Lift explained by Newtonian physics (Force = ma).

Active lift generation using absolute airflow analysis.

Mr. Nicholas Landell-Mills

16 May 2022
Pre-Print DOI: 10.13140/RG.2.2.36518.86081;

Keywords: Aerodynamics; airplane; flight; lift; Newton; physics.

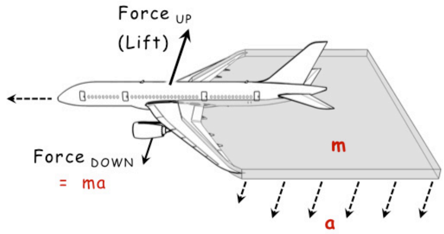

Fig. 1a Newtonian forces acting on an airplane.

Abstract

A re-evaluation of evidence and logic provides novel explanation of how lift is generated by a wing. Newtonian mechanics (Force = ma) is shown to provide a more simple, straightforward and accurate explanation of lift and than currently available. This approach is different to the old Newtonian explanations of lift based on a change in momentum of the relative airflow, or airflow turning created by wings.

According to Newtonian mechanics, wings with a positive AOA flying through a mass of air (m), that they accelerate (a) downwards, to create a downward force (Force $_{DOWN}$). The equal and opposite upward force generated provides lift. See Fig. 1a. This process can be summarized by the equations: Force $_{DOWN}$ = ma = Force $_{UP}$ (Lift). Taken a step further, Newtonian mechanics based on the mass flow rate can better explain active lift generation using absolute airflow analysis.

I. Introduction

A. Insights.

The theory of lift and the physics for how airplanes stay airborne remains unresolved and is still debated (see Appendix I). Newtonian mechanics (Force = ma) challenges the prevailing explanations of lift generation based on fluid mechanics (Navier-Stokes equations), to finally resolve the 100-year-old debate of how wings generate lift.

Newtonian mechanics provides a better explanations of how lift is observed to be generated in practice, including:
- Flight manoeuvers (e.g. inverted flight, …).
- Practical aspects of flight (e.g. ground effect, ….).

In addition, Newtonian mechanics provides new and useful insights that offer a better understanding of lift, including:
- How aircraft momentum affects lift and aspect ratios.
- The kinetic energy used for lift generation.
- Lift distribution across a wing.
- Induced drag.
- Causes of a stall.
- How airfoil thickness affects lift.

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II. THE NEWTONIAN ARGUMENT FOR LIFT

(A one-page summary)

A. The Newtonian approach explained.

Newtonian mechanics based on the mass flow rate is used to explain **active lift generation** using **absolute airflow analysis**. Simply put, the wings fly through and accelerate a mass of air each second (m/dt) to a velocity (dv) downward. This action creates a downward force. The inertia of the air allows for a reactive equal and opposite upward force, which provides lift. This process is summarized by the equations: See Fig. 2a-i.

$$\text{Force}_{\text{DOWN}} = ma = m/dt \times dv = \text{Force}_{\text{UP}}\ \textit{(Lift)}$$

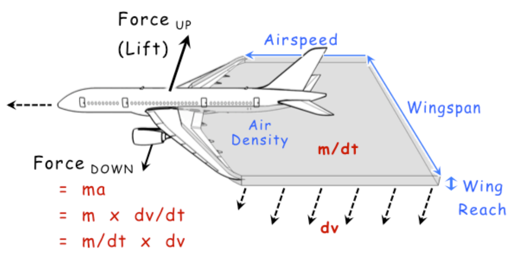

Fig. 2a-i. Newtonian forces acting on an airplane.

Passive vs. Active lift generation

Wings can passively re-direct airflow (headwind) as shown by a relative airflow diagram; or wings actively displace air downwards in flight as shown by an absolute airflow diagram. See Fig. 2a-ii.

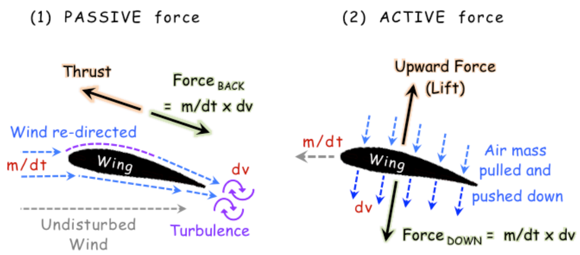

Fig. 2a-ii. Active and passive force creation.

In practice, wings are observed to actively push air downwards and slightly forwards, which can only be accurately calculated using Newtonian mechanics; and not using fluid mechanics and relative airflow analysis. See Fig. 2a-iii.

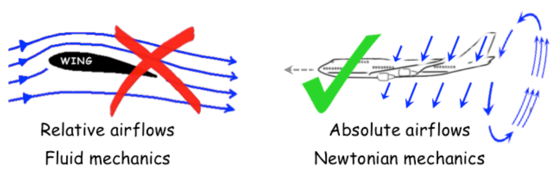

Fig. 2a-iii Relative and absolute wing airflow diagrams.

B. Newtonian Mechanics applied to airplanes.

New insights into lift

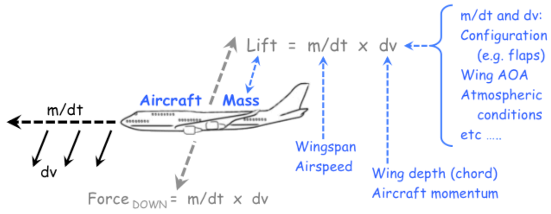

Fig. 2b. 'm/dt' and 'dv' analyzed separately.

The Newtonian approach allows lift (Lift = m/dt x dv) to be analyzed separately between 'm/dt' and 'dv'; to provide the following insights: See Fig. 2b

- Wingspan and wing depth (chord) provide a better measure of lift generation than wing area.
- Lift distribution across a wing.
- Induced drag.
- Causes of a stall.
- Downwash patterns.
- Kinetic energy required to generate lift.
- How aspect ratios and aircraft momentum affect lift.

New explanations of lift.

The Newtonian approach allows for a better explanation of all aspects of lift generation, including:

- Flight manoeuvers (e.g. inverted, ….).
- Practical aspects of lift (e.g. ground effect, ….).
- How energy efficient different wings are at generating lift.
- The standard equations lift and drag:

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

$$\text{Drag} = 0.5\,(\text{Aircraft Velocity}^2 \times \text{Air Density} \times \text{Surface Area} \times \text{Coefficient of Drag})$$

Enigmas and conundrums solved.

The Newtonian approach solves enigmas, including:

- Why lift quadruples if aircraft velocity doubles.
- How a glider can soar into wind.
- A solution to the lift paradox.
- DDWFTTW.
- How a wing generates lift.
- d'Alembert's paradox 1752.

Summary and benefits.

Newtonian mechanics provides a comprehensive description of all aspects of lift generation, which is not currently available. It can be used to improve: wing design, pilot training, and aviation safety; as well as resolving the debate on the theory of lift and how airplanes fly.

III. Active Lift Generation

A. Passive vs. Active lift generation.

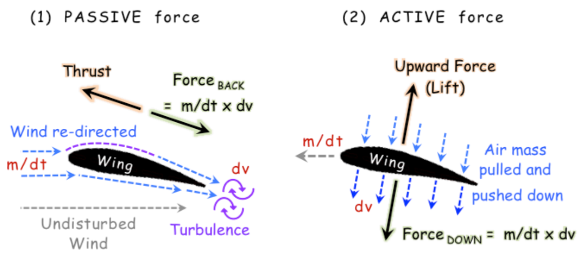

Fig. 3a-i. Passive and active creation of forces.

A wing, propeller blade or sail can passively or actively create forces, calculated based on Newtonian mechanics and the mass flow rate (Force = m/dt x dv): See Fig. 3a-i.

1) An oncoming airflow (headwind) can be **passively** re-directed by a stationary wing. The mass of air re-directed each second (m/dt) decelerates (dv) on contact with the undisturbed wind, at the trailing edge of the wing. This process produces turbulence and creates a backward force ($\text{Force}_{\text{BACK}}$ = m/dt x dv). The inertia of the air provides resistance, allowing for a reactive equal and opposite forward force (thrust) to be generated.

2) A moving airplane wing can **actively** accelerate a mass of static air each second (m/dt) to a velocity (dv) downward and slightly forwards, creating a downward force ($\text{Force}_{\text{DOWN}}$ = m/dt x dv). The inertia of the static air allows for reactive equal and opposite upward force to be generated, which provides lift.

The key differences in the generation of passive and active forces described above include:

- The **reaction to passive forces** arises due to the change in **inertia** from the decrease in velocity of the relative airflow (wind) at the trailing edge of the wing, which produces turbulence. In contrast, the **reaction to active forces** arises from the **inertia** of the static air accelerated by the wing.
- **The direction of the force generated** by active force is almost perpendicular to the alignment of the wing, but for passive forces it is close to the alignment of the wing.
- **Wake airflow** from actively generated forces produces laminar (smooth) airflow that circulates the air around wingtip (or blade-tip) vortices. In contrast, wake airflow from passively generated force produces turbulence, with no air being circulated. See Fig. 3a-ii.

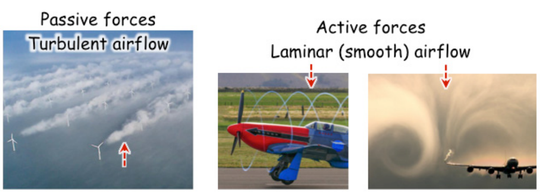

Fig. 3a-ii. Turbulent vs. smooth wake airflows.

B. Relative vs. Absolute airflow analysis.

Wing airflow diagrams are of fundamental importance as they provide the basis of analyzing how airflows create lift. Wing airflows can be depicted in relative or absolute terms. Both diagrams show the same airflow but in different ways. See Fig. 3b.

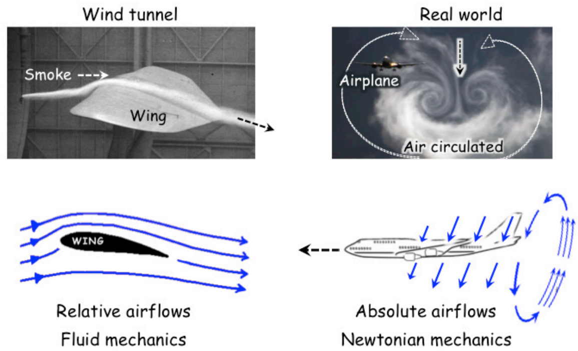

Fig. 3b. Relative and absolute airflows.

These two different wing airflow diagrams are compared:

1) **Relative wing airflow diagrams** have been used for the last hundred years as the basic template by fluid mechanics to analyse how wings interact with airflow to generate forces like lift. For example, relative wing airflow diagrams accurately reflect how moving air interacts with a stationary wing in wind tunnels.

   However, wingtip vortices and the circulation of the air behind the aircraft are notably absent from the relative wing airflow diagrams.

   In contrast, according to Newtonian mechanics relative wing airflow diagrams are an example of passive force creation. It is wrong to use relative wing airflow diagrams to analyze how a wing actively generates lift.

2) **Absolute wing airflow diagrams** show a wing or aircraft moving through stationary air. This is a new type of diagram derived form the airflows observed behind airplanes flying through clouds.

   The wings push air downwards, which is circulated either side of the airplane around the two wingtip (wake) vortices According to Newtonian mechanic, this diagram accurately describes active force creation by a wing.

Summary

The analysis above demonstrates that the prevailing method employed by fluid mechanics to analyze how an airplane wing actively creates a lift force using relative wing airflow analysis is wrong, and the absolute airflow analysis based on Newtonian mechanics is correct.

IV. Newton Explains Lift

A. *Lift = m/dt x dv*

Newtons Laws of Motion describe the relationship between the motion of an object (airplane) and the forces acting on it.

Where:
- Force = ma = m x dv/dt = m/dt x dv [1]
- Force = ma = m x dv/dt = d(m/v)/dt [1]
- m = Mass of air the wings fly through.
- m/dt = Mass flow rate.
- dt = Change in time (per second).
- dv = Change in velocity of the downwash.
- v = Velocity that the downwash is accelerated to.
- a = dv/dt = Acceleration.

The mass flow rate theory: Lift = m/dt x dv

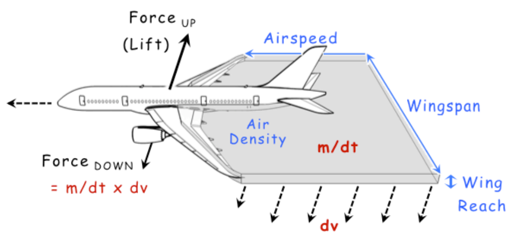

Fig. 4a-i. Newtonian forces acting on an airplane.

In this paper, Newtonian mechanics based on the mass flow rate is used to explain **active lift generation** using **absolute airflow analysis**. Simply put, the wings fly through a thin layer of air that is accelerated down. The equal and opposite reaction pushes the wings up.

For an airplane in stable cruise flight through static air, where the wings have a positive angle-of-attack (AOA). The wings fly through a mass of air each second (m/dt), which they accelerate to a velocity (dv) downwards, to create downwash and a downward force, as summarized by the equation: See Fig. 4a-i.

$$Force_{DOWN} = ma = m \times dv/dt = m/dt \times dv \qquad (1)$$

The inertia of the air provides resistance to the downward force, producing a reactive equal and opposite upward force:

$$Force_{DOWN} = Force_{UP}\ (Lift) \qquad (2)$$

Lift is the vertical component of the upward force. If induced drag is negligible, then lift equals the upward force:

$$Force_{UP} = Lift \qquad (3)$$

Equations (1), (2), and (3) can be combined as follows:

$$Force_{DOWN} = Force_{UP} = Lift = m/dt \times dv \qquad (4)$$

$$\text{Or simply:} \quad Lift = m/dt \times dv \qquad (5)$$

$$\text{Units:} \quad N = kg/s \quad m/s$$

'm/dt' depends on the volume of air flown through and air density. The volume of air flown through depends on airspeed, wingspan, and wing reach (i.e. wing AOA and wing thickness).

'm/dt' increases with airspeed. Therefore, lift is expressed as the mass flow rate 'm/dt', and not 'm', because this factor of lift is time dependent. i.e. Lift depends on the amount of air flown through by the wings each second.

'dv' depends primarily on aircraft momentum (airspeed and mass), wing AOA, and wing depth (chord).

The velocity of the downwash (dv) arises due to a one-off force (impulse) from the wings against the air. Therefore, 'dv' is not time dependent; and not expressed as acceleration 'dv/dt'. i.e. The force from the wings is not continuously applied to accelerate the air. Downwash velocity does not change if the time period changes.

