Ground Effect: It's Not a Cushion, it's an Effect of Lift Creation

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Eye-witnesses, fallen lamp posts and other evidence testify to the flattened final trajectory of Flight 77 in the seconds before it hit the Pentagon on September 11. Some novice commentators claim that this wasn't aerodynamically possible. The claim made is that the high speed, low-level approach would have been affected by "the ground effect", and we're told this effect creates a cushion of air that would make it "aerodynamically impossible" for the plane to impact as it did. Nila Sagadevan, who apparently has never bothered to study simple aerodynamics as they apply to fixed wing aircraft, attempts to use this blatant falsehood to fool people into believing that a non-existent aerodynamic phenomenon, High-Speed-Low-Angle-of-Attack-ground-effect, would have precluded an aircraft in a descent from hitting the ground at that speed, and so, he would try to convince you that no aircraft could have hit the Pentagon. His intellect is either dizzying, or has made him dizzy.

Sagadevan was quick to point out that one of the main problems with the official story is the ultra-low-level trajectory of the airplane during the final phases, something that defies the laws of aerodynamics.

"The evidence indicates that the airplane was flying no more than 20 feet above the ground before it reached the Pentagon lawn since several light poles were sheared off several hundred yards away form the building," explained Sagadevan. "This means the plane was travelling a mere 20 feet off the ground at about 400 knots for a fairly long distance before hitting the Pentagon.

"This in itself is an impossibility since the airplane would have been prevented from getting that close to the ground by a phenomenon termed 'ground effect'. This is a highly energized cushion of air located between the wings and the ground, whose energy increases in direct proportion to aircraft speed. Flying at 400 knots, 20 feet above the ground, in a commercial airliner is a flight domain never experienced by any pilot. This is why it is difficult to impress the impossibility of such a maneuver. The reaction of the energized ground effect layer simply would not have allowed the airplane to get that close to the ground for that long a distance at that great a speed. At around 100 knots this is obviously entirely possible — it happens every day during landings. At 400 knots in a 100-ton airliner — impossible."
http://www.arcticbeacon.citymaker.com/articles/article/1518131/38646.htm

Besides the carelessly vague and postulated "fairly long distance" being traversed at 7 - 8 nautical miles per minute (in a few seconds at 460 knots) Sagadevan's aerodynamic "knowledge" is absent when he claims an "impossibility."

Ground effect is a low speed, near the ground, high angle of attack phenomenon. Approach speeds are typically around 150 knots, about a third of the speed Flight 77 was flying at when impact occurred. "Angle of attack" is the angle measured between the leading edge of an airfoil and the airstream through which it is travelling. In a fixed wing aircraft, it is controlled by pitch (and airspeed) and related to nose pitch angle, which is angle between the nose-to-tail axis of the aircraft, the horizontal/horizon. (For the pilots in the audience, rotation about the lateral axis.)

Many pilots think that ground effect is caused by air being compressed between the wing and the ground. This is not so. Ground effect is caused by the reduction of induced drag when an airplane is flown at slow speed very near the surface.
http://www.pilotfriend.com/training/flight_training/aft_perf.htm

At low speeds and high angles of attack within a wingspan of the ground, the "ground effect" is the ground dispersing turbulent wingtip vortices, thus "increases net lift" by reducing reductions in lift caused by spanwise and turbulent air flow. See these two figures:

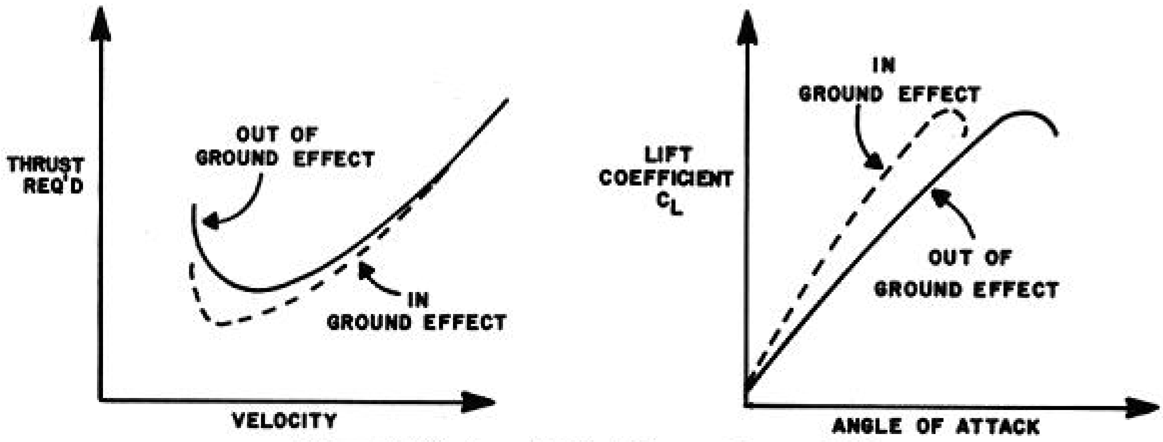

Figure 17–20 Ground Effect Changes Drag and Lift

Left figure: as airspeed increases, the "ground effect" as additive factor to total lift merges with the lift from airspeed, meaning its influence disappears as airspeed increases.

For low angles of attack: in the right figure, note the merging of the lines in the lower left corner of the graph. There is no "ground effect" lift bonus at low angles of attack, as and lift (as well as induced drag) is less per unit airspeed for low angles of attack.

In a full power descent, angle of attack is low or "negative."

Flight 77 was flying "clean," at max power, far to the right on that graph after the lines merge. Clean means wings generate lift: no flaps, no spoilers, no speed brakes, landing gear retracted. This offers the least drag and thus fastest possible speed for an aircraft at full power. Fast speed is desirable if you want to use the Kinetic Energy of your aircraft to do damage to something like a building.
KE = 1/2 m*v^2.

Again: lift from "the ground effect" happens at low, not high, airspeeds and high, not low, angles of attack. At high speeds, flow across a wing tends toward laminar, and spanwise flow is functionally negligible. Ground effect mitigates lift loss when the ground breaks up wing tip vortices from turbulent and spanwise flow over a wing caused by high angle of attack, low speed flight regime.

The light poles being clipped suggest that the hijacker nearly blew it -- he nearly hit short of his intended target. The flattening of his trajectory was from either a small correction (slight nose up?) or some "magic cushion." The slight angle of bank (mentioned elsewhere) suggests he was making corrections as he struck.

A big nose-up correction at that speed would have resulted in a ballooning, and a miss, due to high airspeed/high lift combination. Ballooning is a rapid increase in altitude associated with quick nose up inputs.

"Ground effect's" so called "air cushion" only works for small values of "rate of descent." (R/D) You can hit the ground at high speed, or at low speed, if your speed component downward is great enough and you don't pull up. Any number of fast moving jets have slammed into the ground at high speeds, high R/D. "Ground effect" couldn't save them.

If you watch the movie Final Countdown or Top Gun, you will see how Navy jets slam into an aircraft carrier to land. They don't flare, they fly through ground effect and slam into the landing zone at a deliberately set Rate of Descent (R/D). (IIRC it is 300-800 FPM, depending on model.)

Lift is f(n) airspeed. Vertical speed is the difference between lift and gravity. Gravity always works. (Lift = K * (V^2)/2 where K = combined surface area, coefficient of lift, density of air, and V = airspeed)

Descend at 50 or 5000 feet per minute, and you will hit the ground (or water) unless you arrest your R/D before impact. To land, after reducing power to decelerate, (this also reduces lift) you typically "flare," which is a modest nose up movement. This increases lift via angle of attack, but also aids is bleeding off airspeed. As you decelerate, the lift reduction eventually overcomes any cushioning (lift not lost) from "the ground effect" and you settle, or thump, onto the runway rear wheels first. I have 3500+hours. I have taught flight students how to use ground effect to advantage in landing a fixed wing aircraft.

Flight 77 was not trying to land, nor in a flare, nor at approach speed, thus no high angle of attack, no ground effect, and no "cushion."

