

# Aircraft Building

## A Bit of History

### Chinese invention of kites

Thanks to the very old literary tradition of China, we are able to find written records about the history of kite building and the fascination of flying.

The first kites are reported to have been developed during the Zhou Dynasty (BCE 770-221) in the province of Shandong (Eastern China) more than 2800 years ago in the city of Lu, which is the birthplace of Confucius (551-479 BCE). Typically, the first kites were flat rectangles.

Much later, the book of Han Fei Zi reports that Mozi (who was a philosopher who lived a century later than Confucius) wrote in his texts about the mu yang (wooden kite) he built with Lu Ban (a master of wooden joinery and philosopher). This was during the period of the Warring-Empires (475-221 BCE).

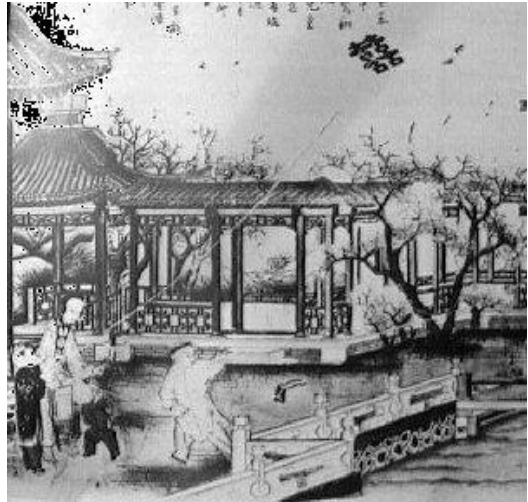
Reportedly it took them three years to create a kite that was successful in lifting a man. They gave it the name Wooden-Black-Eard-Kite and used it for observing the enemy. About a thousand years after the first kites appeared, paper began to be used instead of silk.

It was during the Tang Dynasty (618 to 907 CE) that kites began to be used as a toy or an instrument of pleasure. Following this, kite making became an art form with elaborate and colorful decorations.

Ever since, kite building, using bamboo sticks covered with silk cloth or paper, has been developing into an art form that we see today. Oft times, the kites are shaped and painted to look and move like flowers, birds, turtles, insects like butterflies and fireflies, frogs, fishes and other kinds of marine life, but also themes from Chinese mythology such as centipedes and dragons.

During the thirteenth century, the European explorer Marco Polo reported that shipping merchants would tie someone, usually a drunk, to a large kite and then launch the kite with the attached drunk. If the kite went high and straight, it was seen as an omen of a quick and prosperous voyage. On the other hand, if it crashed or didn't fly well, they would not set sail.

In the seventeenth century, European traders (English, Dutch, Portuguese) encountered kites and brought them back to Europe. The colorful Chinese kites reminded the English of a bird of prey—the kite—so they gave this name (kites) to the Chinese flying device.



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### Daedalus, father of Icarus, fashioned the first set of wings



Daedalus, the father of Icarus, urgently needed to escape the prison that his king, Minos, kept him in on the island of Crete located off the Southern tip of Greece. Daedalus was imprisoned because he had killed King Minos' beast the Minotaur (half man and half bull) and then run away with King Minos' daughter Ariadne. Believing that King Minos controlled all the escape routes by sea or land, Daedalus came up with a plan to escape by flying away.

Hatching a plan for escape (pun intended), Daedalus collected lots of bird feathers, and then fashioned wings for his son Icarus and himself by using wax to hold the feathers in place.

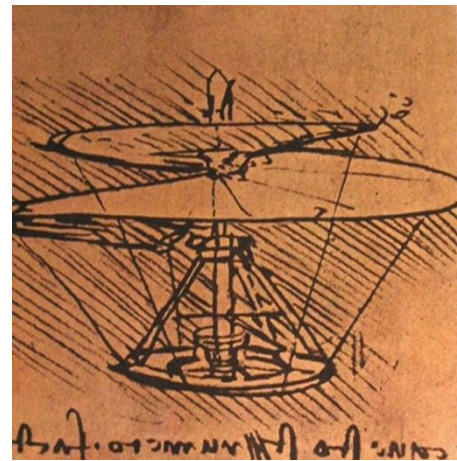
He also realized that watching the weather and planning a proper first-flight route was very important. Because if they did not fly a route that remained out of the sun's heat rays, their feather wings would fall apart.

