Robert B. Elliott is the author of BUILD AND FLY THE FIRST FLYERS and creator of THE TOOTHPICK AIRFORCE™ concept. Especially for the Centennial of Flight Elliott has modified parts of his book and designed additional gliders to demonstrate the progress the Wrights made with their first four flyers. Building and flying toothpick glider replicas of the Wright gliders and flyers require the student use and understand the same knowledge of flight and control surfaces the Wrights pioneered one hundred years ago! Ladies and gentlemen, prepare for flight!

Wright Brothers Aeroplane Co. replicas of 1900 (front left), 1902 (right), and 1901 (rear) glider at Jockey's Ridge State Park, NC, October of 2002. (photo - R. B. Elliott)

THE TOOTHPICK AIRFORCE

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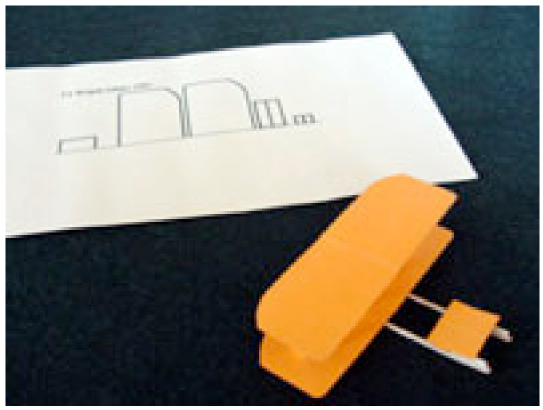
BUILD AND FLY THE WRIGHT FLYERS

THE TOOTHPICK AIRFORCE™ (TA) concept is actually a formula for achieving balance in design and construction that allows the reader to build flying replicas of any aircraft of any era using just paper, paste and toothpicks! To celebrate the Centennial of Flight you can build the Wright 1900 glider, the 1901, 1902, and the flyer that made the world's first controlled, powered flight, at Kitty Hawk in December of 1903.



Toothpick glider replicas of the Wrights' first flyers, that fly just like the real aircraft!

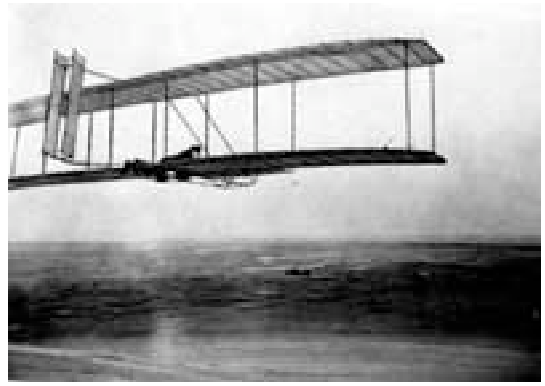
Follow the Wrights' progress with replicas of each of their first manned aircraft, learn the secrets that each successive flyer revealed!

From the wing patterns on the following pages you can construct flying glider replicas of the airplanes that marked man's first successful flight.

Creasing the paper along the "fold line" makes mirror image wing surfaces and parts when cut out.

Always cut on the solid lines, bend and crease on the dotted lines.
Shown are all the supplies you will need.
The clippers will be very handy.

Making Gliders Fly!



Building gliders that really fly can be a challenge. First we need to know why they fly, and there is no better way to do that than to look to the men who invented flight. Wilbur and Orville Wright planned, experimented, worked hard and practiced gliding continuously to conquer the air.

Along the way, they or their fellow pioneer flyers found a lot of ways to describe the mechanics of flight and invented special aviation terms and words you will need to know.

We know now, flight is possible only when there is a balance between three absolute necessities: **lift**, **control**, and **thrust**. But in 1900 the Wright brothers had to figure this out for themselves. These words have special meaning in aviation:

Lift - The force exerted by the movement of air on an airfoil, being opposite the force of gravity and causing an aircraft to stay in the air.

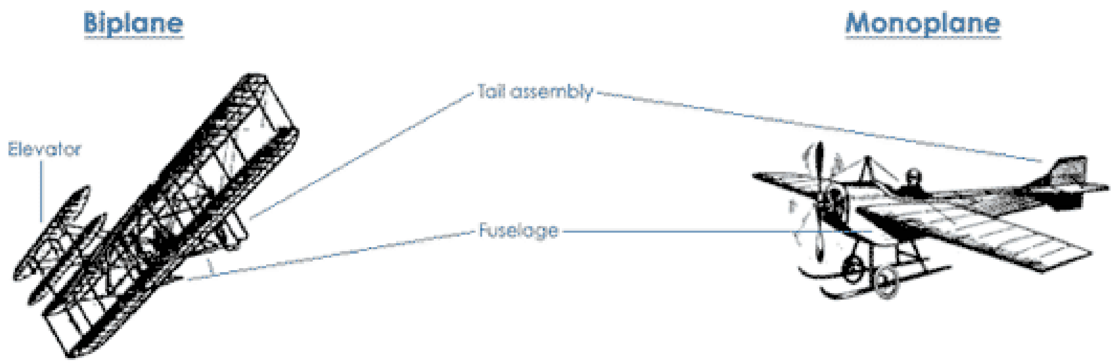
Control - To hold in restraint or check; to regulate; to govern.

Thrust - To push or drive with force.

In their experiments with their 1900 and 1901 gliders the Wrights used information from other pioneers of flight. But this information on how wings created lift did not work the way it was supposed to. The brothers built one of the first wind tunnels to test the data, and found the data was wrong. The Wrights' wind tunnel experiments and experience on their first gliders led to building the 1902 glider, which had new and advanced controls.

The 1902 glider was larger than any of the other gliders built anywhere in the world up to then, making some of the longest glides in history possible. With this glider they were able to perfect their control system, for which they received a patent in 1906. This three axis control system allowed for adjustment to yaw, pitch and roll, and is the basis for all modern aircraft flight.

The final challenge for the Wright brothers was in developing their own engine, and an efficient propeller. When the Wrights finally flew on December 17th, 1903, they had finally mastered lift, control, and thrust! The descriptions and definitions on the following page will be helpful in constructing toothpick replicas of real gliders. Once you have mastered the basic mechanics of flight, experiment with camber in <u>Advanced Wing Structure</u>.



Biplanes have two wings with struts between for strength and support. The Wright elevator was in front.

Special Terms for Airplanes and Flying:

Airplane and aeroplane—An airplane is a heavier-than-air craft that can be propelled through the air supporting itself on the lift from its wings. The British and some Europeans still use the term aeroplane.

Parts of an airplane—Fuselage, wings, tail assembly, engine, propellers, and landing gear. A glider is an airplane technically, even though it has no engine.

Fuselage—The fuselage is the body of the airplane, or the airframe that held the wings, engine and tail assembly in place in the first aircraft. The word comes from the French word *fusele,* meaning "spindle shaped."

Wing—The wing is an airfoil. An airfoil is a surface or body, like a wing, propeller blade, rudder, or aileron, designed to obtain a reaction of lift, drag, or thrust when it moves through the air.

Tail Assembly—The tail assembly is at the rear of the fuselage, and usually includes a rudder and elevator to maintain **stability**. It is sometimes called the empennage, from the French word *empenner,* meaning "to feather the arrow."

Stability—An airplane is stable if it flies straight and level, and can be righted if disturbed by a gust of wind or turbulence. An airplane can be rotated to maintain stability (using the **rudder**, **elevator**, and **aileron** surfaces) through three axes; lateral, vertical and longitudinal. These motions are called yaw, pitch and roll.

Rudder—The rudder is a control surface usually found at the rear of modern aircraft. The rudder controls turns to the right or left, or yaw.

Elevator—Up and down control (pitch) is provided by what the Wright brothers called a horizontal rudder, and we now call the elevator. The Wrights placed the elevator in front of the wing, but most modern aircraft elevators are part of the tail.

Aileron—A control surface set into or near the wing tips, that is used to control the longitudinal axis or roll of the airplane. Ailerons are connected, so that when one is extended up, the opposite wings aileron is extended downward. Ailerons were developed from the Wright concept of wing warping, which increases the lift on one side while simultaneously reducing it on the other.

Practical Applications

The reading and model building activities contained in Build and Fly the Wright Flyers present the opportunity for teachers and students to work with projects that fall within several of the National Science and Mathematics Standards. The activities touch on the nature and history of science. They demonstrate that the Wright brothers followed scientific inquiry and kept records of their findings. Building and flying the model gliders and flyers include measurement, working in scale, form and function, motion and forces, abilities of technology, and awareness of variables. Tuning and flying the gliders and flyers require attention to the principles of flight, as well as weight and balance. The builder will learn to change the flight characteristics of their gliders.

