HUGO T. BYTTEBIER

THE RISE OF THE FLYING MACHINE

FROM FLAPPING WINGS TO INHERENT STABILITY

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We are very grateful to André Delbaere’s family for the cession of the reproduction rights of all the exceptional illustrations of the main world aviation pioneers that appear in this book.

HUGO T. BYTTEBIER

(4th April 1924, Wulvergem, Belgium –
25th March 2004, Hurlingham, Buenos Aires, Argentina).

As an adolescent he developed a passion for the history of aviation. He worked tirelessly during more than 30 years to give us this great and complete historical work. It required the reading and research of more than 165 historical books, and countless magazines, newspapers, encyclopaedias and exhibition pamphlets, many of them original editions from the late nineteenth and early twentieth centuries that are still kept in his vast and valuable library.

In 1972, his book The Curtiss D-12 Aero Engine, a study of the first successful engine built in aluminium block between the two world wars and the precursor of many engine designs, was published in the Smithsonian Air and Space Museum’s “Annals of Flight” series.

He contributed with other writers to various aviation magazines, and donated generously to the Circle of Aeronautical Writers in Argentina.

He died shortly after finishing this work, so his family and many of his friends wanted to publish it for its historical value, as a detailed explanation of how the pioneers of powered and manned flight developed the inherently stable aircraft we know today.

The publication of this book is a posthumous tribute from all who knew him to Hugo and his historical rigour.

Part 1

Preface

To add another history of human flight to the many already published seems like an unnecessary undertaking. Yet, as in many other areas of knowledge, a subject can be approached from various angles and the present study is one more proof of this.

For a long time the author was puzzled by what seemed to be an incongruity. A great number of aviation historians arranged their chronicles around what was considered to be the crowning event: the first recorded, powered and manned flight in history. All previous and later historical events were made to appear of lesser importance or as in some way deriving from that one spectacular achievement.

Yet, when one studies the data available objectively, such a position cannot be held because of two undeniable facts: first, the type of aeroplane that is in general use today has its roots in the vision and work of the most enlightened pioneers of the nineteenth century. And second that the flying machine that made that much-heralded first flight was built according to a concept that stayed outside the mainstream of aviation development, a concept that eventually proved impractical and which had to be abandoned.

One may thus feel that there is some justification for believing that aviation history can be approached from a different angle, one which gives more importance to the continuous evolution that began in the early years of the nineteenth century and progressively led to the modern aeroplanes that exist today.

Another aspect that should not be ignored is the impact that this first flight had on the burgeoning aviation movement of the early twentieth century when the ultimate objective seemed so near, as indeed it was, and the misguided attempt to turn what the inventors believed was the technical predominance of their design into a monopoly and the controversy that followed. It all adds to the fascination that accompanies many a tale of human struggles with their corollaries of triumph and despair.

Introduction

From time immemorial, man has burned with the desire to emulate the flying creatures with which nature has endowed the world in such great profusion. Yet, as long as his approach was idealistic and not scientific, no progress was made and any attempt to copy the bird and its complicated flapping wings was doomed to failure.

For many centuries, the only flying beings were mythical and mythological gods or heroes whose existence remained outside the plane of reality. That all efforts to imitate the flight of the bird were to remain futile is obvious when we take the trouble to observe an aeroplane passing overhead.

It is not necessary to use one's eyes to become aware of the presence of the machine because the first characteristic that strikes us is the noise it makes. That noise derives from the powerplant without which no horizontal flight is possible.

When we look at the aeroplane flying above us, we see a vehicle consisting of a streamlined fuselage carrying a fairly big monoplane wing that remains immobile. At the tail end, we note a small horizontal plane attached to it and on top stands a vertical fin, both as fixed as the wing. Only scrutiny at close quarters will reveal that the wing has small moving surfaces at the tips and others fitted at the rear end of the horizontal tail and of the vertical fin.