We all know the stories of offspring who are inquisitive and dismissive of their parent's advice, spread their wings, and fly the nest to go their own way. From a tall tower, father and son successfully flew away from their prison, but soon Icarus was overcome with the exhilaration of flying and flew up higher and higher towards the sun where upon the heat of the sun melted the wax, disassembled the feathers, and Icarus crashed down into the sea. This sea is forever known as the Icarian Sea.

### Leonardo da Vinci envisioned a helicopter in the 15th century

Truly a Renaissance man, Leonardo was by all accounts a genius. Being curious about everything, he wanted to know how everything worked, and being very good at studying, designing and making all sorts of interesting things, he put his manifold talents to use.

As a scientist, mathematician, engineer, philosopher, inventor, anatomist, sculptor, architect, botanist, musician, writer and painter of "world" renown, Leonardo actively immersed himself into areas that few people even gave thought to.



Born near Florence Italy, he brought much infusion into the lives of many including his friend, the King of France, who gave him a home near the king's castle. With all these traits and experiences,

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and knowing about the spiral thread of screws, da Vinci reasoned that this technique could be used to screw up through the air (as shown in his sketch above) and thereby cause the aircraft to lift up.

Some 500 years passed by until, in the 20<sup>th</sup> century, the Russian inventor and genius engineer, Igor Sikorsky, designed, and built the first successful helicopter.

### 17th Century discovery: Air has mass and We can create lift

In 1640, Evangelista Torricelli discovered that air has mass. When experimenting with measuring mercury, he discovered that air put pressure on the mercury. Francesco Lana used this discovery to begin to plan for an airship in the late 1600s. He drew an airship on paper that used the idea that air has mass.

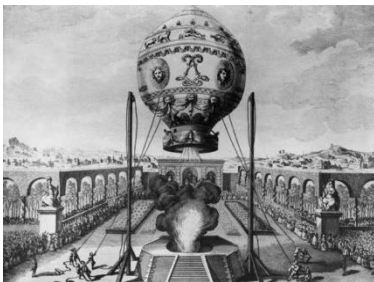
The ship was a hollow sphere which would have the air taken out of it. Once the air was removed, the sphere would have less mass (therefore less weight) than an equivalent volume of air and float up in that air.

Each of four spheres would be attached to a boat-like structure and then the whole machine would float. The actual design was never tried.

### Daniel Bernoulli 1738

In a 1738 publication titled "Hydrodynamica" Bernoulli introduced the concepts which formed the kinetic theory of gasses. To quote Wikipedia " A consequence of this law is that if the velocity increases then the pressure falls. This is exploited by the wing of an aeroplane which is designed to create an area above its surface where the air velocity increases. The pressure of this area is lower and so the wing is sucked upwards."

### The First Hot Air Balloon 1783



The Montgolfier brothers (Joseph-Michel Montgolfier and Jacques-Étienne Montgolfier) designed and crafted the first hot air balloon in 1783. They launched their balloon with King Louis 16th and his Queen Marie Antoinette and their court in attendance.

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Although the scientific knowledge was prevalent about hot air being lighter than cold air, it was the inventive Montgolfier brothers who created the hot air balloon, which at first carried a sheep, a duck and a rooster, and flew some 1600 feet.

A month later they had a flight with a French nobleman aboard using a rope to tether the hot air balloon to the ground.

### **John Stringfellow created a steam power engine airplane**

Weighing only 9 pounds, John Stringfellow created a steam-powered unmanned fixed-wing aircraft. It was powerful enough that it could fly unmanned (by itself) without having to have a catapult, nor take-off from a tower, nor be dropped from high up to achieve sustained flight.

First flight was made in Chard England in 1848.

### **Sir George Cayley built first man carrying glider 1853**

Even from a young age he was determined to solve the old riddle of human flight. When he was 10, the Montgolfier brothers invented hot air balloons, but he foresaw that flying people required wings, not just hot air-filled balloons.

Sir George Cayley had begun his aerial experiments in 1796 (at the time of the revolution in the British Colonies south of Canada), when, at the age of twenty-three, he built a helicopter device of cork and feathers. Daedalus' idea of using feathers has been used again.

From then until his death in 1857 at the age of eighty-three, the problem of manned flight-and possible solutions for mankind were aspects never far from his inquisitive thinking.

