

Buoyancy Explains How Planes Fly

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Abstract

Buoyancy explains how planes fly. To fly a plane needs to displace a mass of air down equal to its own mass, each second. Planes are effectively floating on a cushion of air that the wings create by pushing air downwards.

This is a similar explanation to how boats float according to Archimedes principle of buoyancy, and how birds fly by pushing air downwards. Correspondingly, this theory predicts that for all planes to fly, they must displace a mass of air down equal to its own mass each second.

If the current equation for lift is adjusted to include "the distance down that air is displaced by the wing" Then a good estimate of the mass of air displaced by the wing (and thus buoyancy), is provided. Hence, the proposed new equation for lift is:

$$\text{Lift (Force)} = \text{Air Mass Displaced each second} \times \text{Aircraft Velocity (i.e. } F = mv)$$

This theory is proposed as the current theories of flight have severe limitations and remain unproven. There is no scientific experiment on a real aircraft in realistic conditions that proves any theory to be correct. Pilots, aviation authorities, academics and engineers still debate the different theories of flight whereas; it is possible to prove buoyancy. Current theories of flight ignore buoyancy.

This theory of flight has been presented to numerous pilots, engineers, and academics. No one has been able to provide a valid scientific argument or evidence to disprove it.

Keywords: Buoyancy; Fly; Planes; Aerodynamics; Wing; Buoyancy; Theory

Executive Summary

Introduction

This paper demonstrates that buoyancy explains how planes fly. The planes achieve vertical lift and fly based on the principle of buoyancy. Dynamic buoyancy is a new concept that is simply buoyancy that involves some action to achieve buoyancy; such as a plane pushing air down to fly. This is consistent with existing laws of physics and aerodynamic knowledge. It is simply applying the principle of buoyancy to planes.

Why is this important?: This theory significantly changes our understanding of buoyancy and how planes fly. This will change how pilots are trained and how planes are designed; to achieve better aviation safety. This also resolves a 100 year old debate on how planes fly.

Additional comments: Conclusive proof of dynamic buoyancy will need to be provided later via a scientific empirical experiment. This paper is only on the theory of dynamic buoyancy.

The time frame in which a plane must displace its own mass is open to debate. The one second time frame proposed above is unproven and speculation. The actual time frame may be different; either shorter or longer. Research and experimentation needs to be done on this. Planes do displace air downwards. So, planes will displace a mass of air equal to their own mass over a given time period.

The Explanatory Videos (on Vimeo, by Nick Landell) for this Paper Include Buoyancy Explains How Planes Fly

Synopsis (9 minutes) <https://vimeo.com/185759671>, Summary (20 minutes) <https://vimeo.com/175567433>, Full video (60 minutes) <https://vimeo.com/172578440>.

The 12 theories of flight summarized. <https://vimeo.com/172574660> (10 minutes).

The current explanation of flight is impossible. <https://vimeo.com/149561151> (30 minutes).

New Concept that is Consistent with Existing Physics and Knowledge

Dynamic buoyancy is a new concept for aviation. This has not been argued anywhere else before. In fact, this theory has received extremely strong objections; albeit mostly emotional and not based on valid logic, science or evidence.

Dynamic buoyancy is consistent with the key laws of physics; specifically:

- Newton's laws of motion;
- The conservation of momentum, mass and energy;
- Archimedes principle of buoyancy.

Dynamic buoyancy is consistent or compatible with many of the current theories of flight; they're not necessarily mutually exclusive.

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Dynamic buoyancy is also consistent with the standard wing airflow diagrams and wind tunnel experiments; which all show the wing displacing air downwards.

Dynamic buoyancy is also consistent with most of the current aerodynamic equation for lift.

$$\text{LIFT} = 0.5 (\text{Velocity}^2 \times \text{Air Density} \times \text{Wing Area} \times \text{Lift Coefficient}).$$

All the factors that are acknowledged to affect lift, such as aircraft velocity, air density, wing area and wing angle of attack (lift coefficient), also affect the amount of air displaced by the wing; and thus the mass of air displaced and the dynamic buoyancy generated.

The Current Theories of Flight Have Severe Limitations

There is neither “official” or generally accepted theory for how planes fly nor any theory that is universally accepted as true. A variety of theories are debated among academics, aeronautical engineers, pilots and aviation authorities.

There is no scientific experiment on a real plane in realistic conditions that conclusively proves any theory of flight to be correct whereas, dynamic buoyancy could be proved with a scientific experiment on a real aircraft.

This document does not focus on explaining the current theories of flight in any detail. Current theories of flight and equations ignore buoyancy; therefore, they can be shown to be incomplete. This does not mean that they are necessarily wrong, just incomplete.

Why is this important?: Buoyancy has been overlooked and ignored by current theories of flight. This theory significantly changes our understanding of buoyancy and how planes fly. This will change how pilots are trained and how planes are designed; to achieve better aviation safety.

This theory is new as it is contrary to some of the physics what we're taught at school & university; that Archimedes principle of buoyancy does not apply to moving objects (which has never been proved or disproved). The logic of dynamic buoyancy is that: gravity applies to moving objects, buoyancy is a product of gravity; therefore buoyancy should apply to moving objects (e.g. planes).

A safety problem is that fatal aircraft accident rates have been broadly unchanged since 1990, despite new technology. The most common reason for fatal plane crashes is the pilot's 'loss of control' of the aircraft [1-6]. No wonder, if pilots don't even know how the plane flies in the first place! A better understanding of flight should lead to fewer plane crashes due to better pilot skills and better planes being built. This should also boost public confidence in aviation.

This helps to resolve a 100 year old debate in aviation as to how planes fly. Experimentation to prove dynamic buoyancy will conclude the debate. After 100 years of aviation, engineers should have conclusive evidence how planes fly; but they don't at present.

Once the theory is established as accurate and valid, experimentation can then be done to prove the theory in practice. It will represent a critical insight to physics if it can be proved in what time frame a plane displaces its own mass, for example whether the time frame is one or ten seconds.

Background Information

Method

This work was completed after extensive research, as well as

numerous discussions with academics, engineers, pilots and aviation authorities.

Extensive flying was done on small, single engine aircraft, to confirm the validity of the assertions documented in this paper. The findings are consistent with what pilots experience and the observed aerodynamics when flying a plane.

Definitions

Dynamic buoyancy: To fly a plane one must displace a mass of air downwards equal to its own mass. “Dynamic buoyancy” is an active form of buoyancy where a fluid (air or water) needs to be constantly displaced downwards to allow an object to maintain buoyancy. For example, stationary boats achieve ‘static’ (inactive) buoyancy as they simply rest on water. By comparison, planes achieve ‘dynamic’ (active) buoyancy as the wings are constantly pushing air down in an active process. If the action to push air down stops, then the buoyancy is lost and the plane sinks downwards.

Wing reach: “Wing reach” is the vertical distance away from the wing that the wing influences the air. It is the volume of air (m^3) displaced by each 1 m^2 of effective wing area. Wing reach depends on the wing's angle of attack and the wing shape (i.e. lift coefficient). The greater the wing reaches the greater the volume of air displaced by the wings. So a “wing reach” of 1 m means that: 1 m^2 of wing area can displace at least 1 m^3 of air (at least 1m downwards). A 1.0 m wing reach is calculated as 0.5 m both above and below the wings (Note: 0.5 m is about knee height of an average-height adult) (Figure 33).

A note on diagrams in this paper

In this paper, the wing diagrams are shown as a cross section of the wing (Figure 1).

Summary of each section of this paper

Executive summary: See abstract.

Background: See background information above.

Logic and Philosophy

First, the logi and philosophy is explained, specifically why buoyancy should apply to planes.

1. Gravity applies to moving objects, so buoyancy should also apply to moving objects.
2. Air currents can push planes up; so planes can push an air mass down to create lift.

Dynamic buoyancy is consistent with the laws of physics, Newton's

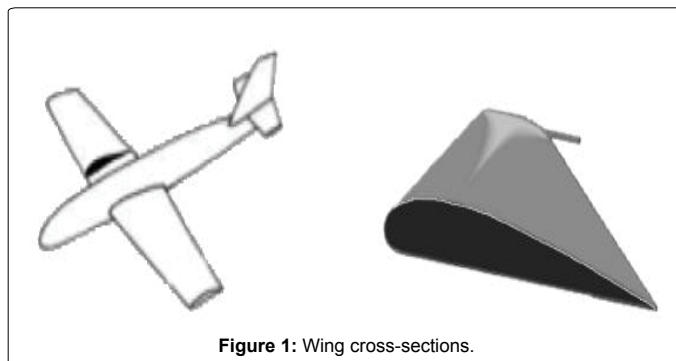


Figure 1: Wing cross-sections.

laws of motion, the conservation of mass and energy, as well as Archimedes principle of buoyancy.

Dynamic buoyancy is consistent with standard 2-D wind tunnel experiments and air flow diagrams.

Current theories of flight ignore buoyancy; so are therefore incomplete. Not necessarily wrong, just incomplete.

The Dynamic Buoyancy Theory of Flight Explained

This is the critical section of this paper. The details of the dynamic buoyancy theory of flight are defined and explained. Physics, maths and equations are used to demonstrate that in flight the mass of the plane must equal the mass of the air displaced by the wings.

As:

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

$$F = MA \text{ (Newton's 2nd law of motion); thus}$$

$$\text{Lift} = \text{Mass of Plane} \times \text{Gravity.}$$

Similar calculation for the buoyancy of a boat:

$$\text{Buoyancy} = \text{Mass of Air Displaced each second} \times \text{Gravity.}$$

Therefore, in stable flight, these two equations must equal:

$$\text{Lift} = \text{Buoyancy.}$$

$$\text{Mass of Plane} \times \text{Gravity} = \text{Mass of Air Displaced each second} \times \text{Gravity.}$$

$$\text{Mass of Plane} = \text{Mass of Air Displaced each second.}$$

The static air in front of the plane is displaced downwards and slightly forwards by the wings (Figure 2).