We all know what these moving parts are for. They are needed to direct and control the aeroplane in flight, along the three axes. The purpose of the wings is clearer still. They are there to lift the aeroplane and carry it through the air. But the purpose of the fixed tail and of the fin is not so commonly grasped; they are there for the sole purpose of keeping the aeroplane on an even keel, and without these fixed appendices safe flying would be as impossible as without the wing.

Leonardo da Vinci, the first Appreciation

The first attempt to study the laws that govern flight and to design a machine that would enable man to fly was made by Leonardo da Vinci around 1495/1500. Leonardo was the first genius of the Renaissance to recognize the endless possibilities of man-made mechanisms and he proceeded to fill notebooks with designs which are still in use today such as the parachute, the ball bearing, scissors, the odometer, portable bridges, and many more that have hardly been improved. Leonardo was one of the first to discover that by means of “an apparatus consisting of a number of rigid or elastic parts linked together in such a way as to have their motion completely determined, almost anything could be done”.

The idea of attempting flight with a man-made apparatus was too appealing to be left alone and Leonardo filled several more pages of his notebooks with designs, drawings and calculations so as to produce a machine that would enable man to fly. In the process, he invented an aerial screw, a parachute and a helicopter.

But in order to make horizontal flight possible, Leonardo had only the bird to guide his studies. He investigated the flapping movement of its wings and progressed from a machine moved by the arms to one moved by hands and feet but he finally became aware that man would never be capable of lifting himself into the air by means of even the most ingenious machine moved by his muscles, and across one of the last pages of his notes he wrote “*Non è vero*” and let the matter rest there.

Giovanni Borelli and Isaac Newton

Leonardo’s designs inspired none of his contemporaries and two more centuries were to elapse before the problems were again approached scientifically. In 1680 an important book was published posthumously. It was written by Giovanni Alphonso Borelli, a learned Neapolitan doctor who had devoted himself to studying all forms of animal locomotion, including an analysis of the flight of birds, and had been struck by the strength and size of the musculature that moved the birds’ wings.

As a result of these studies, Borelli, like Leonardo two centuries earlier, concluded that man would never be capable of flying with the use of his muscles. This time, however, the problems were not shelved as in Leonardo’s time because the second half of the 17th century saw a major development in western thought based on the study of the surrounding material world.

A few years after the publication of Borelli’s book, and inspired by it, the great English physicist Isaac Newton, took up the problems again and he very carefully studied the movements of elongated shapes through fluids and gases to try to obtain a universal formula governing these movements and the resistance they created.

Newton arrived at a very interesting conclusion, that the resistance of a surface moving through a fluid was dependent on the density of that fluid (moving through air is easier than through water). It was also dependent on the surface of the moving shape and on the square of its speed because great speeds create very great resistance and a great deal of power is needed to overcome them.

The most interesting conclusion Newton reached was that the reaction resulting from the resistance induced by the horizontal movement of a flat body through a fluid at a small angle of incidence was that the moving object was pushed upwards with a force dependent on its surface and the square of its speed.

Newton thus arrived at the formula for calculating the resistance as:

$R=KdSV2\ sin2\ \theta$.

He defined the resistance, R as a force acting in a direction perpendicular to the surface, and dependent on the density of the fluid (d), the square of the velocity of the incoming fluid stream (V2), the surface area (S), and the angle that the surface makes relative to the initial flow direction (called the angle of attack and represented by θ). K is a constant which could only be found by experimentation.

This formula, except for the square of sinus θ proved to be correct and indicates that the resistance that generates lift increases with the square of the speed, so that, given adequate power to overcome the resistance, any winged object can be made to fly. The emphasis is here on “adequate power” because this was the big hitch that kept the aeroplane enthusiasts from flying for nearly two more centuries.

In stating that the resistance of a moving wing was also dependent on the square of sinus θ. Newton made an error of far-reaching significance because it caused stagnation in aeronautical research, at least in France. Although Newton's use of the term resistance to describe this force survived until the early twentieth century, it will be less confusing if we substitute it by the modern term reaction force.

