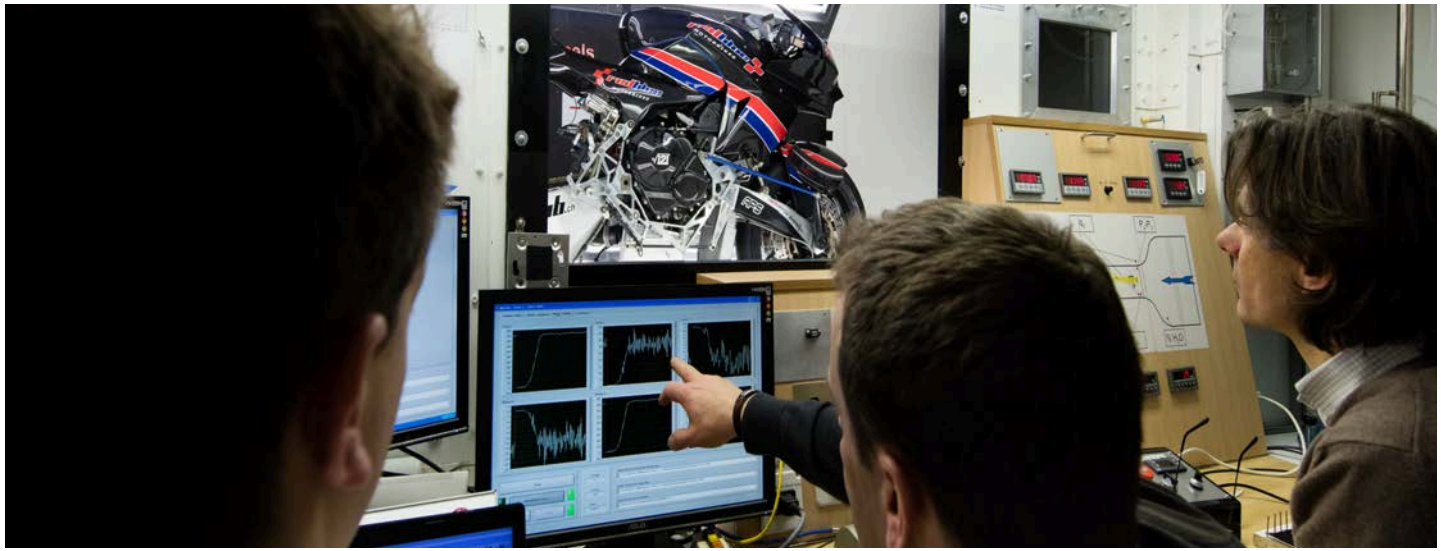

A CFD APPROACH TO IMPROVE WIND TUNNEL TESTS – MOTO2 AERODYNAMICS

THE HEPIA GLOBAL METHODOLOGY

Patrick Haas, Prof. Ord.
Head of the fluid mechanics group (cmefe)
hepia Geneva Wind Tunnels

CADFEM ANSYS SIMULATION CONFERENCE
SWITZERLAND

Rapperswil, 14 June 2018

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THE HEPIA SUBSONIC WIND TUNNEL

KTM Moto2 2017

- Test section: 2.0 m x 1.5 m
- Maximal speed: env. 280 km/h
- 6 component balances
- Measurement robot
- Visualization systems
- Thermal and cooling tests capabilities

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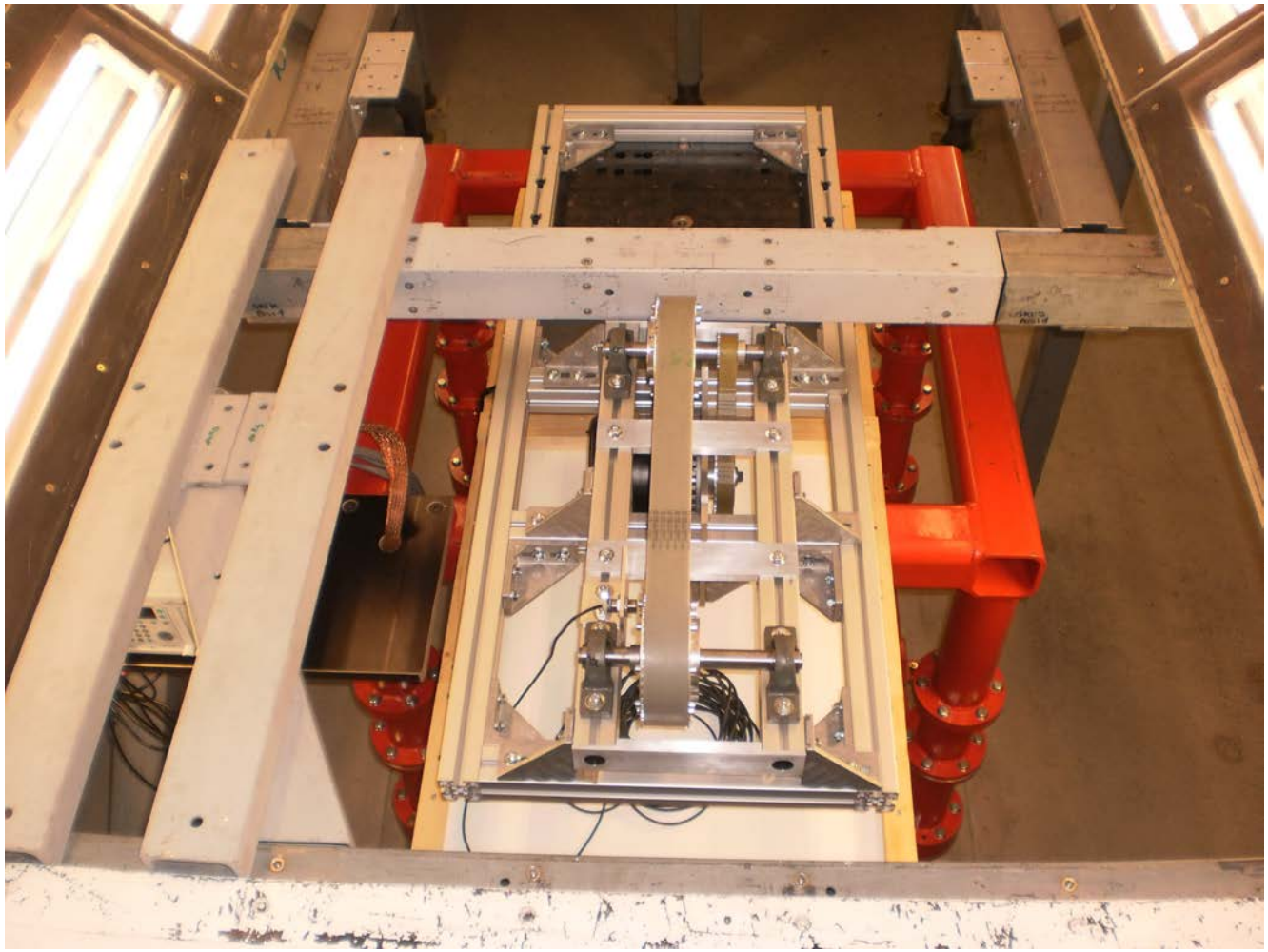
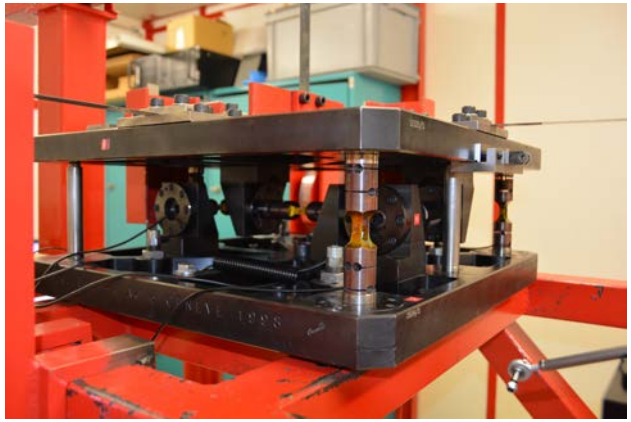
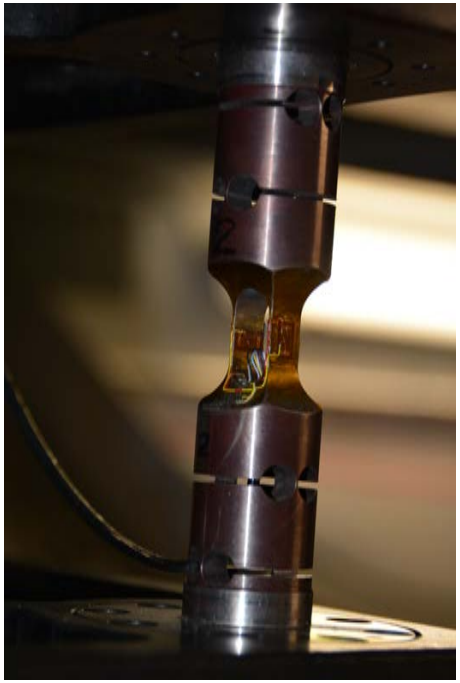
THE HEPIA SUBSONIC WIND TUNNEL

