Formula One 2011:

Chassis Regulation Framework

A Briefing Note in preparation for the Formula One Manufacturers' Advisory Committee

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Ferrari
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Mercedes
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NOTE: *PRELIMINARY DOCUMENT – CHANGE MAY OCCUR DUE TO ONGOING DISCUSSIONS WITH THE MANUFACTURERS AND TEAMS*

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A note on procedure

During the first six months of 2007 the FIA have visited manufacturers active today in Formula One to gather views on regulation change for 2011.

An exploratory note [*Initial Thoughts on Formula One Regulation for 2011 and Beyond, v 1.5, March 8th 2007*] and an initial proposal [*2011 Power Train Regulation Framework v.1.3*, 23rd May 2007] have been circulated and feedback assimilated.

This document summarizes a framework for the 2011 chassis regulations. To convert this framework into proposals for the FIA World Motor Sport Council, the FIA wish to consult the Teams and Manufacturers. The feedback received will be reviewed and considered. A third paper will also be prepared in the coming month focusing on cost reduction. A complete proposal, incorporating Power Train, Chassis and Cost Reduction will be circulated in preparation for the FOMAC meeting at the Frankfurt motor-show in September. While the present set of documents are to prompt discussion and debate, this complete proposal will be the 'prime path' for the new regulations, still subject to change, but only for sound reason. The FIA welcome feedback from both teams and manufacturers and have certainly being encouraged by the reasoned and open-minded response from the majority of the manufacturers after the publication of the first paper.

To convert ideas into a formal set of detailed regulations, the FIA will make use of four working groups: The Power-train Working Group; an Aerodynamics Working Group; The Cost Reduction Working Group; all of whom report their recommendations to The Technical Working Group who work with the FIA on the final drafting.

The objective is to complete the 2011 technical regulations before the end of 2007.

2011 FIA F1 Chassis Regulations

Top Level Principles and Framework

Executive Summary

The two principal reasons for change are, identical to those for the power-train, namely: (1) The need to create a healthier commercial outlook for participants generally and, in particular, by improving the racing and making Formula One research more road-relevant; and (2) the need to react to public concern about the environment.

Commercial Outlook: Future regulations will reduce the effective cost of participation in Formula One by adoption of the following strategy:

> *Research and development relevant only to Formula One will be discouraged, whereas that which has relevance to road car development will be encouraged.*

Formula One chassis technology tends to be highly Formula One-specific; however there are opportunities for road relevance in certain areas. In a similar manner to the power train, the overlap between road car and Formula One chassis technology can give the manufacturers more value for their spend in Formula One. Outside this narrow constraint every attempt will be made to restrict development and lower costs. In this respect the new regulations will mandate:

- A number of specified parts chosen either to lower costs and/or eliminate major areas of non-relevant development, in particular the pursuit of downforce.
- Annual homologation of chassis and main suspension elements

A healthier commercial outlook must also encompass the popularity of the sport. In this respect new chassis regulations allow an opportunity to improve the entertainment provided. Here the FIA wish to increase the likelihood of 'nose to tail' close racing, and make overtaking easier. This is to be achieved by allowing a compensation mechanism to maintain downforce and balance whenever prolonged high turbulence is detected i.e. when travelling in the wake of another car.

Environmental Concern: Chassis regulation will reflect the changes that will be seen on production vehicles in future years; improved efficiency is not just a power-train requirement, but that of the vehicle as a whole. In particular for Formula One the following policy will be adopted:

> *Drag reduction will be encouraged both in the vehicle shape and the cooling assemblies, and extend to the adoption of adaptive devices.*

The intent is a reduction in maximum drag of some 50% compared to today's levels. This will demand significantly less overall power so as not to exceed today's maximum speeds. Simulation demonstrates that an overall saving in fuel used of over 50% is achievable using a down-sized and cheaper-to-produce engine, yet the same overall speed, acceleration and lap times can be retained.

The result is a quite outstanding lead from Formula One in environmental technology change coupled with the opportunity to use the sport to change public attitudes as to what constitutes a truly modern high performance engine.

A set of regulation concepts along these lines are presented for discussion; it is hoped that this will encourage thought and ideas from which a final set of regulations will evolve. This paper focuses on the 2011 chassis regulations, but lists implications for the power-train regulation.

Overview of Power-Train Regulation Framework and Key Decisions Required

In summary, the framework and its discussion points are as follows:

1. Aerodynamics: Compared to today, the 2011 car regulations will aim for ~50% less *maximum* downforce and ~50% less *maximum* drag (i.e. that experienced at maximum speed). The precise figures, including centre of pressure requirements will be fixed through simulation work under the guidance of an FIA Aerodynamic Working Group[1]. The aim will be to make the 2011 cars marginally faster in terms of lap times than the 2009 / 2010 cars, but with broadly similar top speeds. This is to be achieved by:

    a. A prescribed downforce-generating under-tray and skid 'plank' extending to the very rear of the car. This will have a forward centre of pressure to minimise the size of the front wing. This component will generate the majority of aerodynamic downforce. These parts will be supplied by the FIA along with fixing mechanisms which must be rigidly incorporated into the main chassis and power-train components.

    b. Front and rear wings being constrained to fit within defined 'boxes' and consist of a fixed number of elements. The purpose of this is to constrain the designer from producing overly complex assemblies. The rear wing will be the main mechanism by which adaptive drag is achieved, while the relatively small (compared to today) front wing serves as a trim to achieve balance. The front wing 'box' will be close to the ground to minimise the affect of wake turbulence.

    c. Front and rear wing settings maybe electronically controlled, but within set limits defined from time to time by the FIA. This is to allow much reduced drag along the straights to improve fuel efficiency and yet retain the downforce required around corners, under braking and under acceleration so as to retain overall lap times. Fail-safe design, as used on aircraft, will be mandated.

    Discussion Point: *The FIA have considered supply of front and rear wings on the same basis as the under-tray, i.e. fully prescribed and FIA supplied. However, while this will produce further cost saving, it is thought that a variety in design solutions of such a highly visible part will be attractive to the fans. The input of the teams is welcome.*

2. Main Chassis and general body work:

    a. The main chassis is to have fixing points for attachment of the FIA supplied under-tray assembly. These must be rigid with respect to the engine mounts.

    b. Space will be mandated for fitting power-train components within the chassis and bodywork so their design is not unduly constrained by aerodynamic consideration.

    c. The bodywork is to be 'cleaned up' compared to today's cars by a regulation preventing overlapping surfaces, while retaining a similar restriction to today with regards both overall and side-pod height. (This bans barge-boards, X-wings, etc).

    d. Cooling assemblies may incorporate adaptive devices. These may be electronically controlled, but must be contained within fully-ducted configurations with the primary objective of minimising drag.

