STEM on Track: The Next Lap

Engineering the Future of Racing at Albert Park

Companion Booklet for The Next Lap Challenge 2027

HOW TO USE THIS BOOKLET

This booklet is your scientific foundation for The Next Lap Challenge.

Formula 1® is not just about fast cars. It is a complex engineering system where physics, materials, aerodynamics, safety, and infrastructure interact in real time. Every design decision creates consequences – improving one area often creates new challenges in another.

This booklet has been designed to help you think like an engineer working in Formula 1®.

This booklet will help you:

- Understand how speed, forces and airflow affect racing
- Explore how track design changes performance and safety
- Begin thinking like an engineer solving real problems

SECTION 1: ALBERT PARK – THE TRACK THAT NEVER STANDS STILL

Formula 1® circuits are not fixed environments. They are constantly evolving systems, redesigned to improve performance, safety and the quality of racing.

Every change to a circuit has consequences.
Increasing speed in one section can affect braking distances, aerodynamic behaviour, tyre wear and safety in another. Engineers must think beyond individual features and consider how the entire system responds.

Albert Park is a clear example of this.

A Circuit Designed for Change

The Albert Park Circuit is a temporary street circuit built within a public parkland environment. Unlike permanent tracks, it must balance:

- high-speed racing performance
- temporary infrastructure
- safety requirements
- environmental and space constraints
- spectator experience

Because of these constraints, even small design changes can have significant effects on how Formula 1® cars behave.

The Albert Park Circuit combines public roads and purpose-built sections, requiring careful engineering to balance speed, safety, and racing performance.

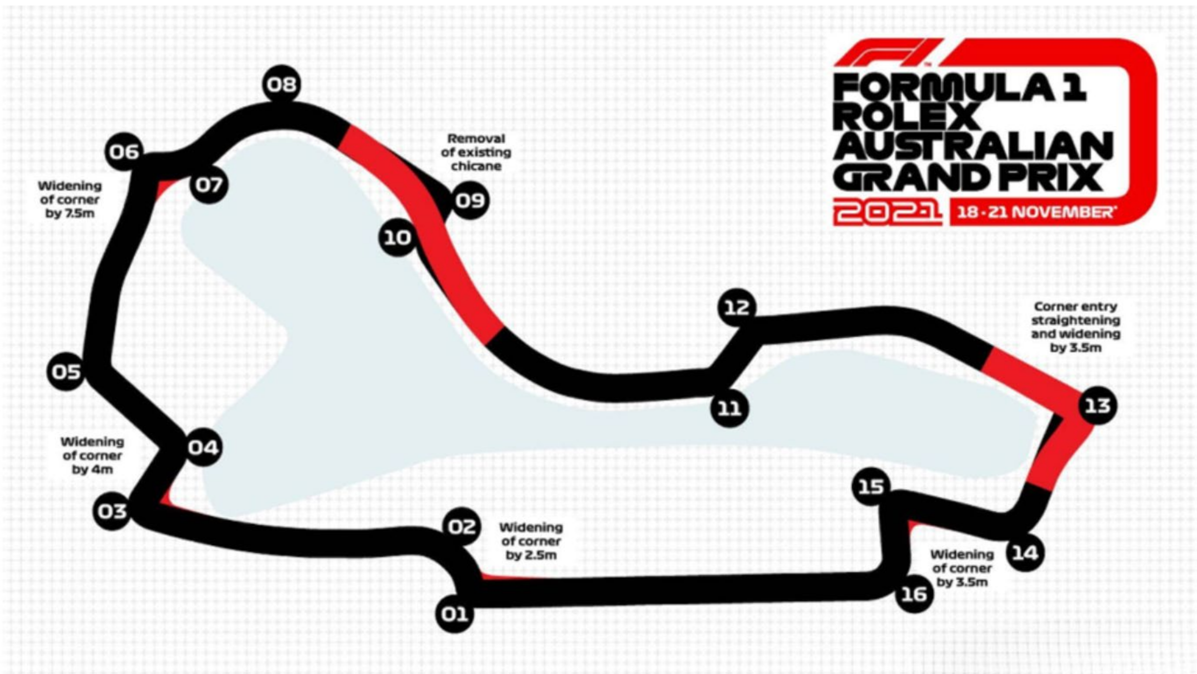
The 2022 Redesign: A Shift Towards Speed

In 2022, Albert Park underwent its most significant redesign in decades. The goal was to improve overtaking and increase the overall speed of the circuit.

Key changes included:

- Removal of the Turn 9–10 chicane, creating a long, high-speed straight
- Widening of multiple corners, including Turns 1, 3, 6, 11 and 13
- Modification of corner profiles to allow higher entry and exit speeds
- Reduction in total lap length to approximately 5.3 km

These changes transformed the circuit from a relatively stop-start layout into one that rewards higher speeds and smoother racing lines.



Although the Albert Park Circuit redesign was announced in 2021, the upgraded layout was first raced in 2022, where it significantly increased speeds and improved overtaking opportunities.

What Actually Changed Physically?

From a physics perspective, the redesign altered several key variables:

1. Speed

Longer straights and wider corners allow cars to maintain higher velocities for longer periods.

