

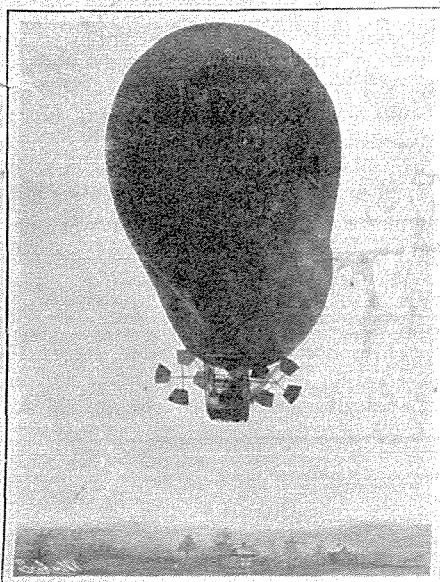
SCIENTIFIC AMERICAN

Entered at the Post Office of New York, N. Y., as Second Class Matter. Copyright, 1903, by Munn & Co.

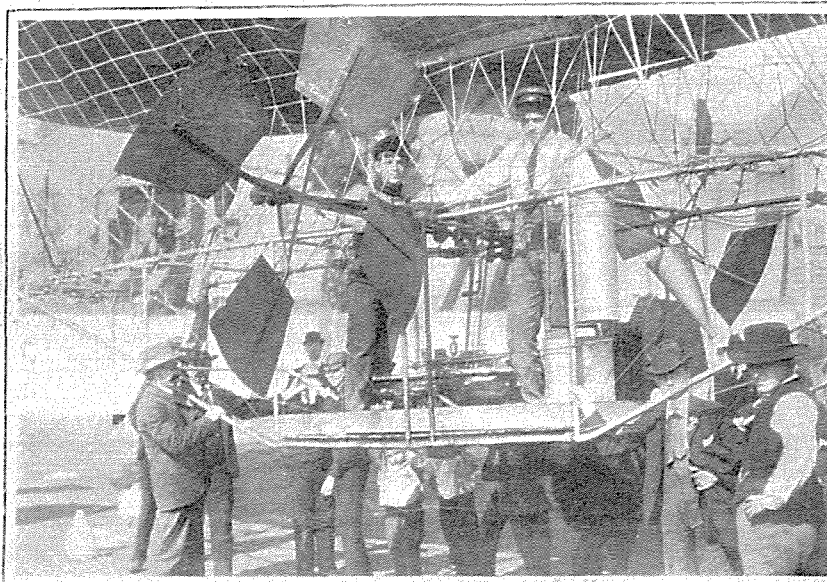
Vol. LXXXIX, No. 19,
Established 1845.

NEW YORK, NOVEMBER 7, 1903.

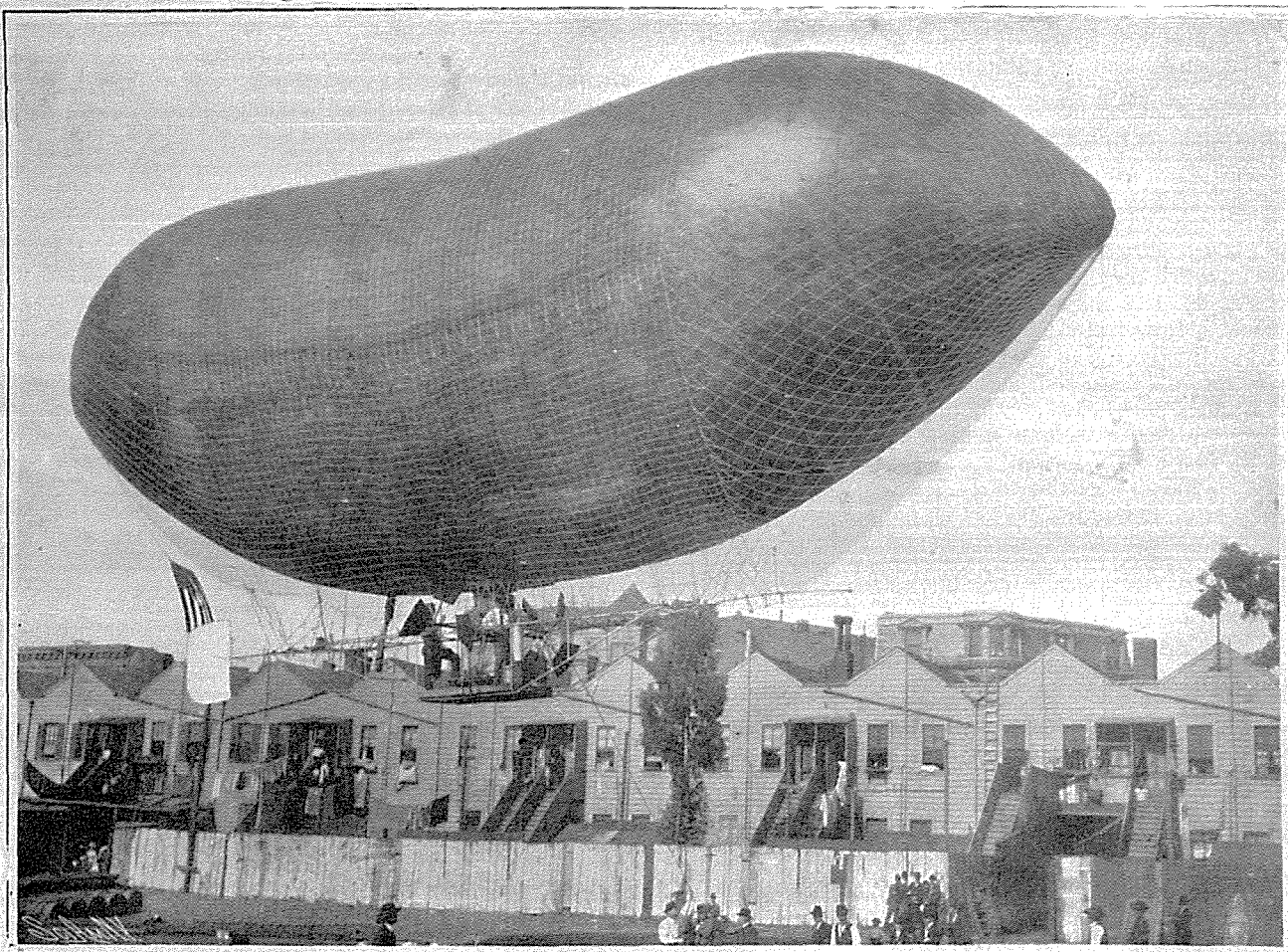
8 CENTS A COPY
\$3.00 A YEAR.