In 1780, two French scholars, Condorcet and Monge, in a "rapport" to *L'Académie des Sciences* arrived at the same conclusions as Borelli whilst Coulomb at about the same time calculated that man, in order to fly, would need wings with a surface area of 12,000 square feet.

Early in the nineteenth century, a group of scientists, among whom were Gay-Lussac, Flourens and Navier, studied Newton's formula and adapted it to bird flight. Navier, who made the calculations, came to the startling conclusion that seventeen swallows in flight developed a force equivalent to 1 hp.

There were opposing voices, from Bobinet and others, but Navier's calculations were accepted and presented to *L'Académie des Sciences* in 1829. So, for about 40 years this brought interest in dynamic flight in France to a standstill.

The Search for Power

At the time when Newton was making his observations, the search for mechanical sources of energy was in full flight. During the last quarter of the 17th century, ideas and proposals were beginning to be formed around the use of heat produced by chemical reactions for use in motors. This started a series of discoveries, which eventually resulted in supplanting animal musclepower as man's principal source of energy, and thereby helped to abolish slavery as a happy side-effect.

The first to convert these ideas into practice was the great Dutch scientist Christian Huyghens. In 1673 he presented an internal combustion engine that burned minute quantities of gunpowder to the French Academy of Science.

Huyghens' machine was used in Paris for pumping water. His young assistant, Denis Papin, later built an identical engine for Charles Landgrave of Hesse. But Papin hit upon a more practical way of raising pressure inside the working cylinder by using steam.

Although Papin's engines worked on the model devised by Huyghens by creating a vacuum under a piston, the use of steam made the control of combustion much easier and this marked the beginnings of the steam engine, which was then rapidly developed, becoming the first type of engine to be used as a power source for aircraft.

Papin was not able to pursue his discovery to any practical end and it was again in Britain that the steam engine was perfected through the efforts of James Watt, who turned it into a powerplant of practical use. At the beginning of the nineteenth century Richard Trevithick had designed and built machines which worked with the direct pressure of steam against a piston in order to obtain much higher powers than could be obtained by the system devised by Watt which still worked with atmospheric pressure.

At the same time one of the most extraordinary minds that ever studied the problems of aviation was active and began to write down his observations and findings. This was Sir George Cayley, a country squire who has been deservedly dubbed “father of aviation”.

Sir George Cayley

Cayley worked and wrote down his observations at a time when those interested in aviation had shifted their ideals and become aware of the possibilities of an artefact they had long been aware of, a plaything they had looked at without seeing, as the French enthusiast de La Landelle aptly put it.

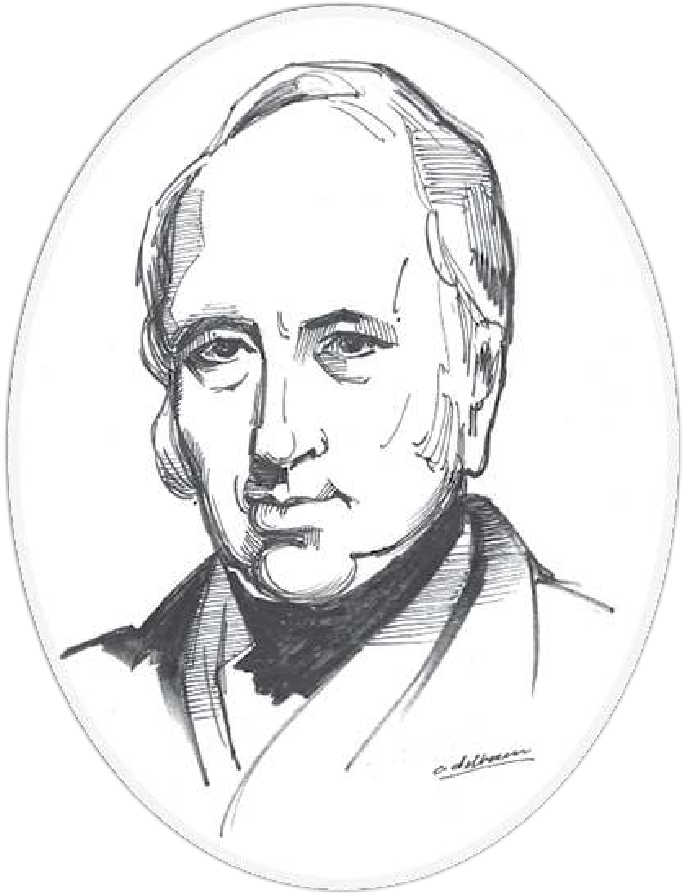
It suddenly dawned on a few privileged minds that the kite, the plaything referred to, was in fact a flying body governed by the same laws of aerodynamics that applied to birds, those same laws that had been formulated by Newton. The kite, it was now believed, would be able to lift man into the air in a more rational manner than could be achieved by trying to imitate birds, so the kite would become a mechanical bird.