2. Braking

Higher approach speeds into corners significantly increase braking distances and brake temperatures.

3. Cornering Forces

Wider corners increase the radius of turns, reducing the centripetal force required and allowing higher speeds through corners.

4. Aerodynamics

Higher speeds increase the importance of aerodynamic stability, especially in turbulent or unpredictable airflow conditions.

5. Energy

Because kinetic energy depends on velocity squared, even small increases in speed result in much larger increases in energy that must be controlled.

The Result: Faster, But More Demanding

Following the redesign:

- Lap times dropped by several seconds
- Average speeds increased significantly
- Overtaking opportunities improved

However, these gains came with new challenges:

- Greater braking loads and heat management issues
- Increased aerodynamic instability at high speeds
- Higher crash energy in high-speed sections
- Greater demand on driver precision and control

During heavy braking, a car's kinetic energy is rapidly converted into heat. At high speeds, this generates extreme temperatures in the braking system, placing significant demands on materials, cooling, and performance. Image credit: Pixabay

2026–2027 Developments: Refining the System

As Formula 1® continues to evolve, so does Albert Park. Recent and upcoming developments include:

- Adjustments to track limits and safety zones, particularly in high-speed sections of the circuit
- Continued refinement of run-off areas to manage increased energy during braking and cornering
- Introduction of new aerodynamic regulations that change how cars balance speed, efficiency, and downforce
- Ongoing upgrades to pit facilities and trackside infrastructure

These updates interact with the existing redesign and continue to shift how the circuit behaves as a system.

Albert Park as an Engineering System

Albert Park is not just a collection of corners or a sequence of straights. It is a connected system where performance is governed by the interaction of mechanical grip, aerodynamic forces, and track geometry. These elements do not act in isolation – a change in one area influences behaviour across the entire circuit.

- Speed affects braking
- Braking affects overtaking
- Overtaking affects racing quality
- Aerodynamic conditions affect stability
- Infrastructure affects airflow and safety

Car behaviour is the result of interacting forces. Speed, grip, and aerodynamic conditions combine to determine stability and control at every point on the circuit.

Cause and Effect: Thinking Like an Engineer

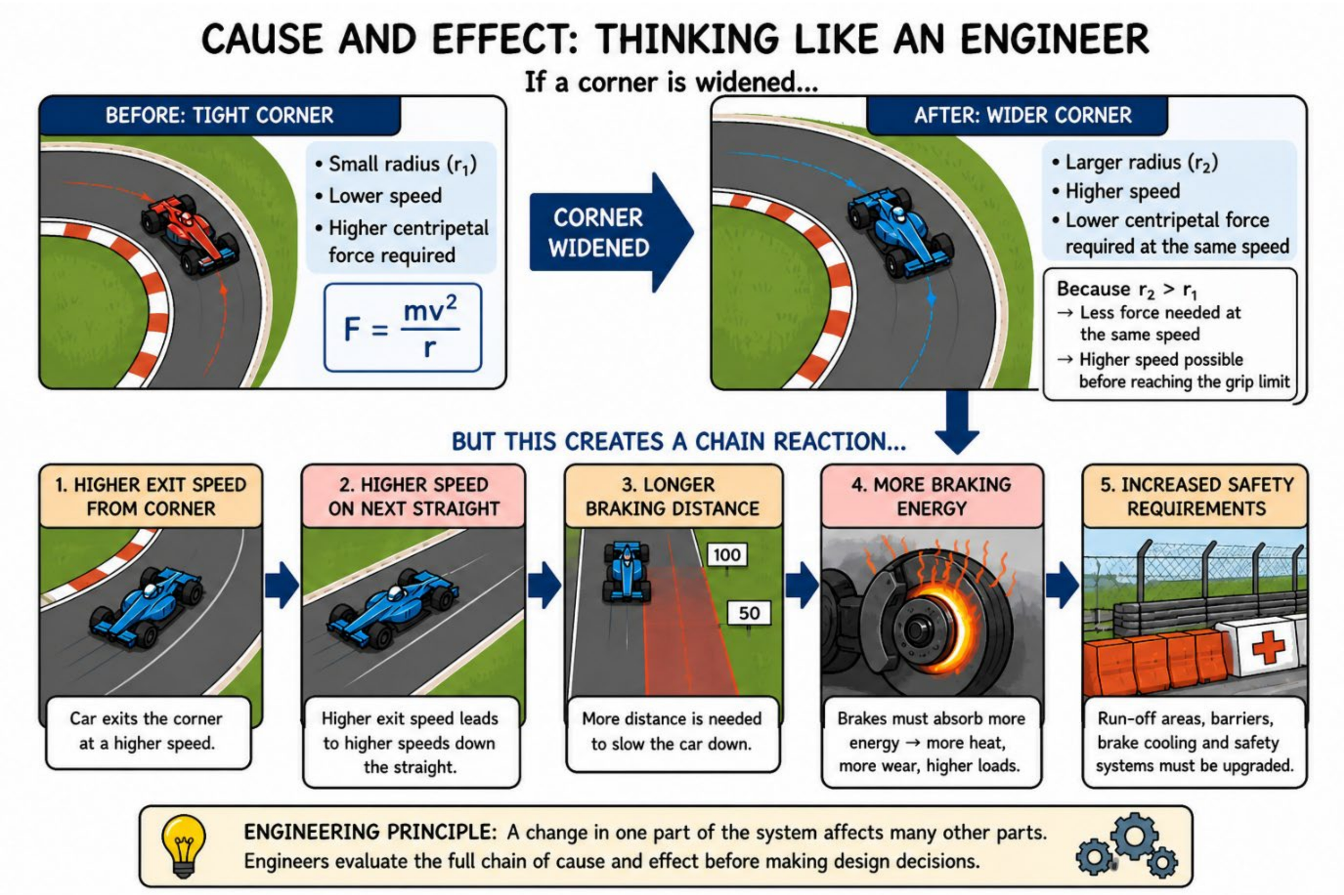
Consider this example. If a corner is widened:

- the radius increases
- required centripetal force decreases
- cars can travel faster through the corner

But:

- higher exit speeds lead to higher speeds on the next straight
- braking zones become longer
- braking energy increases
- safety requirements change

This chain of cause and effect is how engineers evaluate design decisions.



Engineering Insight

There is no perfect circuit design. Every decision involves trade-offs:

- more speed vs more risk
- more overtaking vs more instability
- better fan experience vs tighter infrastructure constraints

The best engineers do not eliminate trade-offs. They manage them intelligently.

Thinking Ahead

As you move through this booklet, you will begin to understand:

- how speed and energy influence braking
- how forces control cornering
- how airflow affects performance
- how materials and design affect safety

These are not separate ideas. They are part of a connected system that engineers must understand and manage.

Student Activity

Choose **one track change or development** (for example: widening a corner, adjusting run-off areas, or introducing new aerodynamic rules).

- **Speed and braking** (How would speeds change? What happens to braking distances?)
- **Aerodynamics and stability** (How would airflow or car balance be affected?)
- **Safety and risk** (Would the change increase or reduce the chance of accidents?)
- **Fan experience or infrastructure** (How might this impact spectators, visibility, or facilities?)

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SECTION 2: SPEED, ENERGY AND MOTION

Formula 1® is fundamentally a study of motion. Every lap is governed by how effectively a car can accelerate, maintain speed, control energy, and slow down safely. At high performance levels, even small changes in speed or force can have significant consequences.

Speed and Velocity

Speed describes how fast something moves:

$$v = \frac{d}{t}$$

Where:

v = velocity (m/s)
d = distance (m)
t = time (s)

In Formula 1®, velocity is more important than speed because it includes **direction**.

Even if a car maintains constant speed, its velocity changes continuously while cornering because its direction is constantly changing.

As the car moves through a corner, its direction is constantly changing. Even at constant speed, its velocity is changing, which is why forces are required to keep it on a curved path.

Image credit: Botond Dobozi

Acceleration

Acceleration describes how quickly velocity changes:

$$a = \frac{\Delta v}{t}$$

where:

a = acceleration (m/s^2)

Δv = change in velocity (m/s)

t = time taken (s)

Formula 1® cars experience extreme acceleration, particularly when exiting corners and entering straights.

Kinetic Energy

When a car is moving, it possesses kinetic energy:

$$KE = \frac{1}{2}mv^2$$

Where:

KE = Kinetic Energy (J)
m = mass (kg)
v = velocity (m/s)

This equation is critical. Because velocity is squared, energy increases rapidly as speed increases.

Example:

- Doubling speed results in **four times the kinetic energy**
- Increasing speed by **50% results in more than double the energy**

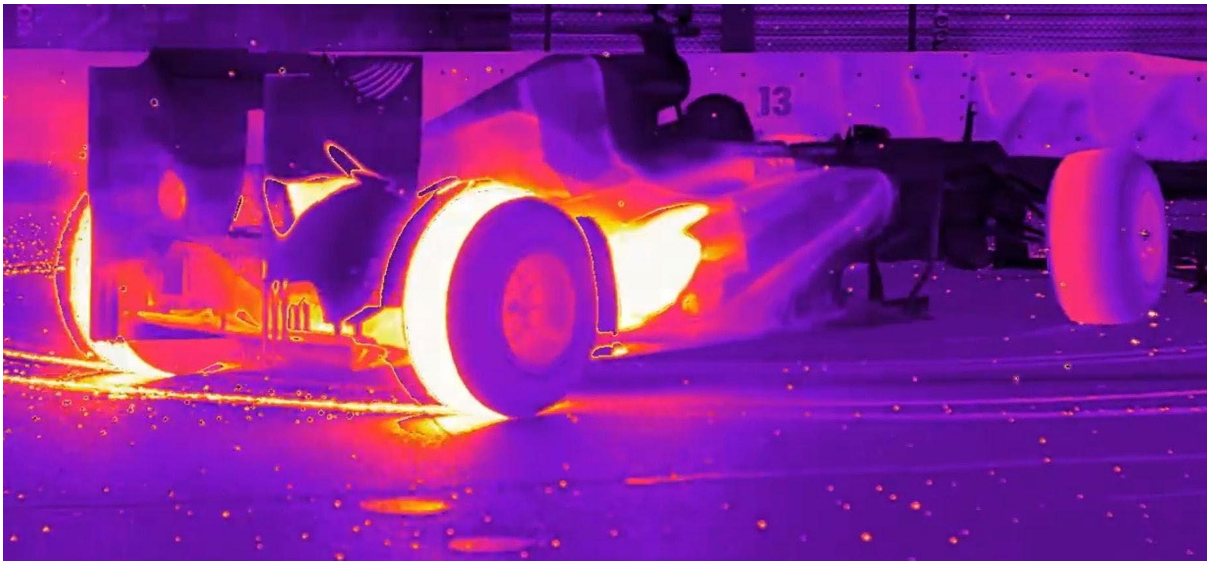
Why Energy Matters in Racing

Kinetic energy must be carefully controlled.