The Explanation of Why Mass of Plane = Mass of Air Explained

According to Newton's Third Law of Motion [6], every force must have an "equal & opposite" force. The wings have a positive angle of attack, so the downward force (ACTION) on the wings pushes air downwards, and slightly forwards. But what exactly is the force (ACTION) pushing down against? Just air? If you push down on a wing, it will fall downwards unless there is something to resist and push back (i.e. upwards). That resistance can only be the high air pressure under the wing in the form of buoyancy (Figures 3 and 4).

The downward force (ACTION) on the wings pushes air downwards and creates relatively high air pressure under the wings (and low air pressure above the wings - i.e. dynamic buoyancy). This provides resistance to the downward force (ACTION) and hence allows for the generation of the REACTION (Lift) force upwards. Without dynamic buoyancy, the REACTION and lift is not possible. Therefore the mass of the plane must equal the mass of air displaced. The plane is being supported by a cushion of air immediately under the wing, as well as all the air recently displaced behind the plane.

Evidence of dynamic buoyancy can be seen in the air or water displaced down by birds, helicopters, speed boats, and planes i.e. backwash.

Mathematical Proof of Concept of Dynamic Buoyancy

Using the example of a Harrier, mathematical proof is provided;

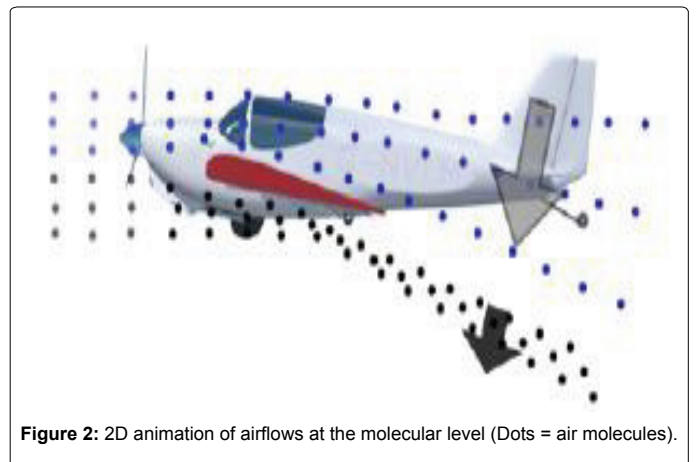


Figure 2: 2D animation of airflows at the molecular level (Dots = air molecules).

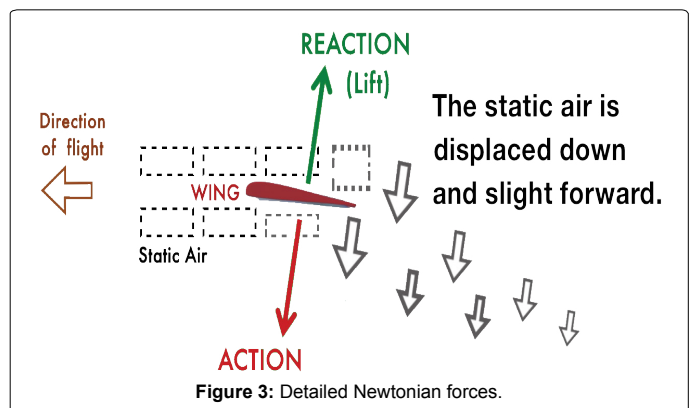


Figure 3: Detailed Newtonian forces.

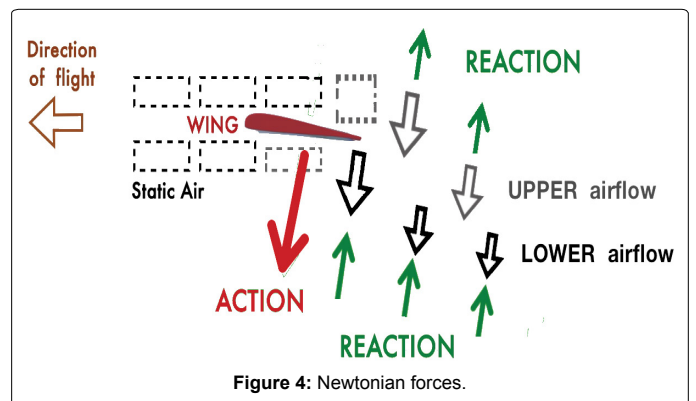


Figure 4: Newtonian forces.

supported by evidence of backwash. This demonstrates that it is feasible that a plane's wings can displace a mass of air down equal to its own mass, every second. Calculations show that a Harrier only has to displace air down a few meters to achieve dynamic buoyancy. The impact of air viscosity and compressibility on lift are discussed. Experimentation needs to be done to prove this in practice.

Aircraft lift and dynamic buoyancy

It is shown that all the factors that current textbooks claim influence lift (eg. air density, aircraft velocity, wing angle of attack, ...); also affect the mass of air that the wings displace. So, dynamic buoyancy is consistent with current theories of lift. Also, all these factors above can be broadly split into two areas:

- Air that the wing travels through.
- The ability of the wing to push this air downwards.

This leads to the introduction of three new concepts in this paper:

- “Wing Reach”, Instead of the lift coefficient (wing shape and angle of attack).
- Effective wing area (m^2); Instead of the actual wing area.
- Distance down that air is displaced; this is a totally new concept.

Lift equations

Dynamic buoyancy proposes that the current mathematical equation for lift Equation (1):

$$\text{Lift} = 0.5 (\text{Velocity}^2 \times \text{Air Density} \times \text{Wing Area} \times \text{Lift Coefficient}).$$

This equation should be adjusted by introducing three new concepts above that affect lift:

- “Wing Reach” (m), Instead of the lift coefficient (wing shape and angle of attack).
- Effective wing area (m^2); Instead of the actual wing area.
- Distance down (m) that air is displaced by the wing.

To produce Equation (2c) the new equation for lift:

$$\text{Lift} = (\text{Velocity}^2 \times \text{Air Density} \times \text{Effective Wing Area} \times \text{Wing Reach} \times \text{Distance Down that Air is Displaced each second}).$$

This Equation (2c) can be re-stated to Equation (4):

$$\text{Lift} = \text{Velocity} \times \text{Air Density} \times \text{Volume of Air Displaced}$$

which can be re-stated to Equation (6):

$$\text{Lift} = \text{Velocity} \times \text{Air Mass Displaced Each Second}.$$

$$\text{Or } F = mv$$

As these equations demonstrate that lift can be shown to be based on the air mass displaced by the wing, this supports the theoretical argument that buoyancy explains flight. Experimentation needs to be done to prove this new equation applies in practice.

A critical change to the current equation for lift, is that if you include “the distance down that air is displaced by the wing” to the existing equation for lift; a better estimate of the mass of air displaced by the wing (and thus dynamic buoyancy), is obtained.

Wing vortices and winglets

Wing vortices and winglets are examined from the perspective of dynamic buoyancy. What is observed in reality is consistent with dynamic buoyancy theory.

Practical Tests - Flight Manoeuvres

Practical tests were conducted to see whether the logic of dynamic buoyancy can explain the dynamics of standard flight manoeuvres; compared to current theories of flight. i.e. This tests if the logic of each theory is consistent with what is expected in reality. Flight manoeuvres: stable flight, “nose-up” climb, stall, descent, vertical descent, banking, banking (ailerons), flaps, wind and up-currents, ground effect, and inverted flight. Results: Dynamic buoyancy theory managed to explain all flight manoeuvres. Whereas, current theories of flight failed to explain almost all of these flight manoeuvres.

Philosophy and Logic

The general philosophy and logic used by the dynamic buoyancy theory can be described as follows:

Occam’s razor - the simplest explanation given the evidence is often true. Current explanations of flight tend to be highly technical and complex; and way beyond the understanding of the typical pilot or layman; as well as many academics.

Dynamic buoyancy theory is based on a rational observation of reality; supported by evidence, logic and reason.

The Logic of Applying Buoyancy to Planes is Straight Forward

- Gravity applies universally to all stationary and moving objects.
- Buoyancy is a product of gravity.
- Therefore, buoyancy should apply universally to all stationary and moving objects (eg. planes).

The Laws of Physics should be Applied Universally, Not Selectively

Currently Archimedes principle of buoyancy is selectively only applied to static objects, and is not applied to moving objects (such as planes). It has never been proved, or disproved, whether Archimedes’ principle of buoyancy applies to objects that move.

The Logic that a plane can displace an air mass to stay airborne is also supported by the following argument:

There’s plenty of evidence that air currents affects the lift generated by a wing. For example, gliders in flight are displaced by convectional air up-currents, down-drafts, while most planes are experience “ground effect” on landing [7].

Boats and hot air balloons float due to buoyancy. There is no reason that planes should be exempt from the need to maintain buoyancy. Wings are not magic.

Many people and theories of flight claim that wings are special and therefore subject to special laws of physics that allow planes to fly. If that is the case, then exactly what is the definition of a wing? Exactly at what point do these special laws of physics apply? Note that no current theory of flight defines a wing nor why special conditions should apply to wings.

Dynamic Buoyancy is Consistent with the Conservation of Mass and Energy

The energy from the engine is used to push the air mass down and the plane up, with the help of wings directing the air mass downwards. There is no net loss or gain of mass or energy. In summary, energy is transferred from the plane to the air to achieve lift.

Dynamic Buoyancy is Consistent with 2D Wind Tunnel Experiments and the Standard Airflow Diagrams

As shown above, these images show air being pushed or deflected downwards by the wing. i.e. The airflow at the trailing edge of the wing is lower down compared to the air entering at the leading edge of the wing. So dynamic buoyancy is consistent with 2D wind tunnel (Figures 5 and 6).

Experiments and standard wing airflow diagrams. Thus, dynamic

buoyancy is not a dramatic departure from what is already in front of your eyes (Figure 7).

Dynamic buoyancy describes the wing airflows differently, as shown in figure 7. The static air in front of the wing is pushed downwards and slightly forward by the moving wing (which has a positive angle of attack). The focus is given to the fact that the wing is moving, not the air.

Dynamic buoyancy disputes that view that air is Galilean invariant, as static air behaves differently to flowing air. Meaning that in this analysis it does matter slightly whether the wing is moving and the air is static; or vice versa. Other theories of flight claim that it is only the relative movement here that is significant.