The momentum theory: Lift = d(mv)/dt

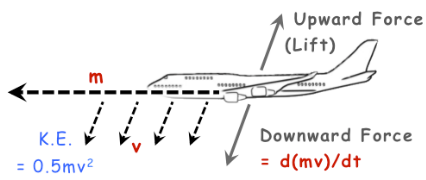

Fig. 4a-ii. Transfer of momentum and K.E. to the air.

There is no net gain or loss of momentum, energy and mass in this process of generating lift. In flight, wings transfer momentum and kinetic energy from the aircraft to the air, by accelerating the air flown through downwards to generate lift.

The transfer of momentum from the aircraft to the air to generate lift, causes the aircraft's velocity (v) to decline, as the aircraft's mass (m) is constant. This process is expressed by the equations: See Fig. 4a-ii.

$$Force_{DOWN} = ma = m \times dv/dt = d(mv)/dt \qquad (6)$$

$$K.E. = 0.5\, mv^2 \quad [1]$$

$$Momentum = mv \quad [1]$$

The reactive equal and opposite upward force provides lift. Combining equations (2), (3) and (6) allows lift to be expressed as the change in momentum of the air:

$$Force_{DOWN} = Force_{UP} = Lift = d(mv)/dt \qquad (7)$$

$$\text{Or simply:} \quad Lift = d(mv)/dt \qquad (8)$$

$$\text{Units:} \quad N = (kg\ \ m/s)\ /s$$

Two Newtonian equations for lift.

The analysis above provides two Newtonian methods and equations to calculate the lift generated by a wing:

$$Lift = m/dt \times dv \qquad \textit{(mass flow rate)} \qquad (5)$$

$$Lift = d(mv)/dt \qquad \textit{(momentum theory)} \qquad (8)$$

Both lift equations (5) and (8) are based on Newtons 2^{nd} Law of motion (Force = ma). Both are correct and produce the same values, but express the same thing differently.

B. *Additional considerations.*

Evidence for wings pushing air down in flight is provided by the **downwash** from airplanes disrupting dust on the ground and cloud patterns behind the airplane. See Fig. 4b-i.

Fig. 4b-i. Downwash evident behind airplanes.

Downwash is more evident from the aircraft with greater momentum. i.e. the heavier and faster airplanes, which tend to be the military aircraft.

A **pressure impulse** (shock waves) observed directly below high-speed, low-flying aircraft provides evidence that wings exert a significant downward force on the air. See Fig. 4b-ii.

Fig. 4b-ii. Pressure impulse below jets. [22]

Supplementary considerations:

- The lift required to fly depends on the aircraft's mass.
- This analysis only relates to the wings. It does not include the effects from the tail or fuselage for simplicity.
- Airflows are described according to absolute airflow analysis. See Section V Wing Airflows on page 16.
- A wing cannot generate lift unless it displaces air down.
- Newtonian mechanics can be used to explain the forces created by airplane wings, propellers, jet engines, and helicopter rotors.
- Wings that rely on generating lift (Lift = m/dt x dv) more from 'dv', as compared to 'm/dt' are less efficient at generating lift. This dynamic arises because the kinetic energy required to generate lift is proportional to the velocity of the downwash squared (K.E. = 0.5 mv^2).
- In the analysis provided above, the amounts for downwash velocity, 'dv' and 'v', are equal.

Newtons Laws of Motion

Strictly, Newtons 2nd Law of Motion does not specifically state that force equal mass time acceleration (Force = ma). "Newton's second law ….. states that the time rate of change of the momentum of a body is equal in both magnitude and direction to the force imposed on it. The momentum of a body is equal to the product of its mass and its velocity." [38]

Therefore, the equation describes force as a product of the mass flow rate and its velocity (Force = m/dt x dt), which is a generally accepted derivation of Newtons 2nd Law. [1]

This difference may have arisen because the mass of the object was assumed to be fixed by Newton and others. Only later was the equation adjusted to account for how the mass flow rate exerts a force. Consequently, the Newtonian equation for the mass flow rate could also be written using 'dm/dt'; as summarized by the equation:

$$Force_{DOWN} = ma = dm \times dv/dt = dm/dt \times dv$$

However, in this paper for simplicity the terminology 'm/dt' is used, rather than 'dm/dt', because in most situations the mass flow rate is only time dependent. The surface area facing the direction of travel (flight) is constant. i.e. The wingspan and wing reach is fixed, while airspeed is variable.

Therefore, it is easier and less confusing to express the lift generated as a function of 'm/dt', rather than as 'dm/dt'. However, this issue is only a presentation consideration, the physics associated with the terms 'm/dt' and 'dm/dt' is the same.

Contrast to prevailing theories of lift

The prevailing approaches to analyzing lift are based on fluid mechanics (Navier-Stokes equations); as well as the old Newtonian change in momentum or flow-turning theories for lift. These approaches use relative airflow analysis. [1] See Fig. 4b-iii.

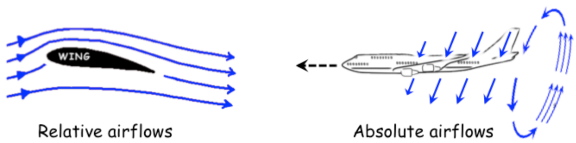

Fig. 4b-iii. Flow turning and absolute airflows.

It is beyond the scope of this paper to described the other theories of lift in any detail.

C. Old Newtonian theories of lift.

Applying Newtonian mechanics to explain is not a new concept. But applying Newtonian mechanics based on the mass flow rate in the detail and depth provided in this paper is new. Using absolute airflows and a focus on the circulation of the air behind the aircraft is also entirely new.

NASA's website states that both Bernoulli (fluid mechanics) and Newton provide correct explanations for lift. [1] However, this is impossible as these are incompatible and non-complimentary theories. It is illogical to claim fluid mechanics explains 50% of lift, and Newtonian mechanics explains the remaining 50%.

The book 'Understanding Flight' [4] uses Newtonian mechanics to explain lift. It states: "In the simplest form, lift is generated by the wing diverting air down, creating the downwash." The author also stated: "We did the calculation for a 250 ton airplane at 35,000 feet, and it is diverting (downwards) its own weight per second to keep in the air." [39]

The book: "Stick and Rudder" by Wolfgang Langeweische (1944) [3], in Chapter 1 states: " The wing keeps the plane up by pushing air down. …. In exerting a downward force on the air, the wing receives an upward counterforce – by the same principle, known as Newton's law of action and reaction, …. " See Fig. 4c-i.

Fig. 4c-i. Books: Understanding Flight and Stick and Rudder.

A paper "A comparison of explanations of aerodynamical lifting force" (1987) [12] calculated lift using Newtons 2^{nd} Law, based on the change in momentum of the air and the mass flow rate of the air pushed downwards by the wing; using the equation: Force = d/dt (mV) = m/dt x V

The old Newtonian 'momentum' and 'flow turning' theories of lift asserted that wings re-direct relative airflow downwards, which transfers momentum from the wing to the air. The equal and opposite force pushes the aircraft up. [1] See Fig. 4c-ii.

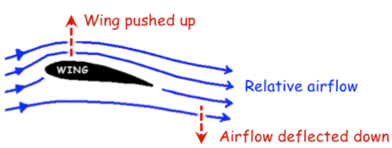

Fig. 4c-ii. Wing airflow diagram – momentum theory.

D. Total lift generated.

The total lift generated is a combination of the lift from the wings and propellers (or jet engines), as summarized by the equations using Newtonian mechanics based on the mass flow rate: : See Fig. 4d-i.

$$\text{Lift}_{\text{TOTAL}} = \text{Lift}_{\text{WINGS}} + \text{Lift}_{\text{PROPELLERS}}$$

$$\text{Lift}_{\text{TOTAL}} = (\text{m/dt x dv})_{\text{WINGS}} + (\text{m/dt x dv})_{\text{PROPELLERS}}$$

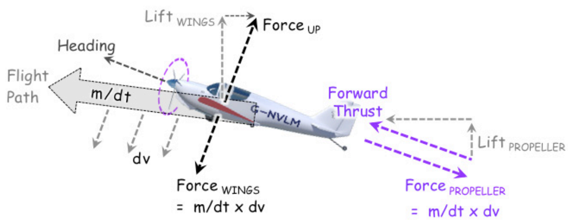

Fig. 4d-i. Forces contributing towards lift.

Specifically, the propellers (or jet engines) can contribute to lift if the airflow they produce is angled downwards, or if wings re-direct airflow from the engines downwards, which is common with STOL aircraft. Lift is simply the vertical component of the thrust generated by the propellers. See Fig. 4d-ii.

Fig. 4d-ii. Engines boost lift.

Thrust generation by a propeller (or jet engine)

The propellers (or jet engines) accelerate a small static mass of air each second (m/dt) backwards to a high velocity (dv). This action create a backward force, which is evident from the strong backwash behind a turning propeller of jet engine. The reactive equal and opposite force provides thrust to push the airplane forwards and up, as shown by the equations: See Fig. 4d-iii.

$$\text{Force}_{\text{BACK}} = (\text{m/dt x dv})_{\text{PROPELLERS}}$$
$$= \text{Thrust}_{\text{PROPELLERS}}$$

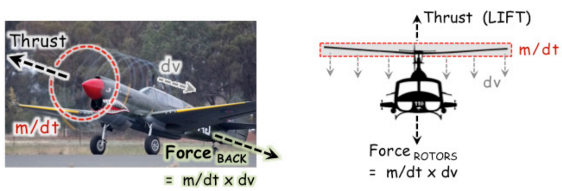

Fig. 4d-iii. Thrust generation by a propeller.

In contrast, helicopters have no wings and rely only on their rotors (propellers) to generate lift. The same Newtonian equation can be used to calculate the thrust and lift generated.

E. 'm/dt' and 'dv' analyzed separately.

Lift generation is complicated as key factors (e.g. airspeed, momentum, aspect ratios, flaps, wing AOA, ….) can affect both 'm/dt' and 'dv' in a non-linear and inter-dependent manner. See Fig. 4e-i.

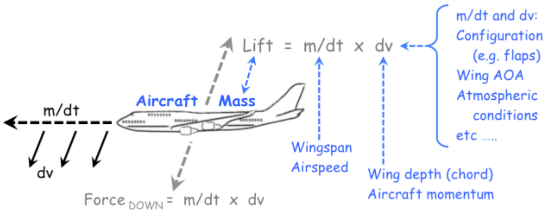

Fig. 4e-i. 'm/dt' and 'dv' analyzed separately.

For example, a change in wing AOA affects 'm/dt' and 'dv', and therefore lift and induced drag. In turn, these changes can effect airspeed and aircraft momentum, which also then effects 'm/dt' and 'dv'.

Combining the Newtonian approach to lift, insights gained above, and the ability to separately analyse 'm/dt' and 'dv' allows for a better explanation of all aspects of lift generation by a wing. The combinations of 'm/dt' and 'dv' can be shown graphically along a constant lift curve. See Fig. 4e-ii.

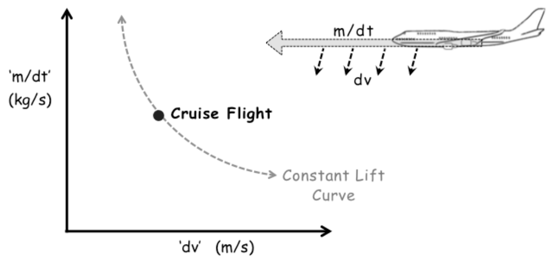

Fig. 4e-ii. Graph comparing 'm/dt' and 'dv', for constant lift.

High-speed flight vs. slow flight

The different aircraft configurations that produce the same total amount of lift, by the same aircraft, can be compared by analyzing 'm/dt' and 'dv' separately. For example, high-speed and slow flight are compared below: See Fig. 4e-iii.

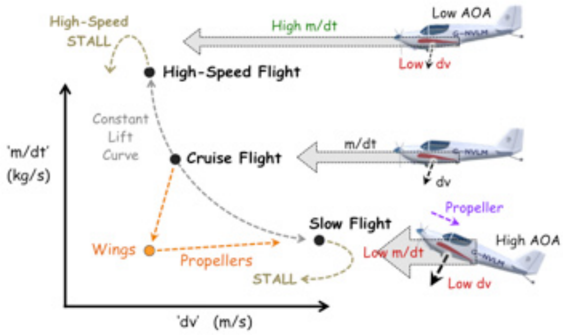

Fig. 4e-iii. Lift composition – 'm/dt' and 'dv compared.

- **In high-speed flight** the airplane adopts a low wing AOA and a flat aircraft configuration. The airplane flies through a high mass of air each second (high m/dt) due to the high airspeed, despite the lower wing reach. Consequently, the air flown through only needs to be accelerated downwards to a low velocity (low dv) in order to generate enough lift (Lift = m/dt x dv) to fly. The increased aircraft momentum is of little benefit. In short, the 3D lift generation is spread out over a wide and shallow volume. This dynamic is summarized by the equation:

  $$\text{Lift}_{\text{WINGS}} = \text{high 'm/dt'} \times \text{low 'dv'}$$

- **In slow (low-speed) flight** the airplane adopts a high wing AOA with its nose raised. The airplane flies through a small mass of air each second (low m/dt) due to the low airspeed, despite the higher wing reach. The air flown can only be accelerated downwards at a less vertical angle to a lower velocity (low dv) as compared to cruise flight, due to the lower aircraft momentum.

  The propellers are required to boost lift in order to generate enough lift (Lift = m/dt x dv) to fly. The propellers accelerate a very small mass of air each second (low m/dt) to a very high velocity (high dv). In short, the 3D lift generation is spread out over a short and high volume. If the wings and propellers are combined, this dynamic is summarized by the equation:

  $$\text{Lift}_{\text{TOTAL}} = \text{Lift}_{\text{WINGS}} + \text{Lift}_{\text{PROPELLERS}}$$

  $$\text{Lift}_{\text{TOTAL}} = (\text{low m/dt} \times \text{low dv})_{\text{WINGS}} + (\text{low m/dt} \times \text{high dv})_{\text{PROPELLERS}}$$

  $$\text{Lift}_{\text{TOTAL}} = \text{low m/dt} \times \text{high dv}$$

- The total lift generated is the same for the three configurations (cruise, high-speed and slow flight).
- These are only examples of how high-speed and slow flight can be achieved. Alternatives combinations of 'm/dt', 'dv', and the propeller thrust exist.

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F. Evidence for downwash velocity (dv).