Approximate Metric Conversion Table for Construction of TA Aircraft

2 1/4”	= 5.8 cm	7/8”	= 2.3 cm
2”	= 5.1 cm	3/4”	= 1.9 cm
1 3/4”	= 4.5 cm	5/8”	= 1.6 cm
1 5/8”	= 4.2 cm	1/2”	= 1.3 cm
1 1/2”	= 3.9 cm	3/8”	= 1 cm
1 3/8”	= 3.5 cm	1/4”	= 7 mm
1 1/4”	= 3.2 cm	3/16”	= 5 mm
1 1/8”	= 2.9 cm	1/8”	= 4 mm
1”	= 2.6 cm	1/16”	= 2 mm

The metric conversion table above is adapted for the purpose of building TA airplanes! It may not reflect exact measures, instead it rounds measures for the express purpose of maintaining the balance and structures of TA aircraft. It is included only for the use of those who prefer to use metric measure.

As this young lady knows, there is only one right way to fly a Wright Flyer - <u>the elevator is at the front</u>!

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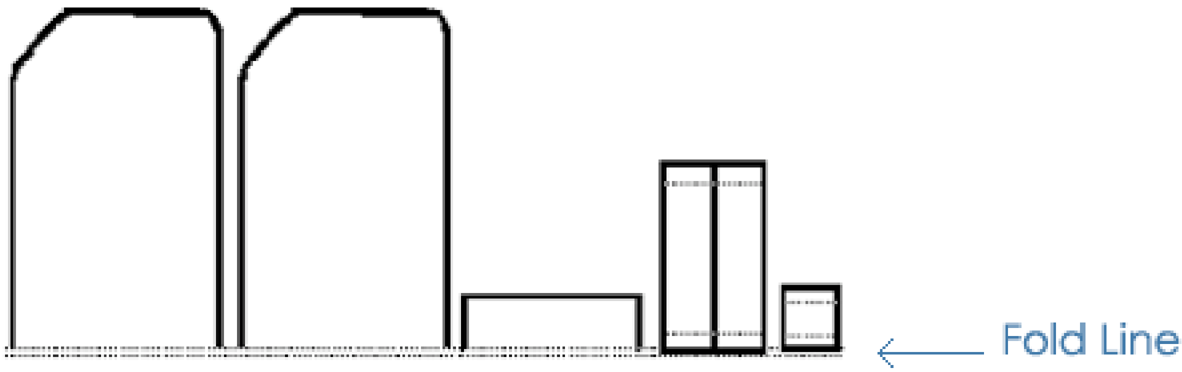
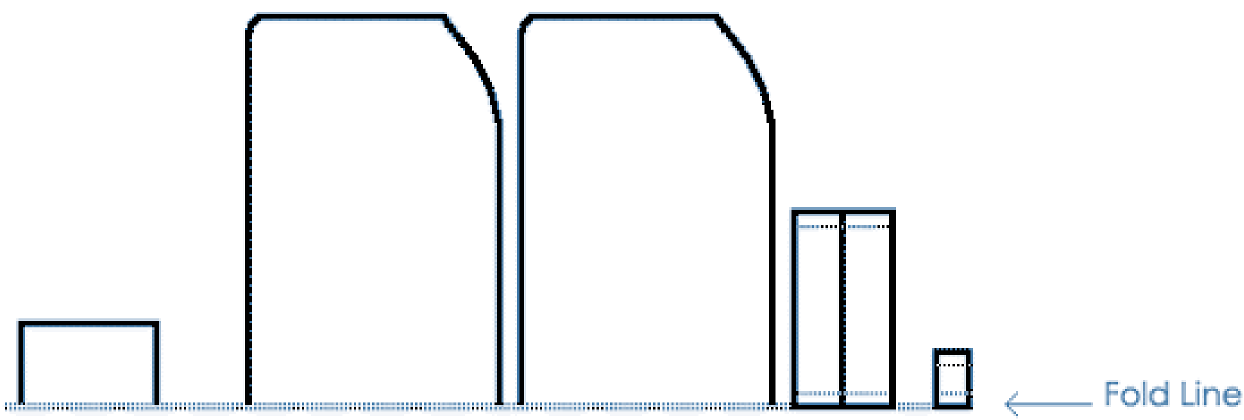
Wright 1900 Glider

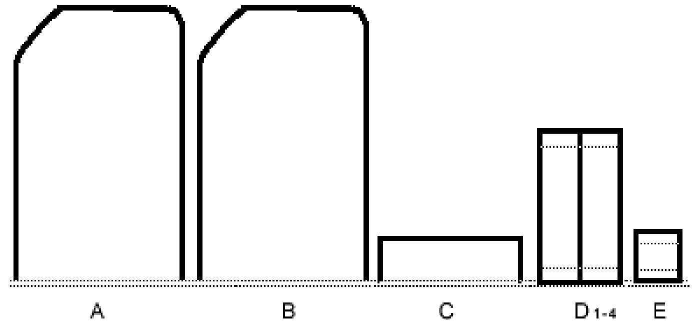


Wright 1901 Glider



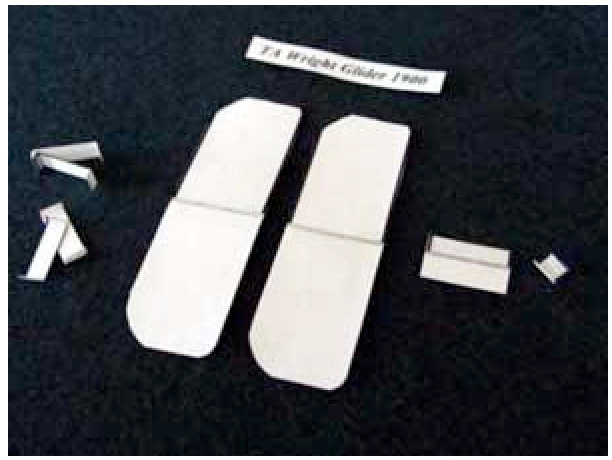
THE TOOTHPICK AIRFORCE is abbreviated to TA throughout this publication.

Parts list for Wright 1900 glider.
A and **B** are wings.
C is the elevator.
D1-4 are wing struts.
E is the elevator strut.
One full length (2-1/4") flat toothpick for the airframe.



<u>**Assembly Instructions**</u>

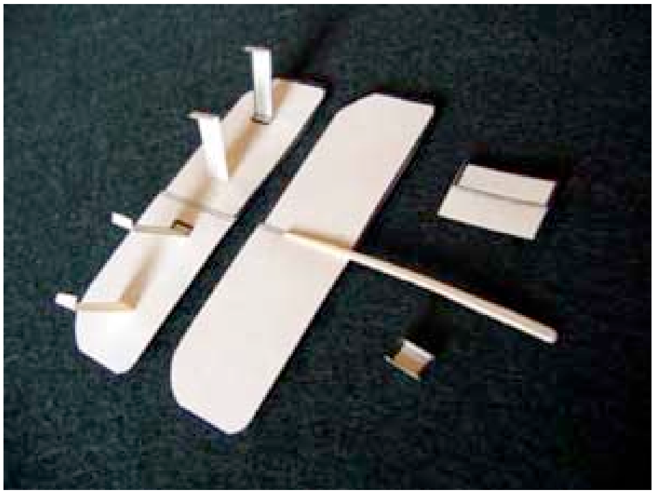
1. Copy, scan and print, or trace the drawing on the previous page on 24 lb paper of any color.
2. Bend and crease the drawing at the fold line (see supplies photo page 2).
3. Cut the glider parts out starting at the fold line. <u>Always cut on the solid lines, fold on the dotted lines.</u>
4. Lay the wings and elevator flat on your work surface, with the printed side up.
5. Bend the struts on the dotted lines to form "feet" on each end of the strut. Make the bend on the end away from the original fold line first.



The parts above are shown as they should appear on your work surface. The wing struts and elevator strut have been folded on both ends to form "feet." The "foot" provides the surface you will need to glue the wings and elevator in position.

6. Cut the struts apart. You will now have 4 identical struts with which to mount the upper wing on the lower.
7. Bend the single elevator strut to form "feet" on both ends.

Learning to make "<u>feet</u>" is an important skill in THE TOOTHPICK AIRFORCE! The foot is formed by bending approximately one-sixteenth inch of the paper part into an <u>L</u> shape. The "<u>foot</u>" on the bottom of the <u>L</u> makes a flat surface large enough for the glue to hold securely. This is important in fastening tail rudders, landing gear, or biplane wing and elevator struts in place.

