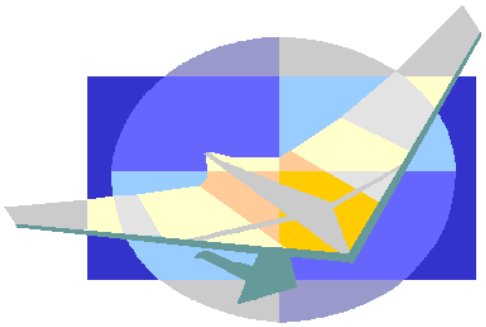


Rogallo's Wing

NASAexplores Express Lessons and Online Resources
http://www.nasaexplores.com/

Objective: To explore the uses and development of a control system called Rogallo's wing.

Transportation Systems content Standards and Objectives:

2448.1.3 Determine the advantages and disadvantages of selected modes of transportation in relation to its efficiency (speed, payload, economics, safety).
2448.2.4 Apply vocabulary and reading comprehension skills used in transportation occupations.
2448.3.1 Perform mathematical computations as they relate to transportation activities (calculating speed, loads, lift, etc.)
2448.3.2 Interpret various charts, graphs and drawings used to display numerical data.
2448.8.3 Design and construct a model vehicle, which demonstrates efficient aerodynamic or hydrodynamic design.
2448.12.1 Describe the two major categories of control systems: speed and direction.

Tools and Materials:

Mylar
Kite string
Hole punch (several)
Scissors
Tape
Rulers

Procedure:

1. Duplicate the Student Sheets (one per group).

2. Each group will need a sheet of Mylar 40 centimeters by 40 centimeters. If you cannot buy a sheet of Mylar, you can buy Mylar balloons and adjust the wing's size to fit the balloon's size.

3. The string needs to be very light. It does not have to be official kite string. Fishing line can be used if you are careful when attaching it to the balloon.

4. Each group will also need a ruler, hole punch, and scissors.

5. Due to time constraints, you may want to build the wings on one day and fly them on another day. You may want to check the weather to plan this activity around it.

6. Read orally the article, "An Idea Whose Time Has Finally Come."

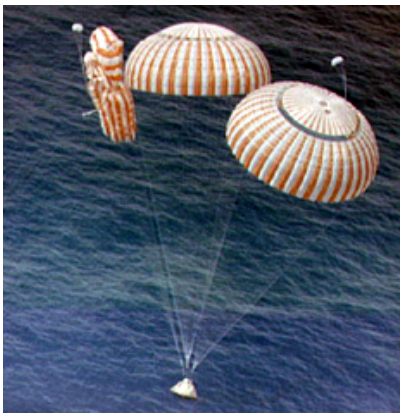
7. Divide the class into groups of three or four and distribute the Student Sheets and materials.

8. Have the groups follow the instructions in building their Rogallo Wing.

9. When they are finished, go outside and try to fly their wings.

10. Discuss how the Mercury, Gemini, and Apollo missions slowed themselves down for landing. What advantage would a parawing have over a standard parachute?

11. Ask the students, “Have you ever been hang gliding? If yes, what was it like? If no, would you like to try it? Why or why not?” Ask the students, “How do you control the direction of a parawing?”



Rogallo's Wing
Student Reading
"An Idea Whose Time Has Finally Come"

They used to do things differently in the space program. In 2002, the Space Shuttle glides to a landing on a runway, much like a jet airplane. The vehicle returning to Earth looks very much like the one that launched; a few boosters are gone, but not much else. In the 1960s and '70s, though, a huge Saturn V rocket lifted off from the launch pad, yet all that returned to Earth was a small capsule containing the astronauts. The Mercury, Gemini, and Apollo capsules splashed down in the ocean, guided by parachutes.

Using parachutes was only one of the proposed ideas for guiding space capsules back to Earth. NASA had given strong consideration to another concept: the paraglider. The Rogallo wing, invented by Francis M. Rogallo in the early 1960s used flexible, controllable fabric airfoils arranged in a V-shaped configuration. The flexible wing could be guided more precisely than a parachute, and when controlled by the astronauts inside the capsule, could be maneuvered so that the landing could glide to the ground instead of splashing into the ocean.

Engineers tested the Rogallo wing for several years in NASA's wind tunnels at Langley Research Center, eventually deciding to stick with the original parachute plan instead of the paraglider. That wasn't the end of the Rogallo wing, though. Researchers at NASA's Dryden Research Center saw potential for the flexible fabric wings to be used as part of a new flying vehicle. The wing was attached to steel tubing, and the craft ended up looking like an oversized tricycle with a mast. The pilot sat strapped in the seat without any kind of cockpit enclosure. He controlled the rate of descent by tilting the wing from side to side with a control stick. The Parasev was one of NASA's first research airplanes, and it took off in 1962. Technology improved rapidly, and soon the Parasev was outdated. Once again, however, the idea of a flexible fabric wing maintained its appeal.

