drawings. The copper globes, he planned, would be attached to the man-carrying car by strong ropes. When air was pumped out of the globes, the entire assembly would travel upward into the atmosphere as the light weight air left in the globes rose to seek its place with air of equal weight. Once aloft, the craft would be propelled by a wind sail (remember Ki-Kung-Shi's flying chariot?) and oars. Lana's plan could not work, but the idea of lighter-than-air flight gained momentum from the widespread reading of his treatise.

The discovery of hydrogen gas by Henry Cavendish in 1776 and experiments with the lightness (thinness) of heated air finally launched man into lighter-than-air flight. In France, Etienne and Joseph Montgolfier first experimented with Cavendish's hydrogen gas in attempts to fly small model balloons, but the gas always escaped through the balloon envelopes' porous paper. They then tried hot air experiments.

In 1782 the Montgolfier brothers succeeded. They used a small silk bag, and suspended burning paper under it in a manner that allowed the heated air to enter the bag through an opening at the bottom. As the balloon filled with the heated air, it rose until it reached the ceiling of the room in which their experiment was conducted. This success encouraged them to keep experimenting toward greater achievements.

By 1783 the Montgolfier brothers had built a balloon capable of lifting a considerable weight. In September, they demonstrated their balloon's lifting power to the King and Queen of France by placing a sheep, a chicken and a duck in the balloon car. The demonstration was an outstanding success, especially so since the balloon returned to earth without injury to its passengers.

About one month later (15 October 1783), another Frenchman came through with a "first." Francois Pilatre de Rozier anchored a hot air balloon to the ground so that it could rise only "so high." (De Rozier was not eager to take too many chances at this point.) With De Rozier in the car, the balloon rose 80 feet, making him the *first man to ascend in a balloon.*

On November 21 (still 1783), De Rozier and the Marquis d'Arlandes made the *first free flight* in one of the Montgolfiers' hot air balloons. The aerostat, as any lighter-than-air craft may be called, ascended easily into the atmosphere to an altitude of 280 feet. Twenty-five minutes later and after having traveled a distance of five and one-half miles, De Rozier and his passenger, d'Arlandes, landed in a

field outside Paris. De Rozier continued to fly until he died while attempting a balloon crossing of the English Channel.

Professor Jacques Charles (another Frenchman) had been experimenting with hydrogen and some means to contain it in an enclosure or envelope. He succeeded by rubberizing an envelope made of silk. Charles and the Robert brothers built a two-man hydrogen balloon and had it ready to fly on December 18, 1783. Charles and M. N. Robert entered the car and went on a long distance flight (for that time). They traveled, or floated, about 27 miles, and stayed aloft for more than two hours. Upon landing, Professor Charles decided to make a flight by himself. To his surprise, the balloon rose rapidly without the additional weight of his companion. Within twenty minutes he was at 10,000 feet altitude. By venting the hydrogen and skillful use of ballast, Charles was able to land safely some time later, but he complained of the cold and intense pain experienced at peak altitude. We can conjecture that this experience frightened Professor Charles because he never went up again.

Although we consider Charles and M. N. Robert to have made the first long distance flight, the feat that Jean-Pierre Blanchard performed was the most daring of the early long-distance flights. On January 7, 1785, Blanchard and his companion, Dr. John Jeffries (an American), took off from Dover, England, and crossed the English Channel to land approximately 12 miles inland from Calais, France.

Balloon flights had become fairly commonplace in the late 1780s and early 1790s, and the balloonists were looking toward refinements. They could go up and travel some distance, but there were two problems: They could not control the direction of travel and they needed some means of propulsion against the winds encountered. All kinds of apparatuses were tried. After all, the balloonists reasoned, air and water behaved in basically the same manner. Boats traveling on water used sails and oars for propulsion, and rudders for steering. Thus it seemed reasonable to them that the devices used on boats would obtain the same results on balloons.

Again and again the balloonists tried. They used oars, paddle wheels, "air screws" (propellers), rudders, and sails. Even Blanchard tried silk-covered aerial oars and a rudder on his channel crossing in 1785. The idea was basically sound, but most of the propulsion system designs relied on human body muscles as their power sources, and man simply cannot supply the power required—over a significant period of time.

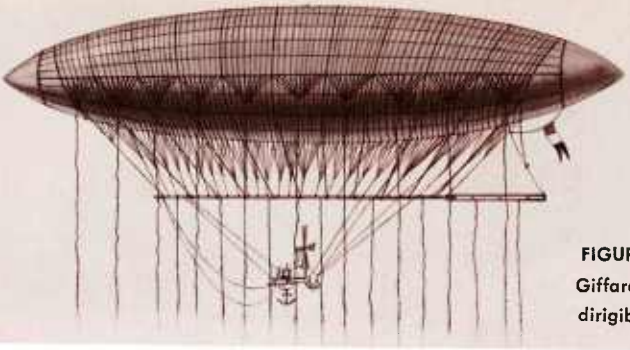

FIGURE 5
Giffard's
dirigible; 1852

M. Henri Giffard, a French engineer, was the first experimenter to use mechanical power for a balloon, or *dirigible* as a steerable balloon craft is known. Giffard designed a special steam engine for aerial use. His engine weighed 350 pounds and generated about 3 horsepower; yet it was powerful enough to turn an eleven-foot propeller at 110 revolutions per minute.

In 1852, Giffard built a dirigible with a cigar-shaped envelope which was 144 feet long and 40 feet in diameter. Covering the envelope was a net from which a beam was suspended. The aeronaut's car, engine, and propeller were suspended from the beam. Extending outward from the rear of the beam was a rudder, of sorts.

Giffard's dirigible was successful. It reached a speed of about six miles an hour, and it responded to directional changes of its rudder.

A new propulsion power source for dirigibles was used in 1883. Albert and Gaston Tissandier (Frenchmen again) fitted a small dirigible with an electric motor capable of developing about 1½ horsepower. The motor drove a two-blade propeller which had a diameter of nine feet. Although their dirigible couldn't be considered the greatest success, the Tissandier brothers could maneuver it. On one experimental flight they were able to "fly" within a specific area, even though an eight-mile-an-hour wind was blowing.

French Army Colonel Charles Renard improved the electric power propulsion technique. It took a varnished silk envelope 165 feet long to lift Renard's 1,174 pounds of electric motor and accumulators

FIGURE 6 Renard's dirigible; 1884