Boats, Seaplanes and Buoyancy – A Quick Summary

Boats float due to an upward buoyancy force equalling the downward weight of the boat. To float, boats must displace a mass of water equal to their own mass. The buoyancy force is just the upward water pressure at the bottom of the boat. Pressure and weight are both due to gravity. According to physics established by Archimedes [8], the mass of the boat will equal the mass of the water displaced by the boat (Figure 8).

This is the same principle for planes; the wings must displace a mass of air over a given time period (each second) equal to the mass of the plane. Note that in physics, air and water are both fluids; so, both boats and planes are subject to the same principles of physics. Wings are not magic and not exempt from the laws of physics such as buoyancy.

Speed Boats, Hydrofoils and Seaplanes

Archimedes principle of buoyancy explains why boats float. If a boat starts moving, buoyancy doesn't stop being relevant. There is no scientific experiment that has proved if Archimedes principle of buoyancy does, or does not, applies to moving objects such as planes (Figure 9).

The principle of buoyancy applies to a moving boat. Speed boats can achieve lift and rise out of the water without wings. In addition, some boats have hydrofoils (that are like air foils) which provide lift and raise the boat higher out of the water. Add wings to a boat and at high speed the boat becomes a seaplane that floats on the air. Planes are just boats with wings; boats float due to buoyancy in water; planes fly due to buoyancy in air. It is a simple progression from a static seaplane

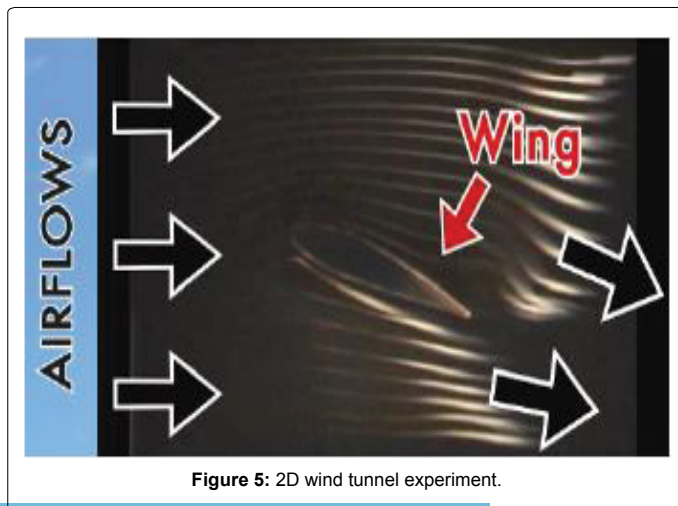


Figure 5: 2D wind tunnel experiment.

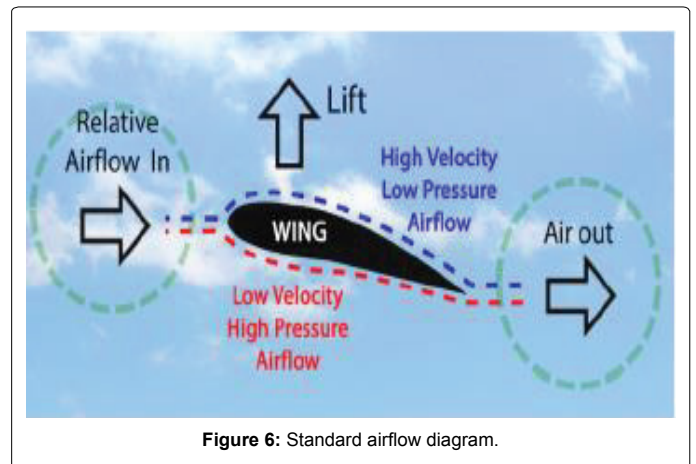


Figure 6: Standard airflow diagram.

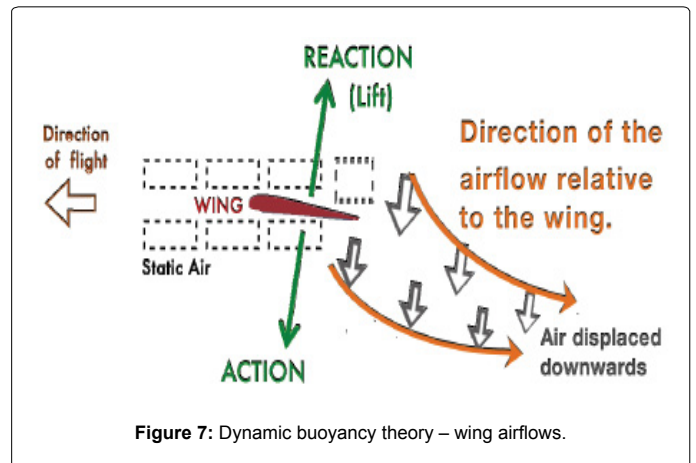


Figure 7: Dynamic buoyancy theory – wing airflows.

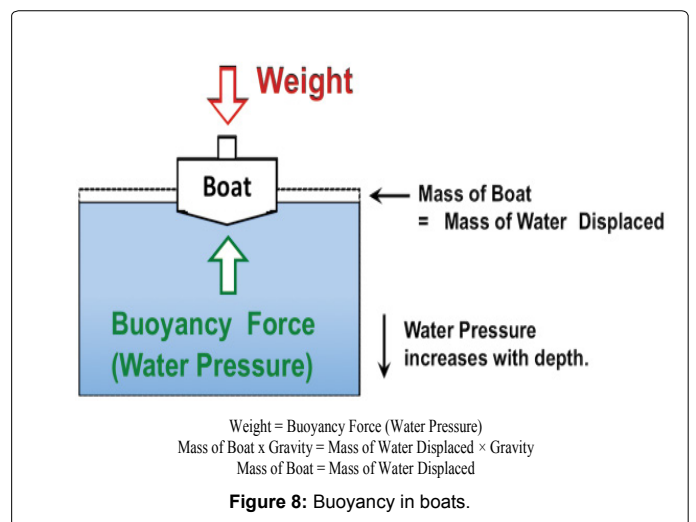


Figure 8: Buoyancy in boats.

floating in water to flying in the air. Gravity and buoyancy applies all the time. Buoyancy doesn't stop acting on the seaplane just because it's moving (Figures 10 and 11).

Dynamic Buoyancy Explained

Definition of dynamic buoyancy: To fly, a plane must displace a mass of air downwards equal to their own mass, each second. If they don't, then they sink due to gravity.

- The faster a plane flies, the more air it displaces each second and the greater its dynamic buoyancy.
- Over a given time period of one second, the pressure on the wing is equal to the force required for the plane to stay airborne (Figures 12 and 13).

Birds fly by pushing air downwards: This is easily established by watching a slow motion video of a bird flying (Figure 14).

Wings re-direct air downwards to generate lift: Wings re-direct air downwards to generate lift is shown in Figures 15 and 16.

How the wing re-directs air down: Propellers (or jets) push the plane forward and thus push the wings through static air. The wings convert this horizontal relative airflow into vertical lift – by pushing the air down.

(1) The underside of the wing faces the direction of flight. It pushes the lower air mass down; producing high air pressure under the wing as it compresses the air.

(2) The topside of the wing faces away from the direction of flight, it re-directs the upper air mass downwards, and producing low air pressure on top of the wing; as this air is expanded (Figure 17).

Wings tend to have low angles of attack, of just a few degrees. Therefore, the evidence is that the wing is re-directing (displacing) air down, rather than directly pushing it down. If the action to push air down stops, then the buoyancy is lost and the plane sinks downwards.

Inverted flight: In inverted flight a positive angle of attack (AOA) is maintained; and airflows are essentially similar to normal flight. The main difference between inverted and normal flight is that the plane has a much less aerodynamic orientation to the direction of flight, so is less efficient at generating lift (Figure 18).

The Physics of Flight at the Molecular Level

In aerodynamics, air behaves as a fluid, not as molecules. But air consists of molecules and this analysis provides insight by demonstrating how lift can be explained by the interaction between the air molecules and the wing. Note that this analysis focuses on how a wing affects the air. This analysis ignores the impact of the propeller; which pushes the air horizontally backwards (Figure 19). In flight, the underside of the wing is angled towards the direction of flight; i.e. the wing maintains a positive angle of attack (AOA). So, the underside of the wing hits more air molecules, and hits each molecule with greater force; compared to the topside of the wing (and compared to when the plane is at rest). This produces high air pressure under the wing and generates lift (Figure 20).

The topside of the wing is angled away from the direction of flight. So, it hits less air molecules, and hits each molecule with less force, compared to the underside of the wing (and compared to when the plane is at rest). Hence the low air pressure on top of the wing. This allows the plane to rise upwards or to put it another way, the plane is coming into more direct and violent contact with a greater mass of air molecules underneath it, than above it. This supports the plane's mass in the air. (This also explains why air pressure is higher under the plane than above it). Air density is a critical factor that affects lift. The denser the air then the better the lift is. i.e. Wings push a greater mass of air down with each cubic meter of air displaced. Also, planes are limited to how high they can fly, because they generate less lift in thinner air. The less dense the air, the less air mass the wings can displace each meter flown. i.e. The wings effectively have a less hard substance to push against.

Evidence of Dynamic Buoyancy - Backwash

Evidence of dynamic buoyancy can be seen in the air or water displaced down by birds, helicopters, speed boats, and planes to maintain buoyancy (Figure 21).

Explanation of Why: Mass of Plane = Mass of Air Displaced

First note the standard explanation, according to Newton's laws of motion [1].

The plane exerts a force on the air, pushing the air downwards



Figure 9: Speed boat gaining lift.



Figure 10: Hydrofoils.



Figure 11: Seaplane.

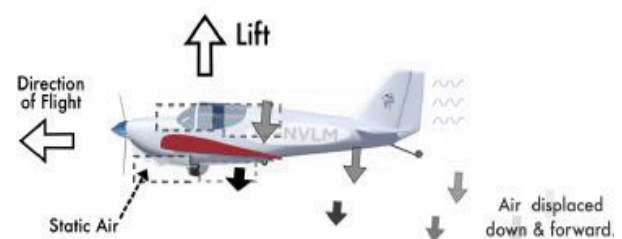


Figure 12: Dynamic buoyancy airflows.