By his early twenties, he'd built a laboratory at his ancestral home of Brompton Hall where he did sophisticated aerodynamic studies. He also had the wits to hang out in a local watchmaker's shop, studying mechanics while he read Newton's theories.

Cayley made several important discoveries:

- He realized the secret of flight wasn't to be learned from birds' flapping wings, but by watching birds glide with their wings fixed. He identified the three forces acting on the weight of any flying object -- lift, drag, and thrust.
- He conceived the idea of a lifting airfoil.

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In a remarkable burst of insight, he saw that trout have the ideal, minimum-resistance, body shape for an airplane. Why a trout and not a bird? A century later we'd have rules of dynamic similitude. They show that a small fish in water behaves more like a large machine in the air than a small bird in the air does.

By 1799 he had the basic shape of a modern airplane with a fuselage, wing, and tail. By 1804 he was flying model gliders. By 1807 at age 36, he had come to understand that a curved lifting surface would generate more lift than a flat surface of equal area.

In 1809 and 1810 he published a series of articles on his theories and experiments. He also showed how to scale up his models to make controllable human-bearing gliders.

By 1810 Cayley had published his now-classic three-part treatise "On Aerial Navigation" which stated that lift, propulsion and control were the three requisite elements to successful flight. Apparently, he was first person to so realize this and publish his findings.

By 1816 Cayley was thinking about lighter-than-air machines and designed a streamlined airship with a semi-rigid structure. Using separate gas bags, he made his design a lot safer, because if damage occurred, having more than one airbag would limit an airship's lifting gas loss and make it less likely to crash.

In 1837 Cayley designed a streamlined airship to be powered by a steam engine.

In 1843, still inventive at age seventy, Cayley designed a helicopter whose rotating blades could be converted into fixed wings for forward flight. This is a much more refined concept than da Vinci had nearly three hundred years earlier, and a concept that is still being refined for the US military in the 21<sup>st</sup> century.

There in the North of England, Sir George Cayley designed and built a glider that would support a person.

In 1849 Cayley built a triple wing glider, along the lines of his 1799 design, and tested the device with a 10-year old boy as the pilot. The gliding machine carried the boy aloft on at least one short flight.



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The first adult-carrying glider flight was made across Brompton dale in the north of England by Cayley's coachman who, under his master's watchful eye and with the entire household of Brompton Hall looking on, gamely climbed aboard.

The machine rolled forward on its tricycle undercarriage and the coachman found himself hurtling swiftly down the slope toward a narrow valley.

The ground seemed to drop away beneath him and he was alone in the sky, crouching in a boat-like shell suspended from a billowing set of cloth wings.

From the far side of the valley, another low hill seemed to advance on the coachman with frightening speed. The flying craft dipped, leveled out and jounced to a landing on the slope. Excited onlookers rushed to the scene as the shaken coachman pulled himself free and blurted out, "Please, Sir George, I wish to give notice. I was hired to drive, not to fly!" Evidently, he was not as gutsy as the ten-year-old boy had been.

Cayley's granddaughter, who recounted this picturesque incident years later, was a child at the time, and hers is the only eyewitness report. But evidence pieced together from 'her grandfather's notebooks suggests that the event took place much as she described it, and that Cayley's coachman had made the world's first manned flight in a fixed-wing glider.

## Frederick Marriott's steam propelled, hydrogen filled dirigible 1869

In the United States, people were on the move and the climate was robust for expansion. Prior to completion of the transcontinental railroad, travel from New York to California was a six-month journey, by land or by sea.

In 1866 Frederick Marriott of San Francisco formed *The Aerial Steam Navigation Company* with the goal of building and operating a large steam-powered airship between New York and California, bridging the gap between the population centers of the United States and the burgeoning gold fields of the Pacific.