Based on FDR evidence: full power, 460 knots. At full power, a descent requires a nose low attitude. Even level flight near maximum airspeed calls for a low angle of attack. As you speed up, lift increases, so you must adjust your nose attitude (and thus airfoil angle of attack) downward if you want to descend at high airspeed. That is what Flt 77 did.

R/D for flight 77 from 4 nm out based on FDR info, ground plot, and altitude points. (Roughly 4 nm away @ 2000' MSL to about 40' MSL' at impact point at 400+ knots) ~ 7 nm per minute, lose about 2000 feet of altitude, it's about 3500 fpm. Between 3000 and 4000 fpm is a good range of values, if the pilot was able to maintain a uniform R/D, which I doubt he did.

If, as it appears, he flattened out at the end and reduced his R/D in the last few seconds to stay on target and not hit the ground prematurely, (See below) his angle of attack is still low, and "Ground effect" does not come into play.

"Fluid compression" within a wingspan's distance from the ground (125' for a 757), besides not existing in that flight regime as any "ground effect, would be experienced as the transient compression of a small column of air that disperses quickly, below or behind the center of lift. At low angles of attack such "compression" would happen behind the center of lift on the wings relative to the direction of travel. In the direction of travel, with nose down (below horizontal) air is being compressed above the wing and at the leading edge as the aircraft skin meets the air molecules. The aircraft keeps moving ahead of the alleged "compression wave" under the wing. (Take a toy plane, tilt the nose 5 degrees below the horizontal, and see where an air cushion would have to be under the airfoil.)

Flt 77 wasn't flaring, air below thus could not form a non-existent "cushion" to break downward momentum. (Momentum is Mass * Velocity.) Flt 77 hit the building before it hit the ground in any event, (and clipped a few light poles.) This "Scholar" inadvertently has made a case for why the building was hit with no ground impact first, but he makes that case for the wrong reason. The alleged "cushion" was simple lift from high airspeed and a slight nose adjustment.

If the hijacker pilot had made a large nose-up control input, increasing the angle of attack considerably, you'd have seen a ballooning (and a miss) though not due to ground effect, but due to normal creation of lift.

At 150 knots, L = 1/2*K*V^2
At 450 knots, you get roughly 9 ((450^2)/(150^2)) times the lift from V^2 increases.

You don't need ground effect, which isn't there anyway.

This all ignores how pilots fly to an intercept point.

You align your plane's direction of travel with your target, and maintain a constant bearing, decreasing range relationship by correcting for changes in bearing with the yoke/stick. You are looking for relative motion in your windscreen when flying with visual references. This eye-hand control is similar to lining up to hit another car in a "bumper cars" arena, albeit in three dimensions rather than two.

If your target remains in a fixed spot on your windscreen, you will hit it as closure reduces range to zero. If the object moves relative to that spot in the windscreen --up or down drift, left or right drift, or a combination of drifts -- it will drift out of your windscreen and you will miss it, unless you make corrections.

If target moves down in the wind screen, you move the nose down to correct. If it goes left, you turn a bit left. So long as you make small corrections, and correct as soon as you see the slightest change in position on your windscreen (which acts as a crude gun sight at this point) you will fly to intercept/impact.

Flying to a point is one of the most basic and simplest of tasks an inexperienced pilot first learns how to accomplish. The biggest risk to hijacker was overcontrolling the nose attitude, or wings. Flying fast required setting a good "first guess" descent angle early on in his attack run, to avoid over controlling close in. Speed of closure required him to pay very close attention to his target's drift in his windscreen. At high speeds, small errors and subsequent corrections are needed: large corrections can be magnified due to large aerodynamic forces (much lift.)

Hijacker pilot's cockpit task load was low. He didn't have to scan his airspeed and correct for it: he had set full throttle. He could focus on a one variable problem: keeping that spot fixed in the windscreen using hands on the yoke.

So, to sum up: the mythical air cushion does not exist in the flight regime and configuration presented by FDR data; the assertion of "aerodynamically impossible" is being made in complete ignorance of aerodynamic forces influencing aircraft in flight; ground effect is not going to prevent a collision between an aircraft travelling at 460 knots and the building right in front of it as it passed, at extremely low altitude, over the ground.