When a car brakes, collides, or changes direction, that energy must be:

- reduced
- transferred
- or absorbed

At Albert Park, where speeds have increased, the amount of energy that must be managed has increased significantly. When a car brakes, its kinetic energy is converted into heat through friction between the brake discs and pads.



Thermal imaging reveals the intense heat generated during braking, as kinetic energy is converted into thermal energy through friction.

Experiment: Braking Distance – How Speed Affects Stopping

Objective: To investigate how increased speed (from track changes) affects braking distance and kinetic energy.

Materials:

- Toy car or small rolling object
- Ramp (cardboard or books)
- Measuring tape or ruler
- Different surfaces (carpet, tile, sandpaper)
- Stopwatch

SECTION 3: CORNERS, GRIP AND RACING LINES

Formula 1® cars are not only designed to go fast in a straight line. A race is often won or lost in the corners.

Corners are where drivers brake, turn, accelerate, defend position and attempt overtakes. They are also where the car is placed under some of the greatest forces of the lap.

When a car travels in a straight line, it naturally wants to keep moving in that same direction. This is due to inertia, which means an object in motion will continue moving in a straight line unless a force acts on it.

A corner forces the car to change direction. To do this, the tyres must create a force that pulls the car towards the centre of the turn. This inward force is called centripetal force.

To follow a curved path, the tyres must generate centripetal force through friction with the track. At high speeds, these forces are extreme, as shown by the sparks produced at the limit of grip.

Centripetal Force

Centripetal force is the force needed to keep an object moving in a curved path.

$$F = \frac{mv^2}{r}$$

Where:

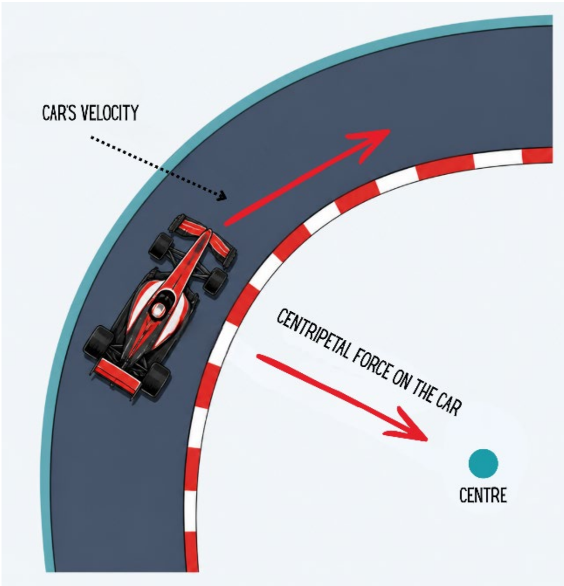
$\boldsymbol{F}$ = centripetal force, (N)
$\boldsymbol{m}$ = mass of the car, (kg)
$\boldsymbol{v}$ = speed of the car, (m/s)
$\boldsymbol{r}$ = radius of the corner, (m)

This formula tells us something very important.

- If speed increases, the force required increases significantly because speed is squared
- If the corner is tighter (smaller radius), the force required increases
- If the tyres cannot provide enough force, the car will lose grip and slide

In simple terms:

- faster car → more force needed
- tighter corner → more force needed
- less grip → greater chance of losing control



Grip and Friction

The tyres provide the grip that allows the car to turn. Grip comes from friction between the tyre and the track surface. Without enough grip, the car cannot generate the centripetal force needed to stay on the racing line. Grip is affected by:

- tyre compound
- track temperature
- track surface
- tyre wear
- downforce
- weather conditions

This is why tyres are one of the most important parts of Formula 1® performance.

Tyre Compounds

Formula 1® tyres are designed for different track conditions, not just different levels of grip.

Dry Tyres (Slicks)

Used on dry tracks. These tyres have no grooves to maximise contact with the surface.

- **Soft (red)** – highest grip, fastest performance, wears quickly
- **Medium (yellow)** – balanced grip and durability
- **Hard (white)** – most durable, lower grip

Wet Weather Tyres

Used when the track is wet. These tyres have grooves to move water away from the tyre.

- **Intermediate (green)** – light rain or damp conditions
- **Full Wet (blue)** – heavy rain, deep grooves to move water and prevent sliding

Engineering Insight

Grip depends on **both the tyre and the track conditions**. Engineers must decide which matters most.

