Formula 1: The show must go on?

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- What is Formula 1
- Comparison of five Formula 1 Engine periods, starting 1966
- Impressive engines for each of the 5 periods
- Looking back to the first Turbo Era
- Hybrid technology ERS (energy recovery system) starting 2011
- Total new regulations starting 2014 with 1.6 Ltr. V 6 Turbo engines and two energy systems and even more complexity
- Summary

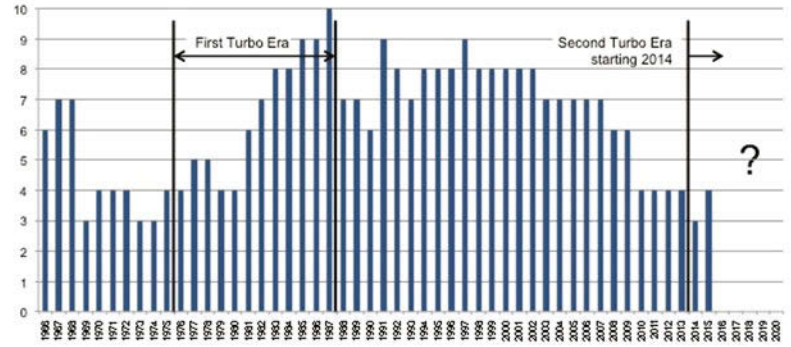
Formula 1

Formula 1 is the world`s biggest motor sporting event with 20 races on five continents per year. Attractiveness grows with the Number of Competitors participating

- Formula 1 should be recognized as the ultimate engineering, technological and sporting showcase
- F1 is governed and regulated by the FIA through the F1 Technical Working Group reporting to the FIA General Assembly (157 motoring organizations from 118 countries)
- FIA set two main regulatory criteria for Formula 1:
  1. Controlling speed in the interest of safety while at the same time preserving the technological excellence of Formula 1
  2. Safety in the event of an accident

Attractiveness of Formula 1

Number of different Formula 1 engines starting 1966



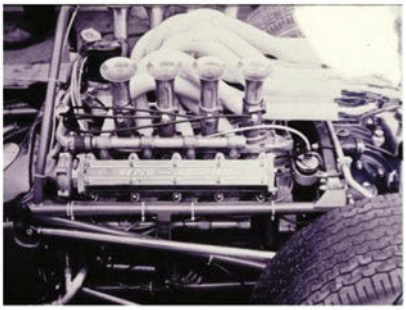
- Attractiveness of Formula 1 grows with number of different engines and with the internationality of companies, drivers and racing tracks
- First turbo period 1976-1988 up to 10 different engines
- Will there be more OEM`s & different engines in the second turbo Era ?

Five periods of Formula 1 Engines

	1st Period	2nd Period	3rd Period	4th Period	5th Period
Year	1966-1988	1989-1994	1995-2005	2006-2013	2014-2020
Displac. Ltr.	3.0 Ltr.	3.5 Ltr.	3.0 Ltr.	2.4 Ltr.	
Cylinders	8, 12, 16	8, 10, 12	10, 12	8	
Power HP	380-520	650	820	760	
/min	12,500	14,500	18,000	18,000	
			PVRS	PVRS	
Turbo					
Displac. Ltr.	1.5 Ltr.				1.6 Ltr.
Cylinders	4, 6, 8				6
Power HP	1000				620+120
/min	13,000				12,000
Car weight kg	580	600	600	640 KERS	691 ERS
HP/kg	1.72	1.08	1.36	1.18	1.07

First period: 1966-1988

Brabham Repco V8 90°
SOHC 2V
380 HP

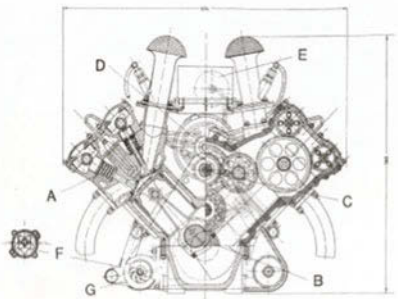


- The most simple F1 engine ever
- 2 valves only and side flow
- The last 2V engine in F1