Wing condensation – evidence for 'dv' and lift

Condensation above airliner's wings due to low air pressure indicates how far the wings affect the air above them. The distance and distribution across the wing indicates how the wings accelerate the air above them downwards. See Fig. 4f-i.

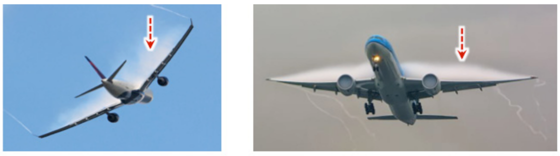

Fig. 4f-i. Wing condensation on airliners. [17][18]

The assertion that wing condensation is associated with 'dv' and lift generation is supported by the following observations:

- Wing condensation is not observed on the ground run (when no lift is being generated), prior to take-off. But it is seen on flare and take-off by airliners (when lift is being generated). See Fig. 4f-ii.

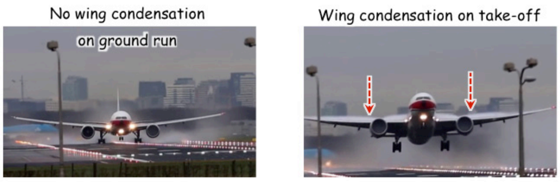

Fig. 4f-ii. Wing condensation on take-off. [19]

- Similarly, wing condensation is observed on airliners on approach to landing (when lift is generated). But it is not evident once the aircraft has landed on the runway (when lift is not generated). See Fig. 4f-iii.

Fig. 4f-iii. Wing condensation on approach. [20]

Conditions for wing condensation

Wing condensation is only evident under certain atmospheric conditions of sufficient humidity. The wing needs to accelerate the air mass sufficiently to lower the internal temperature of the air, in order to trigger condensation.

Condensation does not often arise under the wing, because the air is accelerated away from the wing and towards the atmosphere. Therefore, there is no condensation point. Whereas, condensation arises on the topside of the wing, because the air is accelerated towards a vacuum of air on top of the wing.

Evidence for downwash and 'dv'

Downwash providence evidence for the velocity to which the air flown through is accelerated to by the wings (dv). The video footage of airplanes creating downwash also shows the downwash being pushed slightly forwards.

Downwash can be observed behind airliners flying through clouds (cloud surfing), usually with two wingtip vortices present as well. This allows the speed of the downwash (dv) to be estimated. For example, the distance that the downwash travels in a given time period (e.g. one second) can be estimated using the airplane's wingspan. See Fig. 4f-iv.

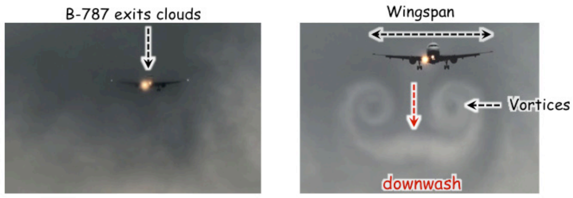

Fig. 4f-iv. Photo sequence of a B-787 in clouds. [20]

Downwash can be observed disrupting the dust on the ground behind low-flying aircraft. This allows the speed of the downwash (dv) to be estimated from the speed and altitude (height) of the aircraft. See Fig. 4f-v and 4f-vi.

Fig. 4f-v. Downwash behind a low-flying fighter jet. 1

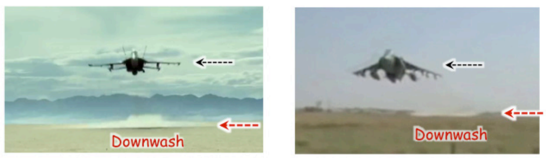

Fig. 4f-vi. Downwash behind a low-flying fighter jets. 2 [22]

Downwash can also be observed disrupting the surface of water behind low-flying aircraft. See Fig. 4f-vii.

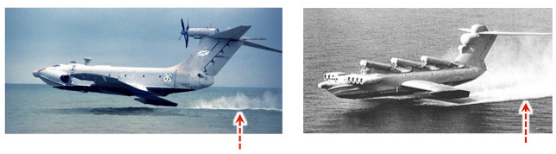

Fig. 4f-vii. Downwash behind low-flying airplanes.

The distance above the ground or water that downwash is evident is usually correlated to the distance at which ground effect is evident; which is when the aircraft is within one wingspan's distance from the ground.

G. Paper airplanes.

Paper airplanes are noteworthy due to their ability to fly and glide despite their straight wings. The lack of wing curvature is significant as it restricts the air pulled downwards by the topside of the wings and means that they stall easily. However, airplanes are light, and therefore, this aspect does not appear significant.

Similar to airplanes, according to Newtonian mechanics the paper airplanes require a positive AOA and wings that accelerate a mass of air downwards each second (m/dt) to a velocity (dv), which creates a downward force. The reactive equal and opposite force generates an upward force which provides lift; as described by the equations: See Fig. 4g-i and 4g-ii.

$\text{Force}_{\text{DOWN}} = \text{m/dt} \times \text{dv} = \text{Force}_{\text{UP}}$ (Lift)

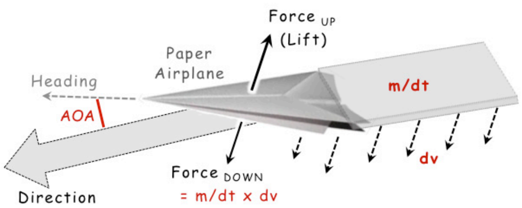

Fig. 4g-i. Newtonian forces acting on a paper airplane.

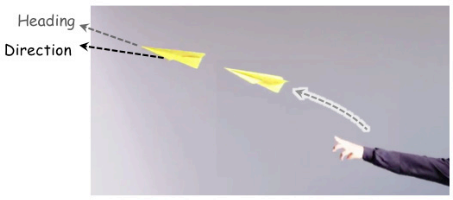

Fig. 4g-ii. Paper airplane trajectory. [37]

Other key differences between a conventional airplane and paper airplane include:

- Paper airplane lacks stiffness and mass, and therefore, cannot withstand large forces.
- Paper airplane lacks an engine, and therefore, cannot sustain flight for long.
- The paper airplane design (ailerons, elevators, ….) can be altered to adjust the airflows produced. This action alters the forces generated and flight path.
- Conventional paper airplanes have a delta wing design, which can benefit lift from Leading Edge Vortices (LEVs) on the topside of the wings.

The same principles of physics can be applied to explain the flight of a frisbee. See Fig. 4g-iii.

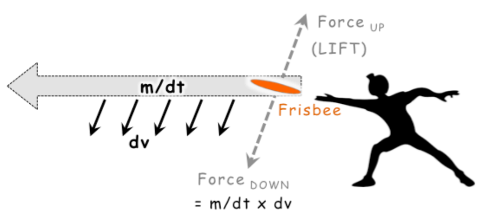

Fig. 4g-iii. Newtonian forces acting on a frisbee.

Flight trajectory

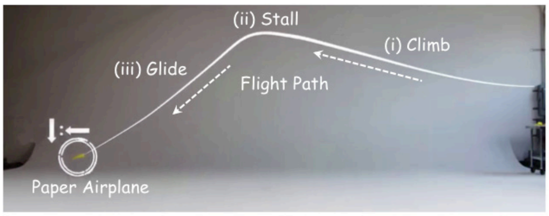

Fig. 4g-iv. Paper airplane trajectory split into a climb, stall, and glide phases. [37]

The typical trajectory of a paper airplane flight can be split into distinct phases: See Fig. 4g-iv.

- **(i) Climb:** Once thrown from an altitude, the paper airplane transfers its momentum to the air to generate lift and forward motion. If the paper airplane generates positive lift then, it gains altitude.

  Drag causes the paper airplane to quickly loose velocity, and therefore, it quickly loses momentum.

- **(ii) Stall.** The paper airplane looses forward velocity due to drag, reducing momentum and lift generation. Eventually it is unable to generate sufficient lift to fly and the paper airplane may stall. How and when the stall occurs depends on wing design and atmospheric conditions.

  The stall can be abrupt and all lift is lost, or more typically, it is less dramatic.

  After a stall, the paper airplane may then enter a downward glide under beneficial wing design and flight conditions.

- **(iii) Glide:** After a stall, if the paper airplane regains a positive AOA by the nose turning down. Then it may be able to generate enough lift to fly. Flight can be maintained in a glide downwards by trading altitude for airspeed and lift. This trade-off can be described by the glide ratio achieved by the paper airplane.

  Towards the end of the flight path, as velocity declines lift degrades exponentially as the paper airplane glides downwards. This aspect arises because the lift generated is proportional to velocity squared, according to the standard equation for lift:

  Lift $= 0.5$ (**Velocity**^{2} x Air Density x Wing Area x Lift Coefficient)

  However, just above the ground, lift may be boosted temporarily by ground effect.

In short, the physics for how airplanes fly is essentially the same as conventional airplanes. Pushing air downwards generates lift.

H. Lift distribution across a wing.

The lift distribution across the wings changes with all the factors that affect 'm/dt' and 'dv' across the wingspan. These factors include:

- Wing AOA, wing thickness and wing reach affects the mass of air flown through each second (m/dt). In most wing designs, these factors tend to increase from the wingtips towards the fuselage. Therefore, 'm/dt' is least at the wingtips and greatest towards the fuselage.
- Wing depth is the primary factor that determines the downwash velocity (dv) distribution across the wingspan.

  Aircrafts' wing shapes vary a lot in depth (chord). Therefore, downwash velocity (dv) also varies a lot with wing depth across the wingspan.

  Wing depth can also affect wing reach to a small extent, and therefore, increase m/dt. But this aspect is minimal and ignored in this analysis for simplicity.

  In summary, 'dv' tends to be greatest close to the fuselage and least at the wingtips.
- 'm/dt' and 'dv' are often minimal or nonexistent in the middle of the fuselage, which generates little lift.

'm/dt' and 'dv' are often presented as a single number. But in practice 'm/dt' and 'dv' vary a lot vertically and horizontally across the wings. Downwash is accelerated more aggressively (higher dv) where the wings are thickest, close to the fuselage.

For example, a B-787 has tapered (thin) wingtips and deep wings (large chord) close to the fuselage. Consequently, most lift is generated close to the fuselage. See Fig. 4h-i and 4h-ii.

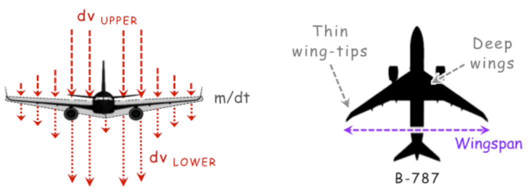

Fig. 4h-i. 'm/dt' and 'dv' vary across B-787 wings.

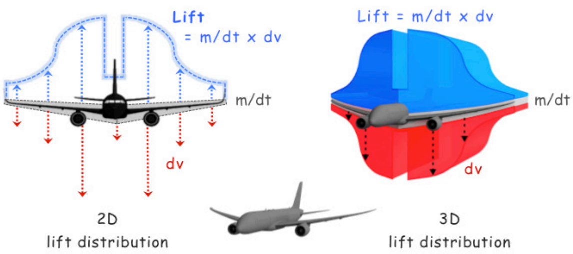

Fig. 4h-ii. 2D and 3D lift distribution on B-787 wings.

The lift distribution across the wings is significant because it affects aircraft performance and manoeuvers and stall speed.

2D lift distribution across different wing designs

According to this logic above, a rectangular shaped wing should provide a relatively even lift distribution (rectangular shaped) across the wingspan. See Fig. 4h-iii.

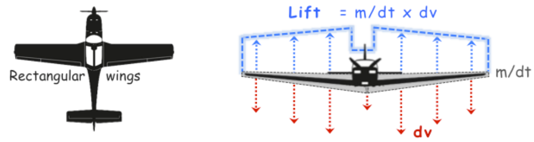

Fig. 4h-iii. 2D lift distribution for a small airplane with rectangular shaped wings.

Similarly, the elliptical wings of a Spitfire should provide elliptical-shaped lift distributions across the wingspan. See Fig. 4h-iv.

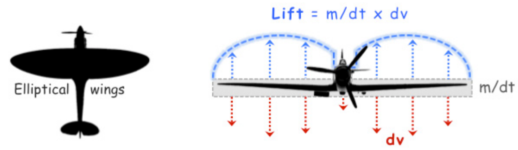

Fig. 4h-iv. 2D lift distribution on the elliptical wings of a Spitfire.

A triangular shaped delta wing of high-speed airplanes (e.g. supersonic Concorde) would provide a triangular-shaped lift distributions across the wingspan. See Fig. 4h-v.

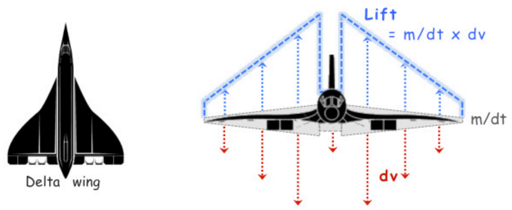

Fig. 4h-v. 2D triangular lift distribution on delta shaped wings of Concorde.

In summary, wing designs (aspect ratios) as well as the momentum (airspeed and mass) of the aircraft, determines the mix of 'm/dt' and 'dv' distributed across the wing, and therefore, the lift distribution (Lift = m/dt x dv). For simplicity, analysis above is focused on the lift generated by the wings and ignores the tail section. See Fig. 4h-vi.

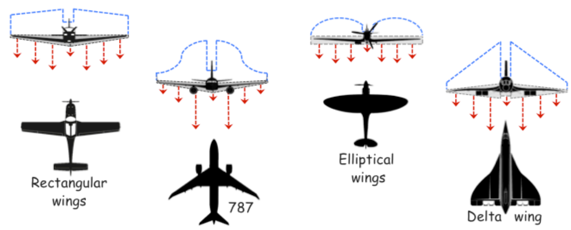

Fig. 4h-vi. 2D lift distribution and wing design summarized.

I. *2D lift distribution: Glider vs. Harrier.*

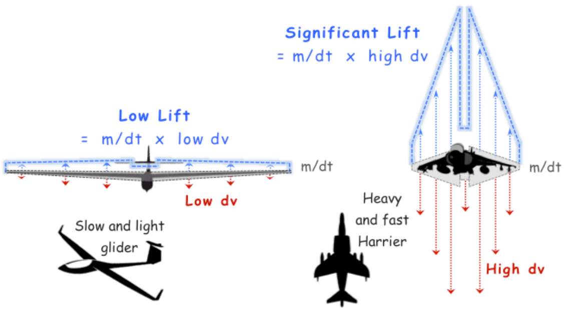

Fig. 4i-i. 2D relative lift distribution each second of a glider and Harrier compared.

