Inventing the Impossible

Is the Polywell a hoax? Carl Sagan once said of hoaxes: "they make us feel good, but are not the way the world really is" [15]. The Polywell is an untested idea for fusing atoms. It offers solve many great problems - so it makes us feel really good - but it may not work. With so much potential, we should be more critical of this. We should be more skeptical. We can't cheat it. We have to test the idea. The science has to be rock solid. If the idea is a flop, we have to accept this.

Arguments for and against:

Right now, the mechanism for Polywell fusion is connected to some established scientific concepts. Concepts like the magnetic mirror - a physical process where particles are reflected by magnetic fields. So it seems reasonable to expect that six ring fields in a box will hold in electrons and ions. Concepts like ion acceleration by voltage drop - a physical process where charged ions accelerate down a voltage drop. Hence, one would expect ions to accelerate to high speeds into a negative electron cloud. Concepts like diamagnetism – a physical process where collections of particles form their own magnetic field in response to an external field. So it seems reasonable that the cloud of electrons in the center go diamagnetic, rejecting the ring fields. We know that one of NIFs stated goal is to get the average particles temperature around 10,000 to 20,000 of electron volts [22]. So it seems reasonable that a single ion could be hot enough to fuse traveling down a 10 or 20 kilovolt drop. Lastly, we have hard evidence that a Fusor - a device of the similar size, cost and concept - can fuse atoms at similar voltages. Is it not reasonable expect, that the Polywell can, at least, fuse atoms?

Not so fast. We also know that the counter argument is connected to real physical processes as well. We know that every time a particle flies by another particle, X-rays are generated. With on the order of 10 billion particles inside the machine - it seems reasonable to expect x-rays will cool off the cloud rapidly. We know that systems with large numbers tend to have a bell curve distribution. It seems reasonable than to expect that the cloud of particles will have a low mean energy, with only a limited number of ions which can fuse. We know that gas clouds do not normally contain any temperature variations. Hence, Rider's estimation that the cloud can at most have a 5% temperature difference seems reasonable. This implies the cloud must be one temperature and that temperature must probably be hot. If this is true, it may be a huge road block for a working reactor. We also know that neutrons, without moderators, destroy material - so it is reasonable to expect that the machine will cook. Finally, we know that there are

plasma instabilities for almost every plasma structure. It seems reasonable to predict that plasma structure will fall apart into a disorganized mess.

These criticisms are real and they need to be considered. You cannot ignore them. You must provide evidence that they are not happening, or that they can be operated around. If established science is wrong, then provide the data which demonstrates this. Experts can make mistakes; so unpredictable outcomes are not so farfetched. We predict that gas prices will continue to rise, that energy will become scarcer and there will be more interest into this idea. We worry that people will rush to easy a conclusion. Talking heads on both sides of this debate will declare - too soon and too eagerly - that this idea is either "a hoax" or "the solution". We want you to know that - as far as we can tell - both sides will be lying. This is important: do not rush this. The answer is still unknown. On this blog, we estimated that fusing 0.2 kg of material in 1 hour with 1% efficiency makes electricity at 91 cents for DD and 17 cents for PB11. Even if the beta version of this reactor was inefficient, crude and ill designed, it still stands a good chance of being profitable. These price calculations depend heavily on fusion rate, fusion efficiency and energy collection efficiency. Right now, what we collectively need to do is research this topic. There should be many more minds and many more dollars chasing this idea.

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A Lesson From History:

"Why! a person could no more do *that* than he could fly!"

Human flight was deemed impossible. Professor Simon Newcomb the eminent authority at the Naval Research Laboratory said this about flight: “Flight by machines heavier than air is unpractical and insignificant, if not utterly impossible” [2]. Not only did the experts deem flight impossible, but the public did as well. At the time, aviation enthusiasts; such as Chicago engineer Octave Chanute, were seen as cranks. Octave’s book “Progress in flying machines” summed this up nicely: “Naturally, the public has taken little heed of the progress really made toward the evolution of this complicated problem, hitherto generally considered as impossible” [16]. Flying was impossible. Anyone pursuing flying was considered foolish. The evidence was all there. For over 100 years professional, amateur and ridiculous attempts had been tried, and they had all failed. What more proof was needed?