BRM H 16
DOHC 2 V
ca. 400 HP

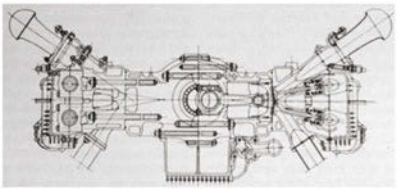
- The most complex F1 engine ever
- The best engine sound ever: enjoy in internet

Ford Cosworth 3.0 Ltr.
V8 90° DOHC 4V
400 up to 500 HP



- The most successful F1 engine
- 154 Grand Prix victories

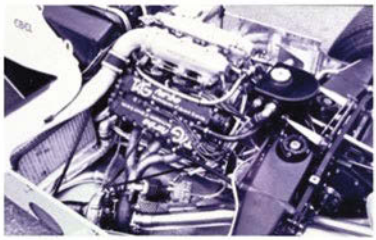
Ferrari 312 B 3.0 Ltr.
V12 180° DOHC 4V
520 HP



- Flat V12 was not a good design for the upcoming wing cars

End of first period: the first Turbo Era

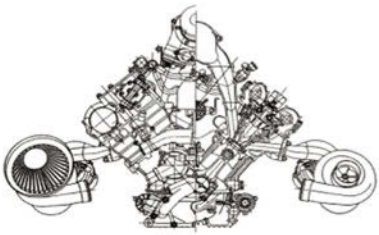
TAG Porsche Turbo 1.5 Ltr.
V6 80° DOHC 4V
up to 1,000 HP 664 Nm



- Highest mean effective pressure:
- 57 bar, boost: 4 bar

Up to ten different engines at that time

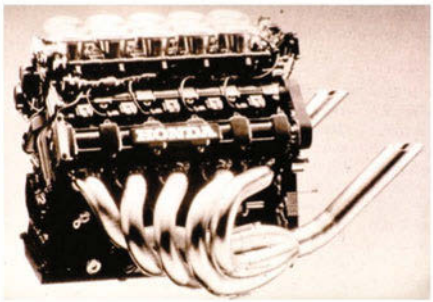
Honda RAI68E Turbo 1.5 Ltr.
V6 80° DOHC 4V
456 kW = 620 HP 440 Nm



- Most efficient F1 engine at that time
- 272 g/kWh = 200 g/HPh at 12,500/min full load, boost: 3.5 bar
- 150 Ltr. for the hole race distance!

Second period: 1989-1994

Honda 3.5 Ltr. V10 DOHC 4V 650 HP
V10 design the best compromise for this period:
V8 not enough power, V12 to long and to heavy



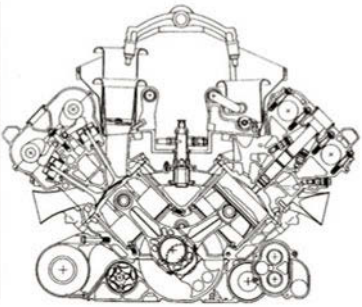
Eight to nine different engines at that time

Third period: 1995-2003

Displacement: 3.5 down to 3.0 Ltr. because of too much power

Ferrari 3.0 Ltr. V10 DOHC 4V
820 HP 18,000/min
extreme aggressive sound

Cross section
Stroke: 39.5 mm
Intake valve lift: 20 mm !