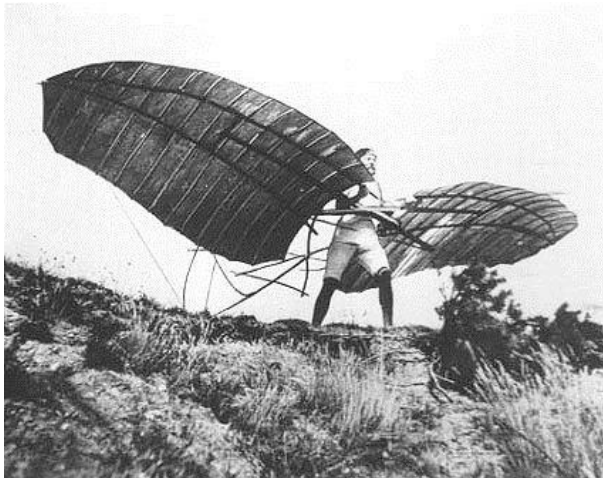
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By 1869, Marriott had constructed a 37' long prototype named the Hermes Jr. Avitor, after the fleet-footed Roman messenger god who flew through the air on winged sandals. The prototype carried no pilot and was powered by a 1-horsepower steam engine. Buoyant lift was provided by a hydrogen-filled envelope, with stabilizers and elevator surfaces attached to allow for controlled flight. The vehicle was successfully tested at Tanforan, near modern-day San Francisco International Airport. The aircraft completed a circular flight of approximately 1 mile and was recovered successfully.

Marriott planned construction of a larger version capable of carrying passengers and crew, but completion of the first rail link between east and west coasts in 1869 reduced transcontinental travel times to a week or less, and the stock market crash of 1870 prevented him from securing the necessary financing.

### **Otto Lilienthal conducted fact driven research prior to 1896:**



Living near Berlin, Otto Lilienthal believed that it is most important to know how to glide, and thus conducted extensive research and made many data driven discoveries. Nearly everyone in the fledgling days of aviation looked with inspiration to the research data that had been compiled by Lilienthal before his untimely death in a glider accident in 1896.

To prove out his theories, he would create gliders and launch himself off from a man-made hill on the outskirts of Berlin.

His belief was that canopied wings (as seen in the photo) were the way to build glider wings rather than the cambered airfoil that the Wright brothers later decided to use.

As is true even today, a nose up angle of attack that is too extreme for the air to flow smoothly over the wing will cause the wing to "stall" and lose its lifting capability. This happened during a test flight when Lilienthal was struck by a gust of wind. The gust of wind forced the nose of the glider up, thereby causing the stall. He was not able to control the resulting stall and crashed. The crash broke his spine and he died shortly afterwards.

But, thankfully, his well-documented theories and test flight results survived to be used by other aviation inventors and designer/builders of aircraft.

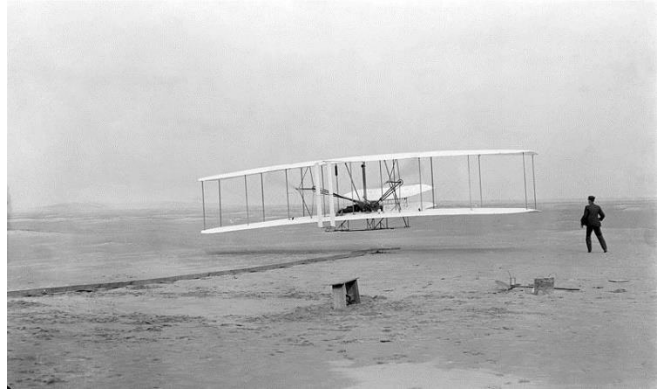
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### First powered flight of a manned aircraft in 1903 by Wright brothers

Wilber and Orville Wright were fascinated with manned flight and spent many years studying the trial and error work of Otto Lilienthal to guide them in building gliders.

Their test results with gliders caused the Wright brothers to believe that control of the of the flight attitudes (nose up or down, turning left or right) was of paramount importance. They made 700 successful glider test flights at Kitty Hawk which gave them a lot of observed data.



- This understanding caused them to find ways to alter the wing tips (called wing warping) for minor attitude changes during flight. They had observed this happening with birds in flight.
- They were the first to understand how the lift from the aerofoil changes in flight.
- And they were the first to design their propellers as a form of aerofoil to push the aircraft forward.

The Wrights made a lot of scientifically tested improvements on their propellers that da Vinci had not implemented. Having an effective propeller was as important as having a strong light engine and having wings that would provide sufficient lift to offset the weight of the airplane and the pilot was crucial as well.

Realizing that a light-weight engine using lightweight gasoline for fuel was essential, Charles Taylor (the Wright brother's skilled bicycle shop mechanic) designed and machined a four-cylinder engine that produced 12 hp. This engine was very innovative, especially because he used an aluminum casting of the block to save weight. It was built in only six weeks allowing them to get back down to Kitty Hawk for more flying tests while the seasonal weather was still favorable to flying.

