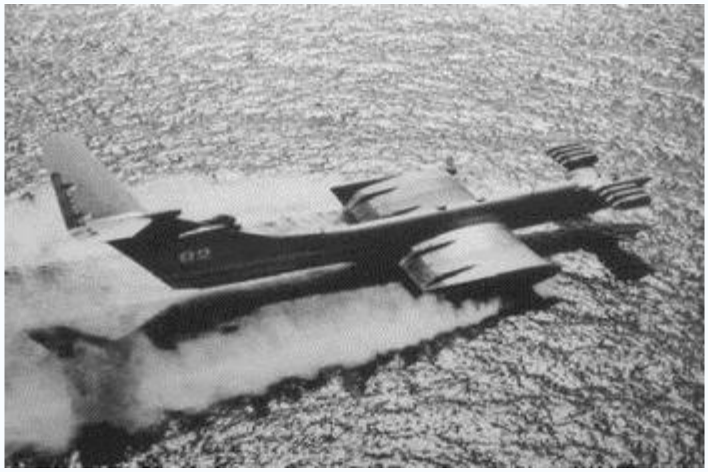
Ground effect

Ground effect (or **Wing In Ground** effect) is a phenomenon of aerodynamics where the flow of air around part of an aircraft or a racing car is interrupted by the ground.

Ground effect in aircraft



A Soviet ground effect aircraft flying over the Caspian Sea

Aircraft obtain increased lift and therefore better efficiency by flying very close to the ground; on a fixed-wing monoplane, about half the distance from a wingtip to the fuselage. Ground effect therefore affects most aircraft only at takeoff and landing. Ground effect also occurs over water.

Most pilots, especially of small aircraft, will experience ground effects on landing; in fact the art of landing largely comes down to understanding when these effects need to be taken into account. As the aircraft descends towards the runway, it will not be affected by ground effect, but as the aircraft flares and descends the last few feet, ground effect will cause a pronounced increase in lift. If not anticipated by the pilot this can cause the aircraft to rise suddenly and significantly — an effect known as a "balloon". Left uncorrected, a balloon can lead to a dangerous situation where the aircraft is rising yet decelerating, a condition which can rapidly lead to a stall, especially when it is considered that landing speeds are generally only a very small margin above the stall speed. A stall even from a few tens of feet above the ground can cause a major, possibly fatal, crash. A balloon may be corrected given sufficient runway remaining, but for novice pilots a better option is to go around. A good landing approach allows for ground effect such that the aircraft flares and is *held off* in ground effect until it gently descends onto the runway. For helicopters the ability to hover *in-ground-effect* or IGE is much improved, on the order of 1200 to 1500 m higher in altitude when compared to *out-of-ground-effect* or OGE hover capability.

The physics which describe ground effect are still very much under debate. A common belief is that ground effect is caused by a "cushion" of compressed air between the wing and the ground. However, wind tunnel testing and experiments have indicated that while a "cushion" effect is present, ground effect is almost solely due to the ground interrupting the formation of wingtip vortices. Wingtip vortices destroy massive amounts of the lift generated by the wing by increasing downwash behind the wing and therefore decreasing the aircraft's theoretical angle of attack. The decreased angle of attack needs to be compensated by pulling back on the control wheel, increasing the angle of attack and therefore increasing drag. This is sometimes referred to as Induced Drag, and decreases the aircraft's efficiency greatly. When very close to the ground, the wingtip vortices are interrupted, and this results in greater efficiency.

Some critics of Howard Hughes' massive Spruce Goose claim the famous flying boat's first (and only) flight was due entirely to ground effect and the craft was incapable of sustaining flight above a very low altitude.

A **ground effect vehicle** (GEV) is an aircraft that always operates in the ground effect and cannot sustain flight more than a few feet above the ground. In the 1980s, the Soviet Union experimented with the jet-propelled Ekranoplan, just such an aircraft. Most GEVs are intended to operate over water since suitable operational areas are rare over land. Physicist Stanley Hooker has proposed huge, 2000 ton craft capable of carrying over one thousand passengers, to exploit the high speed and low cost of wing-in-ground effect flight. Hovercraft are often erroneously called ground effect vehicles.

Ground effect in cars

In racing cars, a designer's aim is not for increased lift but for increased downforce, allowing greater cornering speeds. (By the 1970s 'wings', or inverted aerofoils, were routinely used in the design of racing cars to increase downforce, but this is *not* ground effect.)

However, substantial further downforce is available by understanding the ground to be part of the aerodynamic system in question. The basic idea is to create an area of low pressure underneath the car, so that the higher pressure above the car will apply a downward force. Naturally, to maximize the force one wants the maximal area at the minimal pressure. Racing car designers have achieved low pressure in two ways: first, by using a fan to push air out of the cavity; second, to design the underside of the car as an inverted aerofoil so that large amounts of incoming air are accelerated through a narrow slot between the car and the ground, lowering pressure by Bernoulli's principle. Official regulations as of 2005 disallow ground effects in many types of racing, such as Formula One.

Jim Hall, the first car aerodynamicist to harness downforce, built Chaparral cars to both these principles. His 1961 car attempted to use the shaped underside method but there were too many other aerodynamic problems with the car for it to work properly. His 1966 cars used a dramatic high wing for their downforce. His Chaparral 2J "sucker car" of 1970 was revolutionary. It had two fans at the rear of the car driven by a dedicated two-stroke engine; it also had "skirts", which left only a minimal gap between car and ground, so as to seal the cavity from the atmosphere. Although it did not quite win a race, the competition lobbied for its ban, which came into place at the end of that year. Movable aerodynamic devices were banned from most branches of the sport.

Formula One in the late 1970s was the next setting for ground effect in racing cars. In 1977 Lotus brought out their "Wing Car", the Lotus 78, designed by Peter Wright, Colin Chapman, and Tony Rudd. Its sidepods, bulky constructions between front and rear wheels, were shaped as inverted aerofoils and sealed with flexible "skirts" to the ground. The team won 5 races that year, and 2 in 1978 while they developed the much improved Lotus 79. The most notable contender in 1978 was the Brabham BT46B Fancar, designed by Gordon Murray. Its fan, spinning on a horizontal, longitudinal axis at the back of the car, took its power from the main gearbox. The car avoided the sporting ban by claims that the fan's purpose was for engine cooling. It raced just once, with Niki

Lauda winning at the Swedish Grand Prix. However, the team, led by Bernie Ecclestone who had recently become president of the Formula One Constructors Association, withdrew the car before it had a chance to be banned. The Lotus 79, on the other hand, went on to win 6 races and the world championship for Mario Andretti. In following years other teams copied and improved on the Lotus until, after drivers couldn't stand the physical punishment any longer, flat undersides became mandatory after 1983.