Eight to nine different engines at that time

Fourth period: 2006-2013

Displacement 3.0 down to 2.4 Ltr. because of too much power

The most successful 2.4 Ltr. V8 Formula 1 racing engine was designed by Renault
60 victories, five from eight possible Constructers and Driver Championships
66 Pole-Positions, 56 fastest laps, excellent durability

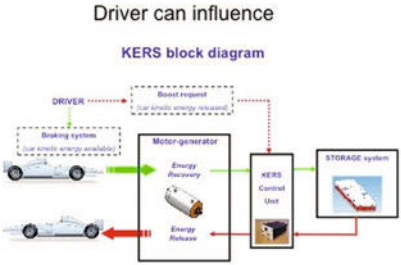
RENAULT SPORT F1

Technical data:

Type: RS27-2013
Configuration: 2.4 Ltr. V8
Cylinder: 8
Valves: 32
Displacement: 2,400 ccm
Weight: 95 kg
Bank angle: 90°
Maximum revolutions: 18,000 U/min
Power: over 750 HP
Piston: Aluminum
Engine block: Aluminum
Crankshaft: nitrated steel with counterweighs Tungsten inserts
Connecting rods: Titanium Alloy

Down to four different engines

KERS – Kinetic Energy Recovery System 2011-2013



Energy consumption

- Gasoline used for one race: 200 Ltr. = 3.6 Ltr./lap = 115.9 MJ/lap
- KERS recuperation: 82 HP for 6.6 sec. = 0.4 MJ/lap
- KERS make cars 0.3 sec. faster/lap

→without KERS and 35 kg less, Formula 1 cars would have been faster, because 10 kg less car weight leads to approx. 0.35 sec faster lap times

Discussions about new Regulations for 2014

Intention: "Green image" for Formula 1 through new regulations
First target: 35% less fuel consumption → 135 Ltr. gasoline per car and race

- First proposal: 4 cylinder engines only
- Ferrari voted for the much better solution: 1.6 Ltr. V6 engines
- Amount of KERS for the „Experts" not enough: ten times higher for 2014
- Use of exhaust energy to make the cars faster and more efficient ?
- New name ERS-H: Proposal for a turbo compound system and double battery capacity
- ERS-K unit: 160 PS, 50.000/min for 33 sec.
- Fuel flow sensor to limit the flow to a maximum of 100 kg/h

Extreme technical complication and extreme cost increase
Down to three different engines

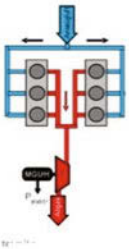
New Regulations

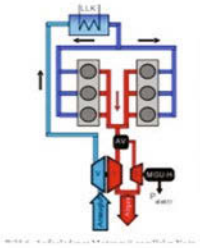
Final regulation starting 2014 - Target: 35% less fuel consumption

Engine		Car	
Displacement:	1.6 Ltr. / 4V	Weight:	691 kg (702 kg)
Bank angle:	90°	Engine weight:	145 kg
Bore / Stroke:	80mm / 52.9mm	ERS:	150 kg
Max. RPM:	15,000/min		
Fuel consumption:	100 kg/h	Pure Electric Drive in the pit lane delayed to 2017	
Direct injection:	500 bar		
ERS: 10 times	60 up to 120 kW 6.6 up to 33 sec.	Gearbox with 8 Gears and fixed Ratios according to race track	
1. Proposal:	electric energy turbocharger only		
2. Proposal:	energy also ERS-K	Again not enough freedom for the engine and too much focus on Hybrid systems	
Turbocharger:	only one		
Boost pressure:	approx. 3.5 bar		

Exhaust energy: Four different Turbo compound systems

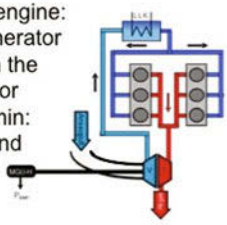
N.A. engine: compressor-generator in the exhaust pipe

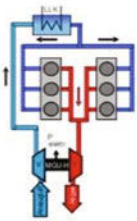




Charged engine: compressor-generator behind the waste gate: Porsche 919 Le Mans

Charged engine: Motor-generator drive from the compressor 125,000/min: Renault and Ferrari