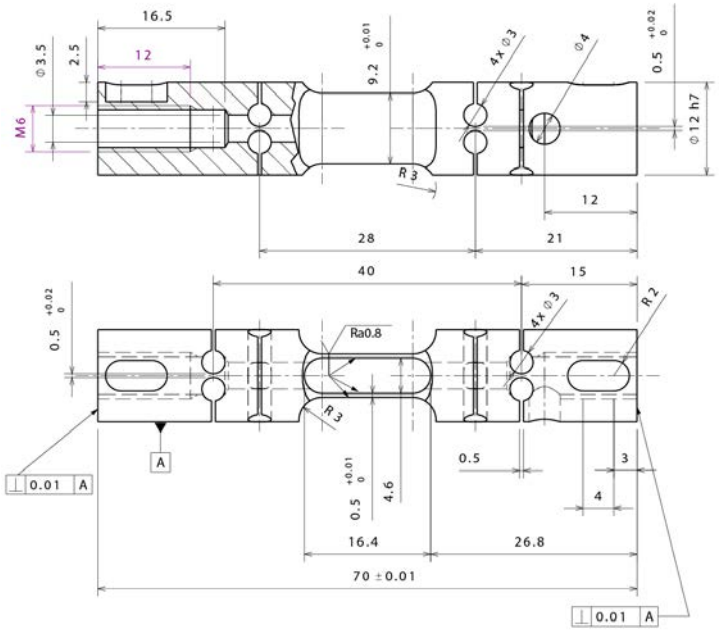


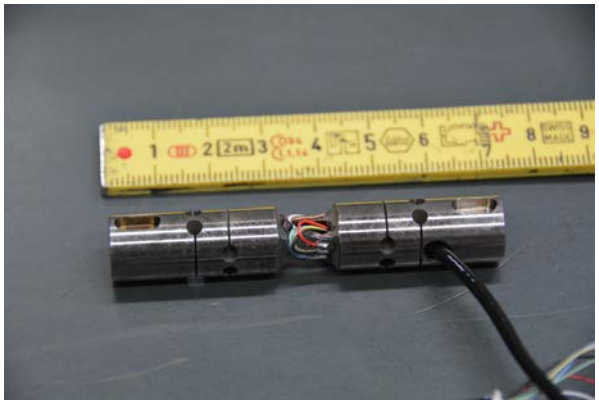
6 component aerodynamic balance with rolling belt

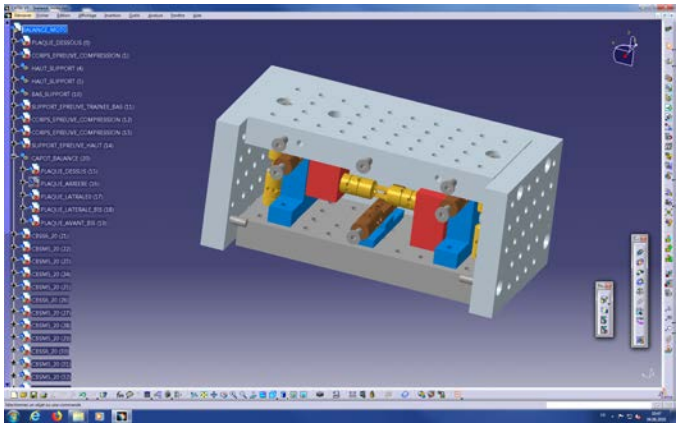
PRODUCTION AND CALIBRATION OF AERODYNAMIC BALANCES











3 or 6 component balances

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THE HEPIA SUBSONIC WIND TUNNEL

Heaters for the evaluation of thermal systems and cooling during aerodynamic tests