    Discussion Point: *Freedom on the top side bodywork and chassis design will differentiate between constructors, but lead to costs that could otherwise be avoided. Input is welcomed as to the extent the FIA should go in this respect. Is the balance about right?*

[1] This will be an evolution from the present Overtaking Working Group

3. Prescribed components: The FIA will put out to tender the following components:

    - Wheels, uprights, brakes, brake ducts – the complete 'corner' of the car. These are to be in a fixed position relative to the under-tray.

    - The under-tray and skid plank referred to above

    - Any other components that the teams can mutually agree via the Cost Reduction Working Group, for example: Fire extinguishers; Drive shafts; Fuel supply / refill / pumping mechanisms; Main radiators; etc.

    Discussion Point: *Input is requested immediately with regards lists of items that might be appropriate to source from a single supplier. It is suggested that the 2007 Constructor's Champion take the responsibility for the specification and design of the complete 'corner' of the car.*

4. Homologation: The chassis, including all bodywork, cooling ducts, radiators and major suspension parts will be subject to an annual homologation process. The list of parts and details of homologation will be decided in association with the Cost Reduction Working Group.

    Discussion Point: *Homologation of these parts will produce significant cost saving, input is welcomed as to the most appropriate level of component homologation.*

5. Longevity: A list of mandatory component lives will be produced in association with the Cost Reduction Working Group for the homologation parts. Initial thoughts are: *The main chassis and fuel tank should last the entire season; suspension members, wings, and bodywork ten races. Crash damage will not incur a penalty, but otherwise a failure will be treated in the same manner as an engine replacement. Damage repair will be allowed under FIA supervision.*

6. Improving the show: A turbulence sensor complete with an aircraft type back up system (for robustness) will be supplied by the FIA. When travelling in high turbulence levels such as those generated by the close presence of a leading car, the ride height of the car, both front and rear, *must* be altered in response to the output of this sensor (within a set range, at a set rate, and with appropriate hysteresis, determined from time to time by the FIA) to compensate for the degradation in performance. In free stream the car is to return to a baseline ride height. The purpose is to allow for full compensation for downforce losses due to being in the wake of another car.

The consequences of adopting the chassis and bodywork regulations for 2011 as outlined are as follows:

- The power train proposal will need to be revised in the light of the drag reduction predicted; otherwise top speeds will be dangerously fast[2]. In particular the aggregate total power will need to be reduced from the nominal 560KW initially suggested for 2011 down to ~ 340KW. This in turn leads to a ~270KW (300KW with exhaust energy recovery) primary engine as opposed to the 450KW (500KW) proposed. Initial simulation by Ricardo suggests that the most efficient configuration for this will be an in-line four cylinder, (although a three cylinder engine is on par as an alternative), 1.3 to 1.5 litre engine. This has a succession of desirable outcomes:

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[2] The design of the circuit run off areas and the FIA safety work in general is based on these top speeds and similar total weight and grip as today.

- ✓ A dramatic overall reduction in fuel usage of over 50%
- ✓ A significant saving in primary power plant costs
- ✓ A significant overall weight reduction probably negating the need for any increase in minimum weight from today and perhaps allowing a reduction.
- ✓ The use of Formula One to typecast small, higher revving (compared to today's road cars), boosted engines, with significant energy recovery as 'modern', 'fast', and at the 'forefront of technology'. This is very much in line with future high performance vehicles given the tough European CO2 proposals and the continuing swing in public opinion across the globe with respect to this issue.

NOTE: *There is no intention here to change the principles described in sister paper for the power-train, just adjust the power to enable similar top speeds and acceleration to today.*

The 2011 Formula One cars will be 100% in keeping with the principle of spearheading technology change in road cars for the coming decades with a number of notable cost constraints and formulation changes with real potential to significantly improve the racing spectacle.

2011 FIA Formula One Regulation

Detail discussion

Introduction: *Why change the regulations at all?*

The reasons for change are set out in the Power Train document dated 23rd May 2007

(1) Discussion of Formula One Aerodynamics and Road Relevance

Aerodynamics is relevant to road vehicles in the following respects:

- Cooling – engine, brakes etc
- Lift avoidance
- Drag reduction
- Stability
- Heating, ventilation, air conditioning (HVAC)
- Noise
- The general development of tools and techniques

Aerodynamics has little direct relevance to the performance of a road car other than determining top speed, which in most cases exceeds legal speed limits. It does affect fuel consumption and hence CO2 emission and thus will be an area for efficiency gain in the coming decade..

By contrast, aerodynamics affects two of the five main performance parameters of a Formula One car. Downforce, along with tyres, dominates the cornering performance; Aerodynamic drag, along with power, controls top speed. Thus a sizeable portion of Formula One R&D budgets is spent on aerodynamics – facilities, design and analysis, models, measurement systems, parts manufacture, and in testing each development.

Fundamental to the irrelevance of current Formula One aerodynamic solutions to road cars is the need to generate downforce on a Formula One car as efficiently as possible, coupled with the difference that the Formula One car has large open wheels. The need to corner well in excess of 1g has no relevance to any but a few very specialist road cars – most passengers would not tolerate the discomfort even if the driver was capable of controlling the car safely.

Let us now consider how Formula One Technical Regulations could be developed to incorporate road-relevant aerodynamics into Formula One and thus encourage road-relevant techniques and technologies and discourage research which is not relevant to road cars. This will avoid resources being wasted.

Cooling

For many years, the only aspect of aerodynamics the majority of road car manufacturers took any notice of was the cooling of the engine. Styling dominated the shape of the car. In a road car, the engine cooling system is sized such that it will meet the demand for prolonged periods of any part of the driving cycle, in any ambient found in the world. Cooling during prolonged tick over and slow movement in traffic and slow hill climbing with a high load and a trailer dominate the specification. Under normal driving and at high speeds, the cooling air part of system is over specified, resulting in excessive drag. Piston engine aircraft have for a long time solved the cooling conflict between take-off and climb, and cruise at high altitude by adapting the cooling air flow to the radiators or cylinders. Road car engineers are exploring similar techniques to reduce drag at speed.

In order for modern engines to meet efficiency and emissions targets, engine temperatures must be maintained within tight limits. The cooling fluid flows are controlled to achieve this.

F1 cars have a much more predictable driving cycle, the minimum speed of which is often higher than the highest speed limits on the road. The range of temperatures at which it must work is limited. Engine temperature must also be kept within tight limits, mainly for power, but also efficiency. The matching of airflow, radiator size and the thermal inertia of the cooling system (to minimise airflow at high speed without exceeding peak temperatures at low speed) is undertaken at the same time as the development of the lift and drag characteristics, as both are adversely affected by cooling air flow. The same comments can be applied to the brake cooling although the gains are substantially less.