The 2D lift distribution for a slow and light glider is compared to that for a fast and heavy fighter jet (Harrier). See Fig. 4i-i.

- The gliders long wingspan (high aspect ratio wings) fly through a large mass of air each meter. But its slow air speed means that it manages to fly through only a relatively modest mass of air each second (modest m/dt).

  This air is accelerated downward at a low velocity due to the aircraft's limited momentum. Overall the glider generates a small amount of lift required to fly.

- The Harrier's short wingspan (low aspect ratio wings) fly through a small mass of air each meter. But its high air speed means that it manages to fly through a relatively modest mass of air each second (modest m/dt).

  This air is accelerated downward at a high velocity due to the aircraft's significant momentum.

  Overall the much heavier Harrier generates a significantly greater amount of lift required to fly, as compared to the lighter glider.

Note: The 'm/dt' can be the same for the glider and Harrier, based on reasonable assumptions. For example if the glider's wingspan is 3x longer, but it flies at 1/3 the airspeed, as compared to the Harrier. Then both aircraft have the same 'm/dt' assuming similar wing reach for both aircraft. In turn, this means that the difference in lift profile between the glider and the Harrier is primarily due to differences in the velocity of the downwash (dv). See Fig. 4i-ii.

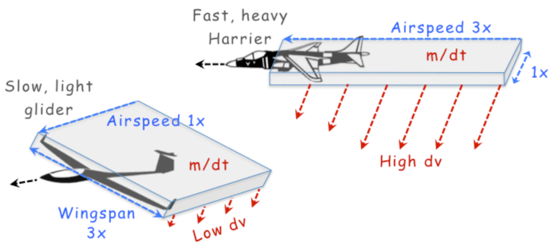

Fig. 4i-ii. 'm/dt' for glider and Harrier compared.

3D lift distribution: Glider vs. Harrier

Using the same metrics above for the glider and Harrier, where the glider's wingspan is 3x longer, but it flies at 1/3 the airspeed, as compared to the Harrier.

The corresponding 3D lift distribution for the Harrier shows a less dramatic difference in the lift generated, as compared to the glider. This change is because the Harrier's lift distribution is spread out over a longer distance (larger area). Consequently, the lift generated each meter flown is less dramatic than the 2D lift distribution. See Fig. 4i-iii.

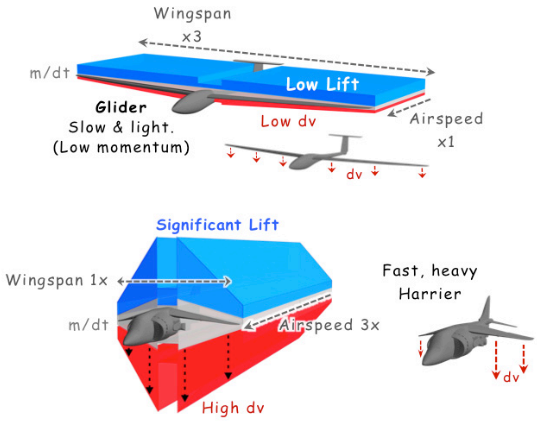

Fig. 4i-iii. 3D lift distribution for a glider and Harrier compared.

For reference, in this example the glider has a 30 meter wingspan, which is about 3.2x greater than the Harrier's 9.4 meter wingspan. The glider has thinner wings (smaller chord) and the same wing area as the Harrier.

3D lift distribution – high-speed and slow flight

A small airplane with rectangular wings is used to illustrate the differences in how lift is generated between high-speed (high m/dt and low dv) and slow flight (low m/dt and high dv). See Fig. 4i-iv.

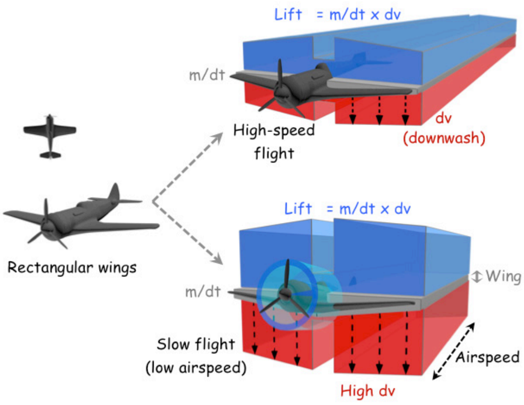

Fig. 4i-iv. 3D lift distribution on the wings of a small airplane with rectangular shaped wings.

J. *Prandtl lifting line theory.*

Lift distribution and the Prandtl lifting-line theory.

In summary, the Newtonian approach to lift based on the mass flow rate (m/dt and dv) challenges Prandtl's proposed lift distribution across a wing. Although both approaches share some similarities. For example, the proposed elliptical lift distribution across a wing proposed by the 1907 of the Prandtl lifting-line theory, is somewhat consistent with the Newtonian two dimensional description above. However, the descriptions vary when considered in three dimensions. See Fig. 4j-i, 4j-ii, and 4j-iii.

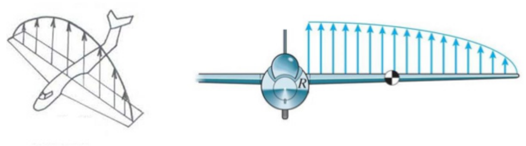

Fig. 4j-i. Prandtl lifting-line theory.

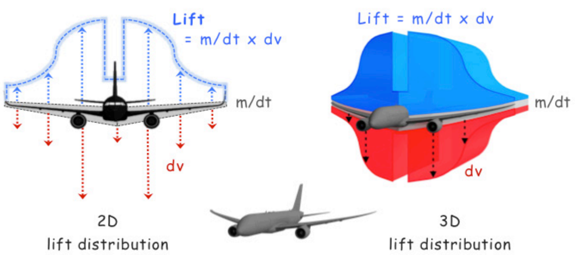

Fig. 4j-ii. 2D and 3D lift distribution on B-787 wings.

However, the Prandtl lifting-line theory has a few problems:

- Prandtl wrongly attributes lift to bounded vortices arising along the wing, which decrease towards the wingtips. See Fig. 4j-iii.

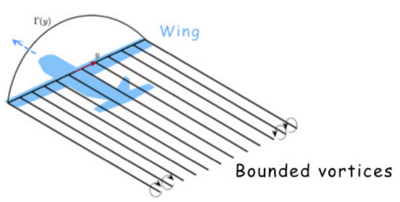

Fig. 4j-iii. Prandtl bounded vortices along a wing.

There is no conclusive evidence that bounded vortices arises along the length of the wing; nor that it is the cause of lift. Prandtl's assertions are made based on deduction of wingtip vortices, not evidence.

- The elliptical lift distribution creates upwash at the wingtip, and thus stronger wingtip (wake) vortices, which is wrongly assumed to have a negative affect on lift. This is incorrect, as downwash, upwash, and wake vortices are simply a product of the lift generation process.
- Prandtl's logic and analysis is limited as it only applies to a particular type of wing: An unswept, simple wing with large aspect ratio at small wing AOA.
- Prandtl overlooked the importance of the downwash pattern on lift. Prandtl ignored how differences in wing depth (chord) can impact the lift distribution across the wing. Though, Prandtl did correctly identify that the wing creates downwash and that vortices are an integral part of lift.
- Prandtl also overlooked how the fuselage interferes with the lift distribution profile. See Fig. 4j-iv.

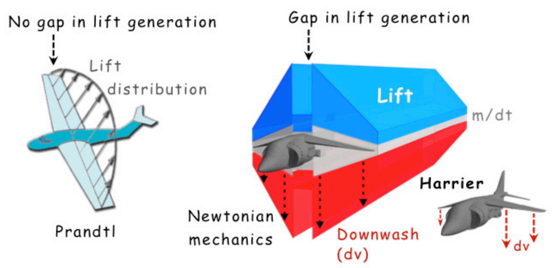

Fig. 4j-iv. Lift distribution across a wing;
Prandtl vs. Newtonian mechanics.

Newton vs. Prandtl wing airflows

In contrast to the Prandtl lifting line theory, the Newtonian approach allows for a 3D representation of the lift distribution across a wing. See Fig. 4j-v and 4j-vi.

Fig. 4j-v. Air flown through and displaced down by the left wing (3D view) of a light airplane. 1

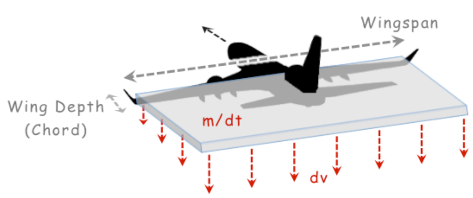

Fig. 4j-vi. Air flown through and displaced down by the left wing (3D view) of a light airplane. 1

K. *Wings, jet engines and propellers.*

Wings vs. Propellers

Wings, propellers and rotors create forces in the same manner, as described by the same Newtonian equation based on the mass flow rate (Force = m/dt x dv). See Fig. 4k-i.

- Wings move through stationary air pushing it downwards, which generates a reactive equal and opposite upward force.
- Whereas, propellers and rotors spin on a fixed hub, pushing stationary air downwards or backwards. This action generates a equal and opposite force.

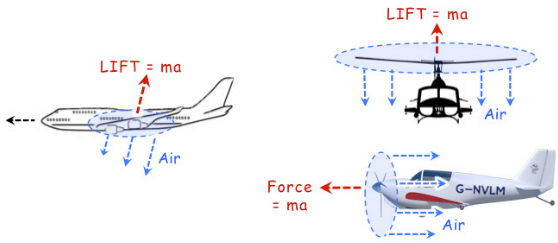

Fig. 4k-i. Newtonian v. Fluid mechanics.

The assertion above is significant as it contradicts claims that propellers create forces in a different manner to wings.

In addition, the Newtonian explanation is logical given that wings, propellers, helicopter rotors, and jet engine fan blades have the same basic shape, design and function. See Fig. 4k-ii.

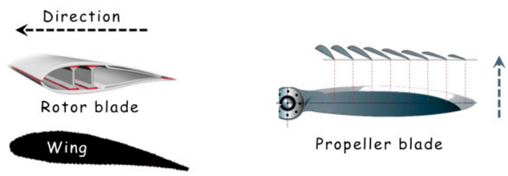

Fig. 4k-ii. Propeller, rotor, fan blades and wing. [13]

Wings vs. Jet engines

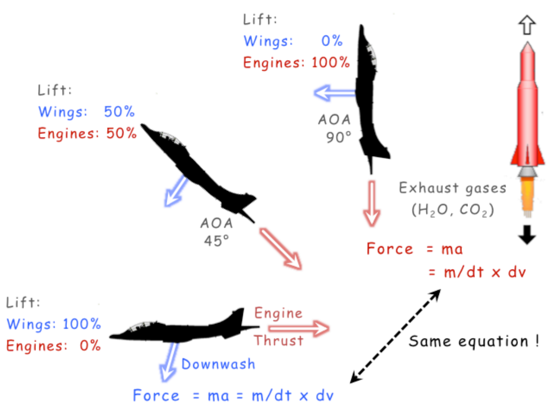

Fig. 4k-iii. Forces generated from wings and a jet engine.

The same Newtonian equation (Thrust = m/dt x dv) can be used to explain the force generated by wings and lift and jet engines. Both wing and jet engine accelerate a mass of fluid (gas) to generate a force (Force = ma). See Fig. 4k-iii.

- The wings push air from the atmosphere downwards, which is mostly nitrogen and oxygen.
- Whereas the jet engines push exhaust gases downwards, which are mostly water and carbon dioxide.

For a military fighter jet in a vertical climb, all lift is generated from the engines and none from the wings. As the fighter jet reduces its angle of trajectory to the horizontal, the wings start generating more of the lift required to fly. At the same time, the engines provide a lower proportion of the lift. The manner in which the lift force is generated changes, but the equation used to calculate the lift does not change. See Fig. 4k-iii.

Propellers vs. Jet engines

Both the propeller and jet engine accelerate a mass of air backwards to create a force. See Fig. 4k-iv and 4k-v.

- The jet engines push exhaust gasses from the burnt fuel (mostly H_20 and CO_2) backwards, as well as gases from the atmosphere sucked into the engines by the fan blades. This action creates a backward force.
- Propellers accelerate the air in the atmosphere backward, to create a backward force. The atmosphere is mostly gaseous nitrogen and oxygen (i.e. O_2 and N_2).

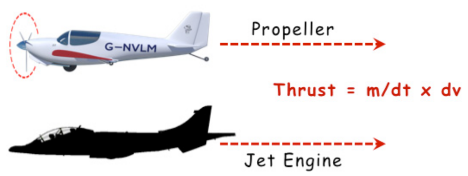

Fig. 4k-iv. Thrust generation by propellers and a jet engine.

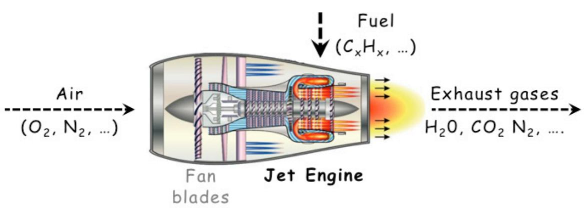

Fig. 4k-v. Combustion in a jet engine.

Summary

The concept of equating how wings, rotors, propellers, and jet engines create a force based on the same Newtonian equation is new. It is not to be found in any textbook. The Newtonian approach is logical and consistent as all objects and processes accelerate a mass of fluid (gases) in a given direction to create a force (Force = ma).

L. Optimal airfoil design – Historical context.

Historical discoveries on optimal airfoil shape and design were made primarily by trial and error, not by a detailed understanding of the physics for lift. These discoveries can be explained by Newtonian mechanics.

Historically, early airfoils designs tended to be thin and curved prior to 1910 and in WWI. Thin wings have the advantage of minimizing aerodynamic drag. Thin airfoils were a critical benefit at low airspeeds with low-powered engines.

Prandtl was one of the first to highlight that thick airfoils provided superior lift performance with wings such as the Göttingen 298 airfoil, which gained acceptance after 1920. Thicker airfoils were increasingly feasible as engine power increased.

In addition, airfoils with rounded leading edges and sharp trailing edges were found to be optimal for maintaining laminar airflow and boosting lift generation.

After 1950, as aircraft speeds increased towards MACH 1 with higher-powered engines, transonic and supersonic considerations (i.e. shock waves) were incorporated into airfoil designs. This lead to the super-critical wing design that had a flat topside (instead of a curved topside), due to the benefits of a reduced supersonic shock wave. See Fig. 4l.