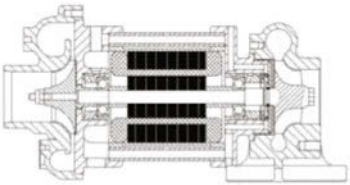


Charged engine: Motor-generator in between the compressor and the turbine: 125,000/min Mercedes

Electric energy from the turbocharger

ERS-H: First tests for passenger car engines many years ago (Turbodyne)

Exhaust back pressure increased:
- Less power because of nocking
- Loss of fuel consumption and performance



Decreased efficiency because of increased wheel gaps on both sides, caused by increased length of the total unit and by different materials

→ Development was stopped: complexity caused increased cost without advantages

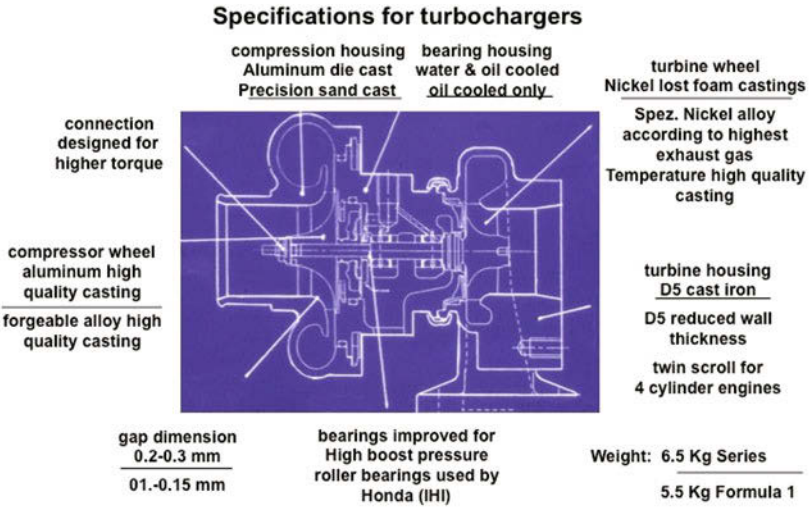
Test example

P_{el} = 3.4 HP

Rotating masses increased by 60%

Engine response can be improved with electric power

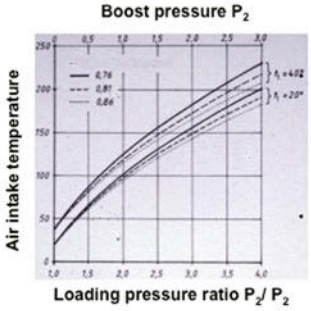
Development of turbo engines



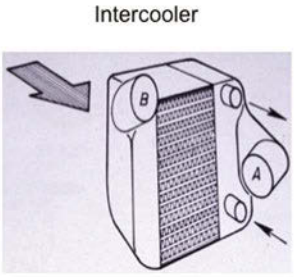
Development of turbo engines

On the intake side a lot of things can be done wrong and even more with the intercooler system. Result: high intake air temperature, bad fuel consumption, reduced power and torque and bad engine response

On the exhaust side short connections with low temperature losses and best turbocharger efficiency are of great importance for the efficiency and response of the engine



- Best compressor efficiency and lowest possible air intake temperature are very important for engine performance and fuel economy
- Differences between very good and very bad can be 50°C