It is generally believed that the kite was invented by the Chinese a few centuries before the Christian era, but another contender for the title of inventor is the Greek philosopher Archytas of Tarent, who lived in the 4th century BC.

When speculating about the kite’s origins, the theory that it could have been discovered accidentally by observing runaway sails or hats or something similar holds little ground because it overlooks the fact that a kite can only rise when it is firmly attached to the ground. It would be more logical to visualize some kind of sail tugging at the hand of someone who held it as tightly as he could.

Kites began to be regarded as subject to the laws of aerodynamics during the 18th century, and in 1756 the German mathematician Euler wrote: “The kite, this child’s toy, despised by the scholars, could nevertheless lead to the most profound reflections”.

Indeed, in order to conceive the kite as similar in characteristics to the bird, a great mental effort had to be made because it was necessary to understand that the forces acting upon the kite had to be inverted.



Sir George Cayley
(1773-1857)

A kite flies by capturing the kinetic energy of the wind, which is air on the move, so that a kite in reality flies by the power of the sun and the traction on the line that holds it to the ground is a measure of that force.

At the end of the 18th century it began to be understood that the force measured by the traction on the line was to be replaced by a thrust created on board the kite, making it move and generate lift.

This was the great discovery, as Cayley explained in his celebrated “triple paper” published in William Nicholson’s

Journal of Natural Philosophy, Chemistry and the Arts (known as *Nicholson's Journal*) in 1809 and 1810: "It is perfectly indifferent whether the wind blows against the plane or the plane be driven with equal velocity against the air... If therefore a waft of surfaces advantageously moved, by any force within the machine, took place to the extent required, aerial navigation would be accomplished."

For the first time, the pessimistic conclusions of Leonardo da Vinci, Borelli, Navier and many others were replaced by the belief that a man-made engine could work the miracle. Again, quoting Cayley: "I feel perfectly confident, that this noble art will soon be brought to man's general convenience, and that we shall be able to transport ourselves and families, and their goods and chattels, more securely by air than by water... To produce this effect, it is only necessary to have a first mover which will generate more power in a given time, in proportion to its weight, than the animal system of muscles."

Once the principles of dynamic flight had been formulated ("To make a surface support a given weight by the application of power to the resistance of air"), Cayley went on to invent the aeroplane practically single-handed and wrote down his findings in a magisterial essay first published in *Nicholson's Journal* in November 1809 and February and March 1810.

Starting with the powerplant, he considered steam as motive fluid but explicitly rejected the unwieldy machines moved by atmospheric pressure which were built by

Boulton and Watt and turned his mind to the newly devised engines of Richard Trevithick (who was a genius comparable to Cayley himself) and which worked with what Trevithick described as “pressure of steam”. In 1804, Trevithick had just built the first locomotives in Britain and in 1808 a steam-driven road wagon.