Why would we want to examine the invention of flying for hints on how to solve the fusion problem? Flight happened over 100 years ago, in a very different world. The reason is flight was not only an innovation, but a machine beyond peoples' comprehension. It is also one of the most recent examples of this. We argue that though the technology, culture and politics have changed in the past century, the general public has not. The world of 1903 had its corresponding established institutions, media outlets, vested interests and similarly; it had its rainbow of people with their own views. How did they react when a machine did something impossible? What can teach us to solve the fusion problem?

Early Attempts:

By the 1890's man had been able to fly in balloons, but heavier than air devices were still elusive. Still, there was evidence that flight was possible. Birds could fly and cheap kites could fly. Today, there is evidence of fusion. Stars fuse and cheap fusors can fuse material in people's garages. It was into this world that a retired engineer named Octave Chanute ventured. He was a sharp engineer, who in retirement saw flying as the defining problem of his time. He decided to devote his time to solving it. There was already a wealth of attempts to draw from. For more than 100 years, all manner of flying machines were attempted. Some of the attempts are pictured here [16].

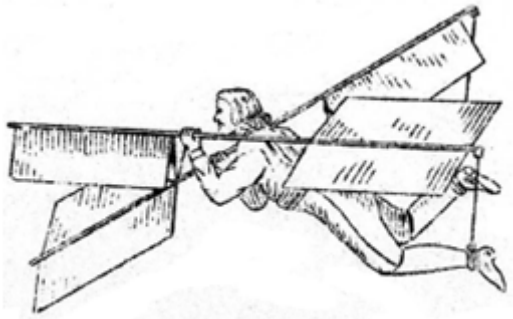


FIG. 3.—BESNIER—1678.

FIG. 9.—DE GROOF—1864.

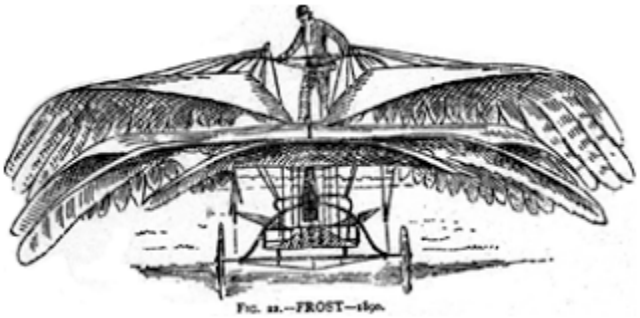


Fig. 11.—FROST—1870.

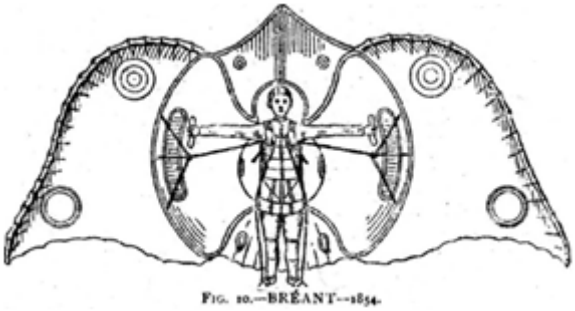


Fig. 10.—BRÉANT—1854.

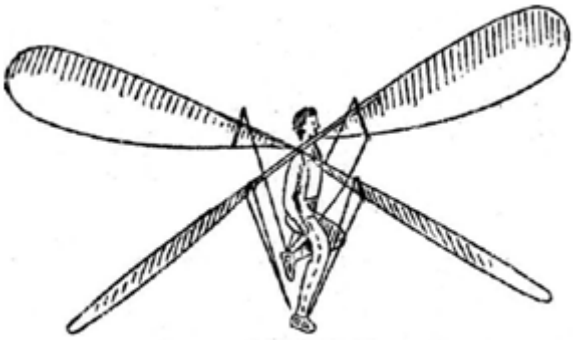


Fig. 5.—BOURCART—1866.