Today, the Rogallo wing is used by the recreational sporting goods industry. You say you haven't seen a Rogallo wing? Have you every watched a hang glider soar from a hillside or cliff? That's the commercial adaptation of Francis Rogallo's invention to help the space program land its vehicles. It's come a long way; hang gliders are now used for fun, exploration, and an environmentally friendly way to fly the skies.

To launch the hang glider, the pilot must run down a slope or jump off a ledge to get air moving across the wing at about 24 to 40 kilometers per hour (15 to 25 miles per hour). This movement of air over the surface of the wing generates lift, the force that counters gravity and keeps the glider aloft. Once it's in flight, the hang glider and pilot's weight pulls the glider back toward Earth and moves the glider forward, continually causing air to flow over the wing. As the hang glider and pilot move through the air, they collide with air molecules. Drag, the frictional force caused by these collisions, slows the glider down. The amount of drag is proportional to the airspeed of the hang glider. The faster the glider moves, the more drag it creates. The pilot hangs in a harness from the hang glider's center-of-mass, maneuvering the hang glider by shifting his or her weight (changing the center-of-mass) in the direction of the intended turn. If the pilot pulls back on the glider, tipping its nose down, the glider speeds up. If the pilot pushes forward on the glider, tipping its nose up, the glider slows down.

Flying for fun isn't the same as helping to land a space capsule, and Francis Rogallo likely had no idea his aerospace invention would end up being a recreational tool. One thing's for sure: the Rogallo wing has sold more units in the private sector than it ever would have in the spaceflight industry.

Interestingly, Rogallo first considered the flexible wing for recreation, and presented it for consideration in the space industry only after deciding that there was no private-sector market for his idea. One of the most popular sites in America for hang gliding is in Kitty Hawk, North Carolina-where the Wright Brothers explored another famous way to fly.

Courtesy of NASA's Aerospace Technology Enterprise
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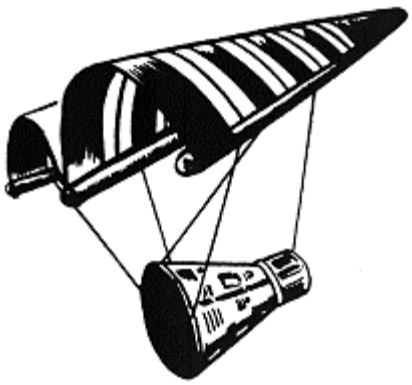
Rogallo's Wing
Student Activity



Background Information

In 1948, Langley Research Center's Francis and Gertrude Rogallo developed what is known as the parawing for use on low-speed aircraft. A parawing is a flexible, controllable, fabric airfoil designed in a V-shaped configuration. At the time, Francis was an employee of the National Advisory Committee for Aeronautics (NACA), the predecessor to NASA. With NACA approval, he obtained patents on a parawing in 1951. In 1958, NASA became interested in the possible use of the parawing to land space payloads. Rogallo was the project engineer and began an extensive research and development effort at NASA Langley Research Center. Many patents emerged from his work, as well as the development of a flexible airfoil base. The patents included both inflatable and nonflexible wings.

Eventually, NASA chose not to utilize the parawing to land Mercury, Gemini, or Apollo spacecraft. However, the military was interested in using Rogallo's wing for parachuting. In the mid-1960s, two parachute companies, Pioneer Aerospace and Irvin Industries, obtained a license from NASA and proceeded to manufacture parawings and later inflatable wings. In 1965, the Army's Golden Knight precision parachute team was the first to jump using these parawings and demonstrate their unique steer ability. Rogallo's work in the '40s and '50s began what is now a $50 million annual industry known as hang gliding. Dozens of companies have been formed to produce parawings, hang gliders, and powered gliders. A national organization, the United States Hang Gliders Association, has been established. Hang gliding schools have been formed, and several international magazines on the sport now exist, as well as numerous Web sites. The technologies used in hang gliding provide a link between the visions of early flight and NASA sponsored research and development. Hopefully, it allows the general public to appreciate the connection that hang gliding has to the roots of aviation and NASA.

Tools and Materials:

Mylar
Kite string
Hole punch
Scissors
Tape
Ruler

Procedure:

1. Look over the instructions before you get started, and be sure your group has all of the necessary materials.

2. Using scissors, cut the Mylar into a 38-centimeter (cm) square. Do not throw away the left-over Mylar. You will need it for the tail.

3. Using the ruler, hole punch, and the wing template, put holes in the places marked by h1-h8.

4. Using the ruler and scissors, measure and cut four pieces of string 20 cm each. Tie the strings to the holes marked h1-h4. You may want to use some of the tape to reinforce the hole to prevent it from ripping.

5. Using the ruler and scissors, measure and cut two pieces of string 24 cm each. Tie the strings to the holes marked h5 and h6. You may want to use some of the tape to reinforce the hole to prevent it from ripping.