Just as with road cars, Formula One cars would benefit from adaptable cooling airflow. Whereas on a road car, adjusting the cooling airflow would be done to minimise drag, on a Formula One car (given a free hand) it would be used to maximise downforce for the least amount of drag.

Lift

High aerodynamic lift relative to vehicle weight is undesirable in a road car, even though most cars generate some lift. Equally, high downforce is undesirable too. Any vertical force generation has induced drag associated with it, as the air flows from the high pressure region to the low pressure, rolling up into trailing vortices. A very low aspect ratio body, such as a car, has high induced drag if any vertical forces are generated.

Some powerful, high top speed road cars generate downforce to increase high speed cornering performance. They also employ moveable aerodynamic downforce generating surfaces, deployed above a set speed. They are moveable, not for L/D reasons, but to maintain styling characteristics when stationary or at low speed.

In Formula One, downforce and L/D are so important to performance that major R&D resources are expended on aerodynamics, and the restrictive regulations are pushed to the limits and beyond to exploit every opportunity to maximise these parameters. Enabling critical parts of the car to run closer to the track surface, whilst passing static ride clearance tests, involves clever engineering. Likewise, the ability to control the attitude of the car relative to the track surface, and vary it with speed in order to control the aerodynamic balance of the car has led to sophisticated suspension characteristics. Aero-elastic tailoring of composite body and wing surfaces could be employed to vary the shape and downforce and drag characteristics with speed as further step. This is illegal, but given that all things move when a force is applied, perhaps very little but move they will, this will always be difficult to police.

The aerodynamic characteristics of the current cars are such that a following car is so disturbed by the wake of the car ahead that its cornering and braking performance are downgraded to the extent that it is not able to follow closely enough to take advantage of the drag reduction in the wake, to slipstream and overtake.

In considering the 2011 regulations there is a dilemma. Downforce is viewed as undesirable from the racing point of view as just mentioned and also because of its lack of road relevance. However if F1 is to remain at the pinnacle of racing, its sheer speed must be retained. Downforce is fundamental to this and therefore must be retained.

Drag

The sources of drag in a road car are:

- Profile drag – shape and x-sectional area. While stylists have taken on board many drag reduction features and details, and incorporated them into the styling, little compromise is made between x-sectional area and packaging and styling.
- Skin friction drag – shut lines, leakage, styling trim, etc. Full length under-trays are a recent feature to reduce drag.
- Induced drag – largely avoided see above under Lift.
- Internal flow drag – cooling and HVAC – see above

At constant speed on a flat road, the aerodynamic drag is the main loss of energy by the car. Drag thus has a major effect on fuel consumption and emissions.

Two developments under consideration to reduce drag are variable cooling airflow, and variable vehicle running attitude as well as some more advanced ideas using adaptive aerodynamic surfaces. The ground clearance needed for off-road and around-town running, for example, could be reduced for high-speed autoroutes, which are inherently smooth.

Formula One cars have similar sources of drag, but different emphasis:

- Profile drag – X-sectional area is minimised and shape optimised for downforce and L/D. Only mild styling is applied, never at the expense of performance. The open cockpit, exposed wheels, and downforce generation destroy any possibility of low drag.
- Skin friction drag – All aerodynamic surfaces on a Formula One car are of minimal skin friction in the same manner as a modern aeroplane
- Induced drag is a most significant component – see above under Lift.
- Internal flow drag – cooling, engine intake and exhaust, brake cooling, electronics cooling, cockpit ventilation - all optimised for performance.

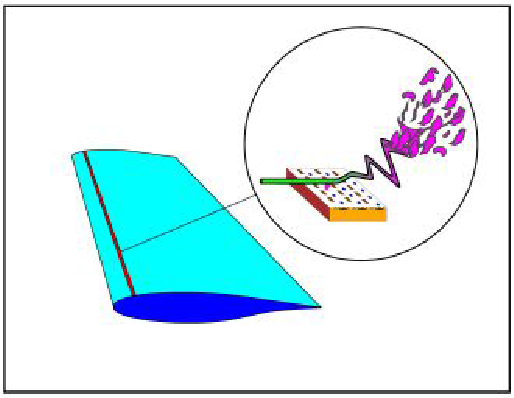
Formula One engineers go to great lengths to minimise drag at high speed using ride height control to set the car at the minimum drag attitude. Even using aero-elasticity will not have escaped their consideration. Controlling these developments within the regulations is extremely hard due to the need to scrutineer the car while moving to determine what is happening.

There are areas of activity within both automotive and aircraft development that are areas of active research with regards to drag reduction. Pertinent to this paper is the renewed interest in 'active' devices – devices that use external energy to improve the efficiency of aerodynamic components with a view to drag reduction. Examples are:

- **Plasma generation:** Here strips of electrode with large alternating electric fields are placed on the leading edge of an aerodynamic surface. These ionise the air, which is then blown downstream. A charged surface strip is place on this surface downstream and this attracts the ions generated. The net effect of this is again to delay separation and thereby lower drag.
- **MEMS (Micro-fabricated Electro-Mechanical Systems) turbulators:** Here strips of tiny piezo-electric crystals are placed on the surface to turbulate the boundary layer resulting in delayed separation and lower drag. These devices are attracting much

interest in mainstream aerodynamic research and have applications to vehicle surfaces as well as aircraft wings.

MEMS Strip: Micro vibration creates a turbulent boundary layer which can lower drag on the wing surface and delay separation



- **Boundary layer suction and blowing:** This is a well known technique that uses jets of air or suction through porous surfaces to control the air flow.

- **Shape-morphing:** Various techniques allow the shape of a surface to change by the application of a electrical signal. These can be thermal in nature (use of different expansion coefficients) or make use of piezo-electric crystals.

Discussion point: *The FIA are minded to allow these surface technologies in defined areas, certainly the cooling and air intake ducts and possibly within the front and rear wings. This is because they are relevant to the development of road cars being a route to drag reduction. The FIA welcome feedback with regard to allowing this type of device for 2011 and beyond.*

Stability

The aerodynamic stability of road cars is now established technology. Some early low drag saloons exhibited marginal cross wind stability, but this is now understood. The side and yawing moment forces on a road car are quite large relative to the forces generated by the tyres.

Formula One cars' side and yaw moment forces are small compared to the tyre forces, even though both increase with the square of speed. There is little if anything to be learned from Formula One in this respect.