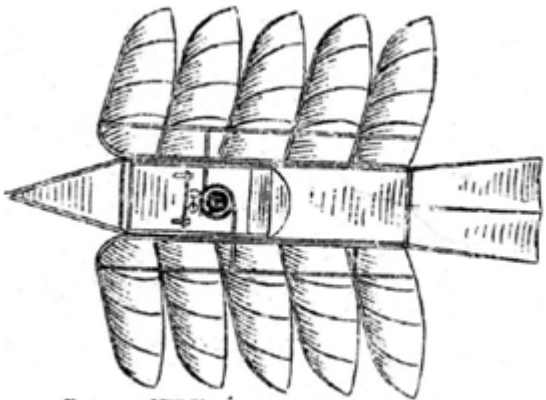


Fig. 13.—STRUVÉ & TELESCHEFF—1864.

The future may look at our attempts to fuse the atom as wildly as we look at these devices, today.

Chanute made several first steps to solving the problem. He collected all the information he could on flying devices. It took him about a couple of years to gather this and publish it in the book “Progress in Flying Machines” [17]. This

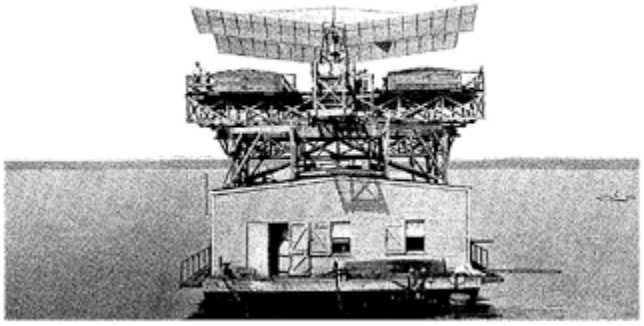
book became essential. It compiled information on every attempt – however crazy or improbable – and systematically classified and analyzed them all. This stopped people from repeating the same experiments and helped clarify the problem. Today, fusion has no such book. The books out there take too narrow a view, touting their own solution. Someone should write a fusion book like this. This would be a book which takes a step back; a book which analyzes every idea objectively. The book should look at every idea; regardless of funding amounts, regardless of who supports it and regardless of how unlikely it is. It should - with no agenda - analyze them all. This list includes, but is not limited to: general fusion, tri alpha energy, focus fusion, inertial confinement fusion, the polywell, the tokamak, the Fusor, the penning trap, magnetic mirrors and the z-machine. Sort, organize, explain, classify and analyze all these ideas objectively.

Next, Chanute organized a conference on flight in 1893 in Chicago. Today, Polywellers have talk-polywell but it would be interesting if someone could found the Fusion Society of America. The group could have officers, hold meetings, make webcasts, sponsor conferences or publish a newsletter. Through the conference and different societies, Chanute built relationships with a large group of aviation enthusiasts. He was open about the flying ideas and had correspondence with many of the inventors of the time. This allowed them to interact. This could be improved in today's fusion community. We need to be better networked and we need to be capable of discussing ideas openly, even with people touting a competing idea. Chanute studied, communicated with, teamed up with, supported and even financed other inventors. These included Louis Mouillard, Alberto Dumont, Louis Blériot, Otto Lilienthal and the Wright brothers.

Lilienthal was already 26 years into the flying problem, when Chanute organized his conference. Lilienthal was a German engineer, then in his forties, testing flying ideas outside Berlin. There is a stark similarity between Bussard and Lilienthal. Each individual devoted a long time to their idea, both made pioneering discoveries and both died before their ideas were fully realized. Lilienthal tested ten devices over the course of six years. He died in a glider crash in 1896. Lilienthal dying words were "sacrifices must be made" [8].