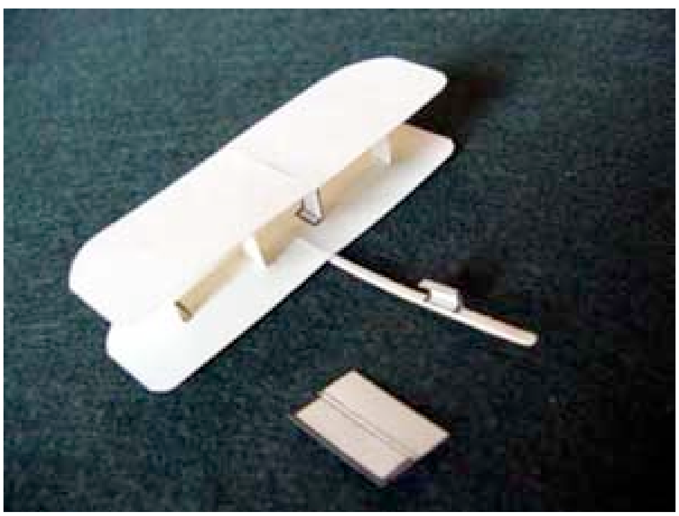


The top wing should still be flat on your work surface, print side up. Once the struts are in place and dry, straighten them up to a 90 degree angle. Then line the wings up to glue them in position

Assembly Instructions (cont.)

8. Smear a small amount of Elmer's (or similar paste) on each strut foot. Warning! Excessive amounts of paste can cause warping of your wing surface. Mount them one at a time on the upper wing, beginning 1/4" from the centerline. Place the outside struts 3/8" from the wing tip, as shown in the photo.

9. Examine your flat toothpick. You will find a slight bevel on both the wide and the narrow ends of one side. Smear a small amount of glue on the small or narrow end of the toothpick on the non-beveled side. Press the toothpick into position, overlapping the leading edge of the lower wing by 5/8".



A 7/8" block from the large end of a toothpick for weight glued to the top of your toothpick airframe should provide balance. Place it as far forward as possible. Prepare your glider to fly using the "tuning" instructions on the next page.

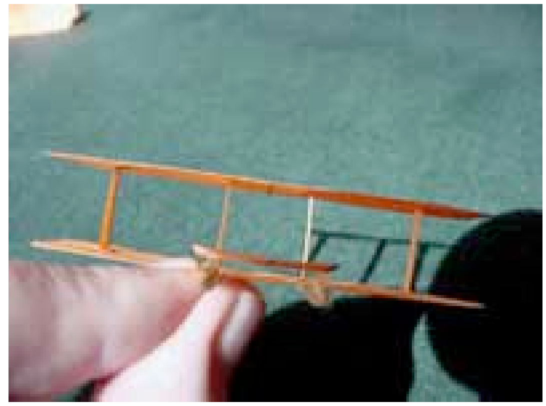
10. Straighten the wing struts to a 90 degree angle from the wing surface. Adjust the feet on the opposite end of the struts so that the surface of the foot will contact the bottom wing when it is lowered into position. Smear each of the four struts with a small amount of glue, and carefully align the bottom wing with the top, gently pressing it into place.

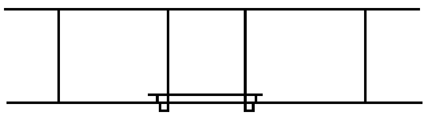
11. Glue the elevator strut 5/8" from the front of the airframe toothpick.

12. Glue the elevator to the strut foot, so that the front of the elevator is 1/8 inch from the front of the toothpick fuselage.

Final Tuning For Wright Biplanes

Look at your TA Wright glider head on, and concentrate on the wing. The wings are usually slightly warped because of the force applied to the paper when the wing is cut out. The sharper the scissors, the less warp you will find.





When tuned, your aircraft should look like the one above when viewed from the front. Only the leading edge of the wing surface should be visible.

If the wing surface is twisted or warped, your aircraft will spin or turn to the left or right. Reducing this twist or warp reduces drag, and will allow the aircraft to use the lift more equally for the left and right wings. The goal is balance, or equal lift for each wing surface.

The TA Wright '01 as it appears in the "head on" view for tuning. This glider's wings are warped in opposite directions. The wing on the right is warped up, while the left hand wing is warped down. Twist the wings gently, in steps to equalize the lift on both sides. Most Wright flyers need some "up" elevator, as shown above. The tuning instructions on this page apply to all Toothpick Airforce aircraft.

When tuning, continuously return to the head on view to observe the twist or warp. Fly the aircraft in between to detect problems, or recognize when you have achieved your goal. If the wing or wings are only slightly twisted, sometimes a simple twist in the opposite direction is all it takes.

The Wright 1900 and 1901 gliders had no tail rudders, or vertical stabilizers of any sort. The TA versions of these gliders are stabilized to good effect by the lateral surface area of the wing struts. While these can not be adjusted for yaw (turning), turns for these gliders can be achieved by wing warping, or adjustment of one side or the other of the elevator.

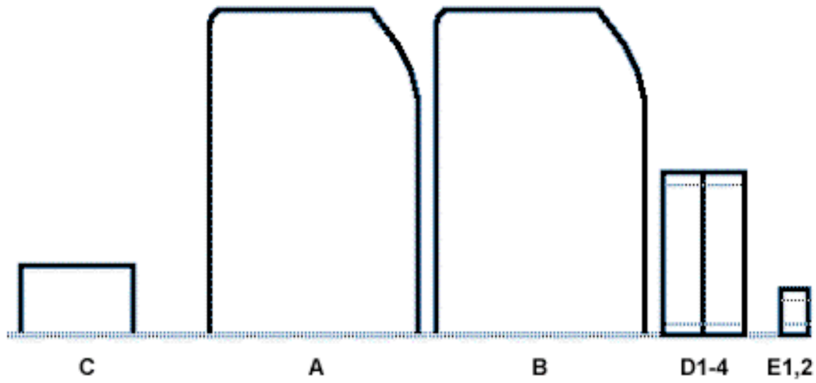
Additional Weight

Adding weight by increments of small lengths of toothpick can improve the glide of your aircraft. While TA gliders can fly excellently with a little weight, sometimes more can make them fly better and faster. Use the elevator to compensate for increased weight.

Wright 1901 Glider

Parts list for the 1901 glider.

A and **B** are wings.
C is the elevator.
D1-4 are wing struts.
E1,2 are the elevator struts.
Two full length toothpicks for the airframe.

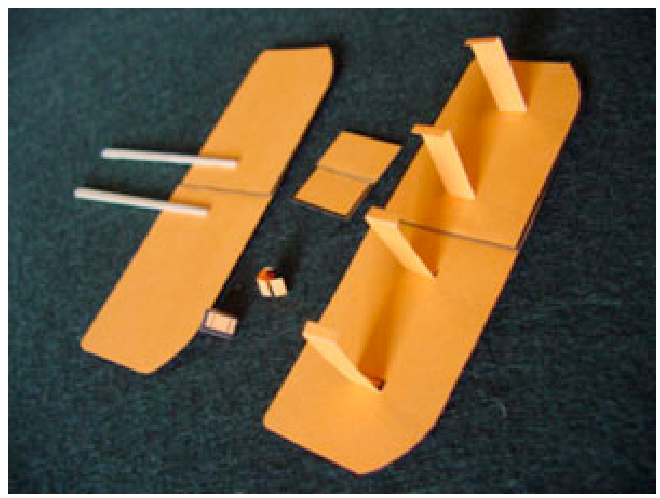


Assembly Instructions

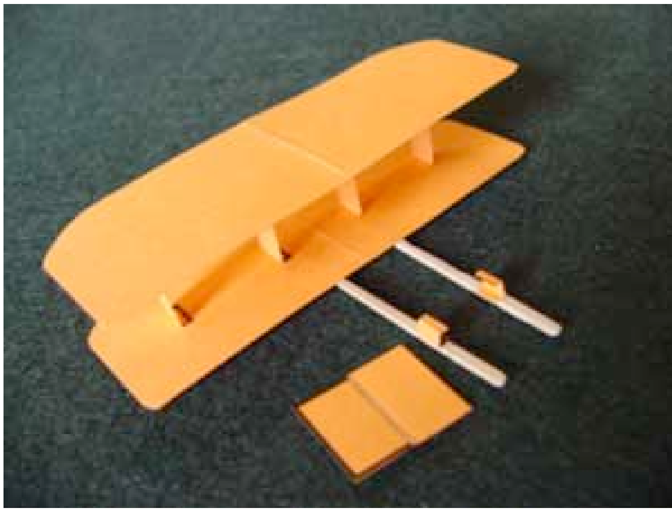
1. Copy, scan and print, or trace the drawing on the previous page on 24 lb paper of any color.
2. Bend and crease the drawing at the fold line (see supplies photo p.2).
3. Cut the glider parts out starting at the fold line. Always cut on the solid lines, fold on the dotted lines.
4. Lay the wings and elevator flat on your work surface, with the printed side up.
5. Bend the struts on the dotted lines to form "feet" on each end of the strut. Make the bend on the end away from the original fold line first.
6. Cut the struts apart. You will now have 4 identical struts with which to mount the upper wing on the lower. Bend and cut the elevator struts apart the same way.