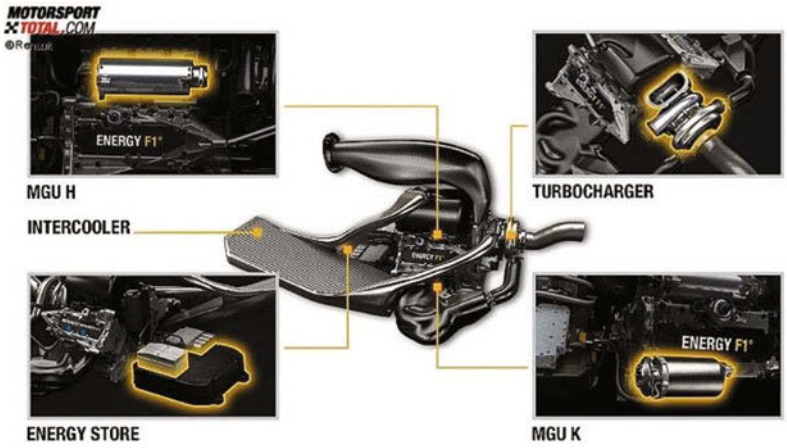


Design Renault RS34 Turbo 2014

Renault RS34 F1 V6 Turbo engine with ERS-Systems and huge air-to-air intercooler. Engine power 580 HP + 160 HP from Hybrid Systems

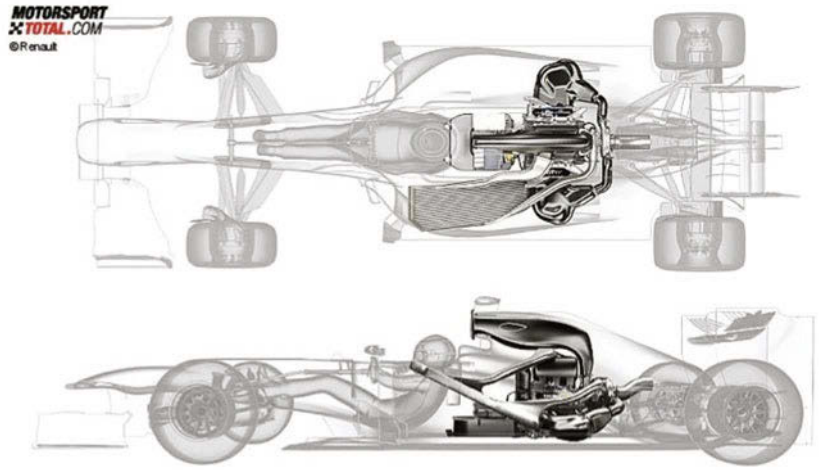
Final design very unfavorable

Final Design Renault 2014



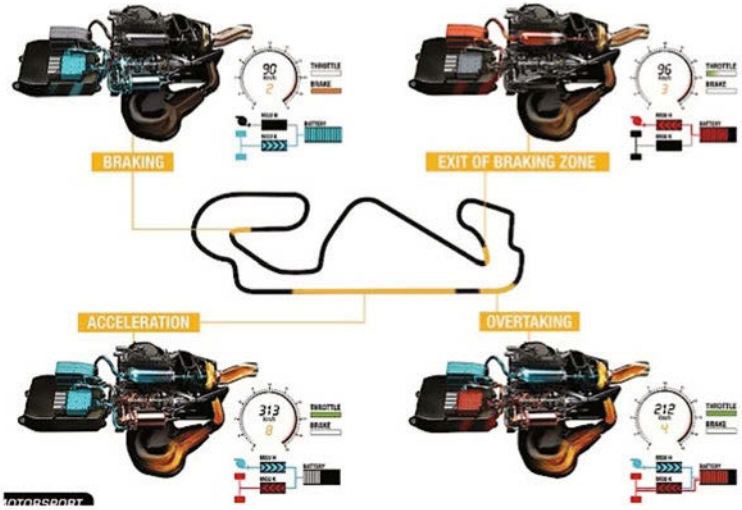
Unfavorable intercooler design, high streaming losses intake and exhaust

Renault Formel 1 car



Huge air to air intercooler on the left side of the car

Electricity flow on the circuit: Driver cannot influence



Comparison of Turbo engines

Renault F1 V6 Turbo (1980) and Renault RS34 V6 Turbo (2014)

Up to 1,000 PS extreme
efficient with 620 HP
4 tailpipes: good engine sound,
Very good engine response

Only one big turbocharger
Long exhaust pipes
Only one tailpipe, bad engine sound
Extreme bad engine response