The flying world of the day also had its' highly funded experts. Sam Langley, who was the Secretary of the Smithsonian was given the full weight of congress and the federal government to solve the flying problem. In 1898 he was given 1.3 million dollars (in 2012 currency) by the war department to build a flyer [18, 19]. Over a million dollars can buy you a large staff, housing, a novel engine and extra equipment – and that is exactly what Langley did. Overtime, he had a staff of 17 people working for him [10]. The team aimed high, and built a wide

four winged machine called the Aerodrome. The effort focused on getting enough power to force the machine into the air. It was launched with powerful springs and a 52 horse power, 120 pound engine. Langley wasted allot of the money on supporting equipment which had no relevance to flight. He built a large, costly, houseboat to hold the plane; with a machine shop, storage space and a launching platform on top. A picture of the houseboat and plane is included below [19].



After spending all this money, Langley only preformed two tests of his plane. These two tests were on October 7th and December 8th 1903. On the first of these tests, the plane hit the supporting platform and crashed [19]. In other words, the unnecessary equipment got in the way. Hence, this test yielded no useful information about the mechanics of flying. On the second attempt, part of the machine collapsed; causing it to fail. We got a hold of his notes: it was reams of paper, equation after equation, tables, detailed observations and designs; all an anthology of wrongness. After all the fanfare and hype for this experiment; this evidence showed the public what it already assumed to be true: man would never fly. Many people began to consider the matter closed. Newspapers openly criticized the work; as did members of Congress. Flight was impossible.

The Ultimate Historical Joke

In the ultimate historical joke, only nine days later, flight was officially invented. Ha. It was done by two guys, unknown and with no college education. The machine they used cost them far less than Langley's' machine, less than 25,400 dollars (in 2012 currency) [3, 18]. It was less powerful, less complex and smaller in size. With no federal support and almost no staff, how did these two guys solve an impossible problem? How did they then convince the unbelieving world that they had done it? And what can we learn here?

Learning From The Wrights:

From an early age, the brothers were obsessed with flying. A common childhood story of the brothers is playing with a toy helicopter. By spinning the helicopter the little device could fly all over a room. After high school, they started in the bicycle business in Dayton Ohio. It gave them a meager income and a grasp of how simple machines can solve problems. With limited spending money they started work into flight. Today, one can think of Mark Suppes, working as a programmer at Gucci during the day and spending his money on Polywell work at night. It is the same idea.

The brothers started with the simplest flying machine they could: a child's kite. From studying this they learned the basic principles. They learned that warping a wing moves the center of pressure and turns the kite. They learned how to steer. This basic information seems so simple, yet very few people had this knowledge. Experimenters kept focusing on getting enough power to get into the air; while the Wrights began by studying something already in the air. Today, the simplest device which can fuse is the Fusor. This is like the child's kite of fusion. High school students build them in their homes. The opposing approach starts with high powered, complex machines. Where, the focus is on getting enough power to initiate reactions. Complex machines are hard to analyze, making it hard to see the underlying principles. One should start simple, learn the basics and add complexity slowly.

Next, the brothers gathered as much information about flight as they could. They objectively questioned and sifted all of knowledge. This was regardless of if it came from experts, their own work or from other amateurs. Not having a college education gave them a fresh view of the problem. In fact, if they had gone to college they probably would have been taught that flight was impossible. From all this sifting, the brothers identified Lilienthal as the most successful flyers so far and decided to build on his work. They started by modifying this flyer by putting the person in between the wings. They also made connections with a community of other people interested in solving the problem. This included Octave Chanute, who gave them a method to mechanically warp wings. This was a critical starting point [21].

Armed with information from past attempts, kite experience, and a basic design; the brothers set off for Kitty Hawk in 1900. They chose Kitty Hawk because the wind allowed them to do extensive experiments. It helped that it was an isolated place with lots of room to work unbothered. They did not have much money. They did not have a staff to document every detail. They relied on simple equipment and lots of tests. The contrast to Langley's high priced effort cannot be

starker. Their first machine had no hope of success, but they learned all they could from it.