Caution, too much glue can warp and twist the wing!

7. Smear a small amount of Elmer's (or similar glue) on each wing strut **(D1-4)** foot. Mount them one at a time on the upper wing, beginning 1/4" from the centerline. Place the outside struts 3/8" from the wing tip, as shown in the photo.
8. Examine your flat toothpicks. You will find a slight bevel on both the wide and the narrow ends of one side. Smear a small amount of glue on the small or narrow end of each toothpick on the non-beveled side. Press the toothpicks into position, overlapping the leading edge of the lower wing by 3/4" as shown in the photo above.



Straighten the struts before mounting wing.



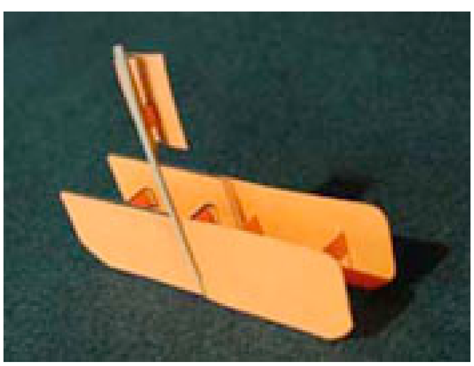
After the wing assembly is dry, glue the elevator in place carefully. Two 5/8" long blocks of toothpick from the wider, heavier end of a toothpick should provide enough balance weight. Consult "Final Tuning For Wright Biplanes" on page 10.

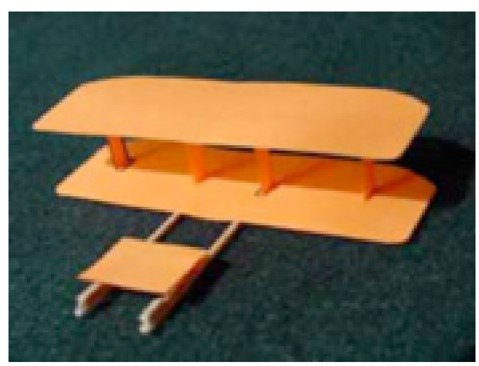
9. Straighten the wing struts to a 90 degree angle from the wing surface. Adjust the feet on the opposite end of the struts so that the surface of the foot will contact the bottom wing when it is lowered into position. Smear each of the four struts with a small amount of glue and carefully align the bottom wing with the top, gently pressing it into place. Continue holding the wing in position for one minute, until the glue sets up.

10. Glue the elevator struts in place about 1/2 inch from the front of the airframe.

11. Smear a small amount of glue on the top of the elevator struts, then press the elevator in place. The elevator front should project forward 3/8 inch in front of the elevator strut

12. Clip two 5/8 inch blocks of toothpick from the wider, heavier end of the toothpicks, and glue them to the airframe in front of the elevator struts for balance.



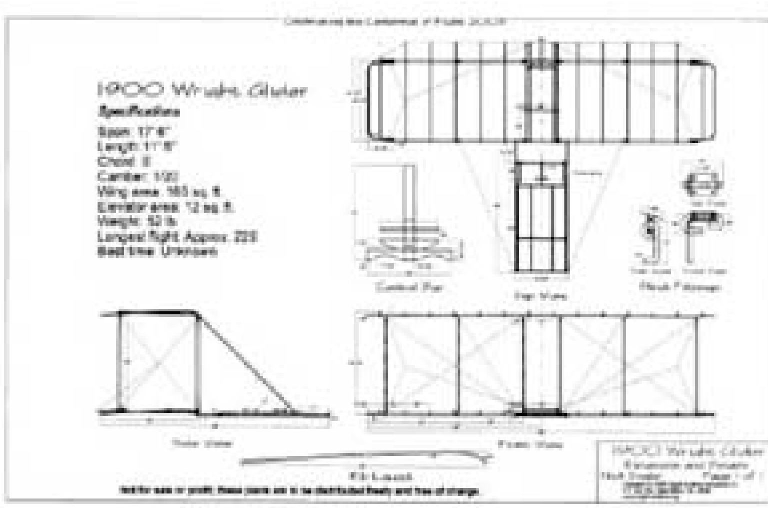


A side by side comparison of the TA Wright 1900 and 1901 Wright gliders. Both fly excellently even though the original Wright gliders did not! Do you know why? One big reason is neither had upright tail or rudder surface. The 1902 Wright glider had a single upright rudder located behind the wing.

Learning From the 1900 and the 1901 Gliders

In 1899 Wilbur and Orville Wright built and flew a kite with which to test their first theories of control. The brothers had requested "all that is already known... about flying machines" from the Smithsonian and other sources. Focusing their attention on control and control surfaces as essential to manned flight, they began a series of experiments. The new kite used wing warping to adjust for roll and turning, and an elevator to adjust for pitch.

The first experiments were successful, and the kite demonstrated it could dive, climb, and roll to the right or left when directed by the operator. The brothers now felt they were justified in turning their attention to a gliding machine capable of carrying a man.



The Wright brothers chose to give their first glider a rectangular shaped wing, with less camber than Lilienthal and Chanute recommended. Although Otto Lilienthal had been killed in a gliding experiment in 1896, his work was well known in the U.S., and he had clearly demonstrated that human flight was possible.

Plans like the one above form the basis for all of the TA gliders. The 1900 plans are available on the Wright Brothers Aeroplane Company web site www.wright-brothers.org.

Octave Chanute also built and flew manned gliders. Chanute's "Progress In Flying Machines" was one of the most influential works of the time, and one of the Wright brothers' sources.

The 1900 glider had a wing span of 17 feet, 5 inches, and a chord of 5 feet. It weighed just under 50 pounds. Like the 1899 kite, the 1900 utilized wing warping and an elevator to control pitch. The '00 was flown mainly as a kite, although the brothers were able to get several three to four hundred foot glides. The glider required twenty two mile per hour wind to become airborne empty, and more carrying a man, which the Wrights felt was too fast for safety.

The 1901 glider had a 22 foot wing span and a larger elevator. In spite of making longer glides in this craft, the brothers were discouraged. The wing did not develop enough lift, and their control surfaces were not working properly.

