LAWRENCE HARGRAVE AND HIS ROLE IN THE DEVELOPMENT OF THE SUCCESSFUL AEROPLANE 2009

On December 17, 1903 at Kittyhawk, North Carolina, the Wright brothers, Wilbur and Orville, made four powered, controlled flights that day to achieve that notable first flight of a powered, controlled, heavier-than-air craft. No one before them can make that claim although there are those that support the fiction of earlier flight by Gustave Whitehead in Connecticut, USA and Richard Pearse in New Zealand. The claims made for these gentlemen are highly dubious and Whitehead and Pearse have left no metaphoric aerodynamic footprint, unlike the Wright brothers.

Even so, the genesis of the successful aeroplane owes much to many people. Sir George Cayley, active at the turn of the nineteenth century, is given credit by historians as the 'father' of the aeroplane and others such as Henson, Du Temple, Ader, Lilienthal and Langley, to name a only a few, contributed to the ultimate success of the Wright brothers in various ways.

Lawrence Hargrave was a member of this elite body of researchers and experimenters and he is a known and important contributor to the development of the successful aeroplane. However, Hargrave is not always given credit for his work. He was internationally famous in his own lifetime but now he is generally disregarded in the histories about the advent of powered, controlled flight. Why should this be so? Who was Lawrence Hargrave and what did he contribute to the development of the successful aeroplane?

Born in Greenwich, England in 1850, Hargrave was the son of John Fletcher Hargrave, a barrister, and Ann Hargrave. Lawrence was the second of four children. The marriage of John Fletcher to his cousin Ann may not have been strong for in 1856 John, accompanied by his solicitor brother Edward and his eldest son Ralph, sailed for Australia.

In his fifteenth year Lawrence sailed from England to join his father. The three month voyage gave Lawrence time to marvel at his natural surroundings and he created quite an impression on one of his fellow passengers who sought the lad's company on a circumnavigation of Australia.

John Hargrave agreed to this voyage provided Lawrence attended to his studies. It was important for Lawrence to matriculate to follow in his father's footsteps in law. Lawrence's failure to matriculate suggests that he paid more attention to his surroundings than to his bookwork but he gained instead an apprenticeship in the Australian Steam Navigation Company. Here he learnt all aspects of his trade and proved to be a highly adept practitioner in all the engineering fields. He turned his skills to his own amusement. In 1869 he built the 'Shark', a 25 foot outrigger. A year later he could be seen walking on the calm waters of Rushcutters Bay wearing boat-shaped shoes with a system of flaps on the bottom to provide traction in the water.

In that same year, 1870, he witnessed the flight of balloonist, Thomas Gale. Lawrence sketched an improved balloon which, in later life he referred to as 'Flying Machine no.1' but his main preoccupation was with maritime matters.

He became enthused about and joined an expedition to New Guinea.
The expedition failed when the ship 'Maria' grounded in a violent storm with considerable loss of life.

Lawrence returned to work in the engineering trade but retained his desire to go to New Guinea. In 1874 he sailed to Torres Strait to gather information for the organisation of another

expedition and spent time becoming acquainted with the area. Before he could organise his own expedition he signed on as an engineer for William Macleay who proposed to sail to New Guinea to collect biological specimens.

For Hargrave the most important aspect of this trip was his meeting with the Italian naturalist Luigi Maria D'Albertis. D'Albertis was gun happy and ruled the natives by fear. Nobody could be less like Hargrave than D'Albertis but their paths were destined to cross again.

With the imminent return of Macleay to Sydney Hargrave transferred to another expedition. Hargrave seemed in constant demand, both on the expeditions and in the base camp. Inventive and resourceful he was never at a loss for a solution to a mechanical problem. However, the expedition came to an end and Hargrave returned to Sydney in late February, 1876.

In May he sailed north again as the engineer to D'Albertis. The purpose of this expedition was to map the Fly River. Needless to say Hargrave and D'Albertis did not see eye to eye but it is a tribute to Hargrave's patience that he saw out the expedition.