HVAC and Noise

Neither HVAC nor aerodynamic noise is relevant to Formula One.

Techniques and Technologies

Formula One has benefited from almost unlimited funding for the R&D of aerodynamics. The salaries and resources made available have attracted the best aerodynamicists and raised their profile and status. In a similar manner the development tools, which are very similar to both disciplines, are well funded indeed better funded in cases in racing, than in production car work.

This is all explained by the fact that aerodynamics has been absolutely key to the performance of Formula One cars during the last four decades, whereas is not a key selling point on a road car.

Moreover Formula One aerodynamics is dominated by the rotating wheels and the presence of the ground. While road cars are affected by these features, the relative lack of importance of lift/downforce has allowed much of the testing work to be carried out without having to simulate them accurately. It is only recently that the moving ground plane wind tunnels developed for Formula One are being considered for road car development. Formula One wind tunnel testing, due to the flow's sensitivity to separation, has forced extreme accuracy of airflow simulation, particularly at the smaller scales and Reynold's Numbers.

One tool in particular, computational fluid dynamics (CFD) was developed by the aerospace industry. Formula One aerodynamics, with rotating wheels, ground plane interaction, large areas of separation, and strong vortex flows have pushed the development of this simulation software. Better simulation in CFD is directly beneficial to the automotive industry.

The list of development tools is more or less identical to road car aerodynamic development:

- Wind tunnel, both scale and full size
- CFD
- Full scale track testing
- Force measurement
- Pressure measurement
- Flow visualization (particle tracking or image velocimetry)

Racing has made a significant contribution to wind tunnels and CFD technologies, as remarked upon above and it is only here that some real benefit has resulted from the substantial spend on Formula One aerodynamics. It is a credit to Formula One that these improved tools now play a significant role in production car work and even some aerospace development, and although an unplanned happy circumstance initially, should not be ignored when considering the future of aerodynamics in Formula One.

Force measurement and flow visualisation techniques have been adapted from the aerospace industry, and are available to both the Formula One and road car industries.

Formula One carries out a good deal of full scale track testing to validate CFD and wind tunnel results, an essential part of rigorous tool development.

This development of improved toolsets has been a welcome outcome from the last two decades of furious aerodynamic activity within Formula One. Fortunately these well developed tools that the teams have invested in are just as suitable for the development of the aerodynamics under the regulations proposed within this paper as today. While further major investment in such test equipment is thought unnecessary, the assets that the teams enjoy today can still be put to good use. It can be reasonably argued that after the initial evolvement of the new cars, the level of staffing and the gain per million dollars spent will reduce significantly as the gains will be second order in nature, (drag reduction is towards an order of magnitude less effective at improving lap times compared to downforce production).

The route forward for 2011

The policy is that only developments that are road relevant should be permitted in Formula One, however it is acknowledged that certain, non-road relevant features are necessary for Formula One racing. In order to guide future regulations two questions must be answered.

The first question is: "Does Formula One need downforce?", the second, "How much?".

Pro's: Performance – cornering and braking to keep Formula One as the premier series
Limits top speed for safety (assuming 750+PS)

Con's: Limits overtaking
Difficult to regulate (banning or limiting downforce radically would still be difficult to regulate without the proposed new regulations – see below)

If we assume that the answer is: "Yes, 50% of 2007 levels" which is the agreed target for 2009, F1 will still remain the premier series in motor sport.

Based on the foregoing, we can assemble a table of car features that relate to aerodynamics and apply the road relevance test:

Feature	Road relevant
Under-tray	No
Top body	No
Wings – F	No
Wings – R	No
Adaptive ride heights	Maybe
Adaptive wings – F	No
Adaptive wings – R	No
Adaptive cooling	Yes
Drag reducing surface activation	Yes
Everything else (susp^{n}., brake cooling, etc)	No
Continued tool development	Yes

Although adaptive wings, front and rear, are not relevant to road cars, they do offer the potential to overcome two of the problems with Formula One. Adaptive front wings, either controlled by the driver, or automated with reference to a measurement of the free stream conditions the car is experiencing, would allow the balance and some of the downforce of the car to be re-established as it entered and passed through the wake of a car ahead, thus facilitating overtaking. The rear wing could be linked to this system as well.

However, adaptive wings would also allow Formula One cars to be freed from one of the least road relevant aspects of their design: *The drag, and hence the fuel consumption is vastly compromised by the need to generate downforce to achieve maximum speed through the corners.* The difference in drag coefficient of a Formula One car in maximum downforce configuration and one in minimum drag configuration is around 2:1. If the wings (and the cooling) could be set on the straights for minimum drag, it would be possible to reduce the power of the core engine including its exhaust energy recovery contribution, from the ~500KW considered to ~300KW and achieve the same top speed on most circuits. The resulting lap time increase is estimated at 3+secs from today (a little faster than the predicted lap time for 2009/2010 with the aerodynamic changes scheduled), and the reduction in fuel consumption would be in the order of 40%. Combined with the efficiency gains of the proposed power-train for 2011, this would yield an overall fuel consumption reduction exceeding 50%. (This subject to confirmation by on going simulation work.)

An optimised 270KW with a 30KW enhancement through turbo power generation (i.e. a 300KW energy efficiency optimised gasoline engine) of the type proposed for 2011 would be around 1.3 - 1.5 litres, and 4 cylinders, offering significant cost and weight savings. The details are under study by Ricardo, so this should not be viewed as cast in stone at this point.

In summary adaptive wings offer:

- ✓ A route to retain balance through an overtaking manoeuvre
- ✓ A route for a dramatic overall reduction in drag allowing an overall reduction in fuel usage of over 50% when combined with a new efficiency-led power train
- ✓ A significant saving in primary power plant reproduction cost
- ✓ A significant overall weight reduction probably negating the need for any increase in minimum weight due to energy recovery devices from today and perhaps even allowing a minimum weight reduction.
- ✓ The use of Formula One to typecast small, higher revving (compared to today's road cars), boosted, gasoline-electric engines, with significant energy recovery as 'modern', 'fast', and at the 'forefront of technology'. This is very much in line with future high and low performance vehicles given the tough European CO2 proposals and the continuing swing in public opinion across the globe with respect to this issue.

These advantages make it overwhelmingly attractive to include them in the proposal for 2011.

(2) Discussion of Measures for cost effectiveness

The FIA has devoted significant effort in understanding the cost involved in fielding a modern day Formula One Team. This has enjoyed considerable support from some participants who have been open with their financial information. Three 'headline' conclusions have been drawn:

a) Making Formula One flourish as a piece of popular entertainment is as important as curtailing costs, indeed initiatives to improve income are just as pertinent as those that reduce costs.

b) Stopping people spending money is difficult if not impossible, directing that spend to specific facets of development, is more straight-forward.

c) Formula One must undergo fundamental change away from being technology based to becoming a marketing based activity if serious cost reduction is to be achieved.