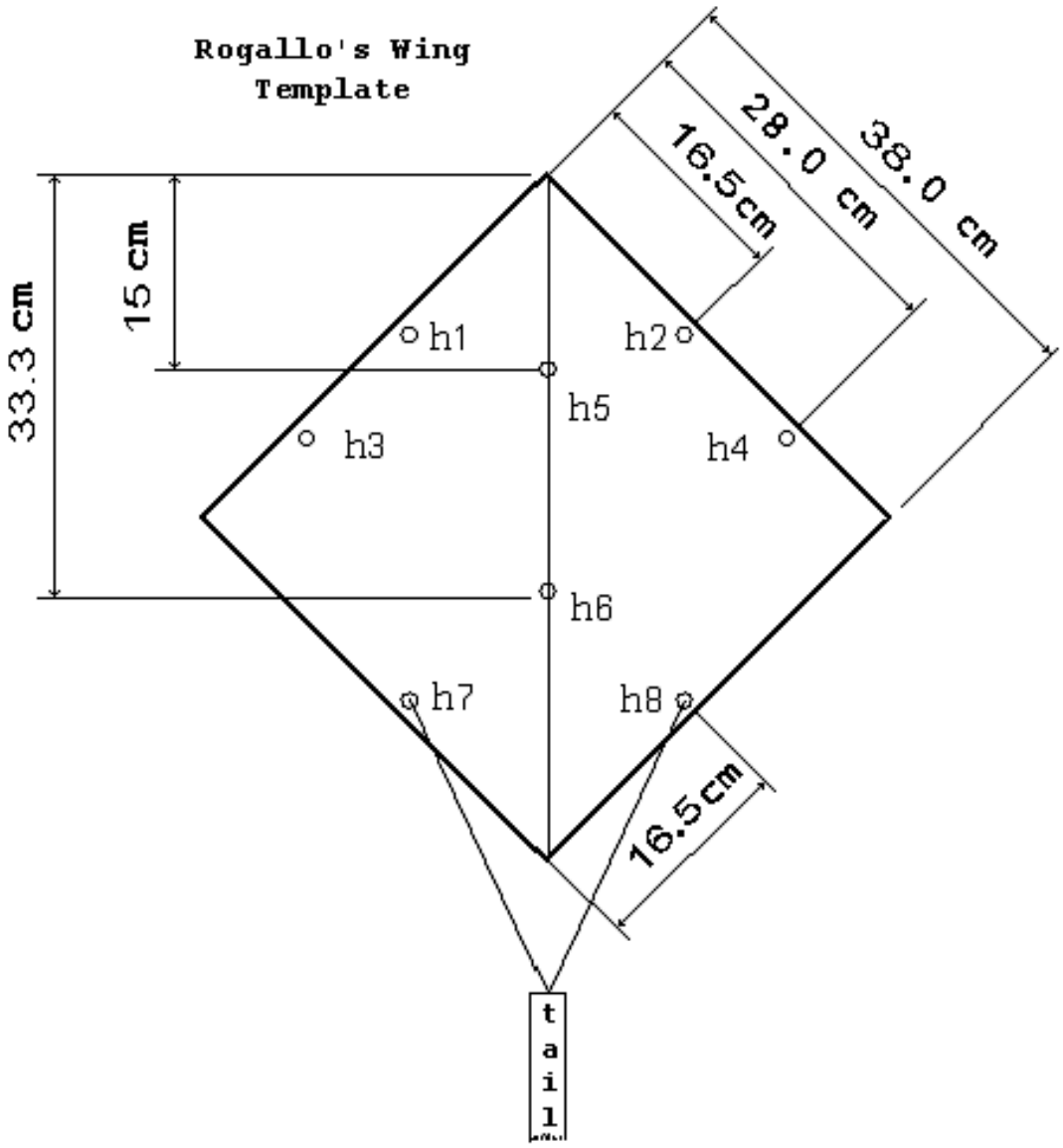
6. Take each of the six string ends and tie them together. The lengths are important for proper shape when flying.

7. Using the ruler and scissors, measure and cut two pieces of string 25 cm each. Tie these to the holes marked h7 and h8. These will attach to the tail.

8. With the leftover Mylar, make a long, rectangular tail. The length can be between 50 and 100 cm based on how much Mylar you have left. You may need to adjust its length for optimum flight results.

9. Using as much string as you need, attach one long piece of string to the knot of six strings. This will be the end that you hold onto for flight.

10. Go outside and wait for the wind. Be sure to hold onto the string tightly. If you have problems with flight, adjust the tail length based on your results. If the Rogallo Wing tends to fall tail first, you may have too much tail (in other words, the tail is too heavy). If the Rogallo Wing tends to flip over and fall top first, you may not have enough tail (in other words, the tail is too light). To remove weight, cut off part of the Mylar tail. To add weight, attach more of the Mylar tail.


Rogallo's Wing
Template
38.0 cm
28.0 cm
16.5cm
15 cm
33.3 cm
h1
h2
h3
h4
h5
h6
h7
h8
16.5cm
tail