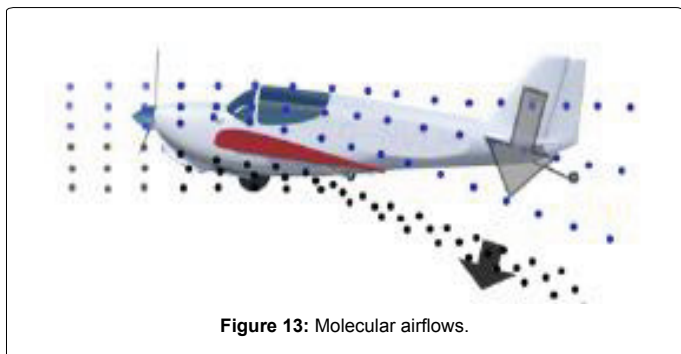


Figure 13: Molecular airflows.

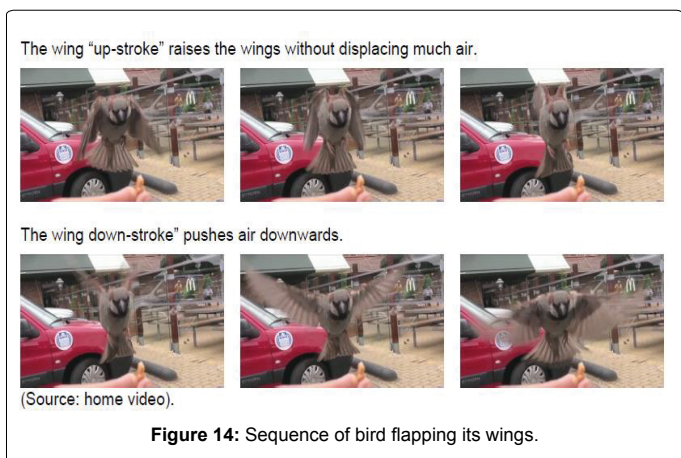


Figure 14: Sequence of bird flapping its wings.

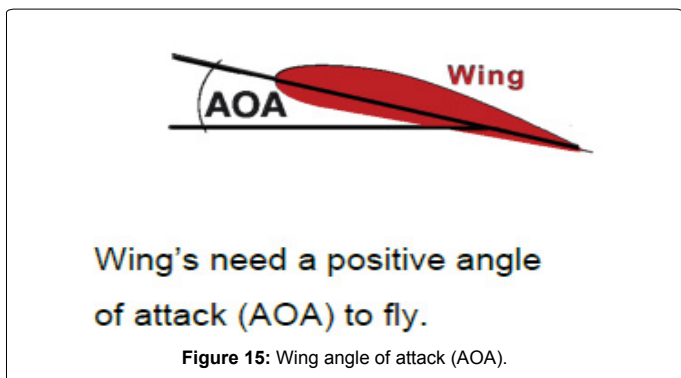


Figure 15: Wing angle of attack (AOA).

(ACTION). If there is sufficient resistance from the air, this results in an equal and opposite reaction (REACTION), a force pushing the plane up and generating lift. In summary, the air is being pushed down and the plane is pushed up (Figures 22 and 23).

Additional notes: Dynamic buoyancy is no more a “Newtonian Theory of lift” than walking or swimming are “Newtonian Theories of walking or swimming.”

Dynamic buoyancy and Newton

Dynamic buoyancy emphasizes that lift is created by pushing the air downwards. So the plane is supported by the air immediately under the wing, as well as all the air recently displaced by the wing (in the previous one second), as shown in Image 19 above.

According to Newton s Third Law of Motion [6], every force must have an “equal & opposite” force. So, what exactly is this force

(ACTION) pushing down against? If you push down on a wing, it will fall downwards unless there is something to resist and push back (i.e. upwards). That resistance can only be the high air pressure under the wing in the form of buoyancy.

So, for an upward force (REACTION) to exist; The ACTION force must be opposed by something that provides resistance. Otherwise

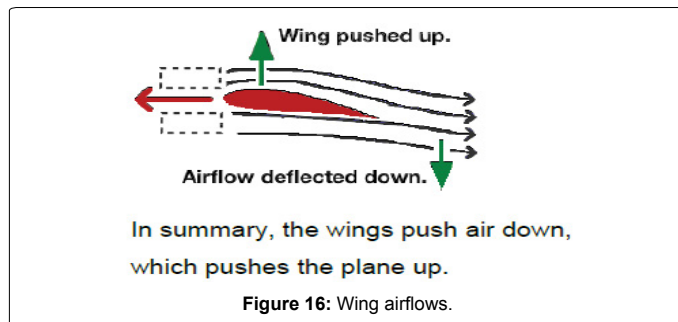


Figure 16: Wing airflows.

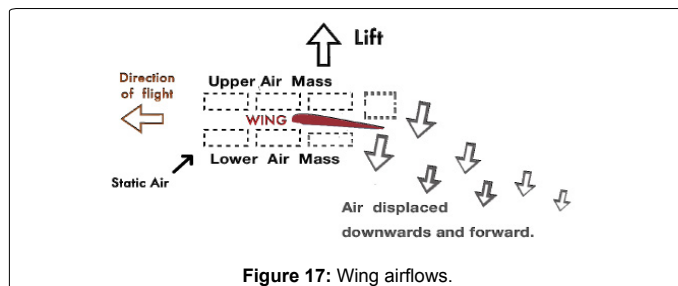


Figure 17: Wing airflows.

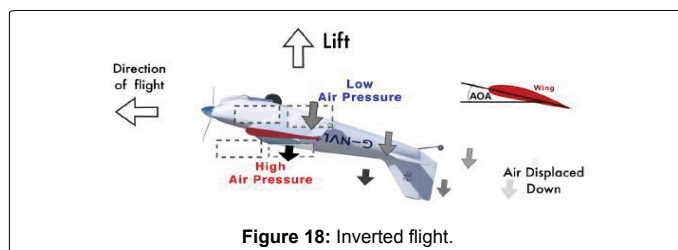


Figure 18: Inverted flight.

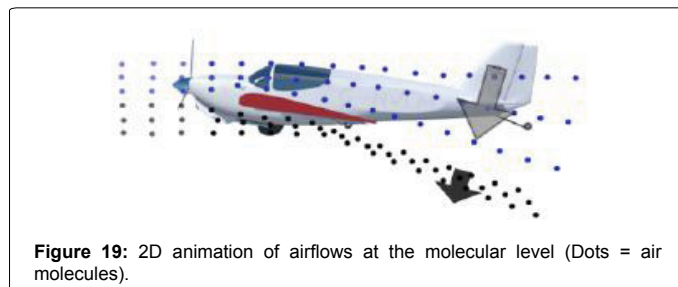


Figure 19: 2D animation of airflows at the molecular level (Dots = air molecules).

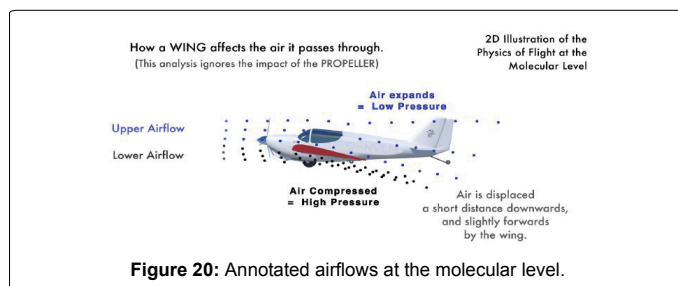


Figure 20: Annotated airflows at the molecular level.

the ACTION will simply push the plane down; without creating a REACTION force. The dynamic buoyancy theory states that, for a plane in flight, this resistance is provided by buoyancy (relatively high air pressure) under the wing. Therefore, the mass of the plane must equal the mass of the air displaced (each second); similar as a boat floating in water. Here dynamic buoyancy means relatively high air pressure under the wing. This includes the effect of both: (i) the high air pressure under the wing, due to the wing pushing the lower air mass down; and (ii) the low air pressure on the top of the wing; due to the wing pulling the upper air mass down. See the explanation on how the wing re-directs air down to generate lift, in Section 4 above. For example, birds push against the air to fly, fish push against water to swim, people push against the ground to walk or jump. You cannot walk on water or air as there is no "equal & opposite" force possible, as there is not enough resistance from the water to your feet. In turn this is due to a lack of substance to push against (and thus insufficient pressure under your feet). People can float when actually in the water, as they have sufficient buoyancy when immersed in water. Therefore, the physical force required to generate lift, needs to be a sufficient force:

- (i) Counter-act gravity and the mass of the plane;
- (ii) Displace enough air mass (i.e. dynamic buoyancy)

(i) Counter-act gravity and the mass of the plane

Using Newton's second law of motion [6];

$$\text{Force (kg m/s}^2\text{)} = \text{Mass (kg)} \times \text{Acceleration (Gravity) (m/s}^2\text{)}$$

(ii) Displace enough air mass (i.e. dynamic buoyancy)

Dynamic buoyancy claims that lift is due to the pressure on the

bottom of the wing exceeding the pressure on the top of the wing. The high net air pressure under the wing (dynamic buoyancy) is calculated in a similar way as buoyancy for a boat:

The standard formula for static fluid pressure [8]:

$$\text{Pressure} = (\text{density} \times \text{volume} \times \text{acceleration})/\text{area.}$$

This can be adjusted to a total upward buoyancy force as follows [8]:

$$\text{(Buoyancy Force) Net Wing Air Pressure} = \text{Density of Air} \times \text{Volume of Air Displaced} \times \text{Gravity}$$

As Mass = Density \times Volume;

The equation can be re-written as:

$$\text{Net Wing Air Pressure (kg m/s}^2\text{)} = \text{Mass of Air Displaced (kg)} \times \text{Gravity (m/s}^2\text{)}$$

Dynamic buoyancy is due to the pressure differential on the wing over a given time period (of one second).

The time frame in which an object must displace its own mass is open to debate. The one second time frame given above is unproven and speculation. The actual time frame may be different; either shorter or longer. Experimentation needs to be done to verify this.