Pondering on the possibilities of making steam engines lighter and more powerful, Cayley proposed the water-tube boiler, which was indeed to become the most efficient and lightest generator, though it appeared many years later. But Cayley looked farther ahead and proposed that a lighter and better engine could be built by using internal combustion, by “firing inflammable air (gas) with a due portion of common air under a piston”, to quote his own words.

However, Cayley had not yet reached the limits of his vision. Once the machine flew, what would happen? It had to remain stable in the air and not behave like a dead leaf, it also had to be steerable and not zoom like an arrow. Incredibly, Cayley solved nearly all these problems too.

He had a good look at the then already known parachute, noted its lack of stability and concluded that lateral stability could only be achieved by an angular form of the wings. “With the apex downwards”, a dihedral angle, as it is called today. Cayley called this “the chief basis of stability in aerial navigation”.

He also considered the need for longitudinal stability and thought that a low centre of gravity and a kind of automatism in the travel of the centre of pressure according to the angle of attack of the wing would achieve the desired effect.

Steerage would be obtained by a horizontal rudder “in a similar position to the tail in the birds” and a “vertical sail … capable of turning from side to side which, in addition with its other movements effects the complete steerage of the vessel”.

He also saw the need for streamlining the body in order to reduce parasitic drag, especially the rear part and also noted that “diagonal bracing” would make it possible to build structures “with a greater degree of strength and lightness than any made use of in the wings of the bird”. This was the principle of trussing which Chanute introduced with good effect in the construction of biplane wings during the late 1890s and which remained in use for nearly forty years.

Giving his imagination free rein, Cayley then prophesied: “By increasing the magnitude of the engine, 10, 50, or 500 men may equally well be conveyed; and convenience alone, regulated by the strength and size of the materials, will point out the limit for the size of vessels in aerial navigation.”

Cayley made several experiments himself, which have been described in other publications[1] but his thoughts ran too far ahead of the possibilities of the moment to achieve any practical result. He even designed a kind of hot-air engine and experimented a couple of times with gunpowder but was moved to remark: “Who would take the risk of breaking their necks or being blown to atoms?”. Yet, gunpowder as engine fuel had been the first used and would continue to be proposed from time to time, which only shows that in the pursuit of their ideals, mankind will not avoid the most appalling risks.

Referring to the experiments made upon the resistance of air by Smeaton[2] and corrected by him by careful and unrelenting observation of the crow and other birds, Cayley came to the conclusion that a wing loaded at 1 lb/sq ft would carry 1 lb of weight as soon as a horizontal speed of 35 ft/sec (equivalent to 21 knots or 24 mph or 38 kph) was reached. This was correct and is the take-off speed of most of the ultralight planes that have come into fashion. What nobody knew was how much power was needed to accelerate a winged machine of a certain weight until flying speed was reached.

Newton’s formula had led Navier to compute impossibly high figures but Cayley, again by observing birds, noted: “The perfect ease which some birds are suspended with in long horizontal flights without one waft of their wings, encourages the idea that a slight power only is necessary”. Sir George was possibly not the first and certainly not the last, to let the soaring birds beguile him with that “slight power only”.

Having calculated that a man running upstairs was able to generate about 2 hp for a short time, he took into account that no man could sustain this rate of power for a long period ("one minute" noted Cayley). Consequently, he calculated the output needed at take-off — the moment at which he believed, correctly, that the greatest effort would have to be made — as 5 hp with a specific weight that had to remain below 30 lbs per hp.

In his day, a steam engine of five hp was a machine of awesome proportions located in a building specially erected to house it. Even so, he was well below the real power requirements, as would be discovered a century later.

Cayley waited all his life for the aero engine to appear, and during long periods he left aeronautics alone and dedicated himself to some of his other manifold preoccupations. The last published reference to the missing powerplant was written in 1853, three years before he died at the age of 83: "It need scarcely be further remarked that, were we in possession of a sufficiently light prime mover to propel such vehicles ... mechanical aerial navigation would be at our command without further delay". This proved correct, but the goal was still more than half a century away.

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1. *Sir George Cayley's Aeronautics 1796-1855*, by Charles H. Gibbs-Smith (Science Museum, London, 1962).