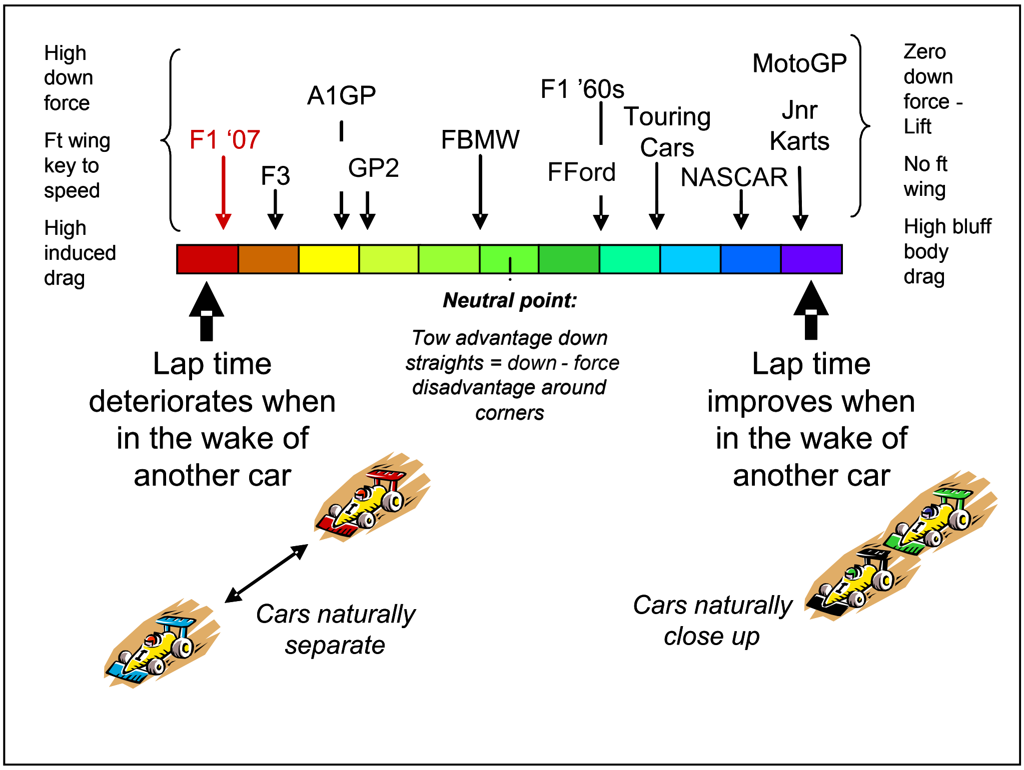
It is noteworthy that the FIA can play its part in assisting to make the commercial environment more favourable for participants, but many factors here are within the domain of others.

(a) Regulations to improve the popularity of Formula One:

The FIA can direct the technical regulations to produce closer racing, encourage the need to overtake, and make races more unpredictable:

Closer 'nose to tail' racing

The diagram indicates Formula One's position with regards to being a formula which inherently provides close racing.   The present work on the 2009 aerodynamic rules may lower costs and move towards making aerodynamics more second order in terms of gains, but is unlikely to have a *profound* effect on the closeness of the racing.



More radical thinking is necessary to achieve closer racing if downforce is retained, which it must be if we are to preserve the speed of the cars (see below).

(b) Directing spend

This is clearly at the heart of the FIA's 2011 policy. There is a desire to lower the minimum spend to be competitive, although the majority of participants will choose to exceed this due to risk avoidance. There is also a desire to make those monies that are spent more likely to produce better value: The FIA wishes to direct the spending towards 'road-relevant' technology as previously explained, as well as towards issues such as environment awareness to protect Formula One's position. Outside these areas all that the FIA can do is to attempt to minimise the return in terms of lap time by the expenditure of large sums.

(c) Formula One: Technology or marketing based?

The FIA, supported by market research, believes that Formula One is fundamentally a technology development-based formula. NASCAR on the other hand, is enjoying considerable commercial success and yet is clearly a marketing-lead (*marketing-led?*) exercise, with technology and its development suppressed to an overwhelming extent. Massive cost reduction for the participants is possible with a swing towards the NASCAR model by keeping Formula One *appearing* as a high technology exercise, but making it so restricted it would be in reality only a marketing lead formula that uses high technology. It would be like GP2, A1GP or even F3 in this respect. One could go as far to make it have a technology façade but manipulate the competition to be wholly an entertainment exercise.

Clearly there is a spectrum of possibilities here, and a balance must be achieved as a pure free technology race would be as dangerous to the future of Formula One as a change to a NASCAR pure entertainment model. However the FIA view it as an axiom that Formula One is to retain a very strong technology development profile. This has the penalty that technology development is fundamentally an expensive exercise, but Formula One has thrived on this platform and the FIA are not receiving any notable input to change this in any fundamental manner. The FIA strategy is to make a technology battle constrained within aspects where some benefit outside Formula One has a good probability as an outcome, and then follow the concept of the restricted, more market-led types of racing on aspects that are Formula One specific.

Discussion point: *This is a fundamental issue. On the one hand there is pressure for lower costs, but on the other there is no wish to tamper with Formula One's technology 'DNA'. The proposed 2011 regulations very much keep Formula One at the technical as well as speed pinnacle of the sport, while making changes to lower costs considered unnecessary along with seeking better value from the money that is spent. The teams' view on the correct balance in this respect is welcome.*

This will be considered further in the next paper on cost reduction.

Proposed Regulations

(1) Aerodynamics

The 2011 regulations will aim for ~50% less max downforce and ~50% less max drag

Compared to today, the 2011 regulations will aim for ~50% less maximum downforce and ~50% less maximum drag, these figures being recorded at the end of the straight. However the downforce around corners will be reduced by less than this. The variation will be primarily achieved by the use of active wings that reduce downforce generation along the straights and maximise it in slow corners. The precise figures, including centre of pressure requirements, will be fixed through simulation work under the guidance of the FIA Overtaking Working Group. The aim will be to make the 2011 cars marginally faster in terms of lap times than the 2009 / 2010 cars, but with broadly similar top speeds.