Analysis - Summary

In stable flight these two forces above (i) and (ii) above will be equal. i.e. In stable flight, the force generating lift, as calculated with Newton laws of motion, will equal the buoyancy pressure under the wing over a given time period (of one second). The plane is being supported by a cushion of air immediately under the wing, as well as all the air recently displaced behind the plane.

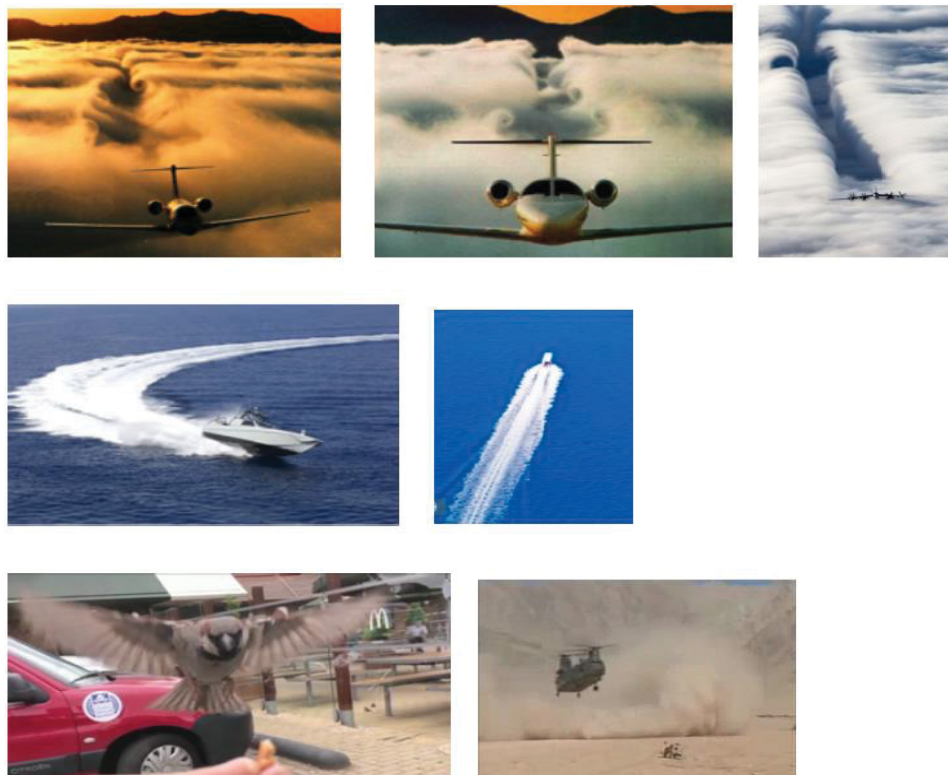
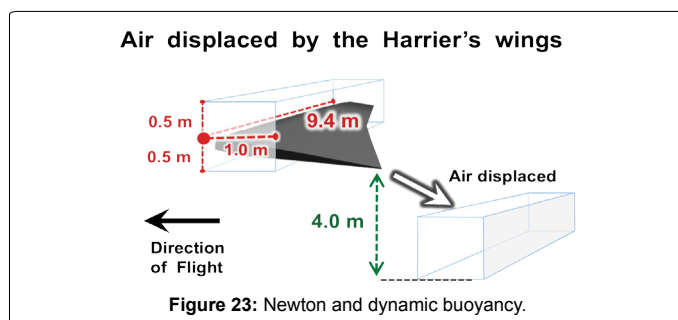
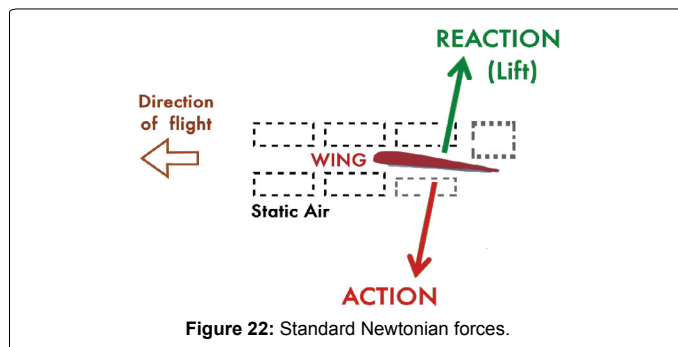


Figure 21: Evidence of backwash (air being pushed down).



Force Up = Force Down.

REACTION (LIFT) = ACTION.

Lift = Net Wing Air Pressure (Newton) (Dynamic Buoyancy).

Mass of Plane \times Gravity = Mass of Air Displaced \times Gravity.

Therefore, removing gravity from both sides of the equation gives:

Mass of Plane = Mass of Air Displaced (each second).

The total air mass displaced includes the air DIRECTLY displaced by the wings and the air INDIRECTLY displaced (due to the airflows created by the wings).

Results

For the plane to fly, and for the forces to be equal and opposite, the mass of the plane must equal the mass of air displaced (each second). i.e. dynamic buoyancy must be sufficient to support the plane's mass.

To put it another way: If there was no resistance from the air under the wings; then there wouldn't be anything for the downward force to push against; in this situation, an "equal and opposite" force could not be generated, and the wings couldn't generate any lift. So, the downward force would simply push the plane itself downwards.

A Key Reference – Understanding Flight

Extracts taken from the well-known book: "Understanding Flight" (2nd edition), by the authors David F. Anderson and Scott Eberhardt [10]

The extracts below from this book, are directly compatible with the physics of the dynamic buoyancy explanation of how planes fly. The critical difference is that the book does not use the terminology "buoyancy" and focus analysis on the velocity of air displaced by the wing, rather than the mass of air displaced. The book wrongly attributes lift to low air pressure on the top of the wing, that results from air being displaced downwards (Figure 24).

Extracts from, Understanding Flight [10]; Chapter 1, Principles of flight

Downwash: "In the simplest form, lift is generated by the wing diverting air down, creating the downwash."

"From Newton's second law, one can state the relationship between the lift on a wing and its downwash: The lift of a wing is proportional to the amount of air diverted per time times the vertical velocity of that air."

"The vertical velocity of the air is proportional to both the speed and the angle of attack of the wing."

The Adjustment of lift: "We have said that the lift of a wing is proportional to the amount of air diverted (down-downwash) per time times the vertical velocity of that air. This is essentially a description of buoyancy".

"And we also have stated that in a rest frame where the air is initially at rest and the wing is moving, the air is moving almost straight down after the wing passes".

Wrapping it up: "The key thing to remember about lift is that it is a reaction force caused by the diversion of air down. But then the book (wrongly) adds: The physics of diverting the air down are expressed by the lowering of the pressure on the top of the wing producing the lifting force. The lift of a wing is proportional to the amount of air diverted times the vertical velocity of that air".

Estimate of Buoyancy

The authors of the book do a back-of-the-envelope calculation to estimate that: "Thus a Cessna 172 at cruise is diverting about five times its own weight in air per second to produce lift."

In detail: "Take, for example, a Cessna 172 that weighs about 2300 lb. (1045 kg). Traveling at a speed of 140 mi/h (220 km/h) and assuming an effective angle of attack of 5 degrees, we get a vertical velocity for the air of about 11.5 mi/h (18 km/h) right at the wing. If we assume that the average vertical velocity of the air diverted is half this value, we calculate from Newton's second law that the amount of air diverted is on the order of 5 (English) tons per second. Thus a Cessna 172 at cruise is diverting about five times its own weight in air per second to produce lift (Figure 25)".

Wing virtual scoop

The book uses the visualization tool of "virtual scoop." This is where the wings diverting the upper airflow downwards. "The concept of the virtual scoop is loosely based on the theoretical aerodynamics law of Biot and Savart. This law gives the change in velocity around a wing by summing (or integrating) the influence of the various parts of the wing's surface. The influence of the wing on the air decreases with distance above the wing."

Mathematical Proof of Concept

Proof of concept - Harrier example

An example calculation to demonstrate that it's theoretically feasible for a plane's wings to displace enough air each second to keep the plane airborne, per dynamic buoyancy (Figures 26 and 27).

This provides the mathematical proof that it is feasible that a Harrier (AV-8) could displace a mass of air equal to its own mass, every second.

Example: To stay airborne, a 10,000 kg Harrier [11] flying at 800 km/hr (222 m/s); needs to displace 45 kg (or 37.5 m³) of air down every meter flown (each second).

$$10,000 \text{ kg}/222 \text{ m/s} = 45 \text{ kg}/(\text{m/s})$$

Mass Speed Mass of air displaced of Harrier of Harrier every meter, each second.

Using standard air density [8], (of 1.2 kg/m³), to convert the mass of air into a volume of air:

$$45 \text{ kg} = 1.2 \text{ kg/m}^3 \times 37.5 \text{ m}^3$$

Thus the Harrier's wings need to displace 37.5 m³ of air, each meter flown, each second.

The feasibility of this can be described in two ways:

1) The Harrier [11] has a 22.6 m² wing area with a 9.4 m leading edge (facing the direction of flight). It is feasible to displace 37.5 m³ of air; If the wings displace 1.0 m³ of air each meter flown, along each meter of its 9.4 m leading edge; down at least 4.0 m.

$$(9.4 \text{ m} \times 1.0 \text{ m}^3) \times 4.0 \text{ m} = 37.5 \text{ m}^3$$

So, each meter of the leading edge of the wing, is displacing 1 m³ of air, down 4 m; each meter flown, as shown by figure 28. This means that each meter that the Harrier flies; It only needs to displace all the air 0.5 m above and below the wing, down 4 m (Figure 28).

2) The Harrier's wings can displace 37.5 m³ of air, each meter flown, each second; If the 22.6 m² wings (with an effective wing area 9.4 m²) has a 1.0 m wing reach, and displaces this air down 4.0 m.

$$(9.4 \text{ m}^2 \times 1.0 \text{ m}) \times 4.0 \text{ m} = 37.5 \text{ m}^3$$

Effective Wing Distance air Volume of air displaced.

Results

These calculations demonstrate that it's feasible for the Harrier's wings to displace enough air to keep the plane airborne. Note that the Harrier [11] does not have to displace the air down very far to allow it to achieve dynamic buoyancy, just a few meters.