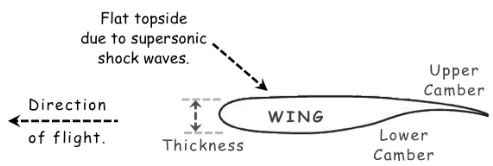

Fig. 4l. Airfoil properties,
for a super-critical wing design.

The development of higher-powered engines also increased aircraft maneuverability and performance possibilities. For example, this allowed military and sport aircraft to fly with higher AOA.

In addition, engineers took advantage of the benefits of thick airfoils for lift, to store fuel in the wings.

Bio-mimicry has affected airfoil design. Engineers have used birds as a reference point to guide airfoil design.

In summary, the optimal airfoil design is a balance of the need for thickness and camber for lift; as well as the practical considerations given the purpose and requirements of the aircraft. These considerations include need to mitigate shock waves in high-speed flight and to store fuel.

M. Wing design according to Newtonian mechanics.

Wings come is all shapes and sizes, each with their own particular advantages and disadvantages in how they push air down to create lift. See Fig. 4m.

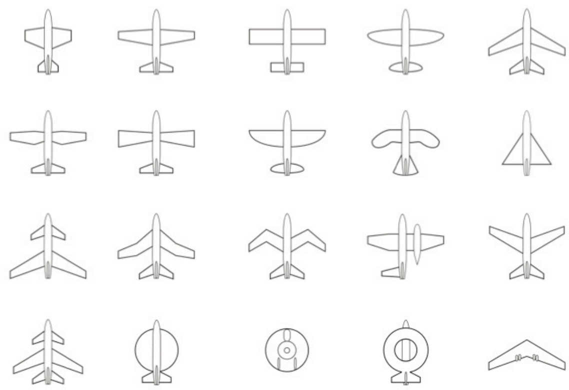

Fig. 4m. Examples of different wing designs – top view.

Given a strong enough engine thrust, airspeed and a positive AOA, even a barn door could theoretically generate sufficient lift to fly. In fact, some fighter jets have flown with only one wing on one occasion, and with their wings folded (unextended) on another occasion. In both cases significantly higher airspeed and AOA than usual was required to maintain flight. This implies that the engines were used to help compensate for the loss of lift from a reduced wingspan. For example:

- In 2016, a F-15 fighter jet landed with only one wing following a mid-air collision with an A-4 Skyhawk during training.
- In 1960, a US Vought F-8 Crusader took-off from Naples, Italy with its wings still folded (unextended). It later landed safely.

Some wing design considerations include:

- The need to maintain laminar airflow over the wing.
- Wing curvature and the Coanda effect.
- Wing design needs to be supported by sufficiently strong and light materials to maintain the aircraft's integrity.
- The features of the aircraft (e.g. engine power, aspect ratio, momentum, propeller or jet, fuel and lift efficiency, location of the engines on the aircraft, ….),
- The circumstances (e.g. maintenance issues, runway conditions, airport restrictions, regulations, ….).
- The purpose of the aircraft (commercial passenger transport, cargo, private business passenger transport, private leisure, military, STOL, VTOL, ….), as well as
- The preferences and priorities of the owners and pilots.

N. Airfoil thickness.

A key insight provided by the Newtonian approach to lift based on the mass flow rate, is that airfoil thickness affects the wing reach. In turn, wing reach is a key factor that determines the mass of air flown through (m/dt), and therefore, the lift generated (Lift = m/dt x dv). See Fig. 4n-i and Fig. 4n-ii.

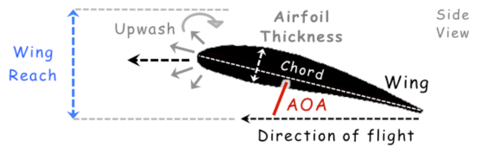

Fig. 4n-i. Airfoil thickness and wing reach.

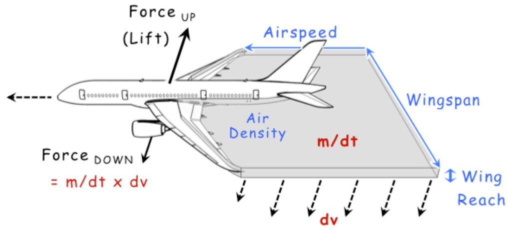

Fig. 4n-ii. Newtonian forces acting on an airplane.

Empirical evidence and statements by industry experts supports [1] supports the assertion that wing thickness affects lift generation at subsonic speeds. Optimal lift generation favors wing designs with a modest amount of thickness, over thin airfoils. For example, thin airfoils were common only in early wing designs at the beginning of the 20th Century. See Fig. 4n-ii.

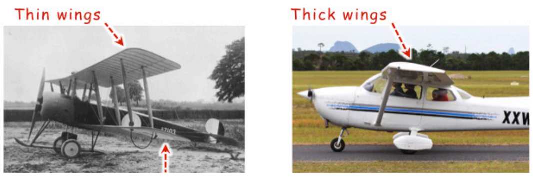

Fig. 4n-ii. Airfoils of old and modern wings compared.

However, at transonic speeds and higher thick wings can produce excess spanwise drag.

Fluid mechanics (Navier-Stokes equations), the thin airfoil, the Newtonian change in momentum, and flow-turning theories of lift consider the airfoil thickness irrelevant to lift generation. This view is despite all the evidence that airfoil thickness affects lift.

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V. Wing Airflows

A. Two absolute wing airflows.

Two key wing airflows are involved in the generation of lift by wing with a positive wing AOA. See Fig. 5a-i and 5a-ii.

1) The underside of the wing pushes air down.

2) The topside of the wing pulls air down, helped by the Coanda effect.

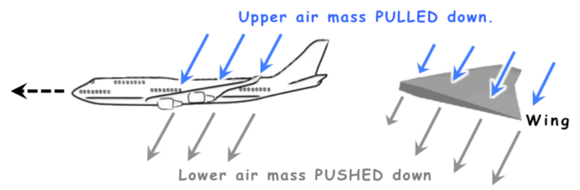

Fig. 5a-i. Two airflows on a wing.

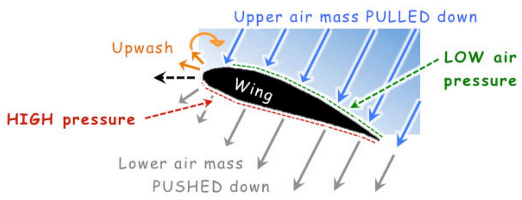

Fig. 5a-ii. 2D diagram of wing airflows.

Some considerations:

- The faster the wing flies, then:
  - The greater the force applied by the underside of the wing to accelerate the lower airflow downward to a higher velocity (dv).
  - The stronger the vacuum or low air pressure on top of the wing that is created, and the faster the upper mass is pulled down (dv).
- The upper and lower airflows can have different velocities (dv) as they have different causal forces. Nonetheless, their velocities are likely to be similar. Therefore, the two airflows create similar low internal air pressures, due to their increased velocity.
- The low-pressure created on top of the wing and the high-pressure created below the wing, are a consequence of the airflows and resultant forces. i.e. The pressure patterns observed are not a direct cause of lift.
- This explanation is somewhat different to the standard or prevailing description of wing airflows. Typically the lower airflow is described as ‘high pressure’, which is inaccurate and misleading.
- It is more accurate to say that the underside of the wing experiences high pressure, and the lower airflow experiences low internal air pressure.

The two wing airflows are described:

1) **The underside of a wing** physically pushes the air flown through below it downwards and slightly forwards. This creates high pressure on the underside surface of the wing, based on the standard equation for pressure (Pressure = Force /Area [1]). See Fig. 5a-iii.

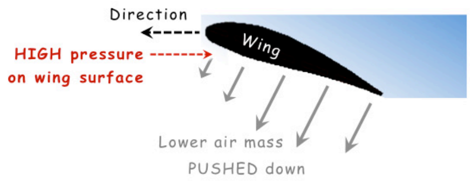

Fig. 5a-iii. Underside of the wing pushes air down

2) **On the topside of the wing** a zone of low air pressure arises, due to the forward movement of the wing creating a relative vacuum (void) behind it. See Fig. 5a-iv.

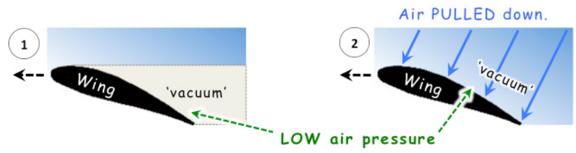

Fig. 5a-iv. Vacuum behind the topside of the wing.

The upper air mass above the wing is pulled downwards towards the topside of the wing by the low air pressure zone, helped by gravity.

In addition:

- After the wing has passed forwards, the upper air mass continues to descend from the momentum it gained.
- Any curvature on the topside of the wing can enhance downward airflows of the air above the wing due to the Coanda effect, as explained below.
- The air above the wing pulled downwards reaches the trailing edge on the wing, to avoid triggering a stall.
- The low air pressure on top of the wing is typically described as being greatest towards the leading edge.
- The theoretical path of an air molecule starting above the wing and travelling downward, as the wing passes through the air, is illustrated in Fig. 5a-v.

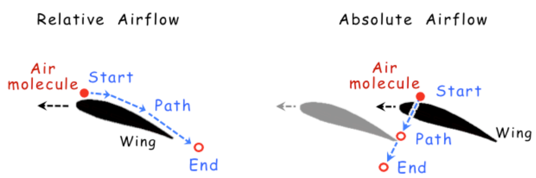

Fig. 5a-v. Theoretical path of an air molecule starting above the wing.

B. The Coanda effect – Spoon experiment.

Fluid flow naturally follows a curved surface due to the Coanda effect. For example, water falling from a tap is re-directed by the curved side of a spoon. See Fig. 5b-i.

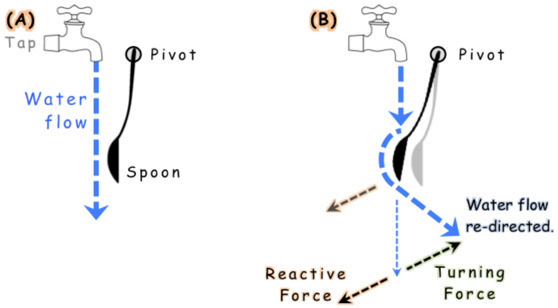

Fig. 5b-i. Coanda effect – Spoon experiment.

According to Newtonian mechanics, the water flow passively re-directed by a spoon due to the Coanda effect creates a small turning force due to the change in momentum of the water flow. The reactive equal and opposite force pushes the spoon diagonally to the left sideways and downward. However the spoon pivots to the left as far as the reactive force allows.

Wind tunnel experiments

Wind tunnel experiments demonstrate airflows arising due to the Coanda effect on the topside of a curved airplane wing, as well as the turbulence that arises on a flat wing. See Fig. 5b-ii.

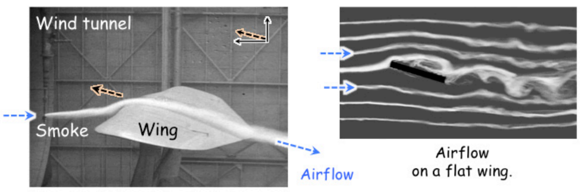

Fig. 5b-ii. Airflow on curved and flat wings. [6]

In general, wings produce a stronger Coanda effect with laminar (smooth / non-turbulent) airflow at a lower AOA, higher airspeed, and where the wings are deepest (largest chord, such as near the fuselage). Conversely, the Coanda effect is weakest at high AOA, slower airspeeds, and where the wings are narrow (small chord, such as at the wing tips). See Fig. 5b-iii.

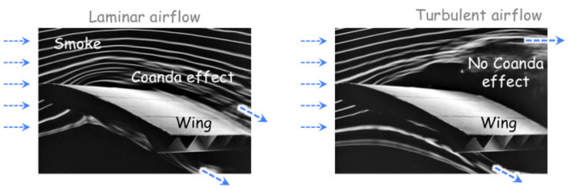

Fig. 5b-iii. Smooth vs. turbulent airflows on a wing. [9]

The flat undersides of wings are typically designed to push air down without inducing any Coanda effect.

Coanda effect and fighter jet wings

Some fighter jet wing and fuselage designs show pronounced curvature that maximizes the Coanda effect. See Fig. 5b-iv.

Fig. 5b-iv. Curved fuselage designs of jets. [7][8]

The Coanda effect helps to explain why airplanes keep the topside of wings clear of any obstructions that could disrupt the upper airflows. For example fighter jets almost always carry their payloads under their wings. There are usually other reasons for this as well (eg. ease of maintenance, many bombs are dropped so cannot be on the top of wings, ….). See Fig. 5b-v.

Fig. 5b-v. Fighter jet payloads. [13]

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VI. Applying Newtonian Mechanics

A. Standard equations for drag and lift.

Newtonian physics explains the standard equation for drag: [1]

Drag = 0.5 (Aircraft Velocity^2 x Surface Area
x Air Density x Drag Coefficient)

The standard equation for drag is simply a mathematical description of how drag is observed to vary in practice with different parameters. Until now there has been no adequate explanation of the physics involved.

All parameters of the standard equation for drag (aircraft velocity, air density, surface area, and drag coefficient) affect the mass of air flown through each second by the fuselage (m/dt$_{DRAG}$); and/or the velocity to which this air is accelerated away from the aircraft (dv$_{DRAG}$). Therefore, the drag equation can be explained by Newtonian mechanics based on the mass flow rate (Force = ma = m/dt x dv); as shown by the analysis below. In subsonic flight, drag arises primarily from the fuselage, vertical tail section, engines, and spanwise wing airflow. See Fig. 6a-i.

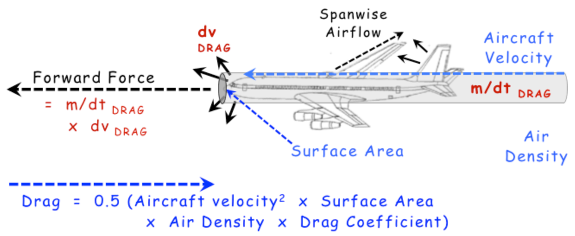

Fig. 6a-i. The standard and Newtonian equations for drag.