He was now a well known and respected explorer with unrivalled knowledge of the Torres Strait and he accepted a commission to sort out the affairs of the pearling industry in that area. With typical authority and pragmatism Hargrave successfully completed his task and now at 28 years of age he was a man of considerable experience and knowledge.

At this phase of his life Hargrave decided to cease his wanderings and settle down. Hargrave married in 1878 and gained employment at Sydney Observatory as Extra Observer (Astronomical). To assist him in his task of the measurement of Herschel's double stars he designed and built four adding machines. One of these is preserved in the Museum.

During his leisure time Hargrave worked on harnessing wave power for ship propulsion. The thinking behind his wave power experiments he called his Trochoided plane theory and set down by him in 1882. It was based on his readings on animal locomotion. Simply it was an explanation of how fish swim by moving from side to side or snakes with their circular muscle motion propel themselves.

Although Hargrave was focussing on ship propulsion he noted that, as air was also a fluid, his theory should be applicable to flying machines.

Meanwhile his family was growing. He began developing a private income from land leases. With sufficient income he resigned from the Observatory and in 1884 commissioned the building of 3 terrace houses in Rushcutters Bay. In the workshop beneath one Hargrave focussed on the design and construction of ornithopters. He constructed tethered models powered by clockwork and produced his first free flight ornithopter powered by rubber bands.

Hargrave increased the power of his ornithopters until he had achieved flights in excess of 300 feet. He realised the limitations of power by rubber bands and began to look at developing an engine to provide, not only for models but for a man carrying ornithopter.

Hargrave's wrote to those who had built the engines that had powered Mozhaisky's flying machine and the Swift ornithopter. He also obtained details of the Brotherhood 3 cylinder air engine which powered the Whitehead torpedo. Early in 1888 he constructed the first of 36 engines, a single cylinder compressed air motor driving two flappers. In 1889 he built his 3 cylinder rotary radial engine to spin a propeller to replace the flappers. It seems he followed this path after reading Cayley's published works. But he experienced trouble with torque and returned to flappers. Also his trochoidal theory required a complimentary undulation of a flat body plane to augment lift and thrust and the propeller did not provide this undulation.

As a member of the Royal Society of New South Wales, an august scientific association, Hargrave presented papers on his theory and the aeronautical experiments it spawned. During the meetings he would demonstrate his model ornithopters, much to the delight of his fellow members.

But Hargrave felt isolated and so sent copies of his Royal Society papers to *English Mechanic* magazine. His letter was ignored and he sent a similar letter to *Engineering*. In 1891 he was advised by the Royal Society that the Aeronautical Society had sent them a series of reports on works in progress; a response to his letter to *Engineering*.

His work became known overseas. Hiram Maxim, world renowned inventor, wrote. Hargrave also sent papers to R H Thurston, Director of the School of Mechanical Movement at Cornell University and S P Langley, secretary of the Smithsonian. Octave Chanute, a great disseminator of aeronautical information contacted Hargrave and sent copies of his publications and G C Taylor, an English experimenter, became one of Hargrave's most frequent correspondents.

In 1891 he donated a number of his flying machine models to the Technological Museum, the forerunner of the Powerhouse.

Throughout this period his family increased. The stress of city living on the family economics decided Lawrence to move to Stanwell Park in 1893. This move also suited the new direction his aeronautical work was taking.

He had begun to experiment with 'chuck' gliders in 1889 launched from a crossbow. In 1892 Hargrave, inspired by Chanute's articles dealing with curved surfaces began experiments using a sextant of a circle. The gliders of 1891 gave way to the soaring machines of 1893 with curved flying surfaces. Some he flew as kites and this became his preferred test method. The results of these experiments led him to produce sketches of his now famed cellular kites. The design promised good flying as well as high stability and robustness.