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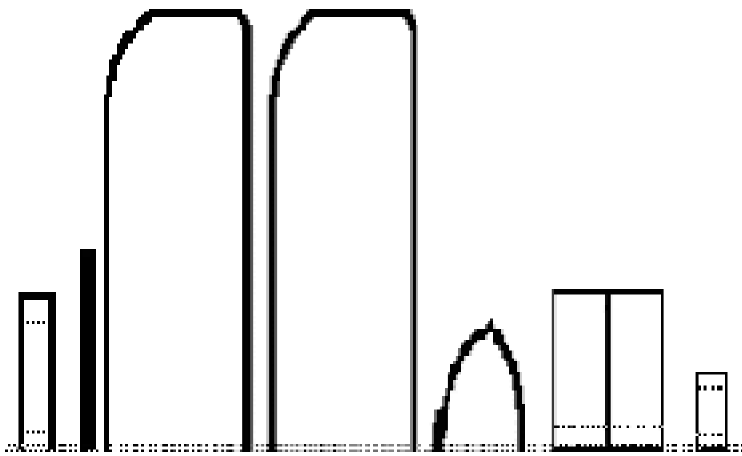
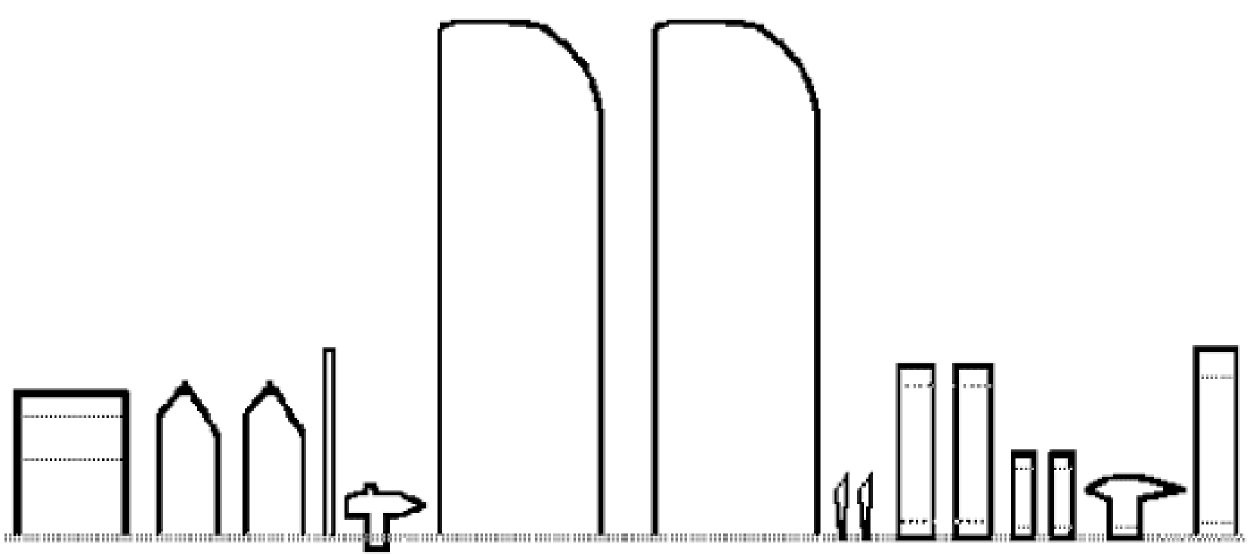
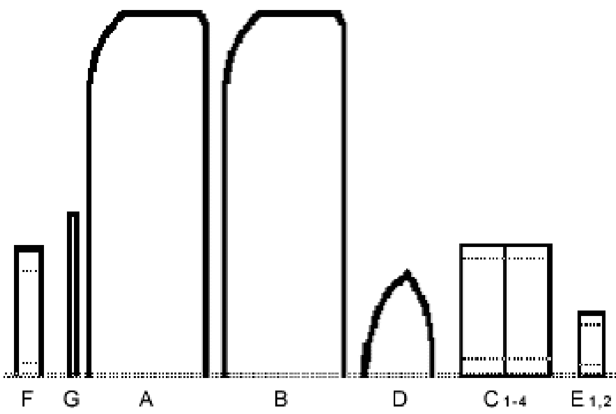
TA 1902 Wright Glider



TA Wright Kitty Hawk Flyer 1903



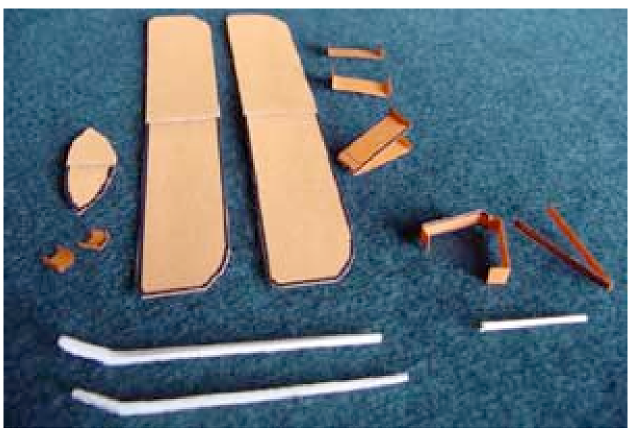
TA 1902 Wright Glider



Parts list for the TA 1902 Wright Glider.

A, B are wings.
C1-4 are wing struts.
D is the elevator.
E1,2 are elevator struts.
F Double tail rudder structure.
G is the tail assembly top strap.
Landing skids are full length toothpicks.

Tail support is 7/8 of an inch long, from the small end of a toothpick.
Lay the parts out with the printed side up on work surface.



Build the 1902 Glider without camber!

Assembly Instructions

1. Copy, scan and print, or trace the drawings on the previous page on 24 lb paper of any color.
2. Bend and crease the drawing at the fold line (supplies photo p 2).
3. Cut the glider parts out starting at the fold line. Make the strut folds for the feet before cutting the struts apart.

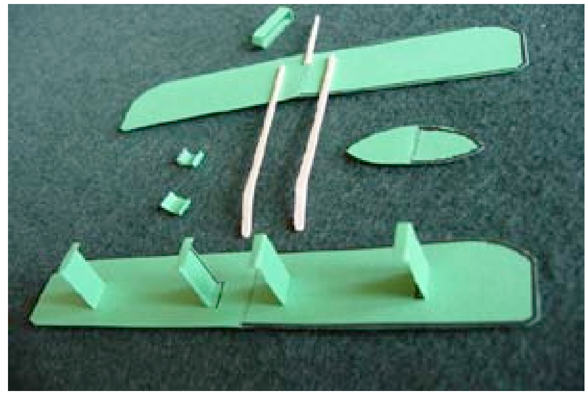
4. Bending Toothpicks. For the next step select two similar flat toothpicks. Not all toothpicks have similar straightness, width, and thickness. Choose carefully because your aircraft will look and fly better.

Grasp the flat, wider end of one of the toothpicks, and bend it three-eights of an inch from the end. When you hear and feel it crack, stop! We want the bent end to stay attached. We are building landing skids for your Wright glider. Bend the second toothpick landing skid to match the first.

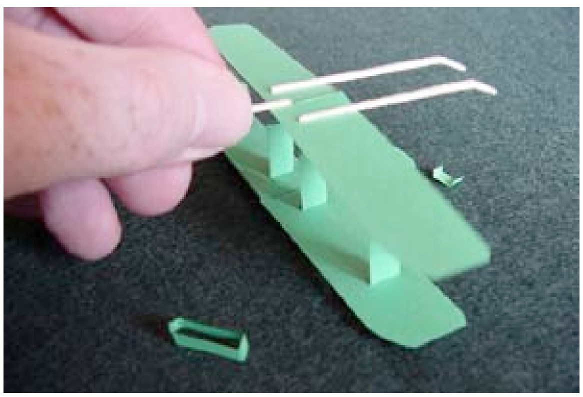
Bend the toothpick to a 45 degree angle or less and it will be less likely to break off. If it breaks, try again.

Smear glue liberally on the top, bottom, and sides of both landing skids at the bend. The glue is to seal and strengthen the skid at the bend.

5. Glue the inside struts in place 1/4 inch from the centerline, the outside struts 3/4 inch from the wing tips. Always use a small smear of glue on wing struts as excess amounts will warp the wing surface.
6. Glue the toothpick landing skids 1/4 inch from the centerline, at a right angle to the wing. When in position, the trailing or small end of the skid should be 1/8 inch from the trailing edge of the wing.

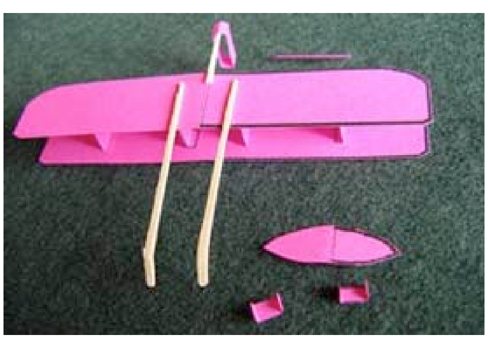


See page 8 for making strut "feet." The struts are positioned and glued in place, the strut feet bent to right angles from struts. The wings are upside down.

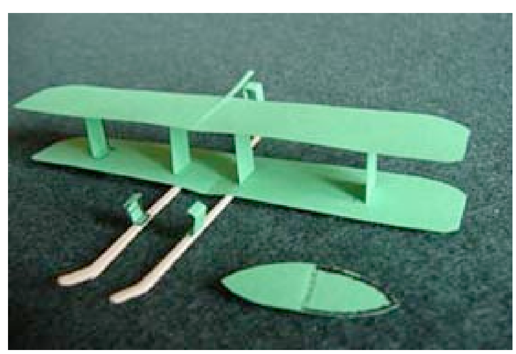


Lower the bottom wing into position, aligning it directly above the upper wing. Note tail assembly ready to hang.