HEPIA CALCULATION CLUSTERS

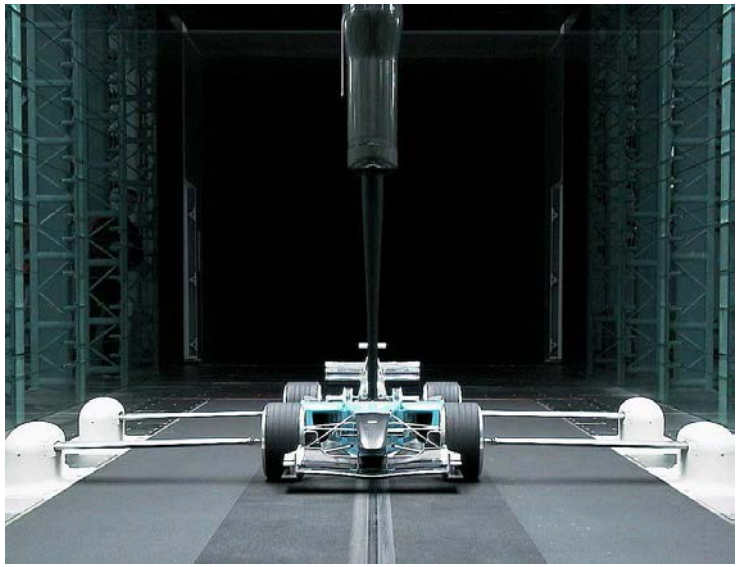
Baobab HPC :	Intel Sandy Bridge, 2'500 cores, 10 To RAM, infiniband (hepia + unige)
Gordias HPC :	ClusterVision, 224 cores, 448 Go RAM, infiniband
EoleC1-5 :	Oracle SUN, 44 cores, 132 Go RAM
EoleC6 :	Dell, 96 cores, 256 Go RAM
Workstations :	8 workstations Dell and HP 16 cores, 126 Gb RAM
Storage (NAS) :	2 x 70 To = 140 To with confidentiality management
CFD software :	ANSYS CFD Associate (industrial), Research and Teaching

MECHANICAL SPORTS AT HEPIA

- Egli Motorradtechnik (1985)
- Motos ROC Annemasse (1992)
- ASM Formula 3 (2006)
- Eco-marathon Shell : Consomini, Biomobile.ch (2003 - actual)
- Motostudent PoliTo Turin (2011-12)
- Moto2 NCS Rapid Inside Modena (2011)
- Audit of the Formula 1 teams (2010 – 2013) P. Haas, R. Putzu
- MotoGP Akira Kawasaki (2014 - 2015)
- Moto2 Tech3 (2014)
- Vyrus 986 M2 Wings (2016)
- Moto2 KTM (2016 – actual)
- Moto2 Garage Plus et Technomag CarXpert : Suter, Kalex, KTM (2014 - actual)
- Moto2 Geotechnology NTS project (2016 – actual)

Moto2 Tech 3 Mistral

AUDIT OF FORMULA 1 TEAMS : WIND TUNNELS

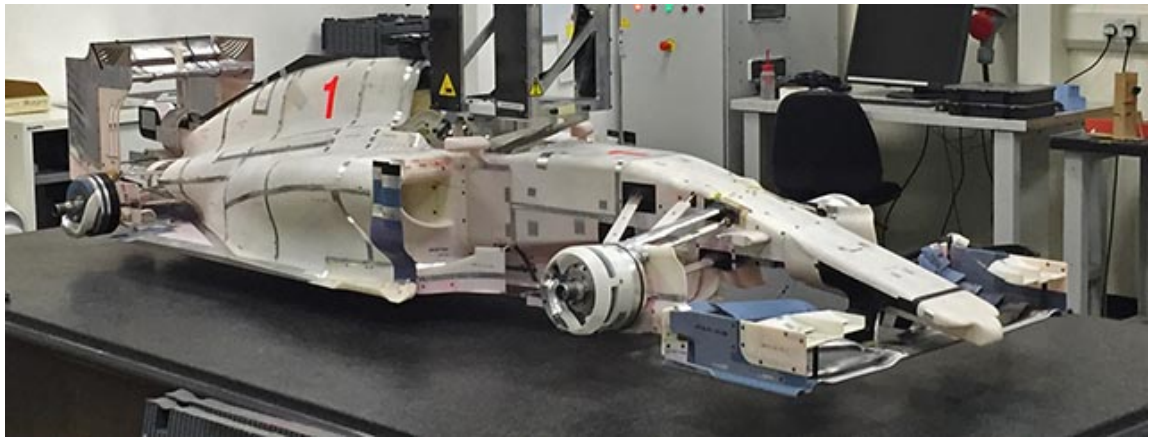


Some F1 wind tunnels

AUDIT OF FORMULA 1 TEAMS : WIND TUNNELS

- Scale of the models 60% max.
- Air speed max. 50 m/s
- Rolling belt and boundary layer suction
- Tests for all angles of the model
- More than 500 wind tunnel tests per month!

A test every 30 minutes !



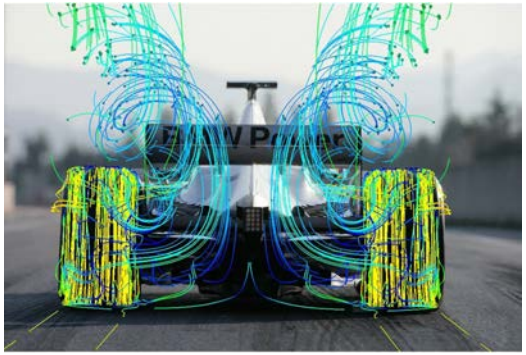
Marussia model (60% scale)

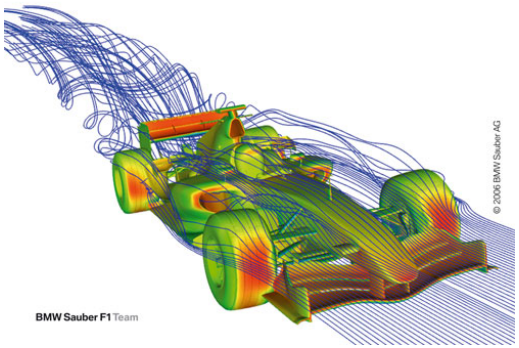
AUDIT OF FORMULA 1 TEAMS : CFD

Albert HPC server, Sauber

- Number of calculus limited per 2 month period
- 18 hour CPU per simulation
- Up to1’500 simulations per month
- Commercial softwares (Fluent, Star CCM+)
- Finite volume method
- Highly parallel clusters of 64 bit CPU (jusqu’à 6’000 cœurs)
- Up to 18’000 Gb RAM
- Infiniband DDR 48 Gbit/s interconnections or more
- Approx. 100 kW power supply… and cooling!

Up to 50 simulations of the full car per day!