Internationally Hargrave's work was viewed with admiration. James Means of the Boston Aeronautical Society was publishing his works in his aeronautical journal, Professor A F Zahm of Notre Dame University invited a paper from him to be read at an International Conference on Aerial Navigation at Chicago's World Columbian Exposition. Octave Chanute, in his book, *Progress in Flying Machines* of 1894, stated that Lawrence Hargrave was the man most likely to fly first.

After a number of experiments with his kites Hargrave prepared to go aloft. With his assistant James Swain he walked to Stanwell beach on 12 November 1894. In Hargrave's words:
On the 12th a southerly buster came in at 11am of what appeared to be the right strength. Swain and I carried...the gear to the beach... Lower kite secured with gun-tackle purchase to the spring balance and two bags of sand. Toggled on the sling seat and got aboard with anemometer and clinometer. Swain slacked away the tackle fall to the end... After a quarter of an hour or so the wind freshened and I went up... Swain read the spring balance...wind fell lighter and I came down... A long and strong puff then sent me up like a shot... Swain read the spring balance... my height above ground 16 feet. Wind fell lighter and I came down...

Typically Hargrave disseminated his information to all his contacts. News of this resounded overseas. Chanute reported that the skies in the eastern USA were 'red with Hargrave kites' as others repeated Hargrave's experiment. Box kites began to replace the huge Malay kites that had carried meteorological packages into the sky in the USA. The Hargrave kites doubled the

height that could be achieved with Malay kites. Box kites also became popular for aerial photography. They were recognised as strong lifters with high stability.

Throughout, Hargrave continued to develop power units for aviation purposes. He developed a variety of types but, with his primitive propellers he could not achieve the required thrust. He refused to look at then-current propeller technology which offered 70% efficiency.

His financial situation was gloomy. He decided to go to England to live and embarked with his family in 1899 but it was a change for the worst and he returned to Sydney.

The focus returned to engines. They were larger, capable of powering a man-carrying machine. In 1902 he worked on a trimaran float plane but could not achieve the thrust from the engine propeller combination. After this failure Hargrave turned to the development of a flapper engine for his trimaran. He fell ill with typhoid and when recuperating received word of the Wright Brother's success from Chanute. Immediately he wrote congratulating them. The illness slowed him and he did not return to work on his projects until 1904. He was less enthusiastic and not as meticulous with his records. Nevertheless he recorded data on wing arms, propeller blades and transmissions as well as built kites and designed aeroplanes.

At the beginning of July 1915 Lawrence fell ill with appendicitis. The doctors operated but he died of peritonitis on 6 July 1915.

After almost a lifetime of aeronautical study and experimentation what was Hargrave's legacy to the world?

Historians of aviation accept without much argument that the Hargrave box kite was the inspiration for Alberto Santos Dumont's aircraft, named *14bis*, which is credited with the first powered, controlled flight in Europe in 1906. Gabriel Voisin, who, with his brother Charles, manufactured the first commercially available aircraft in Europe, stated in his autobiography that they owe their inspiration to their construction of a Hargrave box kite when they were teenagers. He maintains that his commercial aircraft wing structures were always referred to as "Hargraves". Voisin also maintains that Santos Dumont was inspired to take up heavier-than-air aviation after watching Voisin test a boat-towed "Hargrave" on the River Seine in Paris.

However, in analysing influences on the Wright brother's aircraft there is almost universal disregard of Hargrave as a contributor by aviation historians even though some writers, over the years, have noted a similarity of appearance between the Wright brother's aircraft and the Hargrave box kite. After all, in a letter written by Orville Wright to Fred C Kelly, the Wright brother's biographer, in 1946, he stated that, after repeated requests from various Australians about Lawrence Hargrave's association with the Wright brothers, Orville had asked his secretary to comb the correspondence and combine references by name. Orville could say with honesty then that:"It seems the myth that we received technical information directly from Lawrence Hargrave is hard to kill." Later in the same letter he says of any indirect "… special information from Hargrave…" that there was none "…passed on to us by Chanute." Thus historians could be forgiven for not looking further.