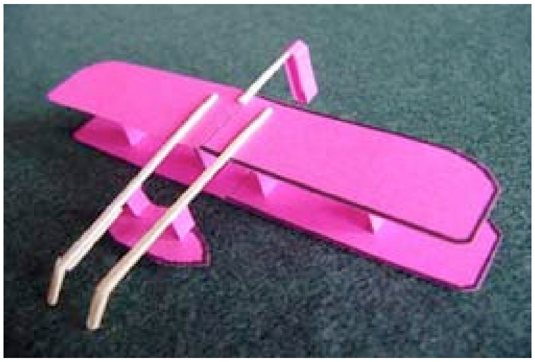
7. Glue the tail support in place on the centerline, extending to the rear of the wing at a right angle, with a 1/8 inch overlap. Allow time to dry.
8. Smear a small amount of glue on the strut feet, and lower the bottom wing assembly into place as shown at left. Press gently on the bottom wing over the strut feet to insure proper bonding.
9. Hang the tail as shown below, gravity holds it in place



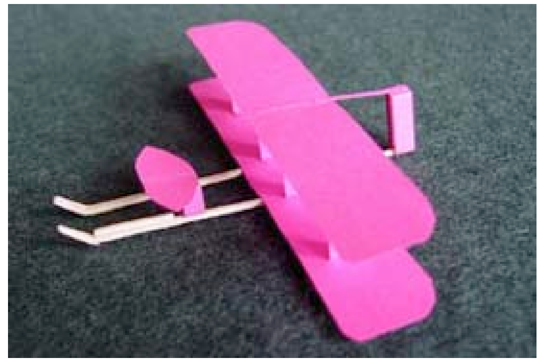
While the glider is upside down –smear glue on the tail support, hang the tail assembly on the tail support.



Glue the elevator struts in place 5/8 inch from the leading edge of the wing.



Glue the elevator struts in place 5/8 inch from the leading edge of the wing.



The Wright glider will need some "up" elevator. Bend the leading edge upward, the rear edge down.

When Wilbur and Orville Wright built their 1902 glider, they had already built a kite (1899), and flown their 1900 and 1901 gliders. They had studied other pioneers' efforts, and used a wind tunnel to perfect their design.

The 1902 Wright glider was the first aircraft ever that had **control over all three axes: yaw, pitch and roll.** A single tail rudder controlled **yaw**, or right and left turns. This glider was first built with a double, non-steering rudder. The Wrights made almost 1,000 glides with this aircraft during September and October of 1902. When the change was made to a single, steer-able rudder, their glide times increased.

Wright 1902 glider.

The Wrights called the elevator, which they placed in front of the main wings, a horizontal rudder. This "horizontal rudder" provided control over the **pitch** (up and down control) of their airplane.

Wilbur Wright discovered wing warping when he was able to visualize the top and bottom surfaces of a bicycle inner tube box as wing surfaces. When one end of the box was twisted down, the other end was twisted up. In this motion, Wilbur could envision the flight of birds and how to control **roll**. The bi-plane design provided strength enough to make wing warping work, while the longer, thinner wings developed far more lift than the 1901 glider.

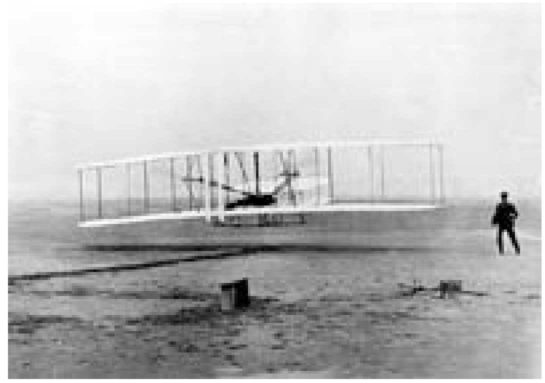
The Wright 1902 glider had a 32 foot wingspan and was 16.1 feet long. It only weighed 112 pounds. The Wrights continued using this glider in 1903, while they worked on the powered flyer. When the single rudder was replaced with a double, steering rudder, they were able to increase their glide time again.

The '02 was the subject of the Wrights' first and most important patent.

The First Powered Flight

On December 17, 1903, the Wright brothers made four flights with their first powered flyer at Kitty Hawk, North Carolina. On their best flights, Orville flew about 120 feet and stayed aloft about 12 seconds. Wilbur managed to fly 852 feet and stayed in the air for 59 seconds.

The Wright brothers had to teach themselves to fly in brief seconds, in an airplane with controls and control surfaces that were barely adequate.

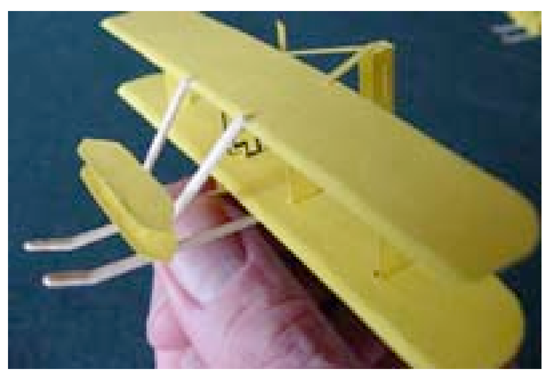


The dream comes true. Powered, controlled flight became reality on December 17, 1903, at Kitty Hawk, North Carolina

The Kitty Hawk flyer had a 40 foot 4 inch wingspan and was only a little over 21 feet long. It weighed only 605 lbs. The Kitty Hawk flyer had twin tail rudders, and a 12 to 16 horsepower engine.

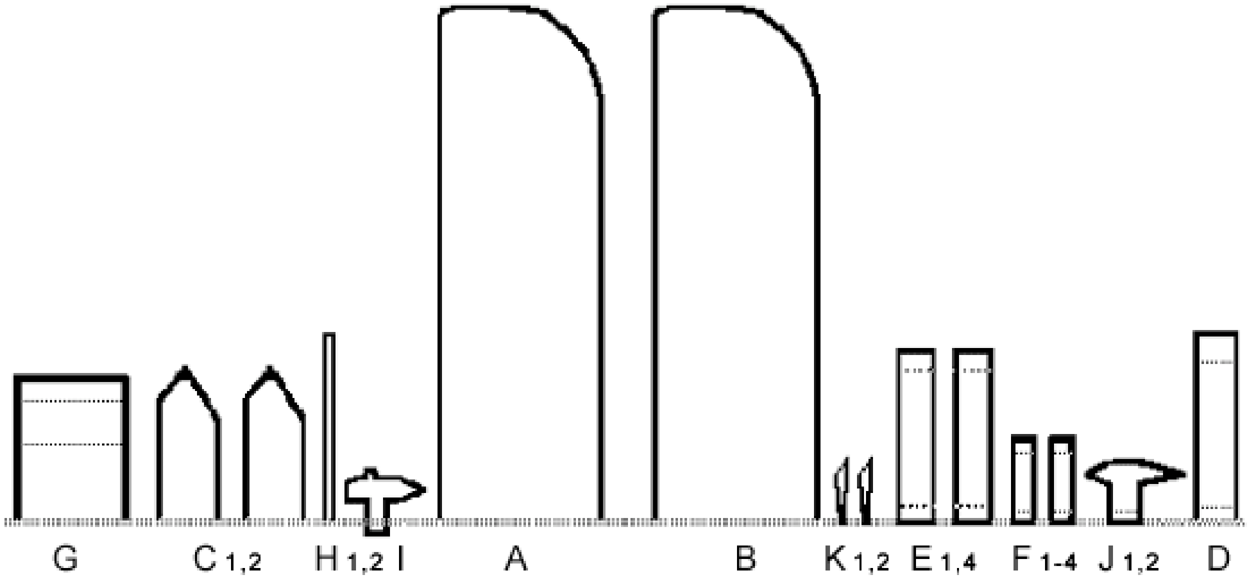
Although the first to actually fly, the Kitty Hawk flyer only made four flights that day. It was damaged by wind after the fourth flight, and the Wrights packed it up and shipped it back to Dayton, Ohio. Its flying days were over.

The Toothpick Airforce version of the Wright Kitty Hawk flyer is the most difficult of the Wright replicas to build and fly. It has 21 paper parts, and at least five toothpick parts (you may have to add weight). This glider may take up to two hours to build, and requires careful attention to detail in construction and tuning. We recommend building at least one of the Wright gliders before attempting the Kitty Hawk flyer. "Bending Toothpicks" instructions are found on **page 15**.



Grasp your toothpick flyer by one of the landing skids, and thrust it forward gently. Add "up" elevator by bending the leading edge of the elevator up and back.

TA Wright 1903 Kitty Hawk Flyer



Parts list for the TA Wright 1903 Kitty Hawk Flyer

A and B are the main wings.
C 1,2 are the elevators.
D is the tail assembly.
E 1-4 are the main wing struts.
F 1-4 are the elevator struts.
G is the landing skid frame.
H 1,2 are the tail assembly top straps.
I is the motor (optional).
J 1,2 are propeller mounts (optional).
K 1,2 are propellers (optional).