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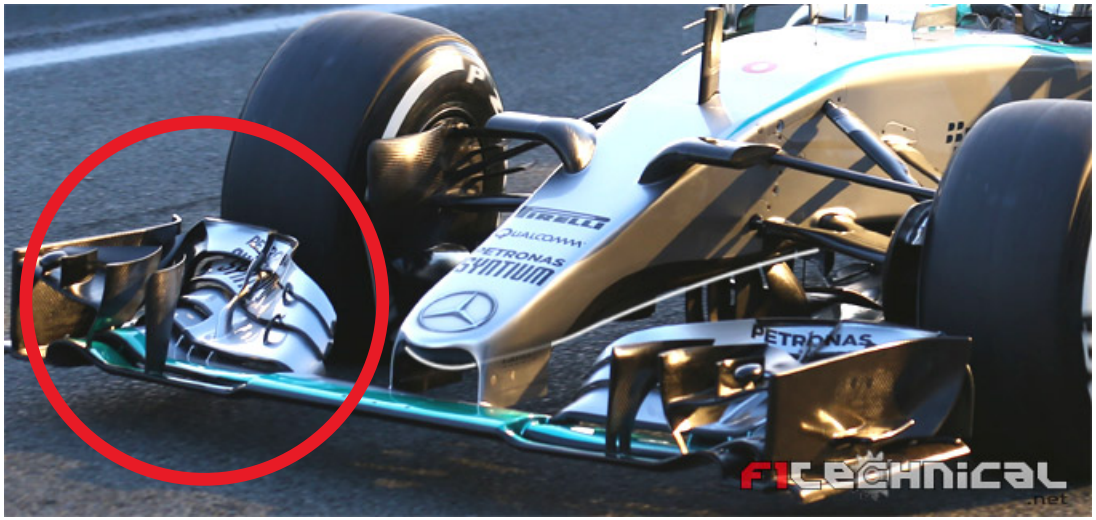
WHAT CAN BE LEARNED FROM THE FORMULA 1 TEAMS ?



Mercedes AMG F1 WA06

Ferrari SF15T, 2015

How they use CFD technics :

- CFD show all flow variables everywhere in the domain without disturbing anything for all scales of space and time !

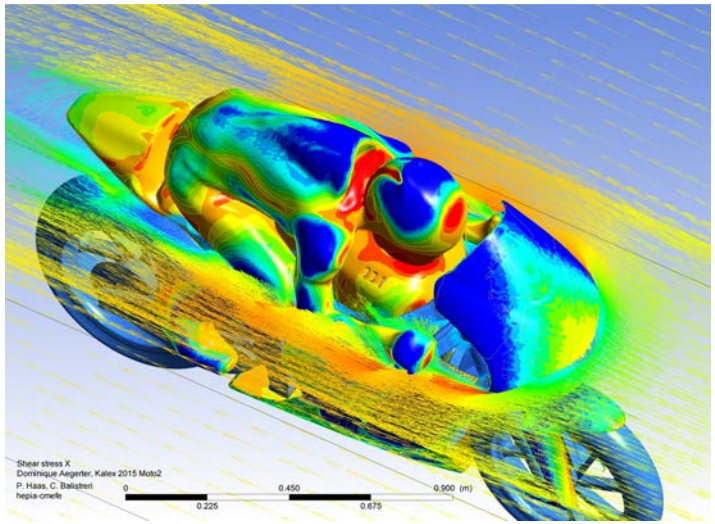
  Understanding of the flow behaviour → New ideas !

- Design optimization – Parametric studies

THE HEPIA GLOBAL METHODOLOGY

Since 2011, hepia uses with success a global methodology including 5 chapters :

1. **Full scale wind tunnel tests**
   - With riders, seat definition and position
   - CFD validation on the wind tunnel case
   - Continuity with experience (known values)



2. **Model wind tunnel tests (half-scale)**
   - Availability of the model all the year long
   - Size of the model for a correct aspect ratio (surface of the test section / surface of the model)
   - Costs (more days to work!)

3. **Simulations (CFD)**
   - Flow behaviour understanding
   - New ideas
   - Motor cooling and thermal studies

THE HEPIA GLOBAL METHODOLOGY

4. **On track measurements**
   - Instrumented motorcycle
   - Full scale
   - In open space (real case)
   - Torque measurements at the wheel
   - Work done on a MotoGP for studying the blocage in the wind tunnel at hepia.

5. **Race data logger measurements**
   - Study of the data obtained during the races

Tom Lüthi 2017

- Recognize each method for their strengths and weaknesses
- Use a global methodology with only one objective: Increasing the results on the track !

HEPIA MOTO2 AERODYNAMIC PROGRAM
RESULTS

Aerodynamic resistance:

$$F = \tfrac{1}{2} \rho \, SCx \, V^2$$

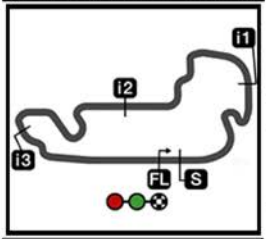
x

		SCx
Moto2 Kalex Aegerter 2015 (with hepia work)		
Simulations CFD	:	0.230
WT full scale (corrected)	:	0.252
WT original Kalex (without hepia work)	:	0.279
Moto2 Kalex Aegerter 2016 (with hepia work)		
WT full scale (corrected)	:	< 0.245
WT original Kalex (without hepia work)	:	0.269
Moto2 Suter Aegerter 2014 (with hepia work)	:	0.262
Moto2 NCIS 2011 original	:	0.320

ON THE TRACK...

- The swiss Moto2 is offently the fastest of the paddock…

anapolis Motor Speedv Results and timing service provided by TISSOT



4170 m.

RED BULL INDIANAPOLIS GRAND PRIX

After the **Race**

Event Best Maximum Speed

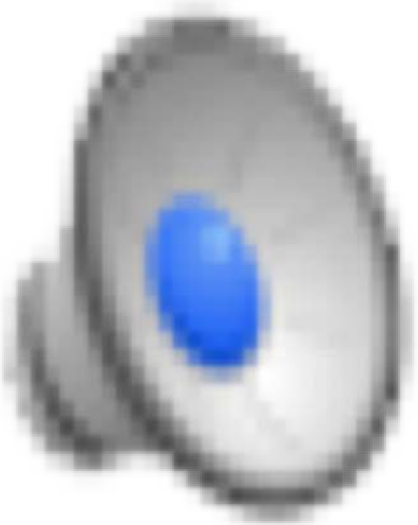
Moto2

33

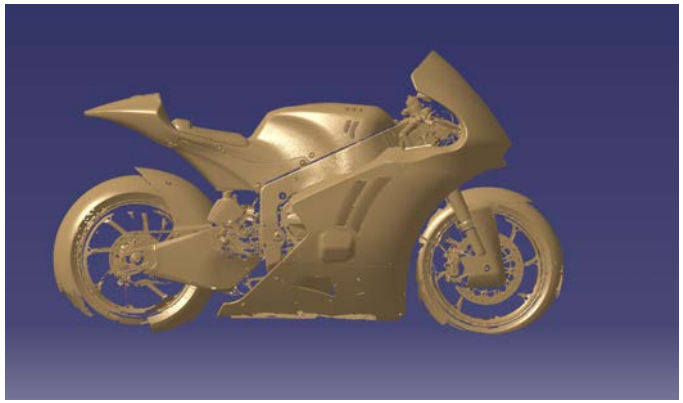
	Rider	*Nation*	*Team*	*Motorcycle*	*Km/h*	
12	**Thomas LUTHI**	**SWI**	Derendinger Racing Interwetten	KALEX	**290.0**	Race
77	**Dominique AEGERTER**	**SWI**	Technomag Racing Interwetten	KALEX	**289.3**	Free Practice Nr. 1
25	**Azlan SHAH**	**MAL**	IDEMITSU Honda Team Asia	KALEX	**288.7**	Race
11	**Sandro CORTESE**	**GER**	Dynavolt Intact GP	KALEX	**287.6**	Free Practice Nr. 3
73	**Alex MARQUEZ**	**SPA**	EG 0,0 Marc VDS	KALEX	**286.9**	Race
21	**Franco MORBIDELLI**	**ITA**	Italtrans Racing Team	KALEX	**286.8**	Race
1	**Tito RABAT**	**SPA**	EG 0,0 Marc VDS	KALEX	**286.8**	Race
39	**Luis SALOM**	**SPA**	Paginas Amarillas HP 40	KALEX	**286.3**	Qualifying
40	**Alex RINS**	**SPA**	Paginas Amarillas HP 40	KALEX	**286.0**	Race
36	**Mika KALLIO**	**FIN**	Italtrans Racing Team	KALEX	**285.9**	Race
97	**Xavier VIERGE**	**SPA**	Tech 3	TECH 3	**285.9**	Race