Mercedes Formula 1 engine

Irritation for the hole Formula 1 world. Official Mercedes picture Formula 1 engine for 2014. But the final solution is significantly different

The turbine remains on the rear end of the engine, but the compressor is located on the front end
Despite of the immense technical efforts the cars are approx. 4 sec. slower on most of the circuits

Mercedes Formula 1 Technology 2014

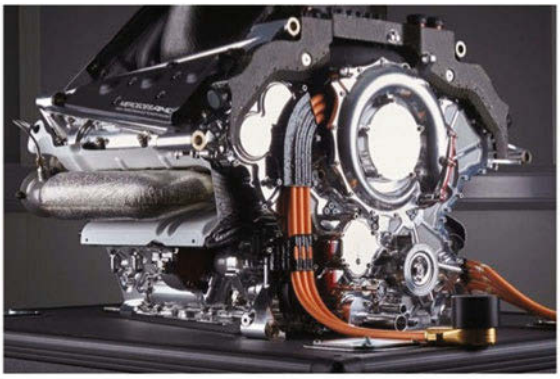
Only the Mercedes Formula 1 developer in England were able to find the best solution for the charging system
Turbine and compressor were separated in two pieces to the front and rear end of the engine. In between, in the valley of the V engine, there is a relative long connecting shaft which also contains the rotor of the ERS-H unit.

The intercooler is partly water-cooled and have short connections to the compressor and the air intake system. This system has a lot of advantages over the Renault and Ferrari solutions and makes under normal conditions the Mercedes Formula 1 cars unbeatable:

- No direct heat transfer from the hot to the could side of a turbocharger
- Reduced gaps because of the separated bearings systems for turbine and compressor wheels
- Minimal dead volumes on intake and exhaust systems
- Optimal conditions for air intake in the compressor, as there is no fast rotating shaft
- Because of the much better engine response a bigger Turbine can be used
- Additional electric energy can be used to accelerate the car and not the Turbocharger itself

Mercedes Formula 1 Turbo engine 2014

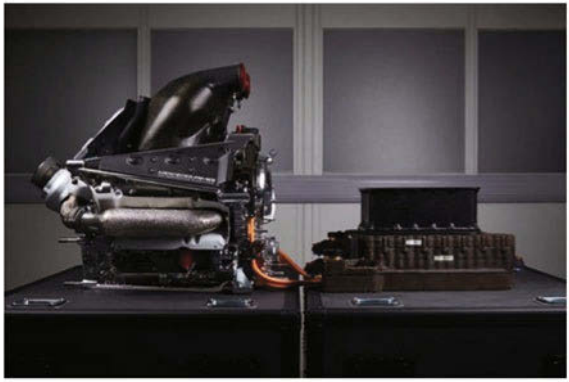
First real picture Nov. 2014 confirms position of turbine and compressor and the extreme short exhaust runners



Winner of the seldom Dewar Trophy 2014 for British engineers!

Ideal conditions for the compressor air intake (Williams installation)

Comparison: size of the ICE and the Battery/electronic pack



End of 2014 saison engine power from 580 up to 620 PS 10,500/min
Very good fuel consumption at full load: 215 g/kWh
Mercedes engine by far the best engine response

Batteries 2014: Lithium Ionen

Cost: min. 60,000 €, with development costs much higher Batteries stand max. two race weekends. Max. 1,000 Volt
For use in racing cars this kind of batteries are unsuitable. Sufficient cooling in the car not always possible, which leads to even less lifetime
For Qualifying and for the race recharging in the pits is not allowed

Energy from ERS-K: 2 MJ maximal/lap 4MJ (after two laps)
No limitation for the ERS-H energy
No comments about CO2-Emissions during production and recycling !