Parts shown ready to assemble. Landing skids are bent, with glue applied to the bends (p.12). Folds for all parts have been made and the struts have been cut apart. Ready for assembly!

Two full length toothpick skids.
One 7/8 inch tail assembly support toothpick.
Two upper air frame toothpicks.

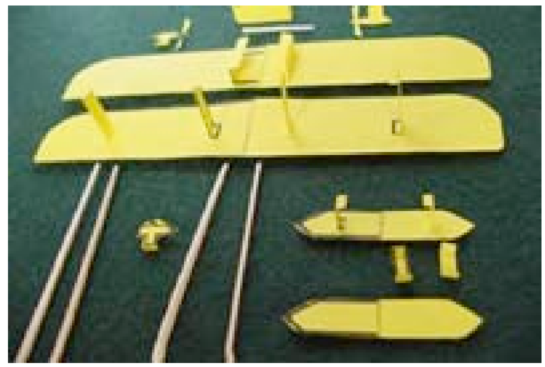
<u>Assembly Instructions</u>

1. Copy, scan and print, or trace the TA Wright Kitty Hawk Flyer on page 11.
2. Crease, then firmly bend the paper at the fold line.
3. Cut out the parts starting at the fold line.
4. Make the additional bends for (feet) struts, motor, propeller mounts, and landing skid frame ***<u>before</u>*** unfolding at original fold line!

Assemble the TA '03 Kitty Hawk Flyer

The TA Kitty Hawk Flyer flies a little better and is easier to build without the engine and propeller assemblies. The '03 can be assembled with or without cambered wings. Read "Advanced Wing Structure" on **page 24** before proceeding. The instructions assume you have completed the construction of prior gliders and grasp concepts like "feet" and "Bending Toothpicks".

5. Add camber to the wings now. Instructions for adding camber are found on **page 25**.
6. Place all paper parts with the print side up on your work surface. Glue the inside struts in position 3/8 of an inch from the fold line, midway between the leading and trailing wing edges of one wing. Glue the outside struts in position 3/4 of an inch from the wing tips, on line with the inside struts. **E** 1-4 are wing struts.
7. Place the second wing print side up on your work surface.



Bottom wing assembly is shown (at top), just below tail assembly, landing gear frame in place. Top wing assembly and elevator have struts glued in place.

Select the landing skid frame (part **G**) and make the two folds along the dotted lines starting at the outside (away from the original fold line). Unfold part (**G**) on the original fold line, so that it will lay flat. Reverse the folds on the unprinted side of the landing skid frame. See the photo above.

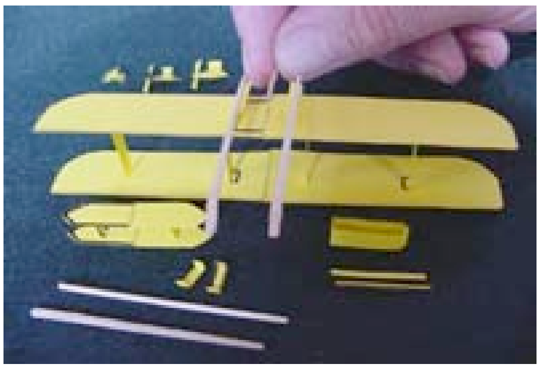
Viewed from the front, part G should look like this.

Smear a little glue along the fold line in the center (on the bottom, or the side away from the print), and the outside edges of the landing skid frame (part **G)** and press it in place on the bottom of the lower wing. The original fold line on the bottom of part **G** should be lined up with the original fold line on the lower wing, 1/8 of an inch from the leading edge of the wing, as shown in the photo above.
8. Smear a small amount of glue on two of the elevator struts (parts **F** 1-4) and glue them in position 1/4 inch from the fold line of one elevator (**C** 1,2).

Your wing and elevator assemblies should look like those in the photo above.

9. Smear glue on one side of the landing skid frame. Glue one of the landing skids in place at a 90 degree or right angle to the bottom wing. The small (narrow) end of the landing skid should protrude 1/8 inch behind the skid frame. Glue the second skid into place, making them parallel to each other. Refer to the photo below.

10. Smear glue on the thicker end of the tail rudder support and glue it into position on the centerline at the trailing edge of the bottom wing assembly. All but 1/8 inch of the tail rudder support should protrude to the rear of the wing assembly. Allow this assembly to dry.



Smear glue on the strut feet, line the bottom wing up with the top, and press it gently in place using the tail support to center one wing above the other.

11. Fold the tail assembly (**D**) into a rectangular box by reversing the folds on one side of the assembly. The tail assembly and top straps (**H**1,2) are shown at the bottom right of the photo at the left.

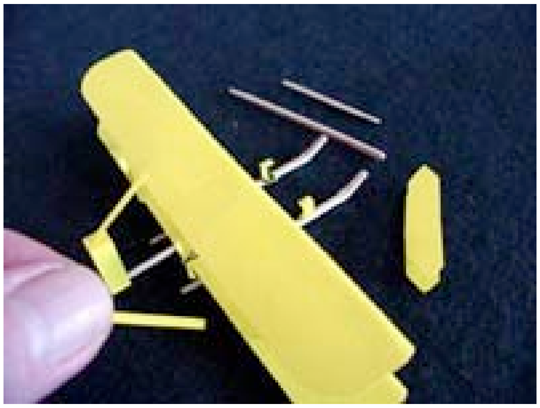
12. Glue the lower elevator on the upper elevator assembly (shown upside down in the photo at the left).

13. If you choose to mount the propeller assemblies and motor, glue the propellers (**K**1,2) to the long protrusion on the propeller mount (**J**1,2) as shown top left.

14. Smear glue lightly on the wing strut feet. The bottom wing assembly should be lined up carefully, and lowered gently in position using the tail support toothpick as shown. **It should be directly above the upper wing.**

When this assembly is dry, you are ready for final assembly.

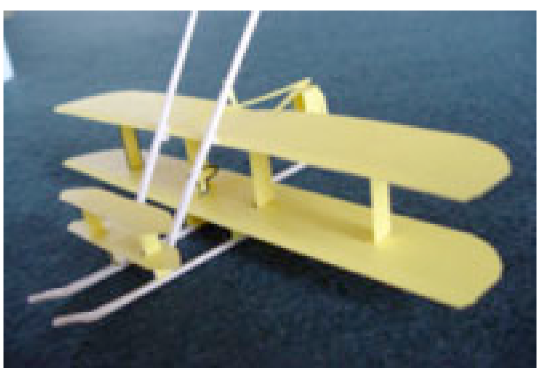
15. Pinch the end of the tail assembly (**D**) that has the original fold line gently, so that the fold line protrudes. Smear glue on the end of the tail support toothpick, and hang the tail assembly on the toothpick support as shown in the photo to the left.



If you choose not to use the engine and propeller assembly parts, ignore steps 13 and 18. These parts are for detail and appearance, and are not necessary for your glider's performance.

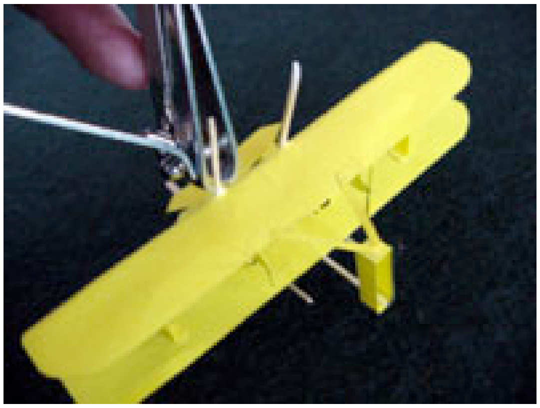
16. Smear glue on the bottom "feet" of the remaining two elevator struts (**F**1-4) and press them in place on the top surface of the landing skids, 5/8 of an inch in front of the leading edge of the lower wing.
17. Smear glue on one end of the tail assembly top straps, and glue them to the top surface of the top wing, 1/4 inch from the center to the left, and to the right of the original fold line. Angle the top straps, so that the other ends are directly above the tail assembly. Refer to the photos on the left.

18. Smear glue on the "feet" of the propeller assemblies (**K+J**) and glue them in position 5/8 of an inch from the original fold line on the bottom surface of the upper wing. Smear glue on the "foot" of the motor (**I**) and use a toothpick to position it on the lower wing's upper surface 1/4 of an inch from the fold line, and 1/4 of an inch from the leading edge.