The analysis is provided in three steps:

(i) The Newtonian and standard equations are equated:

Newtonian = Standard equation
Force$_{FORWARD}$ = Drag
m/dt$_{DRAG}$ x dv$_{DRAG}$ = 0.5 (Velocity^2 x Surface Area
x Air Density x Drag Coefficient)

(ii) The equation above is revised as follows:

m/dt$_{DRAG}$ = (Velocity x Surface Area x Air Density) (a)
x dv$_{DRAG}$ x 0.5 (Velocity x Drag Coefficient) (b)

(iii) Then the two parts of the Newtonian equation (m/dt$_{DRAG}$ and dv$_{DRAG}$) are correlated to two different parts of the standard equation of drag, (a) and (b):

m/dt$_{DRAG}$ = Velocity x Surface Area x Air Density (a)
= (Velocity x Surface Area) x Air Density
= **Volume$_{DRAG}$ /dt** x Air Density
= m/dt$_{DRAG}$

dv$_{DRAG}$ = 0.5 x Velocity x Drag Coefficient (b)

Where: Velocity = Aircraft velocity.
Surface Area = Surface area of the aircraft fuselage, engines, and tail in the direction of travel.

It is no coincidence that the standard equations for lift and drag are similar, as they are explained by Newtonian mechanics.

Newtonian physics explains the standard equation for lift: [1]

Lift = 0.5 (Aircraft Velocity^2 x Wing Area
x Air Density x Lift Coefficient)

The standard equation for lift is simply a mathematical description of how lift is observed to vary in practice with different parameters. Until now there has been no adequate explanation of the physics involved.

All parameters of the standard equation for lift (aircraft velocity, air density, surface area, and drag coefficient) affect the mass of air flown through each second by the wings (m/dt); and/or the velocity to which this mass of air is accelerated downward (dv). Therefore, the standard equation for lift can be explained by Newtonian mechanics based on the mass flow rate (Force = m/dt x dv); as shown by the analysis below: See Fig. 6a-ii.

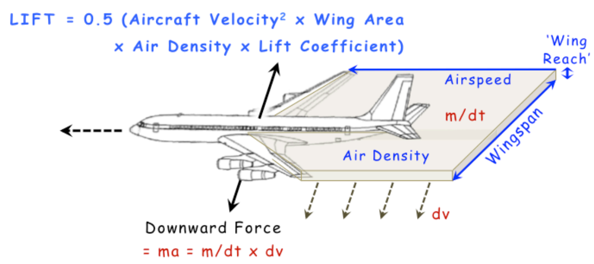

Fig. 6a-ii. The standard and Newtonian equations for lift.

The analysis is provided in three steps:

(i) The Newtonian and standard equations are equated:

Newtonian = Standard equation
Force$_{DOWN}$ = Lift
m/dt x dv = 0.5 (Velocity^2 x Wing Area
x Air Density x Lift Coefficient)

(ii) The equation above is revised as follows:

m/dt x dv = 0.5 (Velocity x Wing Area x Air Density) (a)
x (Velocity x Lift Coefficient) (b)

(iii) Then the two parts of the Newtonian equation (m/dt and dv) are correlated to two different parts of the standard equation of lift, (a) and (b):

m/dt = 0.5 x Velocity x **Wing Area** x Air Density (a)
= 0.5 x Velocity x (**Wingspan x Chord**) x Air Density
= (Velocity x Wingspan x (**0.5 x Chord**)) x Air Density
= (Velocity x Wingspan x **Wing Reach**) x Air Density
= **Volume /dt** x Air Density
= m/dt

dv = Velocity x Lift Coefficient (b)

Where: Velocity = Aircraft velocity.
Wing Area = Wingspan x Chord
Wing Reach = 0.5 x Chord

Conclusions

The analysis above shows that Newtonian mechanics can explain the standard equations for drag and lift. In addition the analysis demonstrates that the drag and lift coefficients depends on 'dv', the velocity to which the fuselage or wings accelerates the air.

B. Why lift increases with airspeed.

The Newtonian approach can be used to better explain all aspects of lift generation. For example, if two almost identical light aircraft (A) and (B) are compared. Where Aircraft (B) has a higher mass, it needs to generate more lift to fly. See Fig. 6b.

Aircraft (B) can generate extra lift (Lift = m/dt x dv) by increasing its airspeed and engine power, while maintaining its wing AOA. As a result it flies through a greater mass of air each second (higher m/dt); which it accelerates downwards to a higher velocity (higher dv).

Therefore, lift increases in the heavier Aircraft (B), due to higher 'm/dt' and higher 'dv', as shown by the equation:

Higher Lift = higher m/dt x higher dv

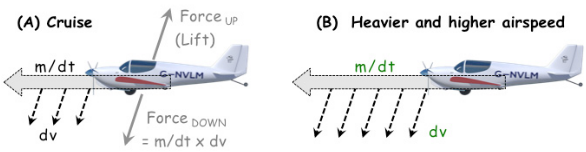

Fig. 6b. Two aircraft compared.

Also, Aircraft (B) has a greater momentum, and therefore, it has more momentum to transfer to the air to generate lift.

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C. Why lift quadruples if airspeed doubles.

Consequently, Newtonian mechanics can explain why vertical lift is proportional to the square of horizontal aircraft velocity, as described by the standard equation for lift :

Lift = 0.5 (**Aircraft Velocity**^{2} x Air Density
x Wing Area x Lift Coefficient)

For example, if the aircraft's velocity doubles, then lift quadruples as: See Fig. 6c.

a) An aircraft travelling twice as fast, so the wings fly through twice the mass of air each second (2x m/dt);

b) The wings accelerate this air to twice the velocity downward as before (2x dv), as aircraft momentum has also doubled (Momentum = mass x velocity).

Then applying the Newtonian equation for the generation of lift: Lift = m/dt x dv

The combined effect of the two changes (a) and (b) above, is to quadruple the Force $_{DOWN}$, and therefore, quadruple the lift generated:

4 x Force $_{DOWN}$ = (2 x m/dt) x (2 x dv)
= 4 x Upward Force (Lift)

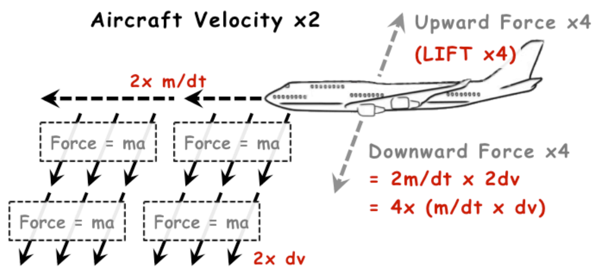

Fig. 6c. Lift ⇔ Aircraft Velocity^2

The explanation above is new and has not been presented elsewhere previously.

VII. Flight Manoeuvers

A. Overview.

Newtonian mechanics based on the mass flow rate is used to explain lift during all flight manoeuvers, using the equation:

$$Lift = m/dt \times dv \tag{5}$$

Flight manoeuvers can be shown to affect lift (Lift = m/dt x dv), depending on how the mass of air flown through each second (m/dt) and/or the velocity to which this air is accelerated downwards (dv) change with the alterations in aircraft orientation and circumstances (e.g. airspeed, wing AOA, …). See Fig. 7a.

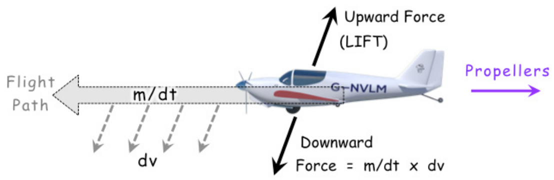

Fig. 7a. Newtonian forces acting on a wing.

The flight manoeuvers analyzed below include: [2]

- Cruise flight.
- Increased airspeed.
- Inverted flight.
- Take-off / 'nose-up' climb.
- Flaps.
- Slow flight.
- Change in aircraft mass.
- Final approach to a runway.
- Landing.
- Vertical climb.
- Vertical descent.
- Steep descent.
- Power-off descent.
- Wing AOA.
- Banking and adverse yaw.
- Side slipping.
- Propeller forces.

Key conclusions:

Flight manoeuvers can be accurately described using Newtonian explanation for lift (Lift = m/dt x dv). Variations in 'm/dt' and 'dv' change how the lift is generated based on aircraft configuration changes.

The composition of lift between 'm/dt' and 'dv' can be shown graphically for different configurations. See Fig. 7b and 7c.

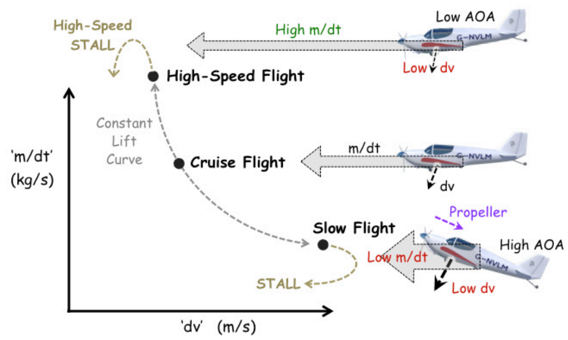

Fig. 7b. Lift composition – 'm/dt' and 'dv compared.

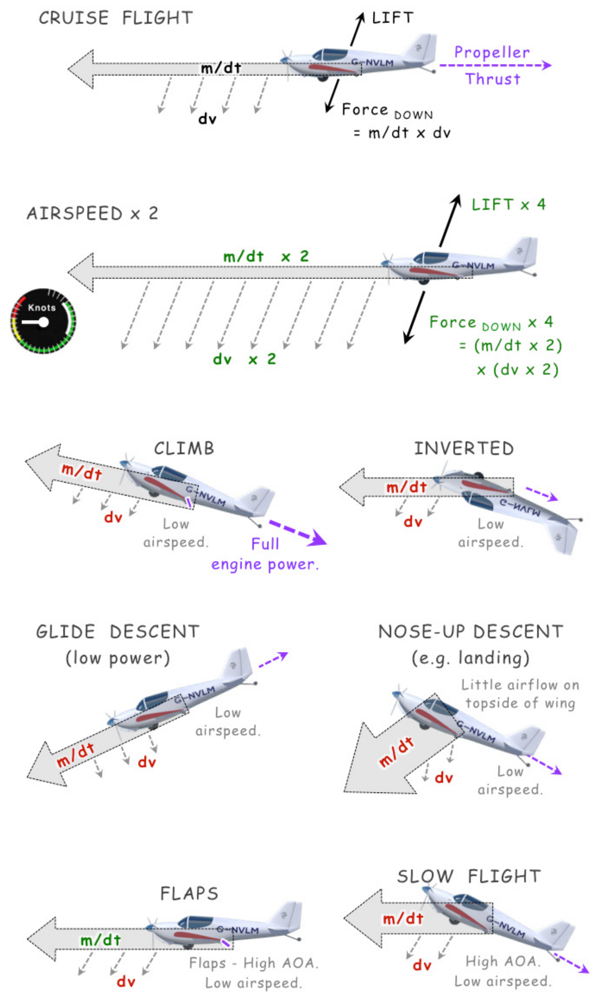

Fig. 7c. Key flight manoeuvers summarized. [2]

Key; compared to cruise flight:

m/dt or dv = Decreased 'm/dt' or 'dv'.

m/dt or dv = Increased 'm/dt' or 'dv'.

See the full report for the detailed explanations [2]

VIII. Practical Aspects of Flight

A. *Overview*

The different practical aspects of flight are explained by Newtonian mechanics based on how the mass of air flown through (m/dt) and the velocity to which this air is accelerated (dv), vary to affect lift (Lift = m/dt x dv), based on the conditions involved. See Fig. 8a-i and 8a-ii.

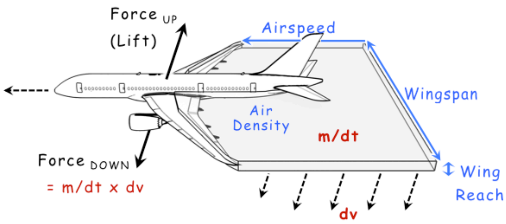

Fig. 7a-i. Newtonian forces acting on an airplane.

The practical aspects of flight include: [2]

- Engine positions on the wings.
- Altitude.
- Wind and air currents.
- Hovering.
- Gliding.
- Anhedral vs. Dihedral wings.
- Winglets.
- Prandtl flying wing.
- Tail section and pitch.
- Canards.
- Variable sweep wings.
- Variable pitch propellers.
- Double propellers.
- Biplanes and box-wings.
- Airfoil thickness.
- Drogue parachute.
- Delta wing aircraft.
- Variable angle of incidence.
- Ground effect.
- Supersonic flight.
- Sonic boom.

Key conclusions:

All practical aspects of flight can be accurately described using Newtonian explanation for lift (Lift = m/dt x dv). Variations in ‘m/dt’ and ‘dv’ change how the lift is generated depending on the circumstances.

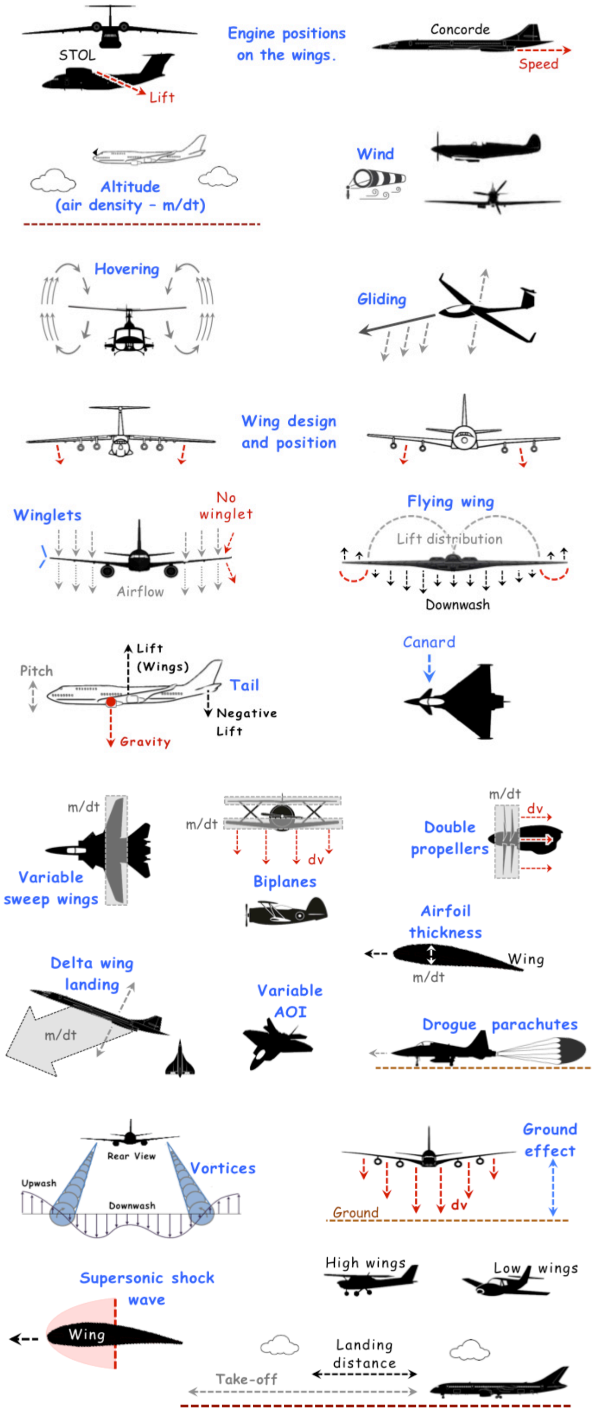

Fig. 8a-ii. Some practical aspects of flight. explained by Newtonian mechanics.