Honda Formula 1 engine starting 2015

First picture Oct. 2014. Honda has the chance to copy the Mercedes design or to find a even better solution for the hole charging system

Typical mock up picture: interesting details are not shown

The Mc Laren Formula 1 cars with the new Honda Engine have the opportunity to be more successful than the Ferrari or Renault cars
Mercedes has a development advantage of more than one year

Importance of weight for Formula 1 cars

Minimum weight for Formula 1 cars:

1966:	500 kg dry weight
2009:	605 kg including driver, oil, brake fluid, cameras and 70 kg additional weight (tungsten, wolfram) in the underbody
2010:	620 kg KERS is permitted, but not used by everybody
2011:	640 kg everybody has to use KERS
2014:	691 kg because of ERS-K und ERS-H

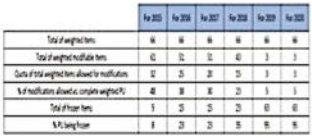
Remark: 10 kg less weight: 0.35 sec. improved lap time
total additional weight: lap time deteriorates up to 3.1 sec.
harder tire compound: lap times get even worse

Development of road cars: clear trend to reduced weight

Trade-off analysis required: Benefits of new technologies versus drawback of additional weight

What can be changed

Significant engine design elements are fixed. Only some modifications are allowed according to two very complicate lists
2015



At the end of season 2014, Renault and Ferrari realized their big gap to the Mercedes engine
They want now to change the regulations otherwise Mercedes would win also the next 5 years

If Mercedes is not willing to accept any modifications the pure Mercedes show will go on

Green Image?

Out-dated technics and non-environmentally friendly regulations will not provide Formula 1 a "Green Image" and Technology leadership at the same time (??)

1. Out-dated Turbo Technology with one Turbocharger only
2. Hot V with short exhaust runners not allowed
3. Weight increase of up to 691 kg (702 kg) was necessary for installation of all components for the double Hybrid System
4. Double electric energy from ERS-H and ERS-K
5. Forced to use the extreme expensive and non-environmentally batteries
6. Forced to use an expensive Flow Meter for max.100 kg/h

Energy Balance

- 135 Ltr./Race = 2.45 Ltr./Lap = 78.9 MJ/Lap
- Energy, for max. recuperation per lap: 2 MJ 1.58%
- Energy, for max. additional power/lap: 4 MJ 3.16%
- according to a maximum of 164 PS for 33 sec.

The only reasonable part of the new regulation is the defined fuel amount of 135 Ltr. per race. Beyond that everything – including the weight of the car - should be free

Formula 1: The show must go on ?

- B. Ecclestone did not like KERS because of the complexity and the higher costs. Till 2014 it becomes even more expensive. He preferred the V8 engines.
- Without the higher car weight, cars with ERS would not have any chance
- Are there new OEM´s ? Honda 2015 engines only
- Criticism on hybrid technologies in Formula 1:
  - „drivers" are directed by engineers
  - modifications for more equal engines are not allowed
  - Safety of high energy batteries

- Hybrid technologies in Formula 1 are not environmentally friendly. Batteries are very expensive and have to be replaced every second race weekend
- Charging technologies are not state of the art. Cars are not noisy enough.
- GP USA 2014: only 18 Formula 1 cars on the grid !

lap times 2014 despite of the huge expenses approx. 4 sec. slower compared to 2013

Summary

B. Ecclestone:
We need to change these regulations
We`re going to try and get rid of these engines, they don´t do anything for anybody. They`re not Formula 1

The Show must go on:

Three options: 1: Going back to the 2.4 Ltr. V8 engines (direct injection)?
2: more polite and environmentally friendly:
Stay withe the new 1.6 Litr. turbo engines and 135 Ltr. gasoline for the races and reduce the car weight down to 600 kg and no regulations for turbo charging
3: modified 1.6 Ltr. V6 engine (p_{mep} from 32.0 up to 57.0 bar)
Two small Turbochargers, similar to first Turbo Era
Car weight 600 kg, no sprit limitation, Power up to 1000 HP
Best solution for the Show

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