A BIT OF AERODYNAMIC HISTORY

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Aerodynamics is a branch of dynamics concerned with the study of the motion of air. Our concern, as associated with aviation, is with efficiency of flight. This article will stay within the limits of subsonic flight.

Early records of fundamental aerodynamics concepts go back to the work of **Aristotle** and **Archimedes** in the 2nd and 3rd centuries BC, but efforts to develop a quantitative theory of airflow did not begin until the 18th century. In 1726, **Isaac Newton** became one of the first to scientifically document experiments to develop a theory of air resistance that was later verified for low flow speeds. In 1738, **Daniel Bernoulli,** a Dutch-Swiss mathematician, described a fundamental relationship between pressure, velocity, and density, now termed Bernoulli's principle. This provides a basic method for calculating lift. This states that the pressure of a flowing fluid decreases as its velocity increases and, as such, was a significant early advance in the theory of fluid dynamics. Bernoulli's Equation ignores compressibility of the fluid as well as the effects of gravity and viscous forces on the flow. **Leonhard Euler** would go on to publish the Euler equations in 1757 that extended knowledge into both compressible and incompressible flows.

Aerodynamics work throughout the 19th century sought to achieve heavier-than-air flight. **Sir George Cayley** developed the concept of the modem fixed-wing aircraft in 1799, and in doing so, identified the four fundamental forces of flight - lift, thrust, drag, and weight, i.e.:

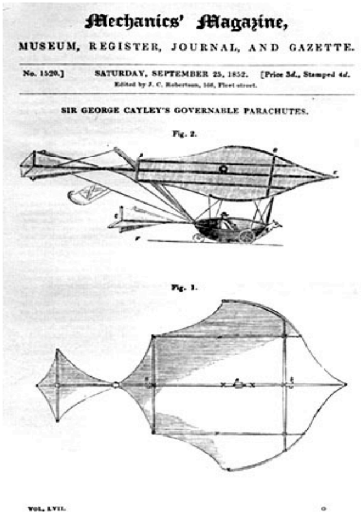
*Weight: Local Gravitational Force (always toward earth surface in earth-space flight)

* Lift: Component of the surface force perpendicular to the oncoming flow direction

*Drag: Component of the surface force parallel to the oncoming flow direction

*Thrust: The force applied on a surface in a direction perpendicular to the surface.

These forces must be equally balanced in order to attain extended flight. Cayley constructed his first model aircraft in 1796 and continued experiments until his death in 1857. Cayley not only identified the four aerodynamic forces of flight, but also the relationships between them. He is also credited as the first person to develop the modem fixed-wing aircraft concept. His first successfully flown glider in 1804 had the layout of a modem aircraft, with a kite-shaped wing towards the front and an adjustable empennage at the back with horizontal stabilizers and a vertical fin. A movable weight allowed adjustment of the model's center of gravity for control of the flight. He then advanced to manned gliders, The drawing shows Sir George Cayley's "governable parachute glider" which was successfully flown in 1852.



Mechanics' Magazine,

MUSEUM, REGISTER, JOURNAL, AND GAZETTE.

No. 1520.] SATURDAY, SEPTEMBER 25, 1852. [Price 3d., Stamped 4d.

SIR GEORGE CAYLEY'S GOVERNABLE PARACHUTES.

Fig. 2.

Fig. 1.

Cayley's work was followed by· **William S. Henson** and **John Stringfellow** who extended into designs for steam powered flight; however, their aircraft never got off the ground due to excessive weight.

To advance wing design, a more precise way to measure resistance and lift was needed. Experiments were performed by **Francis Herbert Wenham,** a member of the Royal Aeronautical Society in England, who constructed the first wind tunnel in 1871. This let him place airfoils in a controllable airstream so that measurements of lift and drag could be made. This created a problem for scaling the effects of small-scale models to the full size components.

The solution to properly scale model measurements was achieved with the invention of the dimensionless Reynolds number by **Osborne Reynolds.** Reynolds also experimented with airflow scaling in 1883. Wind tunnels were key in the development and validation of the laws of aerodynamics. They led to the rapid advances in manned flight.

By the late 19th century, the two problems constraining manned, heavier-than-air flight had been identified and were measurable. The means for creating and testing low-drag, high-lift aerodynamic wings was made possible by wind tunnel experiments. The second problem of how to determine the power needed for sustained flight was defined in 1889 by **Charles Renard,** a French aeronautical engineer, who developed formulas to predict the power required for sustained flight for a given weight aircraft and wing drag computations. Although the theoretical groundwork had been established, other less scientifically inclined enthusiasts were building and testing various flying machines with little success.

Starting in the 1880's, advances were made in construction that led to the first truly practical man-carrying gliders. One of the first modem man carrying gliders was built by **John J. Montgomery,** who flew at San Diego on August 28, 1883.

Montgomery continued improving his gliders and control methods along with launching them from balloons through 1905 when an earthquake and fire destroyed his shop and equipment.

Otto Lilienthal, of Germany, expanded Wenham's wind tunnel work and published his research in 1889. He also built a series of manned gliders that provided flights of up to 250 meters. He thoroughly documented his work and, thus, became one of the best-known early aviation pioneers. After more than 2,500 flights, Lilienthal died in 1896 when a gust of wind caused him to lose control and fall from a height of roughly 50 feet. Lilienthal used thin, curved airfoils to produce high lift and low drag. At the time of his death, he also had been working on small engines suitable for powering his designs.

Octave Chanute took up aircraft design and funded development of several gliders. In the summer of 1896, his team flew several of their designs, eventually selecting the biplane design as the best compromise. Chanute was particularly interested in eliminating aerodynamic instability of the aircraft in flight. He decided that a pilot could regain stability by adding stabilizing and control surfaces or by moving the center of gravity of the aircraft as Lilienthal did. He raised the issues and published his research in an 1893 book, *Progress in Flying Machines,* which materially assisted all future designers and experimenters.

Samuel P. Langley, of the Smithsonian, embarked on a powered, manned development path in 1887 without great regard for the aerodynamics. His initial small steam engine powered models (termed "aerodromes") had tandem wings and were marginally stable. One test traveled 3,300 feet at an altitude of 70 to 100 feet. This led to development of a much larger full scale manned aircraft that was unstable and structurally weak. However, he did develop a light 50 hp engine that performed well. His full scale manned flight trials on October 7 and December 8, 1903 both resulted in crashes on takeoff.

The **Wright** brothers used Chanute's research, and through aerodynamics experimentation starting with manned gliders and subsequent engine design, built and flew the first powered aircraft on December 17, 1903. The Wright brothers' flight confirmed or disproved a number of aerodynamics theories. Newton's drag force theory was finally proved incorrect. This first widely publicized flight led to a more organized effort between aviators and scientists, leading the way to modern aerodynamics.