2. Smeaton disclosed his tables of pressures around 1750, after an extended visit to the Low Countries where he was able to observe the windmills there and their efficient wing-shapes, a result of centuries of practical experience.

Henson and Stringfellow

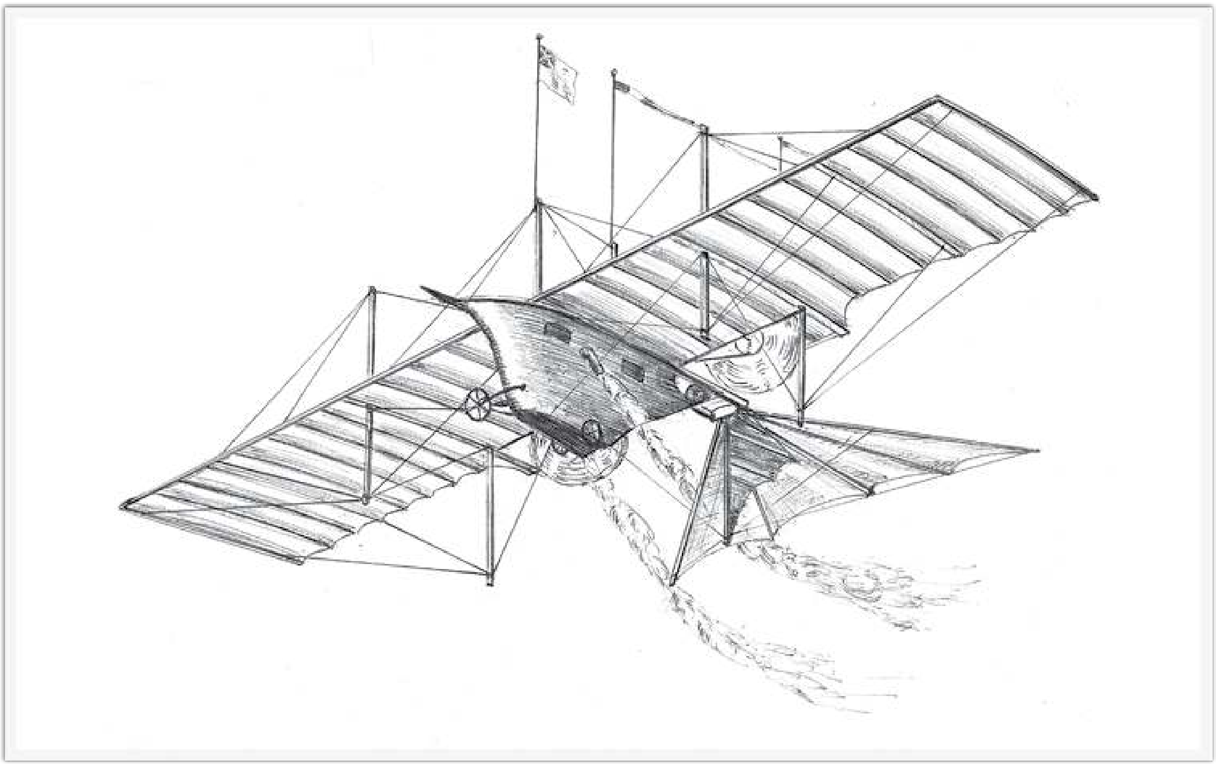
The weight of the man-carrying machine was estimated by Cayley to be about 500 lbs, complete with engine and propeller. He thus arrived at a requirement of 10 hp for every 1000 lbs lifted. This fired the imagination of William Samuel Henson to such an extent that in 1843 he proposed an “Aerial Transit Company” bill in the House of Commons.

His object was the construction of a flying machine powered by a steam engine developing 25 to 30 hp and weighing over 600 lbs. The complete aeroplane would weigh about 3000 lbs with a wing surface of 6000 sq ft. This would, in Henson’s opinion, enable him to organize aerial transit to several distant points of the globe.