Evidence that a Harrier can displace significant amounts of air downwards, is provided from videos of a low-flying Harrier [11-25] (Figures 29 and 30).

A key issue is the distance away from the wing that the wing affects the air. The wings affect the air unequally across the wingspan and the air closest to the wings are affected the most. See the comments on wing reach in Section 6 ("Aircraft lift and dynamic buoyancy").

These images confirm the feasibility of the previous calculations; which demonstrate that it's feasible for the Harrier's wings to displace enough air to keep the plane airborne.

Comment on Air Viscosity and Compressibility

This section is only an additional comment and not a critical part of the dynamic buoyancy theory.

As planes fly faster, the interaction with the air around it changes and the physics of flight alters. It becomes increasingly easier for a plane to generate lift and stay airborne; due to air viscosity and compressibility.

Air viscosity ("stickiness") and compressibility ("springiness"): At higher speeds of interaction with their environment, fluids adopt

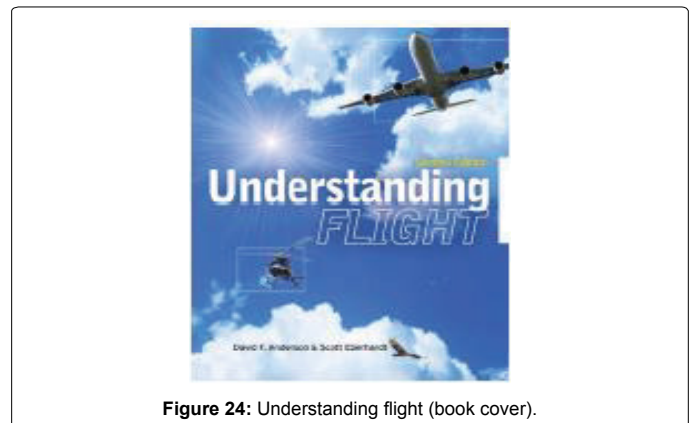


Figure 24: Understanding flight (book cover).

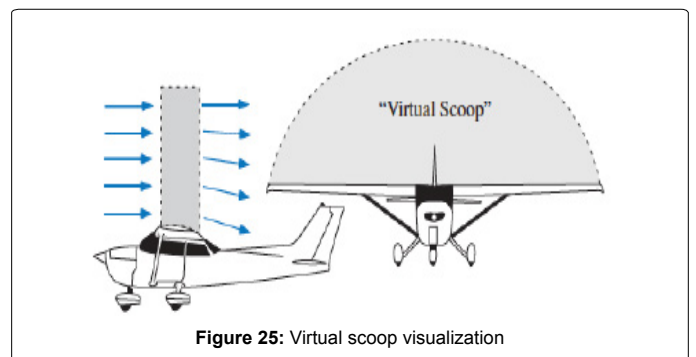


Figure 25: Virtual scoop visualization

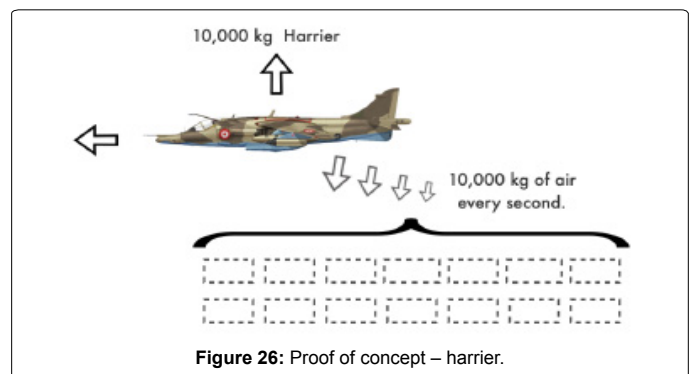


Figure 26: Proof of concept – harrier.

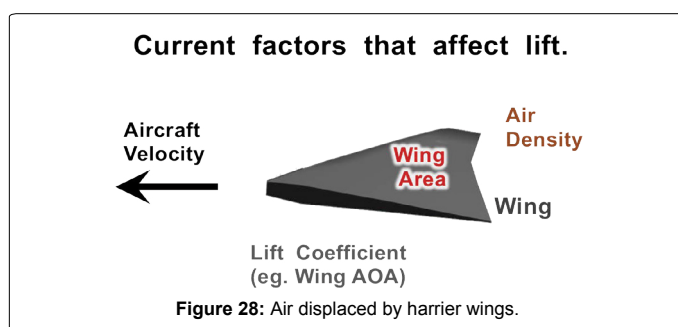
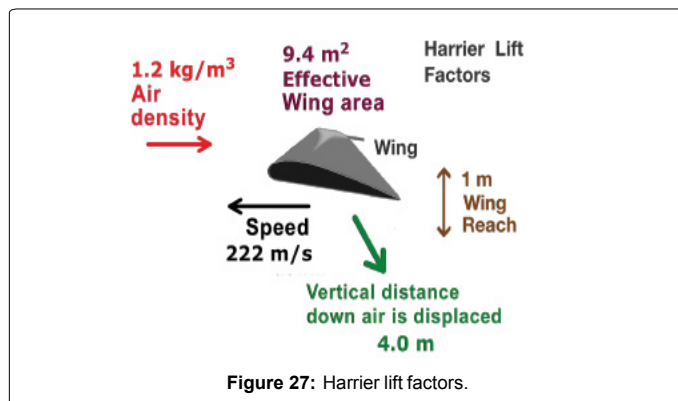
characteristics that are more similar to a more solid material. So, air becomes more like water, and water becomes more like a solid. The fluid is effectively being compressed at high speed. Wings effectively have a harder substance to push against, which provides a disproportionate amount of extra lift than at low speeds.

At the molecular level, this means that there are more air molecules per m³ for the wing to get lift from. The denser air means better lift - due to more air mass (kg) being displaced per m³ of air pushed down by the plane.

Here aerodynamic engineers start talking about the Reynolds number and the Mach number. But this is beyond the scope of this document.

Three New Concepts for Lift

Current aviation textbooks and the accepted aerodynamic equation for lift claim that aircraft lift depends primarily on:



1. Air density (kg/m^3) and altitude.
2. Aircraft velocity (m/s).
3. Wing area (m^2).
4. Lift co-efficient, which includes: The wing shape and the angle of attack (AOA).

All these factors also affect the mass of air (m^3) displaced. So current explanations of lift are consistent with dynamic buoyancy (Figure 31). Note that these text books make no reference at all to any theory of flight nor any mathematical equation (eg. Navier Stokes) other than the accepted equation for lift [8]:

$$\text{Lift} = 0.5 (\text{Velocity}^2 \times \text{Air Density} \times \text{Wing Area} \times \text{Lift Coefficient}).$$

Analysis of these Factors Affecting Lift

Air density (kg/m^3) and altitude

As the plane's altitude increases; the air density declines. The plane needs to displace a greater volume of air to maintain lift, to fly at a higher altitude due to the lower air density. (eg. By increased air speed, greater wing angle of attack).

$$\text{Mass} = \text{Density} \times \text{Volume}$$

So, the mass of air displaced is constant compared to the lower altitude, each meter flown. i.e. A constant force alone is not sufficient to keep the plane flying at a higher altitude. There must also be dynamic buoyancy.

Aircraft velocity (m/s)

The greater the aircraft speed, the greater the air mass that the wings come into contact (displaces), and the greater the lift.

Wing area (m^2)

The greater the aircraft's wing area, the greater the air mass that the

wings come into contact (displaces), and the greater the lift [22]. The shape of the wing has a significant impact on how efficient the wings are at displacing air each meter flown.

Angle of attack (AOA) of the wing has a significant impact on how much air the wings come into contact with each meter flown. The greater the AOA, the greater the air displaced and the greater the lift. This is most evident when a plane is climbing (Figure 32).

Note: This analysis ignores any additional air pushed over the wings by the propeller or jet.

All these Factors above that Determine Lift can be Broadly Split into two areas:

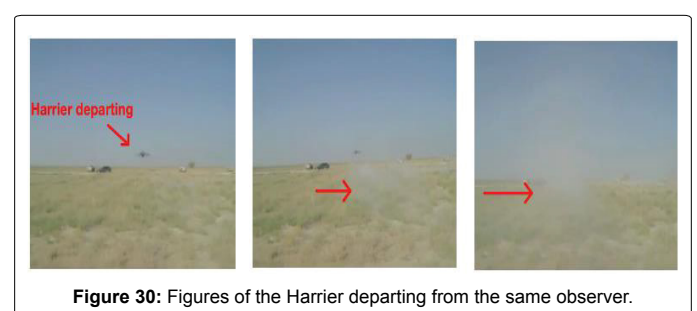
1. Air that the wing travels through.
2. The ability of the wing to push this air downwards.

The Dynamic Buoyancy Theory Introduces three new concepts

- (i) "Wing reach" (m): To replace the lift coefficient (wing shape and angle of attack).
- (ii) Effective wing area (m^2): To replace the actual wing area.
- (iii) Distance down (m) that air is displaced: This is a totally new concept.

(i) Wing reach

"Wing Reach" is the vertical distance away from the wing that the wing influences the air. It is the volume of air (m^3) displaced by each 1 m^2 of effective wing area. Wing reach depends on the wing's angle of attack and the wing shape (i.e. lift coefficient). The greater the wing reaches the greater the volume of air displaced by the wings (Figure 33). So a "wing reach" of 1 m means that: 1 m^2 of wing area can displace at least 1 m^3 of air (at least 1m downwards). A 1.0 m wing reach is calculated as 0.5 m both above & below the wings. (Note: 0.5 m is about knee height of an adult) (Figure 34). For example: If this wing has a 1 m wing reach, and an effective wing area of 5 m^2 , then it can displace 5 m^3 of air each meter flown, down at least 1 m. ($1 \text{ m} \times 5 \text{ m}^2 = 5 \text{ m}^3$)



A key issue is the distance away from the wing that the wing affects the air. The wings affect the air unequally across the wingspan and the air closest to the wings are affected the most.