Be that as it may be, I maintain that there was a link between Hargrave and the Wright brother's aircraft but the link is rather tenuous, and certainly does not impugn Orville Wright's honesty. It does bring into question Octave Chanute's integrity.

Aerodynamics today is based on considerable theory that can trace its origins back to Leonardo DaVinci. Beginning as a study known as fluid dynamics, names such as Isaac Newton appear amongst the body of physicists and mathematicians who developed physical theories and mathematical models to account for the way fluids behaved. These early

researchers had no interest in flying machines but were more concerned with water flows. However, their results were also pertinent to the action of air flowing past objects. By 1850 the fundamental theoretical building blocks of aerodynamics were in place but the mathematics was complicated and flying machines were considered the province of fools. Sir George Cayley had paid regard to Newtonian physics when formulating his aeronautical experiments and in the production of his "triple paper" of 1809-10. But from that point aviation developed from empirical rather than theoretical work. Aeronautical pioneers such as Wenham, Phillips, Langley and Lilienthal paid no regard to the theories and carried out their own tests; in modern parlance, "reinventing the wheel" but they advanced practical aerodynamics. Hargrave was no different and neither were the Wright brothers. They carried out their work empirically.

When Hargrave disseminated information about the box kite to his international contacts he gave them something that they were desperately seeking. In the conclusion to his 1894 book *Progress in Flying Machines*, Chanute listed ten problems that required solution before man could fly: the seventh of these problems was stability and Chanute noted that this was the most critical problem to solve.

The box kite was proving how stable it was in meteorological and photographic service and Chanute wrote to Hargrave frequently, gleaning more and more information about the construction and engineering theory of the kites. Chanute built and tested his own box kite models and a picture of his 24 foot model appeared in the *Chicago Record* of 29 June 1896 and a picture of his ladder kite appeared in the *Century* magazine of 1897. The inspiration for these models is undoubtedly the Hargrave box kite although Chanute has introduced his own design elements. When the opportunity came for Chanute to test flying machines in the sand dunes near Gary, Indiana in 1896, he built a full-size version of the ladder kite to test the layout of wings to provide the most efficient glides. Called the "Katydid", the full-size ladder kite went through six permutations before Chanute was happy with the gliding characteristics of the machine. In the original version features of its Hargrave box kite heritage are discernible in the box kite tail with cross bracing. This was replaced in the later versions by the Pratt truss which Chanute, as a railway engineer, knew well from his experience designing railway bridges. The Pratt truss was a lower drag element than the Hargrave cross bracing.

Having achieved some successful glides with "Katydid", Chanute returned to Chicago and designed and had built his triplane glider and returned to the sand dunes at Gary. The initial tests of the triplane were disappointing and the lower wing was removed, allowing numerous successful glides. The triplane and early biplane glider flights were carried out with "stabilising" side curtains fitted, as a result of a query Chanute had made to Hargrave in 1893. However, the side curtains were quickly removed from the biplane glider, perhaps because they hindered manoeuvrability.

In the correspondence between Chanute and Hargrave over this period Chanute does not acknowledge a debt to Hargrave for the box kite, nor does he acquaint Hargrave with the fact that he had built several box kite-inspired models. After the tests at Gary he wrote to Hargrave but was not forthcoming with details about the aircraft tested and referred to the biplane glider as "one of my own design". It was not until the September and October, 1908, issue of the American periodical *Aeronautics* that Chanute acknowledged that Hargrave had played a role in the evolution of the "Two-surface flying machine" as Chanute called it. However, Hargrave's role is diluted by the acknowledgement of seven other aviation pioneers; F H Wenham, J Stringfellow, Mr Linfield, Commandant Renard, H Phillips, Sir H Maxim, and O Lilienthal. Of these pioneers some such as Wenham and Phillips provided sound information on multiplane, high aspect ratio cambered wings while others made models incorporating this information, and these models were generally unsuccessful. Others built full-size aircraft based on, or parts of, this information but they too were unsuccessful. Only two contributors, Hargrave and Lilienthal made full-size flying machines that were successful

and, when Chanute had a Lilienthal glider tested at Gary, he dismissed it as "cranky", to use his term. No physical feature of the Lilienthal glider, except, perhaps, for the 1/12 camber of the airfoil could be found in the Chanute glider.