- On a dry track → slick tyres provide maximum grip
- On a wet track → grooved tyres provide control and prevent aquaplaning

Why Wider Corners Change Racing

When a corner is widened, the car can take a larger radius through the turn. A larger radius means the car does not need to turn as sharply. This reduces the centripetal force required, allowing the driver to carry more speed through the corner.

This is one reason why changes to corners at Albert Park matter. Wider corners can create faster racing lines and more opportunities for overtaking, but they also increase the speed of cars entering the next section of track.

A wider corner lets drivers take a smoother path, helping them maintain higher speed through the turn. Image credit: Pixabay

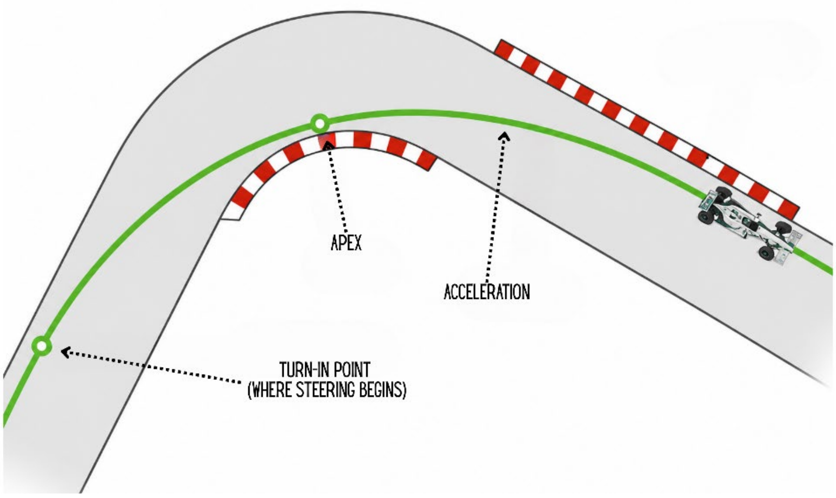
The Racing Line

Drivers do not usually take the shortest path through a corner. They take the path that allows them to carry the most speed. This path is called the **racing line**.

A typical racing line involves:

- entering the corner wide
- turning towards the apex
- exiting wide

This creates a smoother curve and increases the effective radius of the turn. A smoother curve means the car can carry more speed while staying under control.



Test Yourself

a) What force keeps a Formula 1® car moving in a curved path?

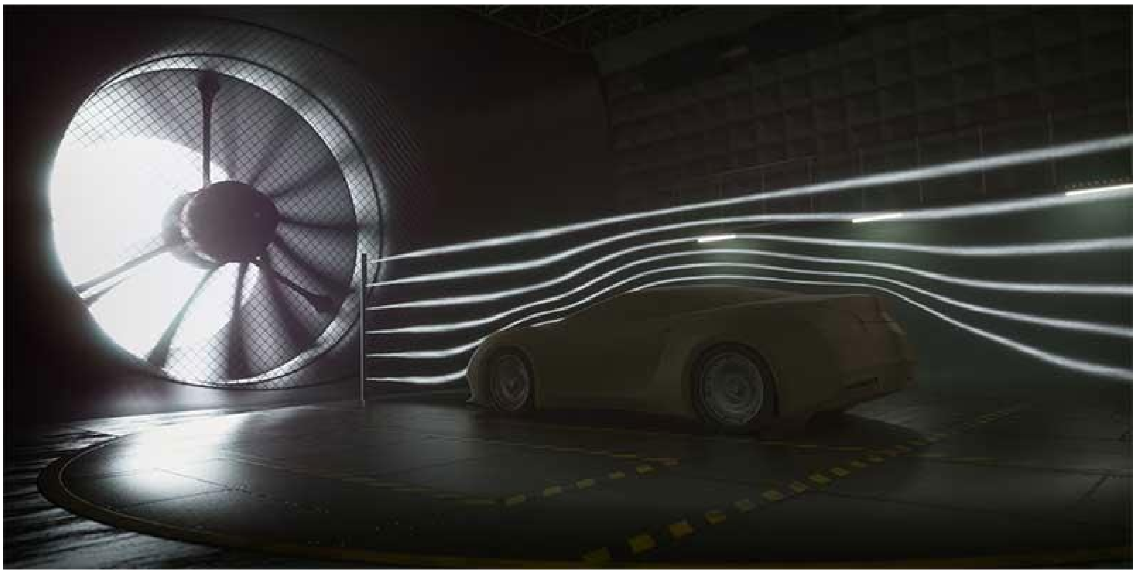
b) According to the equation $F = \frac{mv^2}{r}$, what happens to the required force if:

- the speed of the car increases?
- the corner becomes tighter (smaller radius)?