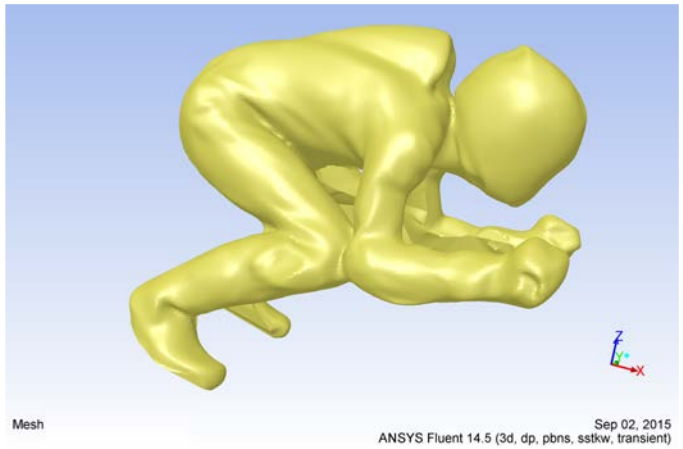
ON THE TRACK...

2016 : Morbidelli and Tom on the straight line of Qatar.



WITH TUNNEL TESTS WITH HALF-SCALE MODEL





Scan 3D and production with 3D printers

Half-scale radiator

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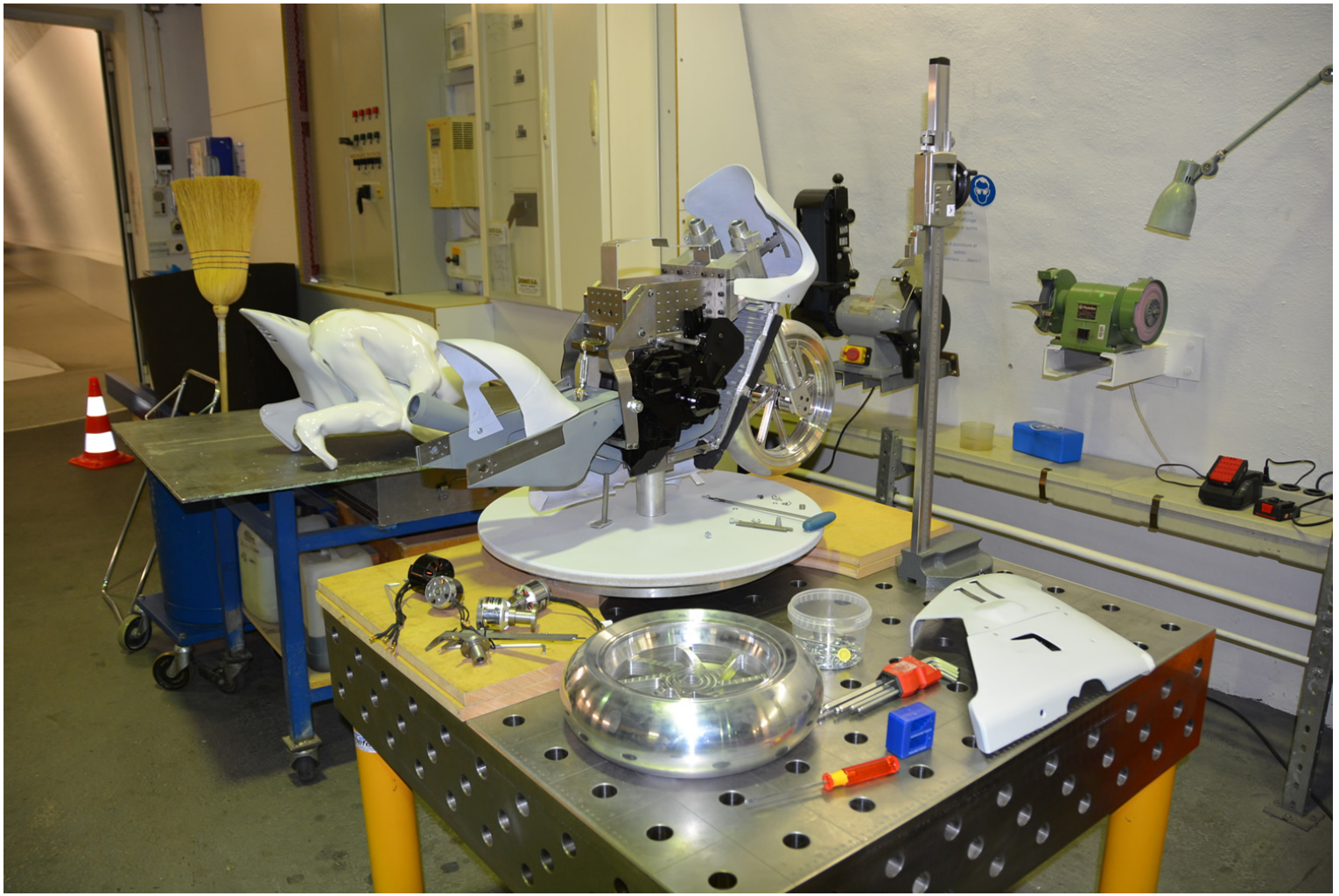
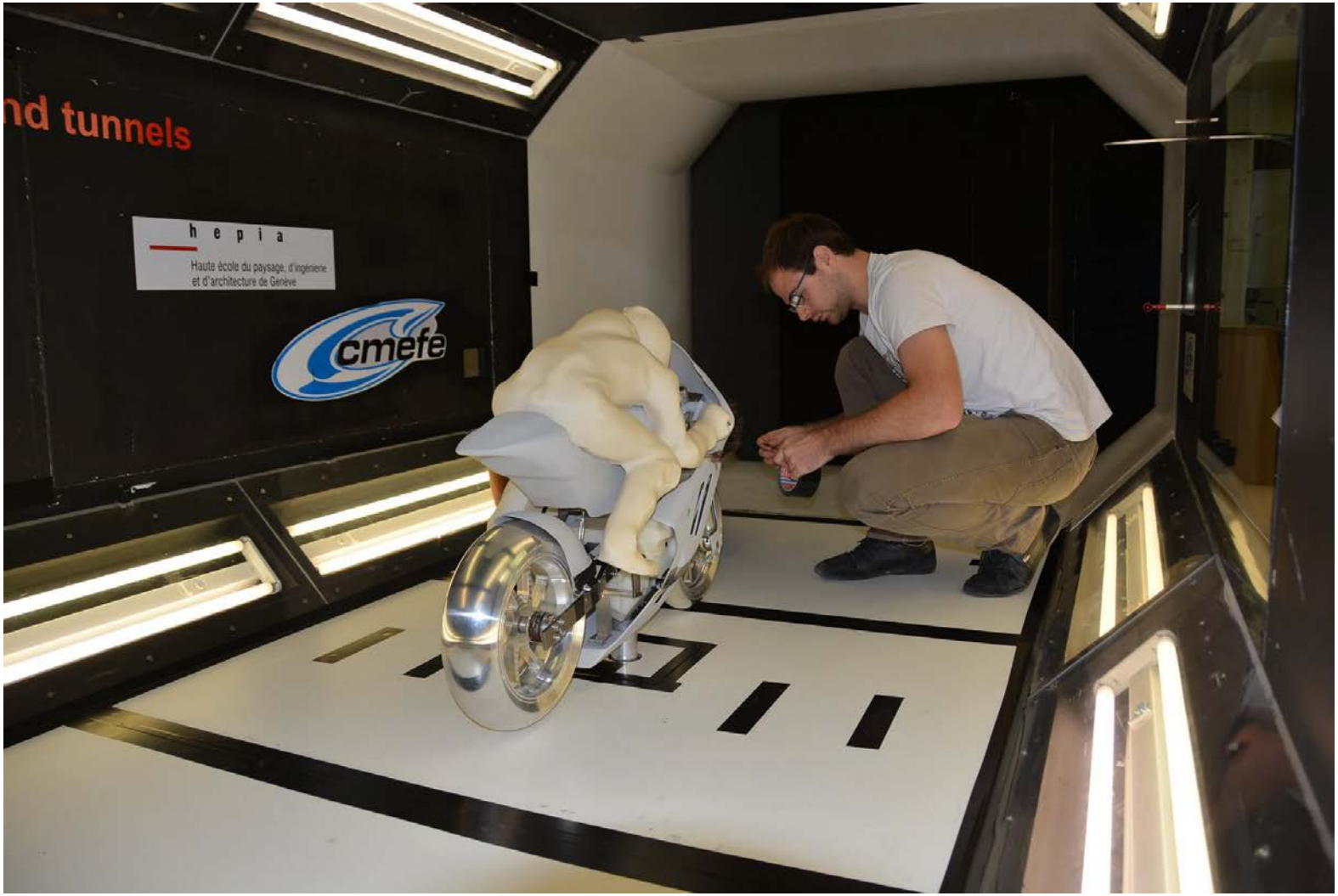
WITH TUNNEL TESTS WITH HALF-SCALE MODEL