The Airship in Flight.



The Car, the Motor, and One of the Propellers.



*One morning seventy-three years ago
San Franciscans gasped as Dr. August Greth
sailed overhead in a remarkable airship.*

DR. AUGUST GRETH and the FIRST AIRSHIP FLIGHT in the UNITED STATES

By Dr. Douglas H. Robinson

All photos courtesy Milton Canfield

Everyone knows the date when the Wright Brothers made their first powered flight. Yet 73 years ago, with many men of science convinced that powered heavier-than-air flight was an impossible dream, the airship, which traced its ancestry back more than 200 years to the balloon, appeared to be the aerial vehicle of the future. After a promising start, the airship was overtaken by the airplane and today is no longer seen in the sky, except for the Good-year blimps. How many can name the first person to fly an airship in the United States? Or the date?

The evidence points to a fellow physician of San Francisco, Dr. August Greth, who on October 18, 1903, ascended from an open tract in front of a large shed at 11th and Market Streets, and in full view of a large number of his fellow townsmen, flew for 40 minutes and attained a maximum altitude of 2,000 feet. Motor failure (a common problem in the early days) caused the airship to descend into the bay off Fort Point, whence it was towed ashore to the lifesaving station.

There are, of course, rival claimants for the glory of the first airship flight in the United States. One Leo Stevens "claimed the distinction of building and flying the first motor-driven navigable airship in the United States in 1900,"¹ and I have seen a photograph allegedly showing a "trial flight of Leo Stevens' airship at Coney Island (1903?)."² Carl Myers, frequently in the headlines at the turn of the century, "reported initial successes with a motor-driven balloon" in 1901.³ Yet there is no corroborating documentation, while Dr. Greth's flight was witnessed by hundreds if not thousands of people, and was front-page news in the San Francisco Call and Examiner, and even made it in the New York Herald and Journal.

Dr. Greth was in goodly company. The balloon, a scientific miracle at its inception in 1783, was part of the atmosphere, drifting with the wind, and inventors had dreamed ever since of making it a useful means of transportation by giving it power and controllability. Most, like the San Francisco physician, were dreamers operating on a shoestring, long on vision and determination, varying in their engineering ability from those competent in a classical environment to the naive and impractical. The efficient, lightweight power plant long eluded them, and as late as

1872 the airship of the great French naval architect, Stanislaus Charles Henri Laurent Dupuy de Lome, had its 30-foot propeller turned by eight sailors fueled with ample libation of rum.

The first powered airship flight had actually been made 20 years earlier. The only possible mechanical power plant was the steam engine, and to Henri Giffard, the inventor of the steam injector, belongs the credit for adapting it for aerial propulsion. His engine, weighing 250 pounds and powered by a boiler weighing 100 pounds without water, produced 3 hp. In a single flight, on September 24, 1852, the 88,000 cubic foot craft traveled 17 miles from Paris to Trappe. The still air speed was reported to be six mph, and this, in effect, was a downwind run with no hope of returning to the takeoff point. No further steam-powered airships were built—the power to weight ratio was far too low.