A year later, in 1901 they returned with an improved glider. There were three surprises in the 1901 tests – all indicated that the accepted science on flight was flawed. The first surprise was that inclining a wing moved the center of pressure backwards – not forwards as was thought. The second surprise was turning one wing up and the other wing down caused the plane to turn – but not in the direction that was expected [21]. The last surprise was the most astounding. The lift tables were wrong. This was a basic measurement: if 1 MPH air, strikes a 1 foot square plane at an angle, what is the lift force?

Modeling The Flying Problem:

This was a hard measurement to make, therefore, accepted numbers from the experts varied by 50 percent [21]. To date, the most celebrated numbers were from Langley, but much of his table turned out to be just guesswork. There is no doubt Langley would have seen his mistake – if he had been spending his resources on flying and not building a house boat. The brothers had complete faith in the numbers - but continual failures slowly led them to the inexorable conclusion these numbers were wrong. Wow. This is at the heart of exemplary science. We look today at the particle loss equation used by Rider to analyze the polywell - one based on theory. An equation; extrapolated from data on magnetic mirror machines, machines which have completely different geometry. Is there a chance our modern day lift tables are wrong?

Octave organized a talk for Wilbur, in 1901, in Chicago. It was at this talk he made the bold statement that the accepted numbers were wrong. This made Orville nervous and spurred him to do his own measurements [3]. It is important to realize, had these researchers not been networked, the wind tunnel tests may not have happened. Good science involves the six sigma principal of eliminating variation. The lift force varied wildly. Hence, these tests had been a mess. The brothers described this nicely:

> "The pressures on squares are different from those on rectangles, circles, triangles, or ellipses; arched surfaces differ from planes, and vary among themselves according to the depth of curvature; true arcs differ from parabolas, and the latter differ among themselves; thick surfaces differ from thin, and surfaces thicker in one place than another vary in pressure when the positions of maximum thickness are different; some surfaces are most efficient at one angle, others at other angles. The shape of the edge also

makes a difference, so that thousands of combinations are possible in so simple a thing as a wing."

Eliminating variations is a key to good science. In this case, they want to pick out one variable: the angle into the wind, and measure one variable: the force it provides. The relationship was made clear by eliminating variations everywhere else. Look at the mess of variables inside the polywell, testing one variables' effect on the fusion rate will require removing variation with all other experimental variables.

The wind tunnel was a model system. From the model they identified a dimensionless number which underlined flight: the aspect ratio. The aspect ratio is the length of the wings against the width of the wings [3]. They also tested the idea of wings on top of one another or behind one another – this eliminated many possible designs in one test. Today, we may model the polywell with simulations, find dimensionless numbers and eliminate a vast array of designs using models. With this data, they now considered the addition of gas driven propellers. Here, they found that propellers were also ill-understood. They fought, they argued, they yelled and screamed at one another for months over this [3, 21]. The brothers explained: "After long arguments, we often found ourselves in the ludicrous position of each having been converted to the other's side, with no more agreement than when the discussion began." The argument forced them to refine their knowledge. Argument is essential to good science. Finally settling on a propeller design and accurate lift tables, the 1903 flyer was built. This machine officially made the first flights on December 17th 1903. It made four flights, the longest being 852 feet [3].

Public Treatment:

After these tests the brothers sent word to the newspapers of their success. They were ignored. One tabloid in Virginia created a fantastical story of a three mile flight with one of the brothers running alongside shouting: "Eureka!" The world did not take the Wrights seriously. In 1904, the brothers invited reporters to tests in Dayton. But, the wind only being 4 mph the plane failed to fly. Being ignored was fine for the Wrights. It allowed them to improve the flyers performance. For months, they flew in plain sight of a highway, passing railcar commuters and local farmers. Despite the attention, they did not make any sensation in the news. Editors at the Scientific American, the Dayton News, Colliers Weekly and the Cincinnati Post all ignored reports from observers. So did the US government. From the fall of 1904 to the spring of 1906 the War department ignored four separate entreaties from the brothers, to buy warplanes.