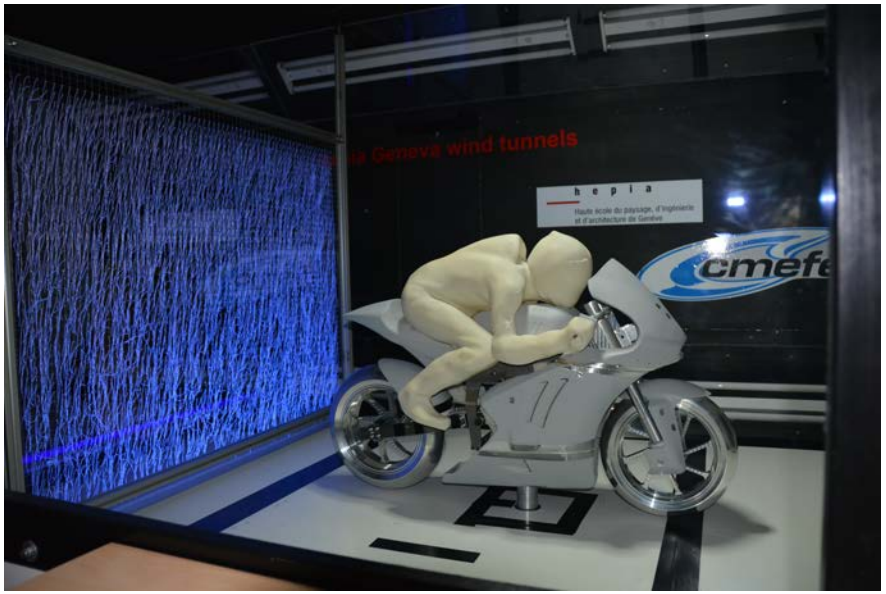
Model production

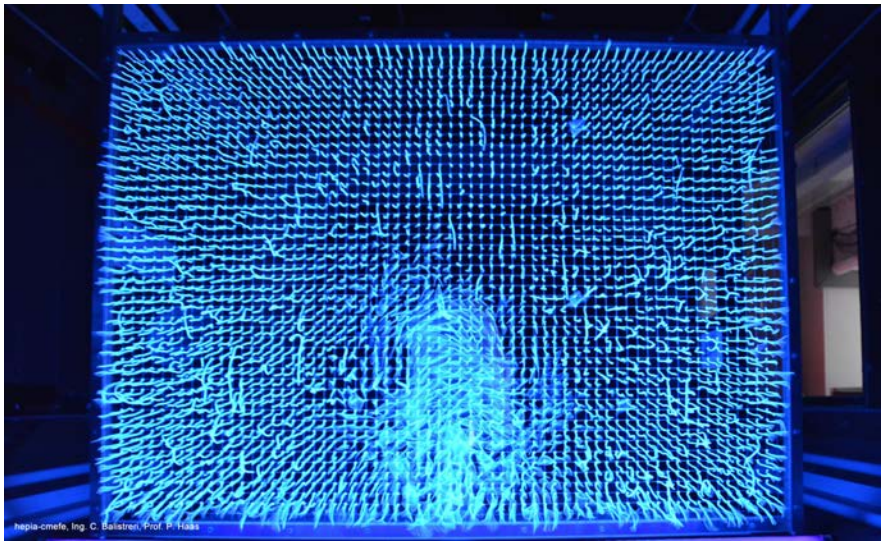
WITH TUNNEL TESTS WITH HALF-SCALE MODEL



Moto2 Kalex with Dominique Aegerter

WITH TUNNEL TESTS WITH HALF-SCALE MODEL

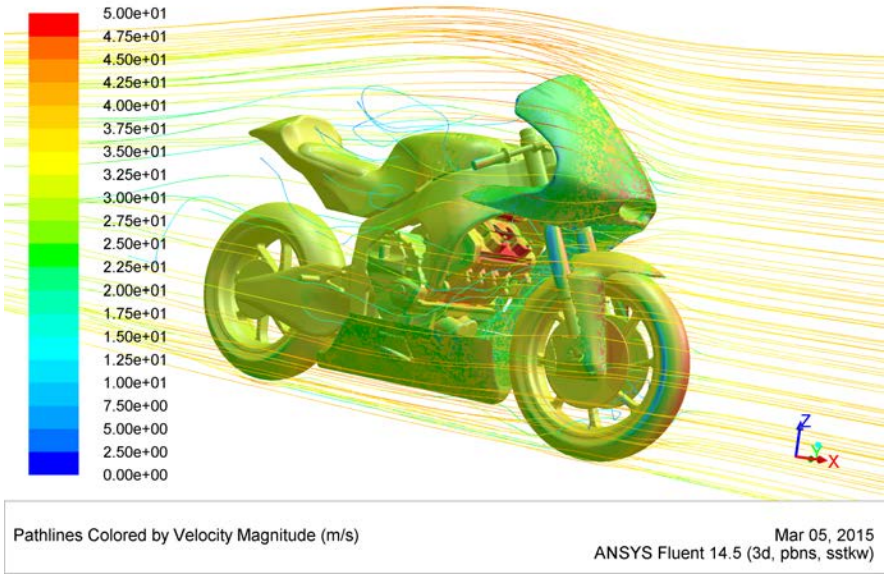