See the full report for the detailed explanations [2]

IX. Kinetic Energy and Lift

A. Kinetic energy and lift.

Analysis using the Newtonian explanation of lift based on the mass flow rate (Lift = m/dt x dv,) proposes the following:

- Aircraft momentum determines the capacity of the wings to accelerate air downwards (dv) to generate lift.
- The kinetic energy required to accelerate air downwards is proportional to the velocity of the downwash squared (K.E. = 0.5 mv^2).

Therefore, fighter jets (Harrier) with significant momentum due to large aircraft mass and airspeed, can accelerate air downwards aggressively (high dv) as the main source of lift (Lift = m/dt x dv). This allows jets to fly with short wingspans, and therefore, as they do not rely on the mass of air flown through by the wings each second (m/dt) as the main source of lift. However, this method of generating lift energy inefficient. See Fig. 9a-i.

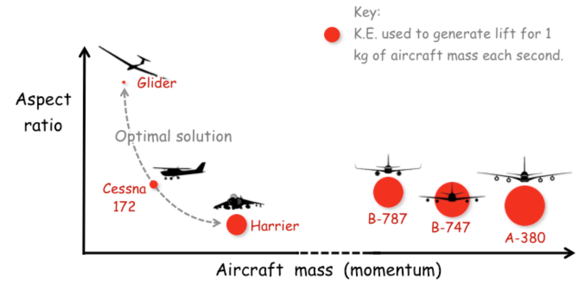

Fig. 9a-i. Graph of aircraft aspect ratios, mass, and K.E. Lift.

In contrast, a slow and light glider lacks aircraft momentum, and therefore, can only produce low downwash velocities (low dv). In the absence of 'dv' as a source of lift, a glider must have a long wingspan (high aspect ratio) to optimize 'm/dt' in order to generate enough lift (Lift = m/dt x dv) to fly.

Similarly, Newtonian mechanics also proposes the following:

- A Boeing 787 (B-787) airliner is more energy-efficient at generating lift, as compared to a heavier Boeing 747 (B-747) with the same airspeed and wingspan. The B-747 generates a greater proportion of lift by accelerating the downwash to a higher velocity (higher dv), which is energy inefficient. See Fig. 2e-iii-1 and Fig. 9a-ii.

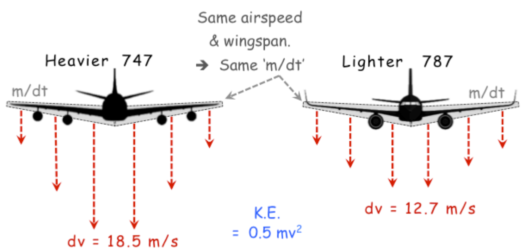

Fig. 9a-ii. Lift generation by a B-747 and B-787.

B. K.E. Lift.

Statistical analysis was conducted on 98 aircraft in six broad types based on the Newtonian approach to lift. The objective was to assess and compare the energy efficiency of lift generation for each 1 kg of aircraft mass (K.E. Lift).

Analysis showed that aircraft mass and K.E. Lift were positively correlated. In general, larger aircraft were found to be increasingly inefficient at generating lift. See the Graph in Fig. 9b.

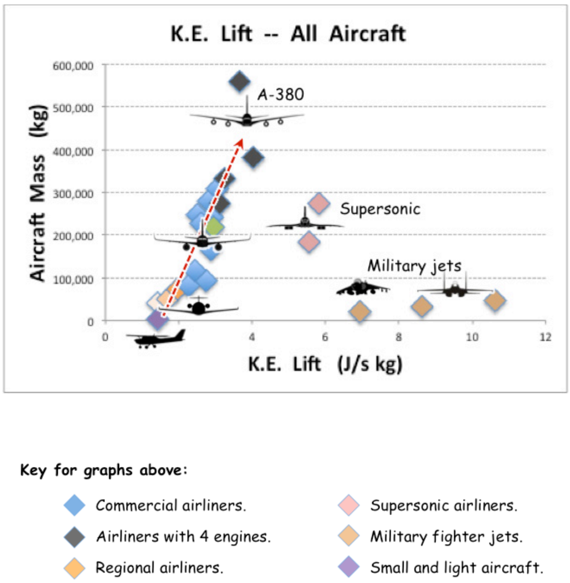

Fig. 9b. Graph 1: Aircraft mass against K.E. Lift for all aircraft analyzed.

In particular, the heaviest airliners with four engines (e.g. A-380) and supersonic airliners were the most energy inefficient as compared to other airliners.

Military fighter jets were also particularly inefficient at generating lift, and were outliers in the results. This is unsurprising as fighter jets prioritize function (speed and heavy payloads) over fuel efficiency.

This dynamic is because the heavier aircraft relied on generating lift (Lift = m/dt x dv) by accelerating the air flown through each second (m/dt) downward more aggressively at higher velocities (high dv). This method of lift generation is energy inefficient; because the kinetic energy required to accelerate the air downwards is proportional to the downwash velocity squared (K.E. = 0.5 mv^2).

In addition, heavier aircraft had greater aircraft momentum available to transfer to the air, allowing them to accelerate air downwards aggressively to higher velocities (high dv).

In fact, due to their relatively short wingspans heavy aircraft have no choice but to generate lift inefficiently by accelerating air downwards to high velocities (high dv).

C. Three example calculations - summary.

The physics for the optimal wing design (aspect ratio) is illustrated below by three example calculations, which compare how different aircraft generate lift (Lift = m/dt x dv), as split between 'm/dt' and 'dv':

1) A glider and fighter jet are compared.

- **A slow and light glider,** which is built for leisure and efficiency. It has no engine, a high aspect ratio wings (long wingspan) and little momentum. See Fig. 9c-i.

  Without an engine and little momentum, a glider has no choice but to fly in an energy-efficient manner. This precludes the ability to accelerate the air downwards very fast (dv). In turn, these factors necessitates the glider having a long wingspan, which is one of the key factors that affect the mass of air that the wings fly through each second (m/dt).

  To put it another way, a glider is energy-efficient at generating lift as its long wingspan that flies through a large mass of air each meter. However, its low airspeed limits the mass of air flown through each second (m/dt), It accelerates this air downwards to a low velocity (low dv), to generate the small amount of lift required to fly.

- **A heavy fast fighter jet (Harrier),** with low aspect ratio wings (short wingspan). It is built for speed (with powerful engines), maneuverability, and the ability to carry heavy payloads (weapons).

  The Harrier is energy-inefficient at generating lift, as it relies on a short wingspan and high airspeed to fly through a large mass of air each second (m/dt); which it must accelerate downwards at high velocity (high dv), in order to generate the substantial amount of lift required to fly.

  The Harrier is able to accelerate the downwash to a high velocity because it has significant aircraft momentum available, which it can transfer to the air to generate lift. In addition, the low aspect ratio wings mean it has enough wing depth to accelerate the air flown through downwards. Wing depth for a wing has a similar function to the accelerator pedal of a car.

  The Harrier is energy-inefficient because the kinetic energy required to accelerate the downwash is proportional to its velocity squared (i.e. K.E. = $0.5\ mv^2$).

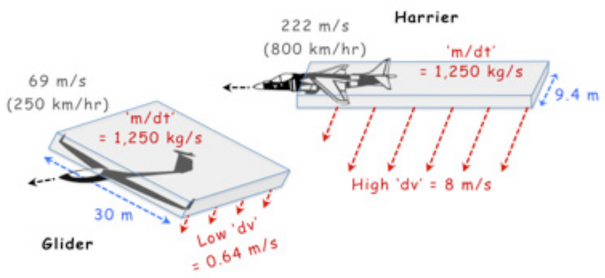

Fig. 9c-i. 'm/dt' and 'dv' for a Harrier and glider compared.

The physics and principles that determines the optimum wing design for aircraft, also determines the optimum wing design for birds. See Fig. 9c-ii.

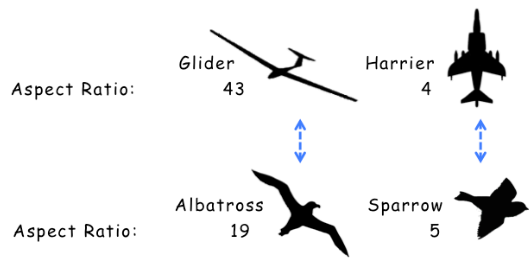

Fig. 9c-ii. Typical aspect ratios of airplanes and birds.

For example, a sparrow's wings have a low aspect ratio with a narrow wingspan and deep wings, similar to the Harrier. Also similar to the Harrier, the sparrow excels at maneuverability and high-speed flight over short distances.

Whereas the albatross' wings have a high aspect ratio with a long wingspan and narrow wings, similar to a glider. Albeit, the glider has a significantly higher aspect ratio than the albatross. Also similar to the glider, the albatross excels at efficient, long distance flight.

2) Two airliners, B-747 and B-787 are compared.

- A heavy B-747 has the same wingspan and airspeed as a lighter B-787. Therefore, both airliners fly through approximately the same mass of air each second (same m/dt). See Fig. 9c-ii.

- However, to generate additional lift required to fly, a heavy B-747 has no choice but to accelerate the air flown through downwards to a higher velocity (higher dv); which is energy inefficient. See Fig. 9c-iii.

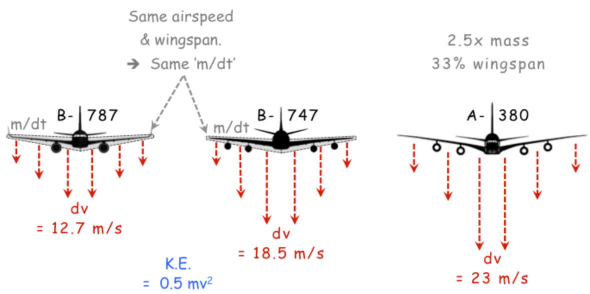

Fig. 9c-iii. B-747, B-787, and A-380 compared.

3) The Airbus 380.

- The logic described above can be applied to explain why the Airbus 380 failed due to cost inefficiencies, as compared to other airliners such as the B-787. See Fig. 9c-iii.

- In short, the A-380's mass was excessive for its short wingspan. i.e. The A-380's aspect ratio was too low for efficient lift generation.

  To generate the substantial amount of lift needed to fly, the A-380 had to accelerate the downwash to a significantly higher velocity (higher dv), as compared to the B-787. This is an energy-inefficient method to generate lift.

D. Significance.

The approach described allows for a straightforward method to assess the benefits (energy efficiency) of any changes in wingspan to an airplane.

Analysis shows that the A-380 was significantly more energy inefficient at generating lift, as compared to other heavy airliners. The A-380's wings were too small for its large mass. Consequently, it relied heavily on aggressively accelerating air downwards (high dv) to generate lift.

Airbus' cancellation of the A-380 loss-making production in 2021 means that it is never recover the estimated EUR 25 bn development costs. These large losses could have been avoided by using Newtonian mechanics to assess the viability of the A-380 prior to their development.

A similar approach could now be taken to assess the energy efficiency proposed new supersonic airliners such as Aerion and Spike. This could potentially save significant amounts of money by avoiding the costly error of building air airplane that is too inefficient at flight.

NASA and the theory of lift.

NASA's website justifies using both Newtonian and Fluid mechanics to explain lift because Newtonian physics provides no method to account for the energy used in flight, but fluid mechanics does.

"Bernoulli vs. Newton: …. For a gas, we have to simultaneously conserve the mass, momentum, and energy in the flow. Newton's laws of motion are statements concerning the conservation of momentum. Bernoulli's equation is derived by considering conservation of energy." [1] NASA uses 'Bernoulli' to mean fluid mechanics in this context.

Therefore, this paper is significant because it provides the method of calculate the kinetic energy used to generate lift, consistent with Newtonian mechanics. In turn, this opens the door to use only Newtonian mechanics to explain lift, and to disregard fluid mechanics.

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X. Discussion of Results

A. Newton explains lift.

Newtons Laws of Motion link the forces that act on objects (airplanes) to the changes in the states of motion (lift and flight) observed in these objects. It is puzzling that anyone would dispute this statement and that engineers overlooked the Newtonian explanation of lift.

Newtonian mechanics based on the mass flow rate (Lift = m/dt x dv) provides a new method to assess how wings produce lift. See Fig. 10a.

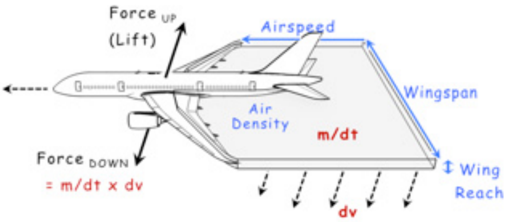

Fig. 10a. Newtonian forces acting on a wing.

B. Significance.

This novel approach to lift and flight has not been proposed previously. It provides new and useful insight, including:

- It differentiates between **actively and passively generated forces,** and therefore, the process and direction of the forces generated.
- It identifies that **absolute airflows** is better than relative airflow analysis and wind tunnels to analyse lift.
- **It provides an equation for lift that can be applied universally** to all aircraft, birds, insects, and objects that fly by pushing air downwards.
- Identifies that **wings circulate a large mass of air** in flight.
- There's no evidence that disproves these assertions.
- The argument for lift and buoyancy can be tested by experimentation, and therefore, verified or rejected.
- No other theory of lift provides this depth of analysis of lift that is consistent with all the aspects of flight above. For example, fluid mechanics typically only attempts to explain lift for an airplane in a stable cruise flight.

This new Newtonian approach fundamentally changes the prevailing views held for the last 100 years that fluid dynamics explains lift based on relative wing airflow analysis; and that lift must equal the weight of the aircraft (Lift = Weight) to fly. Previous research appears to have simply overlooked key aspects of how lift is generated by an airplane wing,

C. Benefits.

The benefits of the Newtonian approach include:

- Allows **lift** (Lift = m/dt x dv) to be more accurately calculated and analyzed by differentiating between 'm/dt' and 'dv'.
- Less resources wasted on inaccurate methods used to assess lift, such as fluid mechanics (NS equations).
- Provides a method to calculate the **kinetic energy** used to generate lift, which is shown to be proportional to velocity square of the downwash (K.E. = 0.5 mv^2).
- Provides significant **cost savings** by reducing the amount of trial and error involved in to **aircraft and wing design,** as well as the extensive amounts of **performance testing** associated with new aircraft. It is possible to more accurately predict wing performance under different conditions (bank angle, AOA, airspeed, ….).