A Prescribed FIA supplied Under-Tray will severely constrain downforce development

The first step in achieving this is to make the car underside shape produce the majority of the downforce required. Here 'underside' refers to the under-tray and skid plank beginning at the start of the side pods and extending to the very rear of the car. This will be achieved by forgoing the present 'flat bottom' rule and allowing for shaped diffusers. The underside will also be designed to sit a little forward of today's side pod leading edge and have a forward centre of pressure. This allows the under-tray downforce to contribute to balancing out the force provided by the rear wing. This results in the need for a smaller front wing, which is desirable to aid overtaking. It becomes more of a trim device set to achieve good aerodynamic balance.

The under-tray will be specified by the Overtaking Working Group and designed (a) to produce the aerodynamic characteristics required and (b) to be mechanically stiff so that aero-elasticity issues are avoided. The part is not only to be prescribed, but also supplied by a third party. This achieves the following:

- ✓ As the under-tray is to be the main downforce generating device its prescription makes the rest of the aerodynamic design second order in terms of improving downforce.
- ✓ The emphasis of aerodynamic development is now forced towards drag reduction.
- ✓ The regulations with regard to fixing this part to the chassis, along with its inherent stiffness, have the intent to bring to an end issues regarding aero-elasticity of the underside. The main chassis is to have mandatory, FIA supplied, fixing arrangements for its attachment.

The top side structure either side of the drive and power-train i.e. the side-pods have an effect on the downforce generating properties of the underside. However because they are highly visible and allow a means for differentiation between constructors a degree of design freedom is thought desirable. In order to minimise this downforce level dependency on the topside design, regulations along the following lines will be devised:

1. The under-tray will include a moulding into which the top body work must mate.
2. No bodywork may extend beyond this moulding's foot print when viewed from above (apart of course from suspension members and the rear wing).

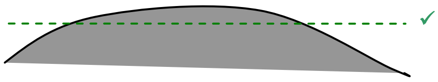
3. No 'appendages' will be allowed i.e. the side-pod must be clean and simple. This will be achieved by a regulation forbidding the use of over-lapping surfaces in both horizontal and vertical planes. The cooling ducts are excluded from this regulation only if of a fully enclosed design. It is acknowledged that some devices within the power-train may require cooling and it will be convenient to mount the surface of these devices in the air-stream. Here small fins of, say, 10mm depth will be allowed. (All subject to the guidance of the Technical Working Group.)

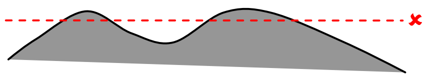
Overlapping Surfaces will be banned to reinforce the constraint on downforce generation

The desire to bring to a halt the pursuit of downforce extends to the whole vehicle. Thus the chassis itself must also comply with the no overlapping surface rule. This effectively bans 'barge-boards', 'X-wings', 'chimneys', 'flip-ups' and the like. For those unfamiliar with this concept the diagram below offers an explanation:

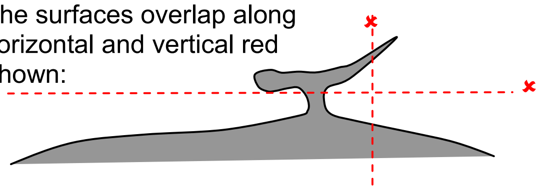
Legal: When viewed along any horizontal or vertical line (parallel or at right angles to the chassis centre-line) no overlapping surfaces occur.

Illegal: Here the surfaces overlap along the horizontal line shown.





Illegal: Here the surfaces overlap along both horizontal and vertical red lines shown:



Discussion point: *Freedom to have overlapping surfaces in one plane, say the vertical, would allow some scope for the cars to look different. This would produce some interesting developments over time and allows perhaps more scope for the integration of cooling vents. It would still severely limit the scope for significant performance gains and avenues for experimentation.*

Front and rear wings will be constrained in shape, but may be actively controlled

Front and rear wings will be constrained to fit within a defined 'box' and consist of a fixed number of elements in much the same manner as in 2007. However the sizes of these boxes are likely to change and be considerably smaller at the front than today. They are both likely to be constrained to just two elements. The detailed regulations will be defined in consultation with the Overtaking Working Group and the Technical Working Group.

The rear wing will be the main mechanism by which adaptive drag will be achieved, while the relatively small (compared to today) front wing is to serve as a trim to achieve balance. The front wing 'box' will be close to the ground to minimise the affect of wake turbulence.

Front and rear wings maybe electronically controlled within set limits defined from time to time by the FIA. This is to allow much reduced drag along the straights to improve fuel efficiency and yet retain the downforce required around corners, under braking and acceleration so as to retain overall lap times. Initial thinking is that the main planes of the wings are to be fixed, but the flaps allowed to move by electronic control, mimicking an aircraft wing as it changes configuration for take off and landing. The detail will be fixed by simulation and Formula One aerodynamicists with regard size and suitable range of movement. Given that this is a new direction for Formula One, the range of movement will be controlled by the FIA. This allows the FIA to 'trim' the regulations to set appropriate top speed should these get too high or low.

Fail safe design, as used on aircraft, will be mandated: Clearly the idea of variable aerodynamic surfaces raises safety questions. Active control is now well established in Formula One and is relatively straight-forward technology for the teams. In the event of failure there must be a mechanism that locks the surface in position with an independent system that warning the driver. The rate of response of the active wings elements is to be restrained to 0.5 Hz for the rear on safety grounds and 0.5 Hz for the front so it can respond just fast enough for a first order balance compensation (actual rate to be fixed by Technical Working Group).

Discussion Point: *The FIA have considered supply of front and rear wings on the same basis as the under-tray, i.e. fully prescribed and FIA supplied. However, while this will produce further cost saving, it is thought that a variety in design solutions of such a highly visible part will be attractive to the fans. The input of the teams is welcome.*

The FIA also view that the adoption of these adaptive wings and a prescribed under-tray will bring to a halt the problems recently experienced with aero-elasticity. Do the teams agree?

Cooling assemblies may incorporate adaptive devices

Active cooling is considered road relevant and is therefore free to be used. The active elements must be fully enclosed within a duct of minimum length upstream and downstream of the active device (say 10cm each side – to be determined by the Technical Working Group) and must be designed with the primary intent of drag reduction at high speed. The rate of response is to be limited to 1 Hz.

Space must be allowed so that power-train components are not aerodynamically constrained

The need for road relevance leads to constraints on the car design as the power-train should not be additionally constrained by aerodynamic 'shrink wrapping'. This will need a rethink from today's aerodynamics rules. The need is to have regulations that mandate space for the power-train components. Present thinking is that one 'virtual' box will be mandated to be fully enclosed by bodywork, except for the cut out required for the driver and an allowance for cooling vents, air intake and exhaust. This 'box' will be designed to provide ample space for power-train elements, both front and rear, given that four wheel energy-recovery will be allowable under these regulations.