Visualization technics

Moto2 Kalex with Dominique Aegerter

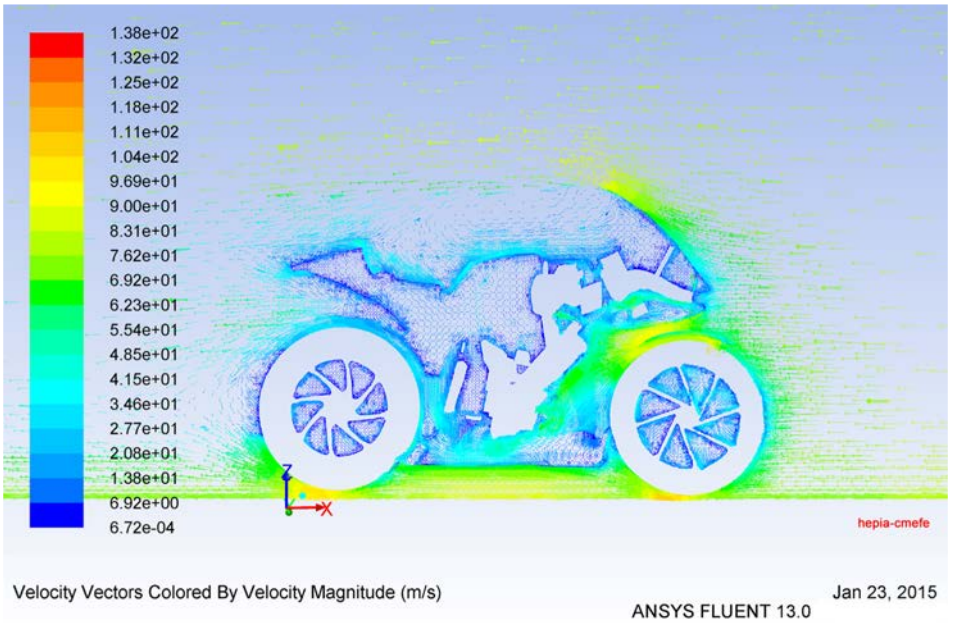
CFD SIMULATION



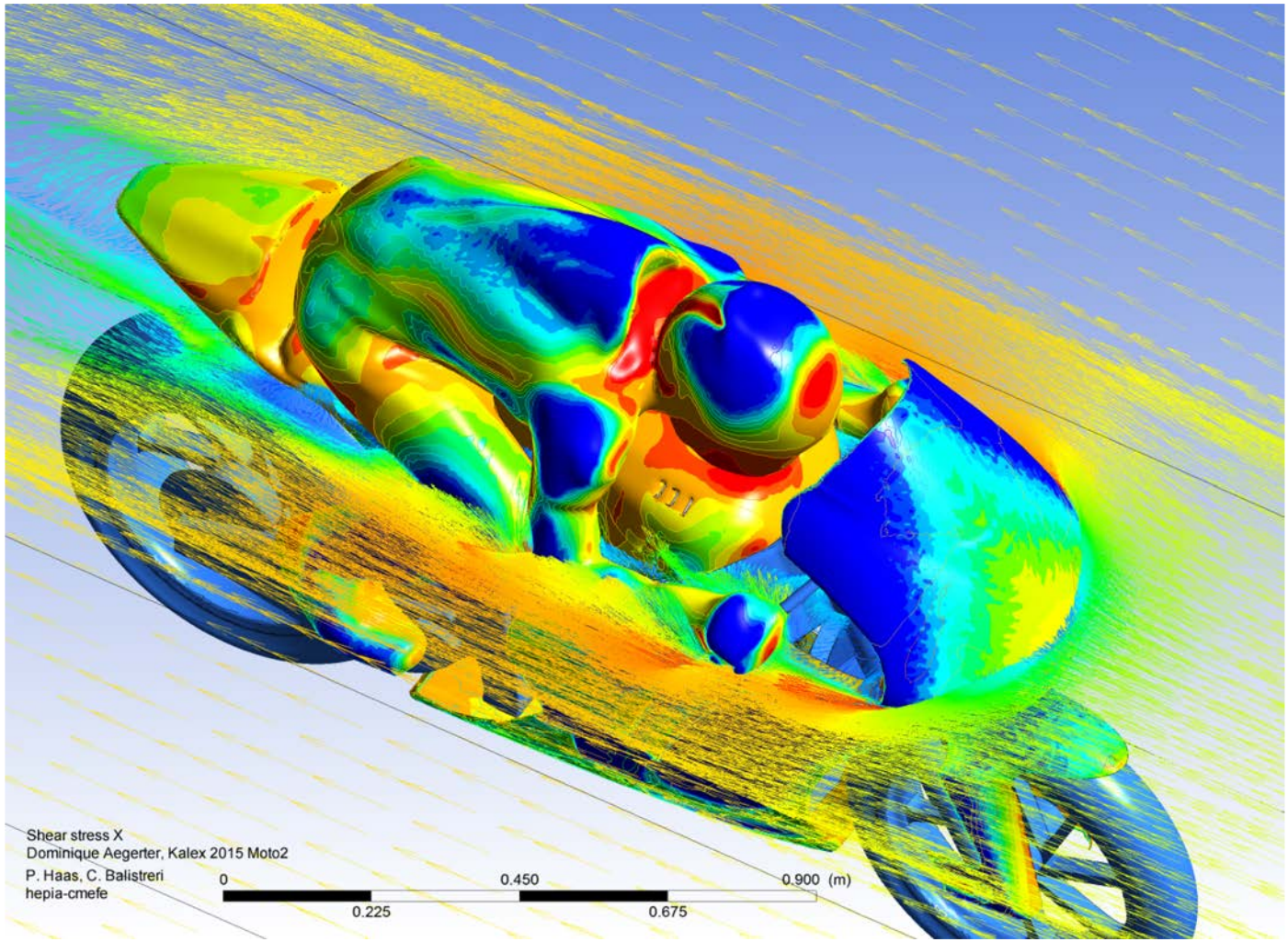
Objectives

- Internal and external aerodynamics
- Drag optimization
- Cooling and thermal evaluation