  For example, aircraft manufacturers rely on intuition, trial and error to design and build airplanes. [27] They do not use any one theory or equation for lift. This is partly why Boeing's latest airliners (e.g. B-787) look so similar to their previous models (e.g. B-747). Boeing just tries to improve on the designs that they know work.
- **Avoid costly new aircraft failures** of making inefficient aircraft, such as Concorde and the A-380.
- Better assess proposed new technologies, such as supersonic and hypersonic aircraft, wing morphing, flying wings, ….
- **Design a more fuel efficient wing.** Aircraft manufacturers can more easily and accurately assess the most fuel-efficient aspect ratio and flight configuration (e.g. wing AOA, airspeed, …) for wings to generate lift under different conditions and priorities.

  For example, at present airliners fly at a standard cruise speed for an entire flight. However, as aircraft mass varies significantly during flight due to fuel burn, the optimum flight configuration varies a lot during the flight. It may be more efficient to fly at a slower airspeed in the earlier stages of a long haul flight.
- **Improve pilot training and aviation safety** by providing a simple, intuitive, and easily understood explanation for lift and flight. If pilots are taught the correct physics of flight, they are likely to crash.

  A better understanding of how airplanes fly could improve pilot responses to a loss of control in-flight and equipment failure. This could reduce the number of uncontrolled descents into terrain; which remain a significant cause of fatal aviation accidents.
- Provide improved **flight instruments**.

  For example, wing AOA is closely related to both 'm/dt' and 'dv', and therefore, the lift generated (Lift = m/dt x dv). Newtonian mechanics provides the intellectual explanation for flying based on AOA indicators, which provide an improved measure of the lift generated. AOA indicators are already installed in many military airplanes and commercial aircraft, but are not installed in all aircraft. See Fig. 10c.

Fig. 10c. Example of an AOA indicator.

- **New developments** can be gained by applying the Newtonian approach described in this paper.

  For example, it is proposed that a glider could circumnavigate the globe against the jet stream, by passively re-directing the relative airflow to generate thrust. In addition, this approach could also be applied to generate thrust by boats or air transport vehicles such as rigid airships (blimps).

- Improve the **reputational image** of aeronautical engineers, physicists, and the aviation industry by resolving the debate on the physics of lift and flight, after over one hundred years of heavier-than-air flight.

- The Newtonian approach **solves a variety of enigmas and conundrums**, including:
  - How a wing generates lift.
  - Why lift quadruples if aircraft velocity doubles.
  - How a glider can soar into wind (dynamic soaring).
  - The lift paradox (thrust-to-weight ratios of 0.3).
  - DDWFTTW.
  - d'Alembert's paradox 1752.

- The Newtonian principles for lift can be applied to **other related areas,** where surfaces (airfoils) actively or passively generate a force. For example designing better propellers, rotors, wind turbine blades, and sails.

No serious attempt to resolve this dispute on the causes lift has been made for a very long time. However, after a hundred years of designing and building airplanes, it is reasonable to expect that academics and engineers should have solved the physics by now. Better late than never?

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D. Pilots become better aviators.

The Newtonian approach to lift is extremely useful to enable pilots to become better aviators. Pilots are taught a variety of incorrect theories of lift at present.

Aviation authorities (e.g. FAA, CAA, EAA; …) recommend that pilots are taught a theory of flight based on the Venturi effect and Bernoulli's principles of fluid dynamics. NASA describes this and some theories commonly believed to be true as 'incorrect'. [1] In addition, some academics discredited Bernoulli's theorem as an explanation for lift in airplanes at least as early as 1972. [35]

NASA's website states: "There are many explanations for the generation of lift found in encyclopedias, in basic physics textbooks, and on web sites. Unfortunately, many of the explanations are misleading and incorrect. Theories on the generation of lift have become a source of great controversy and a topic for heated arguments." [1]

Pilots aren't even taught the prevailing view theory of lift based on fluid mechanics, which is used by most engineers and academics. This aspect is partly because fluid mechanics is mathematically complex and difficult to explain in simple terms.

On the other hand, the Newtonian approach to lift is simple and easy to understand. It is also in line with the Newtonian physics advocated by Wolfgang Langeweische in the book: "Stick and Rudder" (1944). [3] This book is famous among pilots for its accurate, practical and common-sense advice on how to fly an airplane.

E. Associated papers.

This paper is an abbreviated version of a more detailed (300+ page) pre-print research paper by the author: "Newton explains lift; Buoyancy explains flight. The physics of how airplanes stay airborne." [2]

XI. Conclusions

A. Résumé.

Applying Newtonian mechanics based on absolute airflow analysis and the mass flow rate provides a better explanation for how lift is actively generated by wings, than is currently available. This novel approach has not been proposed previously and provides new and useful insight into the physics of lift.

The new Newtonian explanation allows lift to be better understood and more accurately measured. In turn, it can be used to improve: aircraft and wing design, pilot training, computer simulations, and aviation safety.

The consequent financial and economic benefits could be substantial. For example, better wing design could provide large fuel savings. Less time and resources would be wasted on incorrect theories of lift, which provide sub-optimal solutions. Aircraft that generate lift inefficiently, such as the EUR 25 bn loss from the A-380, could be avoided.

XII. Additional Information

Corresponding authors: Mr. Nicholas Landell-Mills. Email: nicklm@gmx.com.

Background: The author is British and was born in 1966 in Botswana. He is an independent researcher and held a private pilot's license (PPL). He flew and maintained a single-engine, home built airplane (Europa XS monowheel reg: G-OSJN).

Affiliations: The author is a graduate of the Dept. of Humanities and Social Sciences, The University of Edinburgh, Edinburgh, UK. He was awarded a M.A. degree class 2:1.

Author Contributions: This paper is entirely the work of the author, Mr. Nicholas Landell-Mills.

Disclaimer: The author confirms and states that all data in the manuscript are authentic, there are no conflicts of interest, and all sources of data used in the paper are acknowledged where possible.

Funding: This paper was self-funded by the author.

If you found this paper to be useful, entertaining or worthy, then kindly support this independent research by a small donation to the author via www.PayPal.com to the email nicklm@gmx.com (not gmail).

This paper could not have been produced through the established system, partly as it directly challenges the prevailing explanation of lift. Thank you.

Acknowledgments: None.

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Appendix I – Unresolved Theory of Lift

A. *The theory of lift remains unresolved.*

The physics of lift is disputed. There is no scientific experiment on a real aircraft in realistic conditions that proves any theory or equation for lift to be true.

Fig. I-a. Unknown.

Experts still cannot agree whether aircraft generate lift by being pulled upwards according to fluid mechanics, or pushed upwards according to Newtonian mechanics; nor exactly what role vortices play. This is surprising given airplanes have been flying for over a hundred years.

Academics, engineers, aircraft manufacturers, pilots, aviation authorities, and other pundits (e.g. NASA) promote over twelve diverse theories of lift. New theories are occasionally proposed.

Worse, there is no accepted universal theory of how lift is generated that applies to all objects that fly. Airplanes, helicopters, birds and insects each have their own unique explanations. Different theories are used to explain lift in different insects. This aspect is highly inconsistent.

B. *Media and academic commentary.*

The media occasionally comment on the ongoing debate about the mysterious, unproven and unknown causes of lift:

- "Staying Aloft; What Does Keep Them Up There?" in New York Times, 2003. [23]
- "How Do Airplanes Fly?" in Live Science, 2006. [24]
- "The secret to airplane flight. No one really knows." in the National Newspaper, 2012. [25]
- "There's No One Way to Explain How Flying Works," in Wired Magazine, 2018. [26]
- "No One Can Explain Why Planes Stay in the Air." in the Scientific American magazine, 2020. [27]

Academic journals occasionally address this issue as well:

- "Quest for an Improved Explanation of Lift," in the AIAA journal, 2012. [28];

The physics on how birds fly is also debated:

- "….to date, flapping flight is not fully understood." [29]
- "….there are still myriad open questions about how animals fly with flapping wings," [30]

C. *Academics, engineers, pilots, pundits, …..*

Various groups promote at least twelve radically different theories of flight, which include:

- **Academics and engineers** prefer complex models based on **fluid mechanics** (e.g. Bernoulli, Navier-Stokes, Euler, ….). They frequently confuse mathematical proof, wind tunnel experiments or computer simulations (e.g. CFD) for scientific evidence.
- **Aircraft manufacturers and designers** (e.g. **Burt** Rutand) design wings by **intuition, trial and error,** rather than by any particular theory or equation for lift. [27][32][33][34]

  Similarly, micro unmanned vehicles (drones) are simply built to **mimic bird and insect flight**, without the designers fully understanding of the physics involved.
- **Pilots** prefer **Newtonian based theories of lift.** Simply put, wings push air downwards and the reactive equal and opposite force pushes the airplane upwards. Momentum is transferred from the airplane to the air.
- **NASA** sits on the fence in this debate, and supports both explanations of lift. "So **both Bernoulli and Newton are correct**." [1] NASA fails to state what proportion of lift is explained by Bernoulli and Newton; 50/50? Or 70/30?

  However, both Newtonian and fluid mechanics cannot be true as they provide very different and incompatible explanations of lift. How can NASA not know which theory of flight is correct?
- **Aviation authorities** (e.g. FAA, CAA, EAA; …) recommend that pilots are taught a theory of flight based on the **Venturi effect and Bernoulli's principles** of fluid dynamics. NASA describes this theory to be incorrect' [1] and academics discredited Bernoulli's theorem as an explanation for lift at least as early as 1972. [35]
- **Other groups** promote a mixture of different theories of lift based on vortices, the Magnus effect, the Coanda effect, …..
- Some group advocate that the **pressure differential** on a wing explains lift. However, pressure is a consequence of a force (Pressure = Force/Area), not a cause. Correlation of pressure and lift on a wing does not prove causality.
- **Empirical observation:** The **factors** that affect lift in practice have been observed and measured; as summarized by the standard equation for lift: [1]

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

However, this equation only describes the factors that affect lift; it does not explain why these factors affect lift.

In particular, fluid mechanics fails to explain the physics of the standard equation for lift, but Newtonian mechanics can. For example, only Newtonian mechanics can explain why lift quadruples if aircraft velocity doubles.

APPENDIX II – DEFINITIONS

A. *Abbreviations for aircraft.*

- A-380 – Airbus 380
- A-320 – Airbus 320
- B-787 – Boeing 787
- B-747 – Boeing 747

B. *Abbreviations and definitions of terms.*

- AOA – Angle-of-Attack.
- Aspect ratio. Wingspan divided by wing depth (chord). See Fig. II-b-i.

$$Aspect\ Ratio \ = \ \frac{wingspan}{mean\ wing\ depth\ (chord)}$$

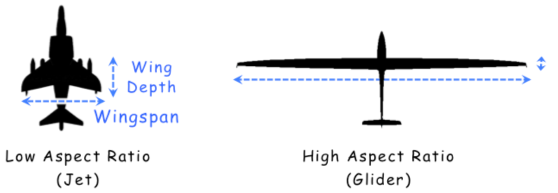

Fig. II-b-i. Aircraft with different wing aspect ratios.

- Chord – Wing depth.
- Engine Thrust − The force generated by the propeller of jet engines by accelerating air backwards, to create backwash and a backward force.
- Flight – when the aircraft or object is airborne (flying).
- The glide ratio is the horizontal distance travelled divided by the vertical distance (altitude) lost an unpowered downward glide, as shown by the equation:

  Glide ratio = Horizontal / Vertical distance
- Gravity – A force towards the ground (or center of the earth) equal to 9.8 m/s^2 [1].
- Lift − Vertical force pushing the airplane up against gravity; in the direction away from the ground.
- Lift v. Flight. Lift is a force that pushes an aircraft up against gravity. Whereas flight describes the conditions when lift is sufficient for an aircraft to be airborne. It is important to note that an aircraft can generate lift but not fly.
- MTOW – Maximum Take-Off Weight
- STOL – Short Take-Off and Landing.
- Thrust-to-weight ratio – The maximum engine thrust divided by the aircraft's maximum take-off weight (MTOW).

  i.e. Maximum Engine Thrust / MTOW
- Thrust – Engine thrust.
- Weight − Mass multiplied by gravity. [1]

  i.e. Weight = Mas x Gravity (9.8 m/s^2)
- Wing reach = This is a new term that includes the vertical distance facing the direction of travel that the wing influences the air. See Fig. II-b-ii.

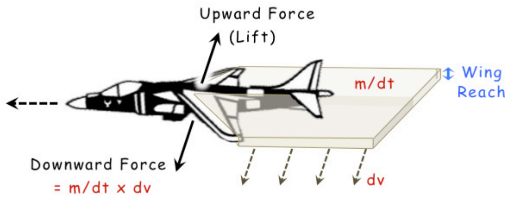

Fig. II-b-ii. Wing reach diagram.

Wing reach includes the air that the wing directly pushes out of its path due to the volume of space that the wing passes through. Therefore, wing reach depends on:

- Airfoil's thickness.
- Wing AOA.
- The air above and below the wing that is directly affected by the wing's path through the air.

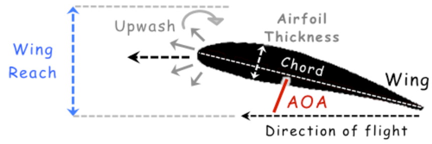

Fig. II-b-ii. Wing reach in a wing cross-section.

Wing reach does not include the air indirectly affected by the wing, which is the air displaced by the air that the wing directly flies through.

Wing reach is a key assumption in the calculation of the air flown through each second (m/dt) by a wing. The greater the wing reach, the greater the 'm/dt', and therefore, the greater the lift generated (Lift = m/dt x dv).

- Wingspan loading. – The amount of aircraft mass (kg) supported by 1 meter of wingspan. This is a similar concept to wing loading, but different. Wingspan loading is a new concept that arises due to the method in which Newtonian mechanics calculates lift (Lift = m/dt x dv).

$$Wingspan\ Loading\ (kg/m) \ = \ \frac{Aircraft\ Mass\ \ (kg)}{Wingspan\ (m)}$$

$$Wing\ Loading\ (kg/m^2) \ = \ \frac{Aircraft\ Mass\ \ (kg)}{Wing\ Area\ (m^2)}$$