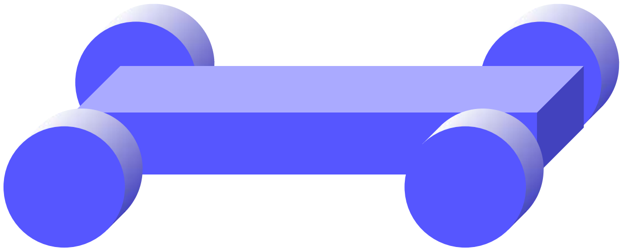
In addition on going work by the FIA Institute is studying the relationship between back injury and the seating position of the driver. Initial results indicate that a more upright position is less likely to result in these injuries. There is also a view that the present side impact regulations can be improved by mandating more protection for the driver from the side impact structures. These will also be accommodated within the new regulations with regards to space constraints.

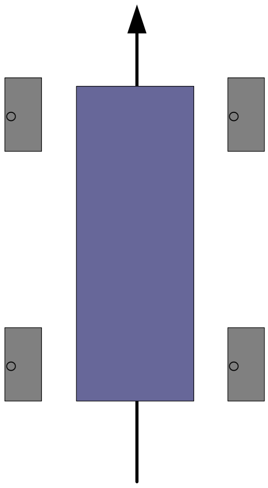
This space must be fully enclosed by bodywork such that it is impervious to airflow, but with the following allowances:

- A cut out for driver access of prescribed dimensions

- An allowance of, say, 10% of frontal and rear faces, 25% of side faces, and 5% of the top surface for fully ducted vents for radiators, intake cooling, airflow for cooling of power-train elements, and intake air for the reciprocating engine.
- The underside will allow for the inclusion of space required by the prescribed under-tray (i.e. the diffuser shape).

The main radiators for the power-train may still be placed in the side pod area. The size of this box (and if it practically can be reduced to just one 'box') and percentage vent area allowance will be set by the Technical Working Group advised by the Power Train Working Group.





(2) Cost reduction via prescription, homologation, longevity

This will be more fully considered in the next paper which deals with cost reduction. Here are the FIA's initial thoughts regarding this objective with respect to chassis regulations:

Prescribed components

There are a number of items on the cars which offer little advantage in terms of anything that race fans would appreciate, but are very costly as they are unique to each team and freedom is allowed in development. Some of these have a marked affect on downforce generation. In particular the whole wheel-upright-brake-and brake-duct assembly (the complete 'corner' of the car) is a sensitive aerodynamic part. Clearly the prescription of these parts offers a double benefit, firstly as it draws a halt to their non-road-relevant development and secondly because prescription should lower the reproduction costs considerably. Thus the FIA will put to tender the following

- Wheels, uprights, brakes (and associated system), brake ducts[3] i.e. the complete 'corner' of the car

[3] There is an argument that, with the underside prescribed and the bodywork cleaned up, the brake ducts could be of free design to further encourage different looking solutions by each constructor. There is a danger that the front wing designs will be very similar if the front brake duct is prescribed as the wing and duct aerodynamics are mutually dependent.

- The under-tray and skid plank referred to above

The introduction of prescribed uprights has the consequence that the outboard suspension pick up points are fixed, constraining the suspension design. It is suggested that the 'corner' design is based on the design that wins the 2007 constructors championship.

There is opportunity for further cost reduction in this manner. However the FIA have restricted this proposal to those parts that affect downforce generation. Any other components that the teams can mutually agree via the Cost Reduction Working Group, for example: Fire extinguishers; Drive shafts; Fuel supply / refill / pumping mechanisms; Main radiators; etc.

Discussion Point: *Input is requested immediately with regards lists of items that might be appropriate to source from a single supplier. It is suggested that the 2007 Constructor's Champion take the responsibility for the specification and design of the complete 'corner' of the car.*

Homologation

Homologation is a proven and accepted mechanism for controlling costs. The FIA propose the following homologation with respect to the chassis and bodywork from 2011 onwards:

- The main chassis, all bodywork, cooling ducts, radiators and major suspension parts will be will be homologated annually from December of the preceding year for the major parts and then frozen from 1st March prior to each season.

The list of homologated components will be produced in consultation with the Cost Reduction Working Group and the Technical Working Group guided by the policies that result from the response to these proposals.

Discussion Point: *The homologation proposal is driven entirely by cost-reduction objectives. It has the consequence that there are few avenues for an uncompetitive car to be improved during the season? Homologation will produce significant cost saving, but this proposal is being made to help the teams, input is welcomed as to the most appropriate level of component homologation.*

For: *The purpose of homologation is to constrain costs. It is effective. In order to reduce costs by any substantial amount, avenues must be taken that are proven to be sound. Moreover the FIA wish to direct the spending during the season towards road-relevant technologies and have given enough freedom with regards to the energy recovery systems to allow progression through the season. There is also the consideration that the difference between best and worst constructor is likely to narrowed in respect to the chassis and bodywork, while still leaving undiminished scope for the best race team to optimise the package presented.*

Against: *Freezing designs can mean that teams are unable to remedy a system of their car which is uncompetitive, thus leaving them in a possibly hopeless position. There is not enough freedom within these regulations to respond.*

Reduce waste by requirements for longevity of components.

There is a need to make these rules embrace other environmental aspects. The waste in Formula One is likely to come under increasing pressure over the next decade. Homologation will assist here, so will regulations that mandate a 'life' of key and expensive components:

- The chassis complete with fuel tank and engine bulkhead to last an entire season.

- All other homologated parts (suspension members, wings, bodywork and other agreed by the Cost Reduction Working Group) to last for ten races.

The list of mandatory component lives will be produced in association with the Cost Reduction Working Group as a common discussion with the homologation proposals.

Crash damage maybe repaired, but in the event of a serious accident that prevents this, the component may be replaced without penalty. Damage repair will be allowed only under FIA supervision during a race weekend. Infringements will be penalised in the same manner as engine/power-train longevity failures.

Regulations will be developed to minimise 'hidden' costs

There are other aspects both within and outside the technical regulations that will contribute to cost containment that the FIA propose for 2011. Certainly new Sporting Regulations may need to be developed in this respect. A third paper will be produced in July to focus discussion and elicit feedback on the subject.

The Cost Reduction Working Group is to be a forum for such discussions and will act to advice on the detail of any regulations in this area. Many ideas have already been submitted to the FIA and any further input the teams or manufacturers have on the subject is welcomed.