Henson’s proposals received a great deal of publicity but, if he had ever been given the green light to proceed with his Transit Company, the business would have floundered because of the lack of adequate power, as well as by the enormous surface requirement of the wing and the tail.

But Henson and his engineering associate John Stringfellow went to work anyway on small-scale models. If there is one thing that continually amazes the historian, it is the optimism with which the early pioneers tackled the host of difficulties that lay before them.

Henson realized that high steam pressures would be required so he set to and designed and built a model engine to work on a pressure of 100 lbs/sq in. After many discouraging years without result, Henson gave up in 1849, whilst Stringfellow continued alone and was at last able to build a small model steam engine which was said to produce about one-third hp for a weight of 13 lbs, including the steam generator.



Henson Aeroplane Project.

France takes up the challenge

After Henson’s experiments, aviation in the UK was allowed to lapse but, curiously enough, interest in dynamic flight arose again in France, in spite of Navier’s calculations, which could have been forgotten in the meantime.

It is significant to note that Cayley was asked to contribute and he subsequently wrote several articles for the *Bulletin Trimestriel* of the first aeronautical society in the world, the *Société Aérostatique et Météorologique de France*, founded by a well-known French aeronaut J. F. Dupuis Delcourt. As will be noted, the title does not mention dynamic flight.

Yet Cayley, in 1853, proposed rather slyly that “As aerial navigation on the balloon principle, can only be carried out on an enormous scale of magnitude and expense … it may not be unworthy of the Society to turn its attention towards making some cheap preliminary experiments to ascertain practically what can be done on the principle of the inclined plane, which appears to be applicable on any small scale from that of a bird to the uses of man, … whenever a first mover, combining sufficient power, within a certain limit as to weight, is discovered.”

There is no evidence that directly links Cayley’s articles and proposals in this French Bulletin to the first attempts by Frenchmen to start experiments with fixed-wing aeroplanes, but the analogies are striking.

In 1857, a French naval officer, Félix du Temple, patented a fixed-wing flying machine moved by a motor. The machine was calculated to weigh one ton and du Temple, with more optimism than Cayley's, estimated the power requirement as 6 hp.

Du Temple's machine had a tail in the rear and a slight dihedral of the monoplane wing. One interesting original feature was the proposal that the aeroplane should take off by rolling across a field in the modern manner. Due consideration was also given to the question of stability.

Experiments were on small-scale models but, as soon as full-scale construction began around 1874, "the inadequacy of all motors known became apparent" as O. Chanute wrote. Du Temple had experimented with steam at high pressures and in due course designed an efficient boiler consisting of small water tubes as advocated by Cayley in 1809. This boiler produced no flight, but it was adopted by the French Navy, so du Temple was in some measure rewarded for his pains.

A second experimenter was Joseph Pline, a pioneer of great originality, who presented a patent in 1855 using a fixed plane in conjunction with a balloon, in an effort to get the best of both aeronautical systems. One interesting feature in this patent was that the fixed plane was for the first time designated with the word *aéroplane*.

Pline's mixed system was not built; it would have been a failure as were all others that followed, trying to add wings to an airship, but Pline soon began to experiment with small flying models and stated that he was certain that it was possible for a plane to rise, sustain itself and fly around in the atmosphere without the use of hydrogen.

After carefully observing aerial currents as well as the organs used for flight by different animals (nature has produced more flying creatures than earthbound ones), Pline came to the conclusion that curved surfaces were the most efficient and he designed several paper models that had wings consisting of half-cylindrical surfaces arranged in the direction of flight, somewhat in the manner of F. M. Rogallo's flexible wings designed in 1948.

Pline's model aeroplanes flew gracefully and, under the name *Papillons de Pline* (Pline's Butterflies), acquired great fame in France during the 1860s. All aeronautical experimenters were able to witness the flights of these flying models, which proved that in case of engine failure, a fixed-wing machine would not fall like a stone but could glide safely to earth.