Meanwhile, the British army was well into talks with the Wrights. Today, it is our hope that the US military developed whatever potential the Polywell may have. However, if the US military ignores this technology, China or Iran or Korea will certainly snatch it up.

In reality, the invention of flight spread by word of mouth through the flying community. In "The Purple Cow" Seth Godin explains how a novel idea travels through the population by starting with: sneezers [5]. Sneezers are people who are local experts on a topic. They spread the idea to their friends and contacts and it works outward from there. People argue that this has changed in the past 110 years. That YouTube means inventions will instantly be recognized and adapted by the public. We doubt it. The public is as skeptical today as they were 110 years ago. Today, if you claim to do fusion, no one will take you seriously.

A handful of people in Boston, France and England did hear about the Wrights. One of them was Frank Lahm. He was wanted to verify these claims so he sent his brother-in-law to Dayton. That man, Henry, first met the Wrights on December 3rd 1905. Henry was very impressed. He wrote: "[Wilbur's] very appearance would disarm any suspicion - with a face more of a poet than an inventor or promoter … very modest in alluding to the marvels they have accomplished" [3]. This is an important and nearly constant observation. The most common impression people got when first meeting the Wright brothers was their mildness, their ease, their humbleness, their calmness, their almost bemused manner. It helped people trust them and accept that flight was possible. Even after the world went nuts with flying fever. Even after the brothers were meeting Princes, Presidents and Kings of Europe, the brothers remained very relaxed.

It was Lahm and his son who got the word out about the Wrights. Lahm took flying reports to the Aero Club in France. That meeting erupted into complete chaos. People "knew" that flight was impossible with only a 12 horsepower engine. Given that the work had no funders and came from unknown men; it was even harder to believe. Lahm got these reports published in two French newspapers and the New York Herald. When the Brothers came to Paris, it was Lahm who invited them into his home. His son was a US Lieutenant and was one of the people who pushed the US military to believe in the Wrights. It took the war department four years to issue a request for warplanes. This caused the newspapers to pay attention. They called the move to build air machines, delusional. Finally, with a signed US war contract, the Wrights started their 1908 tests. Before they started however, the newspapers widely reported they had flown 10 miles out over the ocean! The facts were totally distorted. Even after some newsmen started secretly spying on the Wrights and writing reports, editors still

did not consider this important. It was only after a demonstration for the military - where Tom Selfridge was killed in a crash landing – did flying suddenly become sensational in the US.

Final Advice

The experience of the Wrights is very illuminating for any fusion researcher today. A commercial fusion reactor would be just like a working air machine of 110 years ago. This could be history repeating itself or it could be nothing. We do not yet know what will happen. However, for those who endeavor to invent the impossible, history has the following advice for you:

1. The experts can be wrong. Man can fly.
2. The innovators need a new view.
3. Get a partner.
4. Get as much information as you can and question everything.
5. Connect with a network of people.
6. Use the simplest model - add complexity later.
7. Base conclusions on the evidence.
8. Have a sharp eye.
9. Get into arguments.
10. Get accurate data.
11. Be causal about it.
12. Nobody will believe you.
13. Expect your story to be wildly inaccurate in the media.

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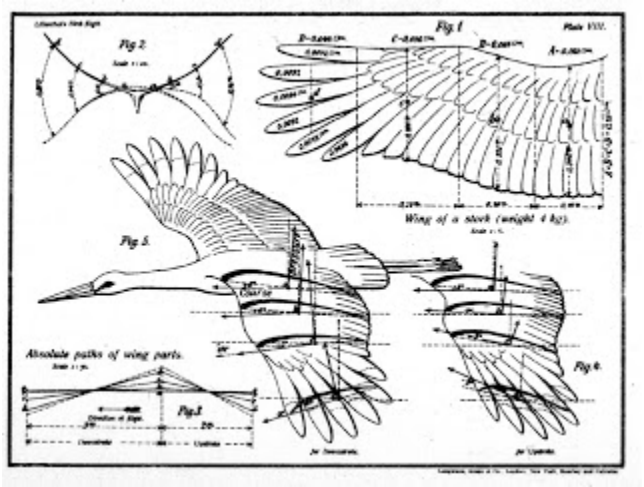

Figure: Otto Lilienthal examinations of a bird's wing.