SECTION 4: AERODYNAMICS – THE INVISIBLE FORCE

Air might be invisible, but in Formula 1® it has a powerful effect on how a car performs. At high speeds, the way air flows around a car can determine:

- how fast it travels in a straight line
- how stable it is through corners
- how closely it can follow another car

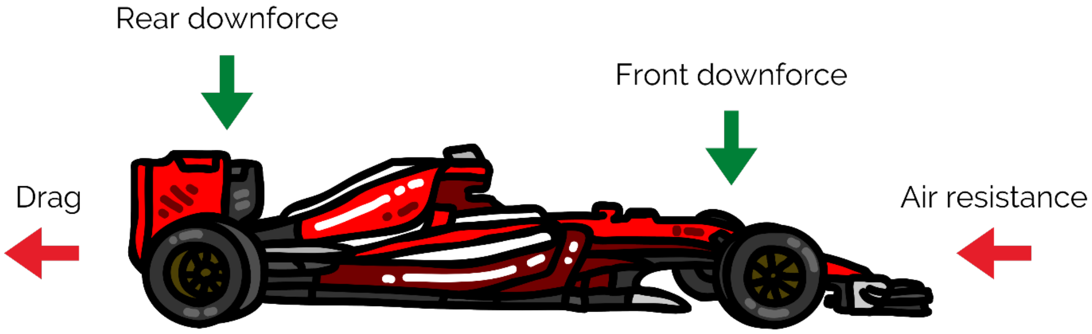


Wind tunnel testing uses visible airflow to show how air moves around the car, helping engineers design shapes that improve speed, stability, and aerodynamic performance. Image credit: Pixabay

Drag and Downforce

Two key aerodynamic forces act on a Formula 1® car.

Drag is the force that resists motion and slows the car down.
Downforce pushes the car onto the track, increasing grip.



Build the Thinking

As speed increases:

- drag increases, making it harder for the car to go faster
- downforce increases, helping the car stay stable and grip the track

This creates an important trade-off:

- more downforce → better cornering and control
- less downforce → higher straight-line speed

How Engineers Think

Engineers do not try to maximise one force. Instead, they ask:

Where does the car need grip?
Where does it need speed?

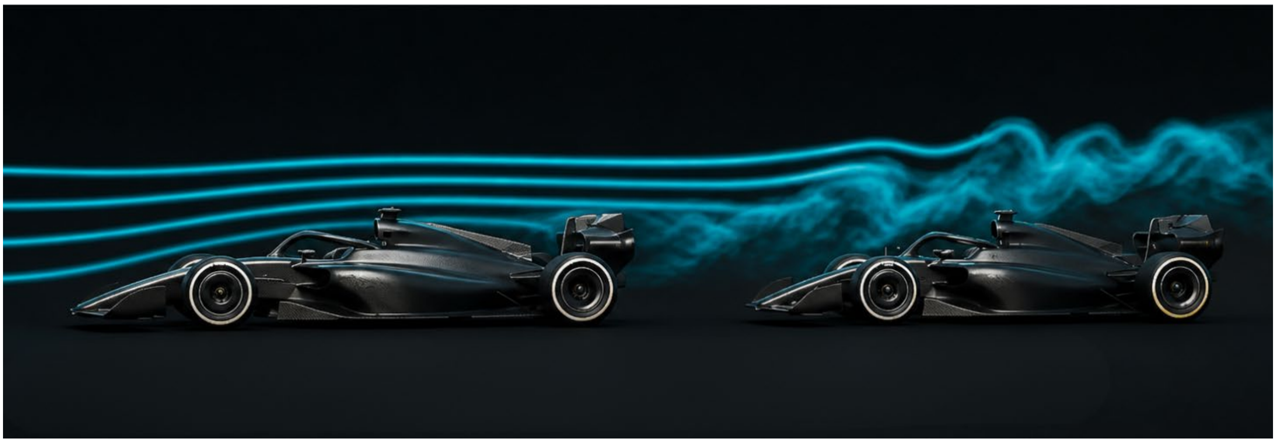
A setup that is perfect for corners may be slower on the straights. A setup that is fast on straights may struggle in corners.

Dirty Air

As air flows over a car, it becomes disturbed and turbulent. This is called **dirty air**.

When another car follows closely:

- it loses downforce
- it becomes less stable
- it is harder to corner at speed


As air flows over the leading car, it becomes turbulent, disrupting the airflow to the following car and reducing its downforce and stability.

Why This Matters at Albert Park

At Albert Park:

- fast corners require strong aerodynamic grip
- long straights reward lower drag
- close racing depends on how cars behave in turbulent air

As the track becomes faster, aerodynamic effects become more important.

Test Yourself

1. A car is very fast on the straights but struggles in corners. What does this tell you about its aerodynamic setup?

2. Why can't engineers maximise both downforce and top speed at the same time?

SECTION 5: SAFETY AT SPEED

Formula 1® cars travel at extremely high speeds. While this creates exciting racing, it also introduces significant risk.

As speed increases, so does the amount of energy the car carries. Managing this energy is the key to keeping drivers safe.

Energy and Impact

When a car is moving, it has **kinetic energy**. The faster the car moves, the more energy it has. If the car suddenly stops, this energy must go somewhere. In a crash, that energy is transferred into the car, barriers, and potentially the driver.