(ii) Effective wing area (wing shape)

The wing is only exposed to air in the direction of flight along the leading edge of the wing. So, each meter flown, only the wing area that is 1 m distance from the leading edge of the wing will be effective at displacing additional air. Each additional 1 m that the wing flies, the effective wing area is limited by the amount of additional air that the wings “catch” (come into contact with); which is 1m horizontally away from the leading edge of the wing (Figure 35).

For example, the wing in the figure 35 above (for a propeller plane) has a 5.6 m leading edge and is 2.0 m deep. Hence it has an effective wing area of 5.6 m²; (i.e. 1 m × 5.6 m = 5.6 m²). This is half the size of the total wing area of 11.2 m². This wing design of a relatively modest leading edge will catch a reasonable amount of air; but the deep wings will push the air a relatively far distance down. (Figures 36 and 37)

In contrast to this propeller plane wing; gliders have no propeller but wide, thin, and light wings. This wide wing design has the maximum effective wing area to the direction of flight, so will “catch” a significant amount of air each meter flown. But the wings are less able to displace air down very far as they are thin.

Conclusion: This difference in wing shape and effective wing area between gliders and propeller plane examples above is consistent with the logic of dynamic buoyancy whereas, the current theories of lift provide no explanation for these differences in wing design.

(iii) Distance down that air is displaced from the wing

The total mass of air displaced by the wing also depends on how far

down that the wing displaces air hitting the wing. The further each 1 m³ air is displaced down, then the more air mass in total that is displaced by the wing, and the greater the lift due to dynamic buoyancy. Also, the greater the energy transferred from the wings to the air, so the greater the lift.

The distance (m) that each 1 m³ of air is displaced down by the wing depends primarily on:

The angle of attack (AOA), the shape of the wing, wing vortices and the mass of the aircraft.

The wings displace air down unequally across the wingspan. Air closest to the fuselage will be pushed down the most, as this is where the wings are deepest (from front to back).

The presence of descending wing vortices (spiralling air), will also impact the amount of air displaced and how it is displaced.

The greater a plane's mass and velocity, the greater its momentum. Thus the greater its capacity to displace air further down.

Lift Equations

Current equation for lift

Current equation for lift [8,9] is - Equation (1) :

$$LIFT = 0.5 (Velocity^2 \times Air Density \times Wing Area \times Lift Coefficient)$$

Note that:

1. Lift coefficient depends on things like the wing's angle of attack and the wing shape.
2. Velocity is the speed of the aircraft relative to the air.

This equation is known not to be accurate and not a precise estimate for lift. It is just the best formula available.

Note that all these factors listed above also affect the volume of air (m³) displaced by the wing; and thus the mass of air displaced (as Mass = Density × Volume). So, dynamic buoyancy is consistent with the current aerodynamic equation for lift (Figure 38).

Dynamic buoyancy theory implies that the current aerodynamic equation for lift is incomplete as it excludes an accurate estimate of the amount of air displaced by the wings.

The current equation for lift implicitly includes and a partial estimate for the volume of air displaced by the wing, but excludes how far down this air is displaced by the wing.

Adjustments and a new equation for lift

Standard (accepted) Lift Equation (1):

$$LIFT = 0.5 (Velocity^2 \times Air Density \times Wing Area \times Lift Coefficient).$$

Three adjustments are made to the current equation (1) for lift; to obtain a more accurate estimate for lift and of the air mass displaced by the wings (Figure 39).

(i) **Wing reach:** Replace the lift coefficient (wing shape and angle of attack) with the “Wing Reach”; these are related and similar concepts. The benefit of this is that wing reach is clearer and more precise.

Equation (2a): Lift = 0.5 (Velocity² × Air Density × Wing Area × Wing Reach

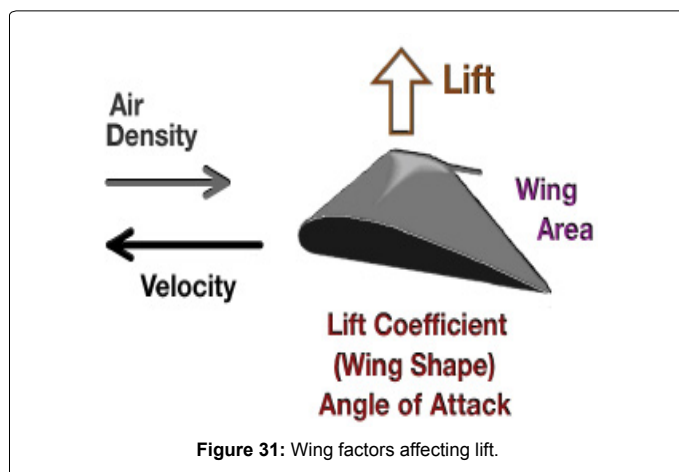


Figure 31: Wing factors affecting lift.

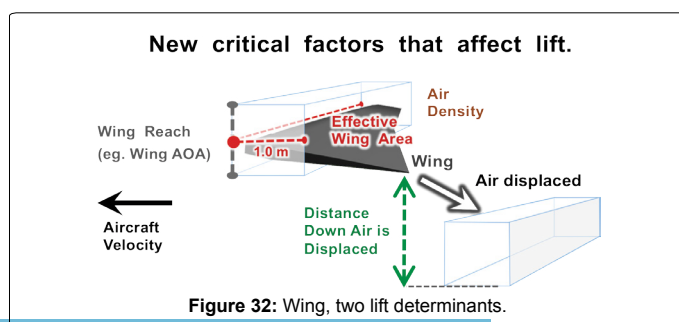
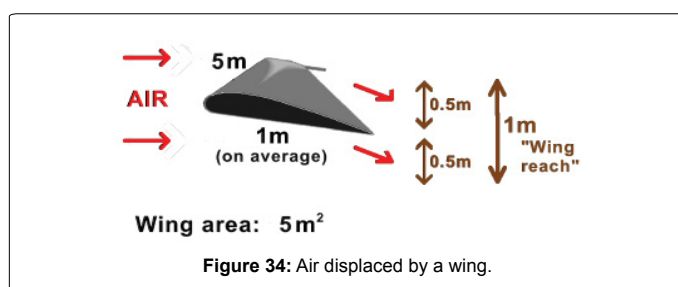
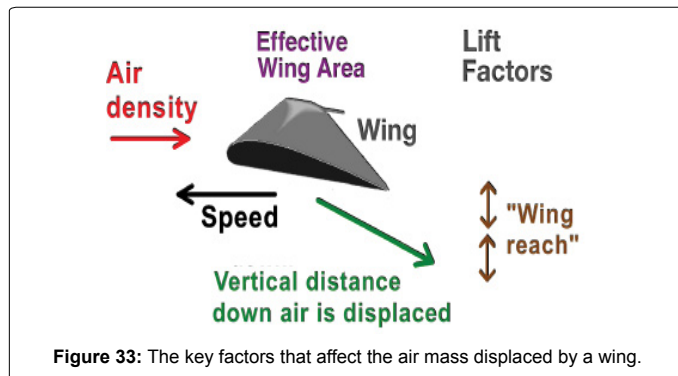


Figure 32: Wing, two lift determinants.



(ii) **Effective wing area:** As only parts of the wing are effective at “catching” air, which is restricted to the area along the leading edge of the wing. Then Insert the “effective wing area” (m^2); instead of the actual wing area. Note that the “0.5” factor is also removed from the equation; as this is part of the calculation of the effective wing area. The explanation of this is complex and beyond the scope of this paper.

But in short; $0.5 \times \text{Wing Area} = \text{Effective Wing Area}$ (approximately).

Equation (2b): $\text{Lift} = (\text{Velocity}^2 \times \text{Air Density} \times \text{Effective Wing Area} \times \text{Wing Reach})$

(iii) **Distance down:** To obtain a more accurate estimate of the mass of air displaced by the wing, insert into the formula: “Distance down that air is displaced” to the equation.

Equation (2c): $\text{LIFT} = (\text{Velocity}^2 \times \text{Air Density} \times \text{Effective Wing Area} \times \text{Wing Reach} \times \text{Distance Down that Air is Displaced each second})$

This Equation (2c) is the new equation for lift, after the three adjustments above have been included.

For example, Equation (2c) indicates that the lift generated is increased if:

1. The aircraft velocity is increased; so more air is displaced.
2. Air density increases; so a greater mass of air is displaced each meter flown.
3. The effective wing area is increased.
4. The “wing reach” is increased. This means that the wing impacts the air a greater vertical distance away from the wing. For example by increasing the wing angle of attack; or changing the wing shape.
5. The wings displace the air a greater distance down; this will increase the total amount of air displaced.

Note: This is only a theoretical new equation for lift; Experimentation needs to be done to confirm that it is accurate.

The New Equation (2c) for Lift can be Re-stated to Show that it Represents the Mass of Air Displaced by the Wing; and that it is Consistent with Newton’s Second Law of Motion

First, note that the formula for the volume of air displaced by the wing:

Volume of Air Displaced each second (m^3/s) = Aircraft Velocity (m/s) \times Effective Wing Area (m^2) \times Wing Reach (m) \times Distance Down that Air is Displaced (m)

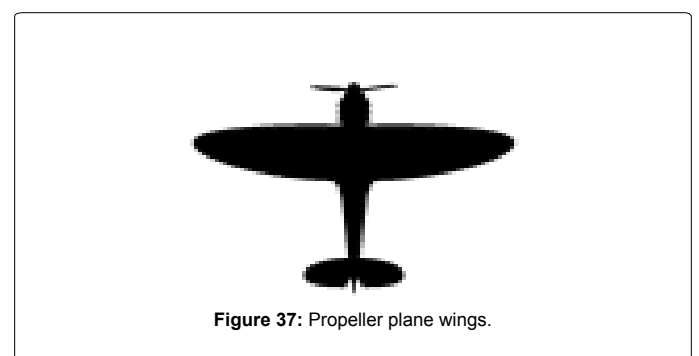
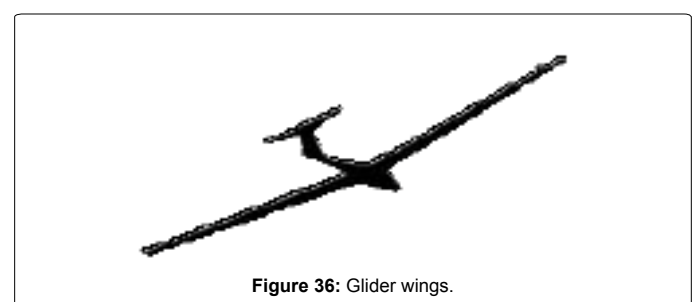
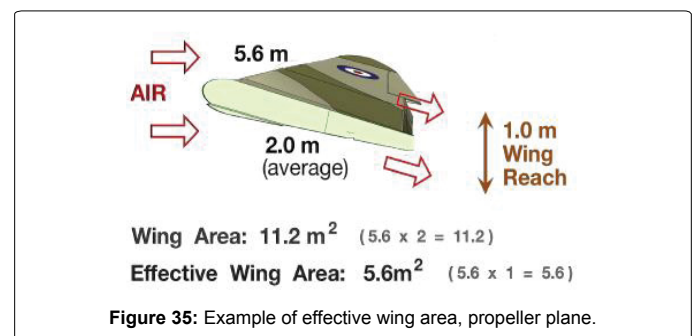
Or:

Volume (m^3/s) = Velocity (m/s) \times Effective Wing Area (m^2) \times Wing Reach (m) \times Distance Down (m)

Example

For example; a plane under the conditions of:

- Aircraft velocity of 100 m/s
- Effective wing Area of $9 m^2$; (and a total wing area of $26 m^2$)
- Wing reach of 1 m ; which is 0.5 m both above and below the wing.
- Air that is displaced 3 m down, below the wing.