When it comes to an exposition of Hargrave's role, Chanute merely gives a brief rundown of Hargrave's aeronautical history mentioning the box kite and its basic construction, a mention of an idea Hargrave has for ganging box kites and suspending a motor and propeller from them as a means of powered flight. He then goes on to mention that, in 1888, he, Chanute, had built a two-cell gliding model, "precisely similar to a Hargrave kite…". Yet in a letter to Hargrave in 1893 he states that "…the cellular kite idea is new to me…". One suspects that Chanute did not want to give away too much credit to others for the success of the biplane glider.

Be that as it may be, the link with the Wright brother's successful aircraft comes through this glider. The Wright brother had a number of basic design layouts to use when it came time to design their aircraft. Samuel Langley had followed the monoplane line of equal span wings equidistant fore-and-aft of the centre of gravity for stability in pitch and given dihedral for stability in roll. This layout was only tried with success in model form by Langley but Hargrave had found by experimentation that a full-size version could be dangerously unreliable. Otto Lilienthal and Percy Pilcher had used a 'bat-wing' layout for their gliders in monoplane and multiplane forms but despite the Wright brother's admiration for the late Otto Lilienthal this layout was not the basis for the Wright aircraft.

They selected the Chanute biplane glider layout as it was seen by them to possess the necessary structure to put into effect their wing warping control. Their sound reason for including the warping for roll control was based on the observation that control by weight shifting, as used by Otto Lilienthal, Percy Pilcher and by the pilots of Chanute's biplane glider was unreliable. The pilots were unable to react quickly enough. As a result Lilienthal and Pilcher had been killed. Perhaps the relative stability of the Chanute biplane glider contributed to its safety.

However, in a deposition given by Orville Wright on 13 January, 1920 as witness for the United States Government in a lawsuit, he stated that, after considering various schemes "… Wilbur showed me a method of getting the same results [roll control] as we had contemplated in our first idea without the structural defects of the original. He demonstrated the method by means of a small pasteboard box, which had…the opposite ends removed. By holding the top forward corner and the rear lower corner of one end of the box between the thumb and forefinger and the rear upper corner and the lower forward corner of the other end of the box in the like manner, and by pressing the corners together, the upper and lower surface of the box were given a helicoidal twist, presenting the top and bottom surfaces of the box at different angles on the right and left sides.

From this it was apparent that the wings of a machine of the Chanute double-deck type, with the fore-and-aft trussing removed, could be warped in like manner…". Thus the layout of the wings of the Wright brother's aircraft follows that of the Chanute glider.

It seems clear that the Hargrave box kite was a major breakthrough in aviation at the end of the nineteenth century. Aeronautical experimenters were searching for a stable machine with good lift on which to experiment with manned flight. Brave souls like Lilienthal and Pilcher had developed unstable machines only to lose their lives. They proved aviation was possible but fatal. It was necessary for someone to bring safety to the research. This was Hargrave's innovation. He gave Chanute the stable, relatively safe basis from which to advance his work. Chanute, the engineer, took Hargrave's basis and modified it by empirical experiments until, with the information gained from the rearrangement and flights of the "Katydid", he had

enough knowledge to develop the biplane glider. Further flights refined the biplane glider into a relatively safe efficient flying machine.

The Wright brothers, faced with the task of finding a structure to accommodate their idea of using wing warping as a means of aerodynamic control of an aircraft, used the concurrence of knowledge of Chanute's biplane glider and the chance bending of a pasteboard box to adopt the biplane glider layout form as the basis of their successful aircraft. Also we should not forget that they used box kites to test their wing warping before incorporating the idea in their manned aircraft.

It seems clear that Hargrave should be given credit for providing the major breakthrough that allowed the progress by Chanute that led to the Wright's success.

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