When a moving car stops suddenly, its kinetic energy must be transferred and absorbed. Safety systems are designed to manage this energy and reduce the forces on the driver. Image credit: Pexels

How Engineers Manage Risk

Safety in Formula 1® is not about removing speed. It is about **controlling what happens when something goes wrong**. Engineers design systems to:

- absorb energy
- reduce impact forces
- protect the driver

Key Safety Features

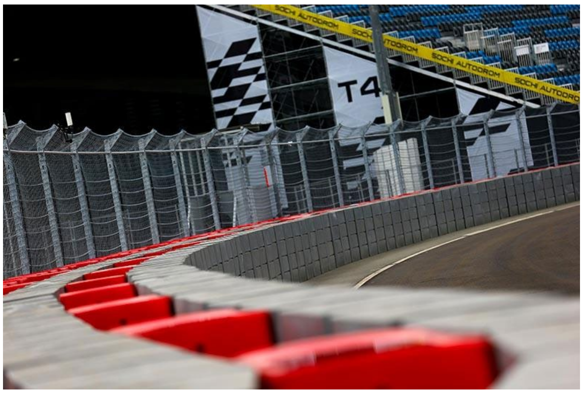
Run-off Areas

Extra space around the track allows cars to slow down before hitting a barrier.

Image credit: Michael Kastelic

Barriers

Modern barriers are designed to absorb energy and reduce the force of impact.



Car Design

Formula 1® cars are built with strong protective structures to protect the driver during a crash.

Image credit: Toby Parsons

The Halo

The Halo is a high-strength titanium structure designed to absorb and deflect impact forces, protecting the driver's head from debris and collisions.

Image credit: Alessandro Dal Bosco

Why This Matters at Albert Park

As the circuit becomes faster cars carry more energy into corners, braking zones become more critical, and barriers must absorb greater impacts. Changes to the track must always consider both performance and safety.

Test Yourself

1. Why does increasing speed make crashes more dangerous?

2. How do run-off areas and barriers help reduce the impact of a crash?

SECTION 6: ENGINEERING THE GRAND PRIX

Formula 1® is more than just cars racing on a track. It is a complex system designed and built by teams of engineers, designers and planners. Every part of a Grand Prix must work together, the track, pit lane, buildings, crowd areas, and safety systems.

Track Design

The layout of the track effects, speed, overtaking opportunities, and safety. Small changes, such as widening a corner or extending a straight, can change how cars behave across the entire lap.

Buildings and Infrastructure

The Grand Prix includes pit buildings and garages, grandstands, fencing and barriers, and access roads and pathways. These structures must be safe, efficient, quick to install and remove.

Crowd and Event Design

A Grand Prix is also designed for thousands of spectators. Engineers and planners must consider how people move around the circuit, how they enter and exit safely, and what they can see from different areas. Good design improves both safety and experience.

Why This Matters at Albert Park

Because Albert Park is temporary:

- structures must be installed and removed quickly
- roads must return to public use after the event
- space is limited and shared

This makes planning and design even more complex.

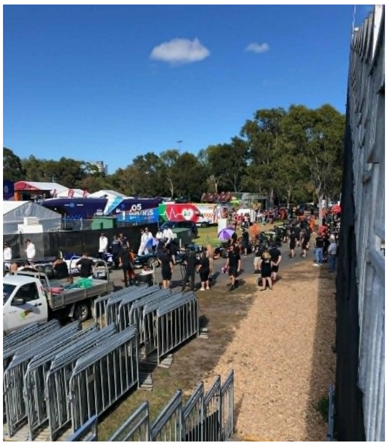
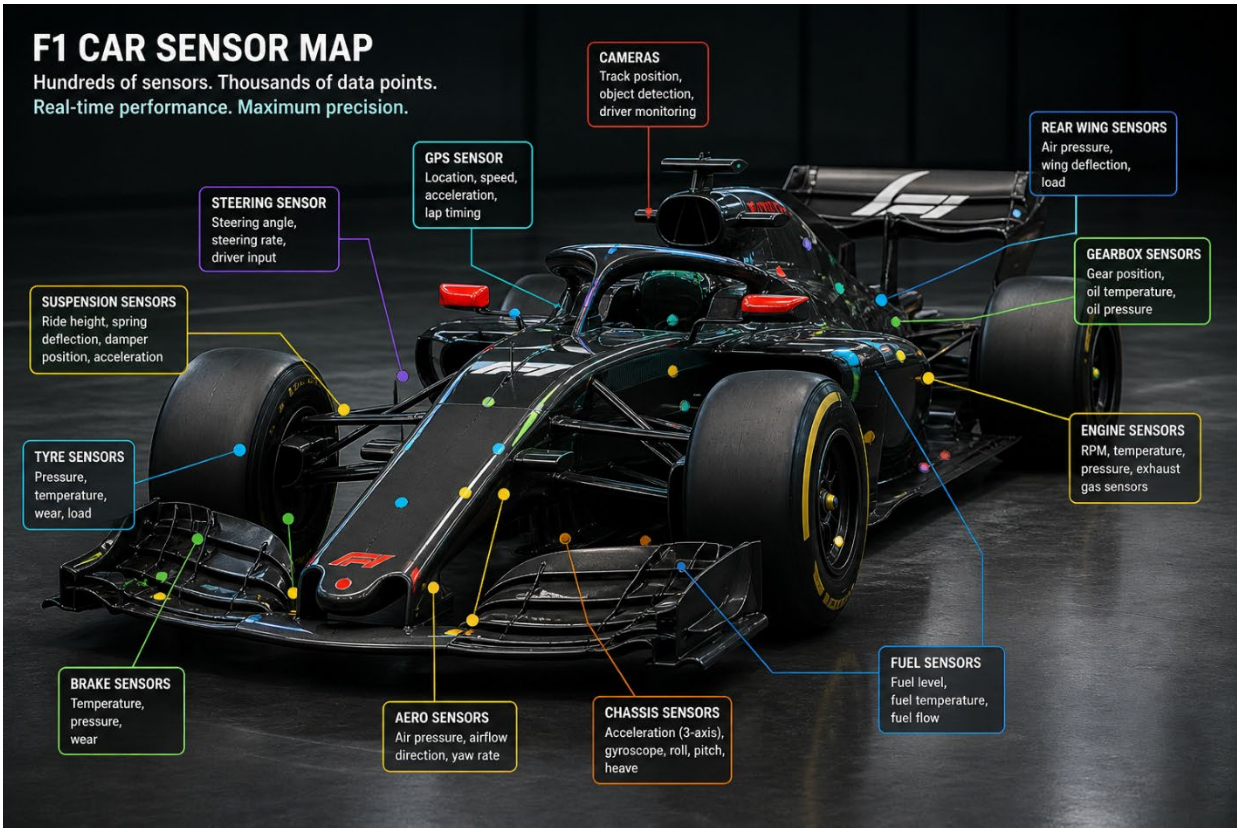