- Radiator as a model (head loss and thermal source)
- Rotating wheels



CFD SIMULATION



Moto2 Kalex with Dominique Aegerter
Shear stress x and speed in a x-y plan

CFD SIMULATION METHODOLOGY

Baobab Cluster (SLURM job manager)

Intel E5-2620 @ 2.00 GHz, E5-2630 v4, E5-2650 v2
Nodes of 16 and 20 cores

#cores	1st step	next steps
40 c	00:05:15	00:04:14
48 c	00:39:10	
48 c	00:39:41	
60 c	00:03:37	00:02.54
80 c	00:02:58	00:02:10
96 c	00:05:43	
100 c	00:02:07	00:01:46
100 c	00:02:11	00:01:47
100 c	00:02:11	00:01:45
102 c	00:05:30	00:04:04
105 c	00:17:00	
110 c	00:27:24	
120 c	00:02:00	00:01:29
120 c	00:01:51	00:01:28
120 c	00:01:54	00:01:26
128 c	00:29:10	
132 c	00:48:52	
140 c	00:13:38	00:09:03
140 c	01:45:59	

How calculations are distributed on the cluster nodes ? What effect does it have?

CFD SIMULATION METHODOLOGY

Baobab with only nodes type V5 (E5-2630 v4 of 20 cores) :

		#cores	1st step	next steps	
17.12.16	slurm-2554888.out	120 c	00:01:50	00:01:26	6 x 20/20
17.12.16	slurm-2555168.out	140 c	00:01:32	00:01:20	7 x 20/20
17.12.16	slurm-2555367.out	144 c	00:12:20		7 x 20/20 + 4/20
17.12.16	slurm-2555370.out	141 c	00:01:34	00:01:15	7 x 20/20 + 1/20
17.12.16	slurm-2555371.out	142 c	00:05:26	00:03:46	7 x 20/20 + 2/20
17.12.16	slurm-2555435.out	143 c	00:09:10	00:06:00	7 x 20/20 + 3/20
18.12.16	slurm-2555612.out	121 c	00:01:55	00:01:29	6 x 20/20 + 1/20
18.12.16	slurm-2555613.out	122 c	00:01:52	00:01:28	6 x 20/20 + 2/20
18.12.16	slurm-2555614.out	124 c	00:09:00	00:06:11	6 x 20/20 + 4/20
18.12.16	slurm-2555615.out	126 c	00:14:39	00:09:51	6 x 20/20 + 6/20
18.12.16	slurm-2555617.out	116 c	00:07:55	00:05:25	5 x 20/20 + 16/20
18.12.16	slurm-2555618.out	118 c	00:01:56	00:01:30	5 x 20/20 + 18/20
18.12.16	slurm-2555619.out	120 c	00:02:05	00:01:26	6 x 20/20
18.12.16	slurm-2555632.out	144 c	00:08:44	00:05:57	7 x 20/20 + 4/20
18.12.16	slurm-2555658.out	138 c	00:01:36	00:01:16	6 x 20/20 + 18/20
18.12.16	slurm-2555661.out	136 c	00:10:15	00:06:33	6 x 20/20 + 16/20

With Baobab (slurm) : Only use full nodes !

CFD SIMULATION METHODOLOGY

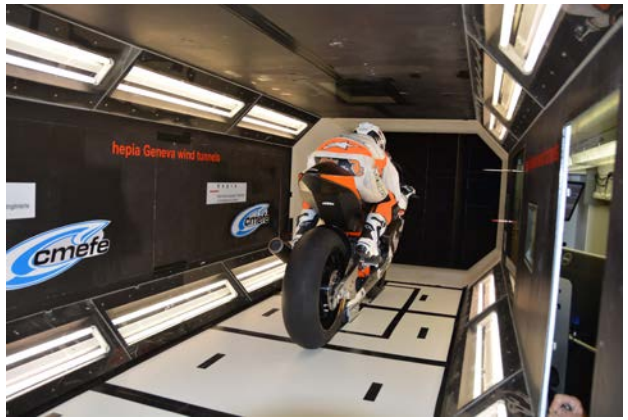
Gordias (SGE job manager)

Intel E5530@ 2.40 GHz
2 processors 4 cores / node = 8 cores / node

#cores	1st step	next steps	
60 c	00:04:47	00:04:13	FLUENT.o2659
80 c	00:03:35	00:03:09	FLUENT.o2658
100c	00:02:53	00:02:31	FLUENT.o2650
105c	00:02:47	00:02:23	FLUENT.o2651
120 c	00:02:56	00:02:20	FLUENT.o2649
120 c	00:02:44	00:02:22	FLUENT.o2652
120 c	00:02:49	00:02:19	FLUENT.o2660
128 c	00:02:25	00:02:06	FLUENT.o2653
128 c	00:02:26	00:02:05	FLUENT.o2655
130 c	00:02:19	00:02:01	FLUENT.o2656
130 c	00:02:21	00:02:00	FLUENT.o2661
144 c	00:02:36	00:02:08	FLUENT.o2654

With Gordias (SGE) : The calculation time decreases approx. linearly with total number of cores used

THE USE OF CFD IN THE HEPIA METHODOLOGY



We have demonstrated in the Moto2 program, CFD is an important part of the methodology. At least:

- Flow understanding
- Blocage ratio correction
- Design optimization

hepia work actually using this methodology in quasi all projects performed for our industrial partners.

In a recent project, the concept has been pushed to the limit :

We performed the validation of the CFD for a case in wind tunnel at full scale and with a very large model for the test section :

- Same physics (flow, thermal, time dependent situations, ecc.)
- Approximately same gradient values
- Full details

→ Then, the final values have been calculated using the CFD model !

THE USE OF CFD IN THE HEPIA METHODOLOGY

The case used for validation

In this project, 90% of the work has been done in CFD.

However, the role of the wind tunnel was important :

- To validate the CFD method (mesh, model choices)
- To validate some data regarding modelized components (such radiators characteristics)
- Others secondary tests : Succion of things in the radiators, noise (feeling), ecc.

Even if, the major part of the work has been done in CFD, the full hepia methodology has been used.

→ This project demonstrates the hepia global approach is very robust and consistent.

QUESTIONS ?

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www.cmefe.ch

hepia Geneva Wind Tunnels

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