The upper air frame toothpicks add rigidity and strength to this TA Wright flyer. The lower end should be glued to the inside back of the lower elevator strut, where its foot is glued to the landing skid, the upper end lays flat on the wing.

19. Clip 1/8 inch from the rounded, large end of two toothpicks. Smear glue on the large end of one of the toothpicks and place a small glob of glue on the forward edge of the upper wing, directly above the landing skid. Glue the upper airframe toothpicks in position one at a time, placing the lower end of each one on the landing skid at the rear edge of the elevator strut. The strut actually helps hold the airframe in place.
20. Smear glue on the elevator feet and center the elevator assembly with the trailing edge even with the rear of the strut foot.



21. Clip the ends off the toothpick airframe where it protrudes above the wing. If the glue comes loose from the wing,or the landing skid below, re-glue, using plenty of glue for this application only. Allow the TA Kitty Hawk Flyer to dry before tuning. ***Line up the blades of the clippers so that they strike squarely on the toothpick, just above the wing.***

22. Use a toothpick to slide a smear of glue under the rear of each tail assembly top strap, then press them in place on the top of the elevator assembly.   Make sure the tail assembly is lined up correctly, use the top straps to hold it in final position. The twin tail rudders should make your glider fly straight.

If you have questions or comments regarding The Toothpick Airforce or the gliders presented here, contact the author at:

booger-gj@att.net

Or write to:

Booger Red's Books Inc.
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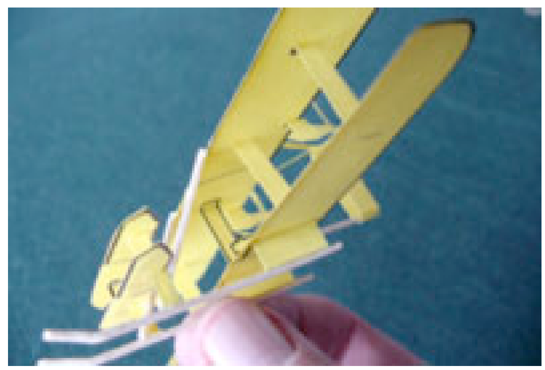
Clifton, CO 81520



Final walk around on your new TA Kitty Hawk Flyer: To add "up" elevator, gently bend entire structure to the rear.

Tune the TA Kitty Hawk Flyer by first examining the wings from the head on view. Gently adjust by twisting or bending the wing surfaces to provide equal lift on each side. There will be some warping from the area the struts attach to, due to the warping caused by gluing the two surfaces together.

Adjust the elevators to provide a slight lift and glide the aircraft by grasping one of the toothpick landing skids. More weight may be required. Add weight in short lengths of toothpick, glued to the upper surface of the forward landing skids.

When tuned, the TA Kitty Hawk Flyer will glide 20 to 30 feet.

ADVANCED WING STRUCTURE

One of the Wright brothers' major achievements was using a wind tunnel to analyze how the shape of the wing affected the amount of lift the wing provided. They found that longer, narrower wings provided more lift and less drag. The best wing shape the Wrights tested had a span six times its chord, or a 6:1 aspect ratio. In other words, for each inch of width, their wing had six inches of length. This was the wing shape they used on almost all their flyers after 1902.

In addition, they discovered that the most efficient wing tested had less camber than those used by pioneer gliding enthusiasts Lilienthal and Chanute. The Wrights used a camber of 1 in 20 (one inch of rise for every 20 of chord) with the high point one fourth of the chord line from the leading edge of the wing. The Lilienthal wing had a camber of 1 in 12, with the high point half way down the chord line.

The TA Kitty Hawk Flyer built with cambered wings flies farther, but a little slower.

Adding camber to the wings of your Wright flyer takes a little time and a lot of patience, but will make your flyer more authentic as well as stronger.

The wing cross-section below shows how chord and camber are measured.

The chord of a wing is the measure of an imaginary line stretching from the leading edge to the trailing edge.

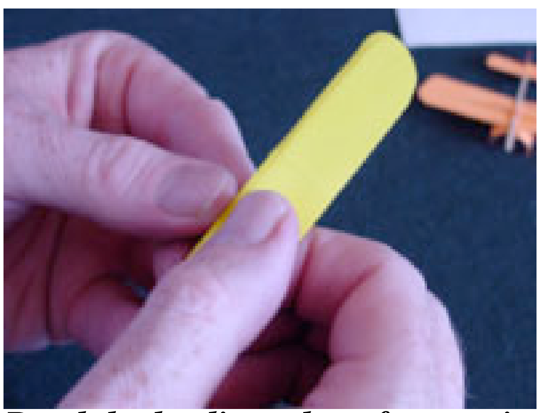
The camber of a wing is its measure from the top curved surface to that imaginary chord line. Most modern wings have both upper and lower camber.

The wing cross section above has under-camber. It is open on the bottom. A cambered wing produces more lift and is stronger. In TA aircraft, flat paper wings can be made stronger, and more like the original aircraft, by adding camber. While making TA wings with no under-camber is possible, the resulting wings are heavier, tend to have worse warping problems, and can be difficult to assemble.

Most of the early aeroplanes were deliberately built with under-camber. Popular theory of the time held that while additional lift was generated by camber, more lift or even speed could be generated by under-camber.

The main reason to resort to a cambered wing in TA aircraft is the increased rigidity of the paper wing. Especially in large TA aircraft, wings tend to sag as they get older. The Wright brothers' biplane designs also help counter this effect and are stronger in general. An added benefit of cambered wings for TA aircraft is realism. Many of the stability problems you will encounter will be recognizable when you read and explore accounts of the original pioneers and their aircraft flight.

HOW TO ADD CAMBER



Bend the leading edge of your wing down. Your airplane will fly slower, glide farther.

Grasp the first wing between your thumb and fore-finger beginning at one side, about 1/8 inch from the leading edge. Place the printed or traced side down, or away from you, just the way it will be mounted on the Wright aircraft. Press the leading edge of the wing down, bending it to the same shape along the entire width of the wing. Repeat this procedure for the second wing.

This simple modification changes the way your TA glider flies. Because of the wing's changed shape, the camber (and under camber) creates more lift and drag! Your aircraft may fly more slowly, but will probably fly farther with less thrust. Experiment by moving the cambering fold farther back on the wing, or making a second, more shallow fold behind the first.

From the author of *BUILD AND FLY THE WRIGHT FLYERS:*

My purpose in writing and publishing THE TOOTHPICK AIRFORCE series is to share a concept I have enjoyed since I was very young. My children enjoyed building toothpick gliders, and I eventually had to show nearly every youngster in the neighborhood how to build them. I wrote the first book, *REAL GLIDER REPLICAS* (ISBN 0-9650751-1-7*)* when various parents asked for the instructions to send to their out of state relations. The TA Wright 1900 and 1901 gliders were designed especially for the Centennial of Flight, while the 1902 Wright glider and the Kitty Hawk Flyer are redesigned for simpler assembly and fewer parts. Both of those TA aeroplanes first appeared in *BUILD AND FLY THE FIRST FLYERS* (ISBN 0-9650751-2-5).

I worked out most of the bugs in building and flying toothpick airplanes when I was between 11 and 13 years old (1960 to 1963), growing up in Lakewood and Georgetown, Colorado. It all started in Georgetown, with an issue of Boy's Life. The magazine had an article and drawings describing a miniature rocket engine using a length of small soda straw, glued to a second section of straw. One end of the straw was to be glued shut, then packed full of match heads. We had an old coal stove, so kitchen matches were available. The second piece of straw was to be placed on a string, to act as a guide when the match heads were ignited. I remember it did not work very well.

I knew I could do better. The string was causing too much friction, I thought. First I attached wings and tail empennage. I had great difficulty making the wings on both sides equal dimension-wise. My mother asked me if I had never made paper dolls, and I said I had not, somewhat annoyed (I was the seventh of eight children) so she really did not know which ones she had shown that particular trick to. She folded a piece of paper in half and had me cut out my wings and tail planes and I was very impressed.

My rocket powered airplanes burned up before they could get airborne, but I had a whole pile of stripped kitchen matches. Thus was borne the Matchstick Air Force. My mother wanted me to sell the idea to Boy's Life. Unfortunately their standard offer of the time was something like $35. Again, I thought I could do better.

It seemed that there was a continuing shortage of wooden matches to start the fire in the mornings and in the mountains it could get very cold at night. My mother bought me a box of flat toothpicks, and the rest is history.

THE TOOTHPICK AIRFORCE