Image credit: Christian Peperoni

SECTION 7: DATA, SIMULATION AND DECISION-MAKING

Modern Formula 1® is not just about driving fast – it is about making the right decisions at the right time. Every lap produces vast amounts of data that reveal exactly how the car is performing. Engineers combine this real-time data with simulations to predict behaviour, optimise strategy, and improve performance. In a sport where small changes can have major consequences, data-driven decision-making is critical to success.



Formula 1 cars use hundreds of sensors to collect real-time performance data across all systems. The coloured markers are indicative only and are not exact sensor locations but demonstrate the scale and distribution of data collection throughout the car.

What Do Engineers Measure?

During a race, engineers collect data on many aspects of the car's performance, including:

- speed and acceleration
- braking forces and pressure
- tyre temperature, pressure, and wear
- engine performance (RPM, temperature, fuel flow)
- aerodynamic behaviour and airflow
- suspension movement and ride height
- steering input and driver controls
- forces acting on the car (g-forces in multiple directions)
- energy systems (battery use and recovery)

This allows engineers to see what is happening inside the car in real time – often in ways the driver cannot feel or measure directly.

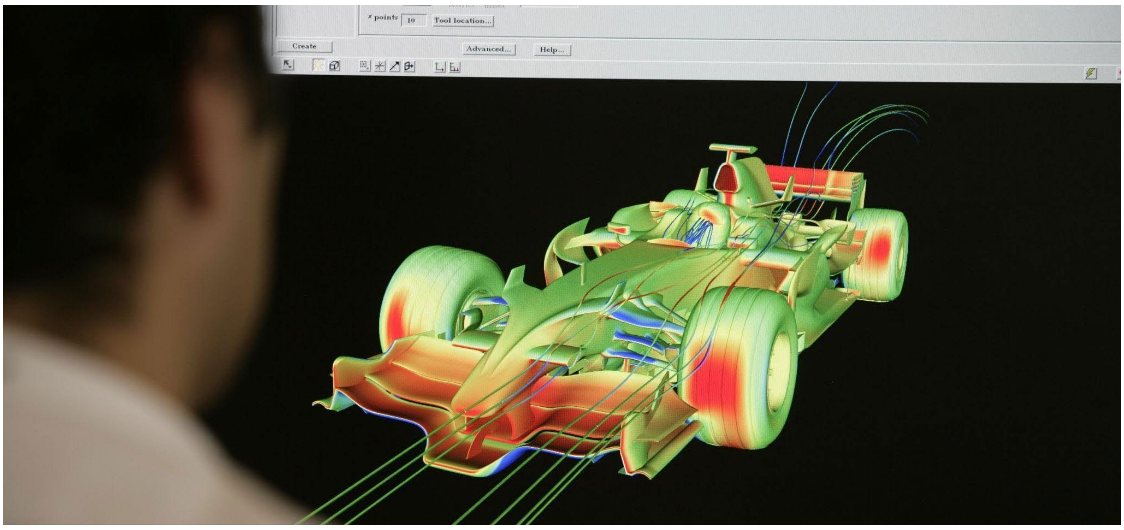
Engineers use live telemetry data to monitor performance, analyse trends, and make critical decisions that optimise speed, reliability, and race strategy.

Simulation and Testing

Before anything is built or changed, engineers test ideas using simulations. These include:

- computer models
- virtual track testing
- airflow simulations

This allows teams to explore solutions safely and efficiently.



Computer simulations help engineers see how air flows around the car and improve its performance before it ever goes on track.

Why This Matters at Albert Park

As the track evolves speeds change, corner behaviour changes, braking zones shift. Engineers rely on data and simulation to understand these changes and adapt quickly.

Test Yourself

1. Why is data important in improving the performance of a Formula 1® car?

2. How might engineers use simulation to test a new idea before applying it to a real car or track?