(3) Chassis regulations to encourage closer racing

There is public demand for regulations to encourage closer racing and more overtaking. The addition of active aerodynamic balance control will allow the maintenance of balance while a trailing car crosses the wake of a leading car. This will be a major step in allowing for easier overtaking. However the trailing car will still experience a considerable reduction in downforce. To compensate for this a robust turbulence sensor will be supplied by the FIA designed to have independent backup as is standard practise in the aircraft industry. When travelling in high turbulence levels such as those generated by the close presence of a leading car, the ride height of the car, both front and rear, must be altered in response to the output of this sensor (within set limits determined from time to time by the FIA and at a set rate and appropriate hysteresis) to compensate for the degradation in performance. In calm free stream conditions the car must return to a baseline ride height.

This will be implemented by electronically controlled variable height 'platforms' that can lower or raise the height of the car at the front and the rear. Many teams use something similar to this today for runway aerodynamic testing to scan through ride heights and pitch settings. The base line for these settings will be a set distance, specified by the FIA, above the lowest possible position of the car on each axle line. When the FIA sensor signals that the car is in the wake the platforms <u>must</u> each drop to a position specified by the FIA (which will be calculated to increase the downforce by a suitable compensatory amount), otherwise the platforms are to remain in the base line position at all times. Mechanisms that attempt to interfere with the relationship between platform position and mean ride height (which must be linear and of a specified nature) are illegal. The FIA will set the base line and compensatory ride heights from time to time as experience is gained in their use. An FIA regulatory data logger will be used to police this system (as referred to also in the power-train regulation paper).

The 2011 chassis regulations will not diminish the speed of the cars

These regulations present a 2011 vehicle that is in line with the modern trend for superior efficiency and the need for radical new technology to achieve the 50% fuel reduction demanded by the recent G8 summit over the next forty years.

The proposed aerodynamic regulations allow speeds to be retained, in all respects, but using a much smaller engine than today. Indeed the dominance of aerodynamics as a performance parameter has been used to the good to produce a better formula, but constrained as a differentiating area of development. The FIA have control over the cornering speeds and the straight-line speeds by judicious setting of limits for the active wings described. The sophistication of today's simulations ensures that the power requirements, the designs of the under-tray and wing sizes will be a good first approximation to achieving similar lap times with the new regulations. The limits of the active devices can then be fine tuned to improve or degrade performance as experience is gained.

The 'awe' of Formula One, both technically and as racing spectacle is enhanced

In considering the regulation direction outlined the FIA have attempted to retain and build upon Formula One's unique and premier position in the world of motor racing:

- Formula One will still be very fast in keeping with its position at the pinnacle of motor sports.
- Active aerodynamic devices will be unique to Formula One (at least initially) and add to its awe.
- There will be real technical competition but only in the road-relevant aspects of development. This will be fascinating to observe, unpredictable and indications are that it may well be quite varied compared to the relative homogeneity of today.
- The racing excitement will be enhanced by clear cut routes to improving overtaking and by restoring the competitiveness of a trailing car, yet still allowing downforce to be retained.

Cost reduction summary

The proposed regulations are far reaching in their approach to cost reduction through the mechanisms of true road-relevance, homologation and longer life parts. These should produce a pronounced effective cost reduction after the initial change. Summarising this:

- Annual homologation of the main chassis parts.
- Prescribed parts where appropriate
- Longer life components
- An effective reduction in the number of engineers and mechanics necessary during a race weekend
- A considerably increased probability of a flow of technology from Formula One to road car development
- A set of regulations aimed at designing a formula of racing that has more overtaking and nose to tail action to raise popularity and thereby revenues

Summary of Chassis Proposals

Feature	Regulatory principles
Under-tray	Downforce development constraint (cost) FIA specified and supplied
Top body	Downforce development constraint (cost) Min x-section, no vanes etc. with no overlapping surfaces rule, homologate yearly, ten race life requirement
Wings – F	Environmental Concern – energy reduction Size constrained, fixed number of elements, rigid, limited active adjustment range and response time (<0.5Hz?)
Wings – R	Environmental Concern – energy reduction Size constrained, fixed number of elements, rigid, limited active adjustment range and response time (<0.5Hz?)
Chassis	Cost containment Annual homologation, twenty race life requirement
Adaptive ride heights	Improve entertainment – revenue enhancement Limited range and response time (<1Hz?), turbulence compensation mechanism
Adaptive cooling	Road Relevance Free within duct – limited response time (<1Hz)?
Everything else (susp^{n}., cooling components, etc)	Cost containment As free as now, but with annual homologation, ten race mandatory life
Common single supply parts	Cost containment Bodywork, suspension, and other components as the Cost Reduction Working Group agrees with the FIA
Electronic controllers	Cost containment No parameter adjustment except by the driver, no download of tables over a race weekend

Note: The 'active' devices such as plasma generation, boundary layer blowing, MEMS devices and shape-morphing technologies typically have response times in the 1.5KHz bracket. They are inherently failsafe (on the whole) so faster response might be allowable here. This will be decided by the Aerodynamics Working Group.

Appendix A: The Cost Reduction Working Group

A consultative working group will be formed to assist the FIA in the translation of the framework agreed by the FOMAC meetings into detailed technical regulations.

The group will consist of:

a. A member from each Team with the following profile:
   i. Credible experience in Team Management
   ii. An understanding of costs associated with development of Formula One cars
b. Representatives of the FIA

The mandate of the group is to make detailed recommendations on costs, adhering to the following principles:

a. seek to implement the framework agreed by FOMAC.
b. seek to maximise Formula One's overlap with road-relevant technology research and development.

The group will conduct its activities in line with the objective to produce a complete set of technical regulations by the end of 2007.

The group is not expected to make recommendations about the specifics of the power-train and cost related issues therein; this will instead be the mandate of the Power Train Working Group.

Appendix B : The Aerodynamics Working Group

A consultative working group will be formed to assist the FIA in the translation of the framework agreed by the FOMAC meetings into detailed technical regulations.

The group will consist of:

a. A group of four team members with credible experience in Formula One aerodynamic development and techniques, preferably of Technical Director or Head of Aerodynamic Department status. Cost knowledge is essential for at least two of these representatives.
b. Two manufacturers' representatives with credible experience in aerodynamic research and development within the automotive, aerospace or academic industries
c. Representatives of the FIA

The mandate of the group will be to make recommendations to the Technical Working Group on aerodynamics, adhering to the following principles::

c. endeavour to formulate detailed regulations based on the framework agreed by the FOMAC committee.
d. endeavour to maximise Formula One's overlap with road-relevant research and development in draft regulations.

The group will conduct its activities in line with the objective to produce a complete set of technical regulations by the end of 2007.

The group is not expected to make recommendations about the specifics of the power-train and cost related issues therein; this will instead be the mandate of the Power Train Working Group.