The Wright Flyer, pictured above, is a wing warping design, which when coupled with a powerful and relatively light engine produced the hoped-for results shown in the first flight picture. The first powered flight carrying a person was made in the strong steady winds of Kitty Hawk Heights, North Carolina USA and only lasted an estimated 12 seconds while covering about 100 feet, but what an accomplishment at that time.



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Experimentation continued with renewed vigor, and by 1905 they had produced the Wright Model B biplane which showed much better results. So much better that a competitor, Glenn Curtiss inspected their airplane very closely to look for engineering design concepts that he could use to improve upon his own designs.

Replicas of the Wright Model B airplane made nearly a century later have shown that is necessary to fly basically in a straight line because the high amount of drag causes unrecoverable wing to droop to one side or another and that wing droop that leads to the likelihood of a crash.

## Henry Farman's numerous contributions to controlled flight 1908



Henry Farman's piloted the first cross country air flight in Europe in 1908. He was very involved with the development of powered flight aviation once the Wright brothers had shown the flight characteristics of their airplane.

Farman's addition of ailerons to the wings (aileron is the French word for little wing) made a significant improvement in controlling flight. When the pilot wants to turn left, the left aileron raises up to spoil some of the lifting properties of the left-wing tip, simultaneously the aileron on the right-wing tip goes down (which increases the lift capability of the right-wing tip). The result is that when the amount of lift on the left wing is less the airplane dips to the left (this is enhanced by the increasing lift on the right-wing tip), and thus turns to the left. The addition of ailerons to wing tips greatly increases the ability to control turns and makes the airplane much safer to fly.

Note the aileron on the left-wing tip (right side of this photo) which is tilted down to create a right turn. Farman was not the inventor of the aileron, but he is credited with being the first to practically and effectively apply the aileron principle to aircraft.



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### 1910 Maupin & Lanteri designed and built “Black Diamond” biplane

Maupin and Lanteri, who worked in a shipyard in Pittsburg California, decided to build a wood with cloth covering biplane in 1910. Lan Maupin was a dredge captain working in the Pittsburg, California, shipyard that was owned by Lanteri. Pittsburg, located in the delta area East of San Francisco Bay, was once named Black Diamond after the Black Diamond company that built the railroad to neighboring coal mining operations.

This duo was swept up in the euphoria of powered flight that was sweeping across the globe. Making good use of whatever they could learn about the Glenn Curtiss designed airplanes, they put together their design which was larger than those of Curtiss.



Using whatever was available from hardware stores, bailing wire, nails, screws, belts and buckles, they built an aircraft out of wood and covered it with cloth.



After hiring a race car driver to learn how to fly, this airplane was demonstrated at numerous airshows around the San Francisco Airport, California area. At one airshow the plane made 60 take offs and landings in the same day, and another time in Los Angeles it flew a record breaking 23 hours and 23 minutes within a five-day period. It flew to a record 5600-foot altitude, and set other records flying over Oakland and Napa Valley, California.

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### 1926 design of the Ford Tri-Motor airliner and short field freight carrying airplane

Designed in 1926 by John Stout for the Ford Airplane Company, this metal airplane was a radical departure from the wood and cloth airplanes of the early 20<sup>th</sup> century. The first all metal airplane and one fitted with three powerful radial engines, it used corrugated aluminum for the fuselage and wing skin covers. This made it extremely strong and yet light weight.



Notice the extreme improvement (development) that has occurred in only 23 years in aircraft and engine development since the time of the Wright brother's first flight in 1903.

The three powerful engines coupled with very high lift capabilities made it perfect for operating on un-improved grass fields requiring short take-offs and short landings. This capability opened up worldwide possibilities to carry freight or passengers or both.

This airplane is still in use today. Come inspect this immaculate Ford Tri-Motor that the Experimental Aircraft Association has professionally restored and now uses for public education and enjoyment.

Number NC8407 is the EAA's airplane, was the 146<sup>th</sup> airplane off Ford's innovative assembly line and first flew on August 21, 1929. It was sold to Pitcairn Aviation's passenger division, Eastern Air Transport, whose paint scheme is replicated on EAA's Tri-Motor. This is why our Ford resides in the Pitcairn hangar at Pioneer Airport. Pioneer Airport is the private grass airfield owned by EAA-National and is adjacent to Oshkosh's Whitman Regional Airport in Oshkosh, Wisconsin, USA. Eastern Air Transport later became Eastern Airlines.