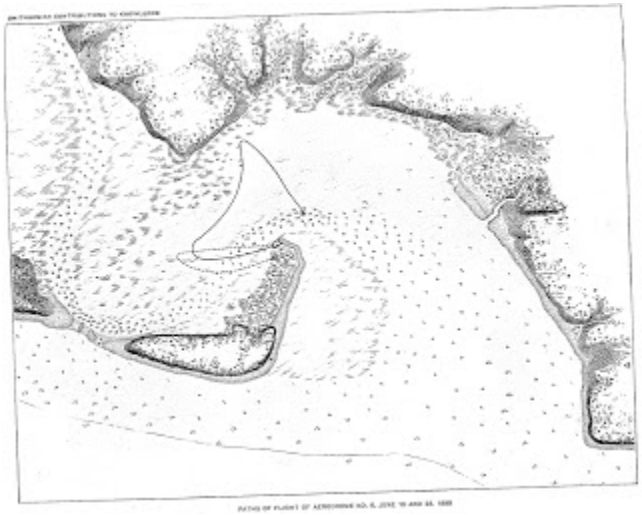

Figure: Aerodrome flight path, in bay, with soundings.

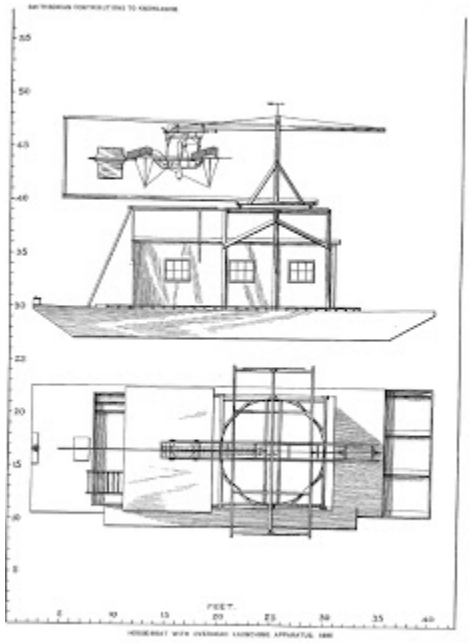

Figure: Aerodrome and houseboat.

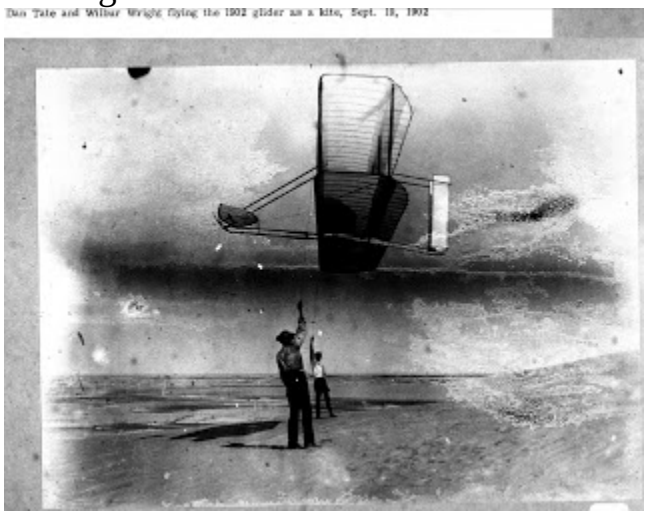

Figure: Wright's 1902 kite.