Under these conditions, the volume of air displaced by the plane's wings will be:

$$\text{Volume} = 100 \text{ m/s} \times 9 \text{ m}^2 \times 1 \text{ m} \times 3 \text{ m} = 2,700 \text{ m}^3 / \text{s}$$

i.e. 2,700 m³ each second.

Or 27 m³ each meter flown (27 = 2,700 m³ /s / 100 m/s)

See also the Harrier example above in Section 5; "Mathematical proof of concept for dynamic buoyancy".

Equation (2c) the new equation for lift:

Lift = (Velocity² × Air Density × Effective Wing Area × Wing Reach × Distance Down that Air is Displaced each second)

Then Equation (2c) can be adjusted by inserting the formula from Equation (3) for the volume of air displaced:

Equation (4):

$$\text{Lift} = \text{Velocity} \times \text{Air Density} \times \text{Volume of Air Displaced each second}$$

Given that mass, air density and volume have a known relationship:

Equation (5):

$$\text{Mass of Air} = \text{Air Density} \times \text{Volume of Air}$$

Then Equation (4) for LIFT reduces to a new equation:

Equation (6):

$$\text{Lift} = \text{Velocity} \times \text{Air Mass Displaced each second}$$

This Equation (6) is essentially the same formula as:

$$\text{Force (Lift)} = \text{Mass} \times \text{Velocity} \text{ (or } F = mv)$$

Which is Newton's second law of motion.

Since acceleration is the change in velocity divided by time, the equation can be adjusted:

$$\text{Force} = \text{Mass} \times (\text{Velocity} / \text{time})$$

$$\text{Force} = \text{Mass} \times \text{Acceleration (gravity)} \text{ (or } F = ma)$$

This demonstrates that the proposed new Equation (2c) for lift is consistent with current physics (newton's second law of motion).

Conclusion on the Equations for Lift

The current Lift Equation (1):

$$\text{Lift} = 0.5 (\text{Velocity}^2 \times \text{Air Density} \times \text{Wing Area} \times \text{Lift Coefficient}).$$

Should be adjusted to provide a better estimate of lift, by including:

(i) Wing Reach

(ii) Effective Wing Area

(iii) Distance down that air is displaced

To produce Equation (2c) the new equation for lift:

$$\text{LIFT} = \text{Lift} = \text{Velocity}^2 \times \text{Air Density} \times \text{Effective Wing Area} \times \text{Wing Reach} \times \text{Distance Down that Air is Displaced each second}.$$

which can be re-stated to Equation (4):

$$\text{Lift} = \text{Velocity} \times \text{Air Density} \times \text{Volume of Air Displaced}$$

Which can be re-stated to Equation (6)?

$$\text{Lift} = \text{Velocity} \times \text{Air Mass Displaced each second}$$

$$\text{Or } F = mv$$

For this new equation to fit with established physics, then "velocity" must be the velocity of the air displaced; not aircraft velocity; as this equation relates to the energy transferred from the wing to the air.

As lift can be shown to be based on the air mass displaced by the wing, this supports the theoretical argument that buoyancy explains flight.

Wing Vortices and Winglets

Wing vortices

Wing vortices are powerful airflows that spiral downwards behind the wings, typically from the wingtips. Vortices displace significant amounts of air downwards (Figures 40 and 41).

The dynamic buoyancy theory views wing vortices as a source of lift; by pushing extra air mass downwards. The further that air is pushed down by vortices; the greater the air mass displaced; and the stronger the lift that is generated. Detailed discussion on vortices is beyond the scope of this paper [21,23].

Vortices from large commercial aircraft can descend up to 900 ft.; helping them to fly with relatively small wings. The current theories of flight tend to see wing vortices only as a form of drag & turbulence or a consequence of lift. The sequence of images below shows wing vortices as 3D airflows from the wings; in a real plane in a realistic environment (Figure 42).

Winglets and wing vortices

As an additional comment, winglets are known to alter wing tip vortices; to reduce drag. But there is no evidence that winglets reduce backwash. Detailed discussion on winglets is beyond the scope of this paper (Figure 43).

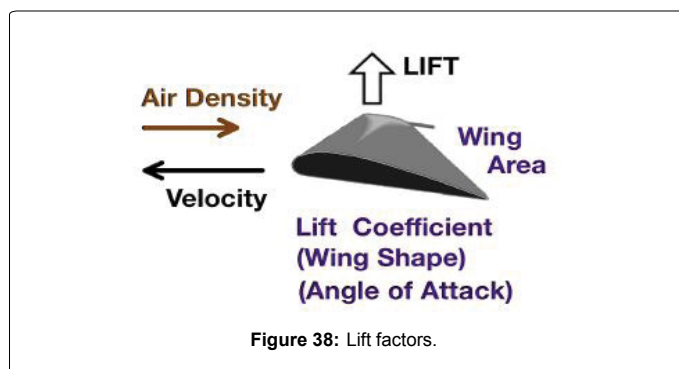


Figure 38: Lift factors.

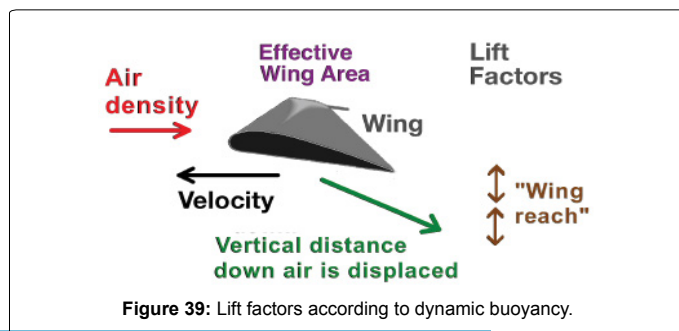


Figure 39: Lift factors according to dynamic buoyancy.

For example, the images above clearly shows strong backwash with vortices - from planes with winglets. This is consistent with dynamic buoyancy theory of flight (Figure 44).

Practical Tests - Flight Manoeuvres

Practical tests were conducted to see whether the theories of flight can explain the dynamics of standard flight manoeuvres listed below; such as: take-off, climb, banking, descent, inverted flight. This tested if the logic of the theory was consistent with what is observed in reality when flying a plane. A problem is that most current theories of flight only describe planes in stable cruise flight or stalls; and ignore flight manoeuvres.



Figure 40: Wing vortices.



Figure 41: Wing vortices from a jet.

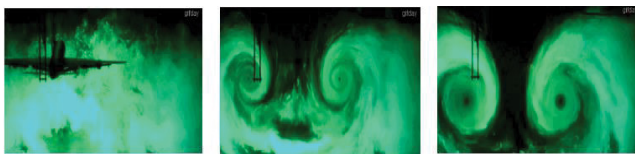


Figure 42: 3D airflows and vortices in green smoke experiment.

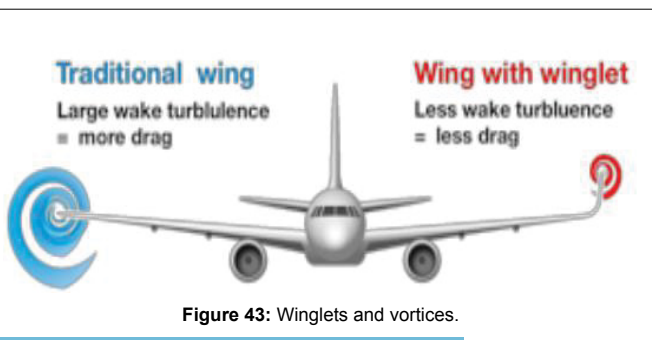


Figure 43: Winglets and vortices.



Figure 44: Figures of vortices from winglets.

Results of practical tests & flight manoeuvres

	Current Theories	Dynamic Buoyancy
Stable Flight	✓	✓
Climb	✗	✓
Stall	✗	✓
Descent	✗	✓
Vertical Descent	✗	✓
Banking	✓	✓
Banking (Ailerons)	✗	✓
Flaps	✗	✓
Wind & Up-Currents	✗	✓
Ground Effect	✗	✓
Inverted Flight	✗	✓

Figure 45: Results of practical tests and flight manoeuvres.

Flight manoeuvres: Stable Flight; “Nose-up” Climb; Stall; Descent; Vertical Descent; Banking (Ailerons) ; Flaps; Wind and Up-Currents; Ground Effect; and Inverted Flight.

This analysis is beyond the scope of this paper. This is just a summary of the tests & results. The details are available at the end of a video on Vimeo; “Dynamic Buoyancy Explains Flight Full” <https://vimeo.com/172578440>.

Result

Dynamic buoyancy was able to explain the dynamics of all these flight manoeuvres whereas the other current theories of flight failed to do so (Figure 45).

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