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### World War II (1940's), Wars always provide impetus for improvement

Just as wars in China were the genesis for designing the Wooden-Black-Ear'd-Kite (a man carrying kite), WWII created the need for large lifting capacity and efficient flight bombers and swift well-armed fighter airplanes.

To produce these aircraft quickly and in great numbers, many of the existing automobile manufacturing production-line plants were converted to producing airplanes, trucks, and tanks.



The U.S war effort put automobiles onto rationing in 1939 to save fuel, steel, and free-up manufacturing capabilities for the war efforts. This stirred the pot for much better metal alloys and manufacturing production methods which, in turn, paved the way for new aircraft design philosophies and materials.

Note the improvement within 13 years of the load, range, and flight abilities of the B-17 compared with the Ford Tri-Motor. Fighter planes made similar advances, to the point where Germany was able to develop a prototype for a jet engine fighter plane just before 1945. This jet engine technology was, of necessity, coupled with radical improvements in aircraft design and improvements and led to rocket technology which was then utilized by the United States in the 1960's and 1970's for the race to the moon. Later, the International Space Station was created with the USSR where some people have lived for nearly a year!

### Modern Developments in the amateur homebuilt arena

The 1960's and 1970's saw a prolific number of plans for new designs arrived for homebuilders.

The 1980's and 1990's introduced ultralight airplanes and a growing number of amateur builders.

2000's and 2010's brought manufacturers that provided winning designs in kit form for easier amateur build projects. Carbon fiber use is getting extensive in some kitplanes, and some component applications in other aircraft. Boeing and EADS are putting extensive resources into designing and building airliners from weight saving carbon fiber.

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### 2012 Jetman, Yves Rossi

Jetman, Yves Rossi, has designed, built, and flown the ultimate jetpack including a carbon fiber wing structure that allows him to wear it on his back and fly formation with slow flying jets and vintage aircraft.



### 2013 Randall Fishman's electric motor, carbon-fiber motor-glider

Randall Fishman has developed an electric motor with lithium batteries and controllers to power his newly designed carbon-fiber motor-glider.



This rear engine motor-glider can stay aloft for about two hours powered only by electricity from the battery packs. Empty weight (without energy source) puts it into the Ultralight Class and coupled with the 20:1 glide ratio, it has very good performance thanks in part to the 37-foot wingspan. The twin tail booms add a box-like structure to the wings-fuselage and provide structural support for the main landing gear.

The sleek, brushless, electric motor is only 9.5" x 3.5", yet it provides the electrical equivalent of 20HP (15 kilowatts). This gives it power to take off in 200 to 250 feet and climb at the rate of 500 to 700 feet per minute. All this with serene quietness and no engine vibrations! With the low sink rate of only 236 feet per minute, this aircraft can keep itself in level straight flight by only using 3 kilowatts of power.



As designer Fishman likes to say, "it is the closest thing to riding a magic carpet ever attained".

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### 2013 Solar powered airplane flew across USA

Solar Impulse is the first solar-powered plane capable of flying both day and night without using any fuel. During the day, the plane collects and stores energy from the sun to power its four electrical motors and onboard batteries, allowing the aircraft to fly even when the sun goes down. The Solar Impulse is pictured flying towards the foreground as it prepares to land at JFK airport. Note the Statue of Liberty off the left-wing tip (right wing tip has the green navigation light).



André Borschberg and Bertrand Piccard alternated flying the solar plane, called [Solar Impulse](#), on the five legs of the aircraft's cross-country journey. To save weight, there is only the seat for the pilot. Part of the pilot training program to prepare for the around the world non-stop flight is to learn how the pilot will cope with what will be about a twenty-four-hour flight. Their ultimate objective is to fly around the world using only solar power.

The two Swiss pilots who flew a solar-powered airplane on a record-setting coast-to-coast flight across the United States say they hope their accomplishment will draw the world's attention to the vast potential of sustainable energy.

**Let us not lose our inquisitive inventing spirit, there are always new areas for opportunities in aviation.**

**Share your data driven ideas.**

**Stay fired up! Ready to go!**