The German Paul Haenlein, in 1872 proposed to fly his airship with a primitive internal combustion engine burning coal gas from the balloon, and developing six hp, but his craft was never flown untethered. The first airship to fly free and return to its point of takeoff was "La France," built to government order in 1884 by Colonels Renard and Krebs; but for lack of a more efficient power plant, they chose an electric motor developing 7½ hp and driven by 1,232 pounds of batteries. At 210 lb./hp, this was no real advance on the Giffard steam engine. Yet in seven local flights in calm air, "La France" developed a speed of 14½ mph and on five occasions was brought back to her starting point. Twice she force-landed away from her shed and had to be deflated.

The ultimate solution to the problem of a lightweight power source—the gasoline-driven internal combustion engine—was being developed at this time by Otto and Langen, and refined by Gottlieb Daimler and Wilhelm Maybach. The first to take it aloft was the German, Karl Woelfert. The primitive Daimler engine which he used was incredibly dangerous when attached to a hydrogen-filled gas bag: instead of electrical ignition it relied on a platinum tube fed with gasoline and kept at a high temperature by an open flame burner! This led to disaster in the only flight of his airship at Berlin in 1897: an ascent to 3,000 feet caused hydrogen to be vented from the bag; this was set afire by the burner flame, and



the airship fell blazing, killing Woelfert and his mechanic, Robert Knabe.

It remained for Alberto Santos-Dumont, a wealthy young Brazilian living in Paris, to demonstrate the practicability of the gasoline engine with magneto ignition. Beginning in 1898 he produced a series of small pressure airships powered by modified automobile engines, and being very much the showman, he soon attracted great enthusiasm not only in Paris, but throughout the aeronautical world generally. In 1901 his No. 6 airship won a 100,000 franc prize by flying seven miles from its base around the Eiffel Tower and back at a speed of 14 mph.

Santos' success inspired other inventors. Two of these died horribly in full view of thousands of Parisians on their first ascents: the Brazilian, Augusto Severo, along with his mechanic Sachet on May 12, 1902, when because of improper ballasting and sealing of an automatic valve, his airship shot rapidly to 2,000 feet and exploded; and the Austrian Baron Ottokar Bradsky, with his mechanic Morin, on October 13, 1902, when due to mistrimming the airship nosed up, the gondola tore free and fell 330 feet.

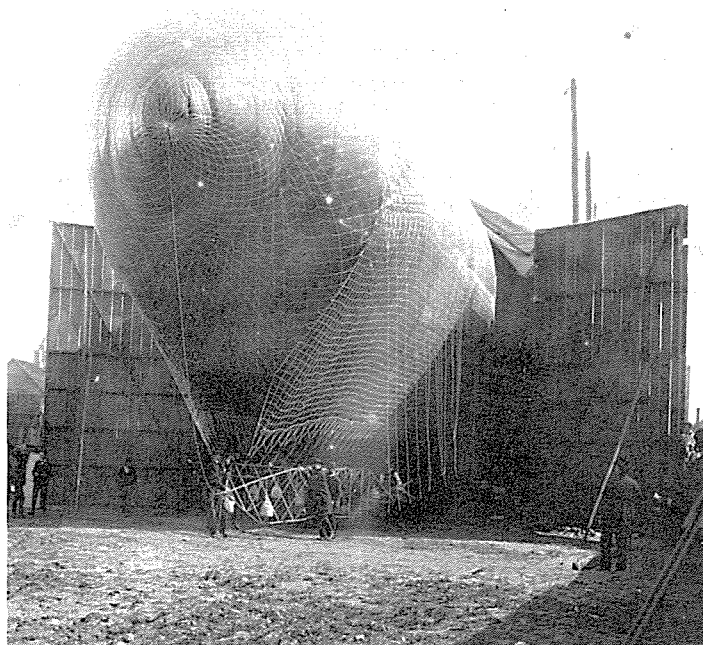
Dr. Greth must surely have known of these disasters, as well as the successes. In interviews, he claimed to have visited Santos-Dumont during a journey to France, and hoped to surpass his achievements. Dr. Greth also referred to the Englishman, Stanley Spencer, who first flew a small airship in London on September 22, 1902.

All these craft were of small capacity, with varnished silk or rubberized fabric bags, most fitted with ballonets to maintain a constant pressure without loss of hydrogen; and only able to carry the pilot and possibly a mechanic, with fuel for short journeys in light winds. Larger craft were about to appear, however, and to attract the government backing necessary for a real program of development and production: the semi-rigid Lebaudy which made its first flight in November, 1902, and the huge metal-frame rigid airship of Count Zeppelin, which made its first ascent from Lake Constance on July 2, 1900. Dr. Greth would have to proceed on a much more modest scale.

Who was Dr. August Greth? Originally of French nationality, he was born May 24, 1856 in Mulhouse in Alsace, which after 1871 was annexed by Germany. His father was a mechanical engineer. In later interviews he related that he attended school with Alfred Dreyfus, the army officer who in 1894, in a scandal that rocked France, was convicted of treason on trumped-up evidence and sent to Devil's Island. Greth himself served as a youth in the French Army in North Africa. In 1878 he first came to America, in 1880 he returned to France, but two years later came back to America and settled in San Francisco, though making several further journeys to France. He earned a medical degree at the University of California, thereafter practicing in San Francisco. In 1903 he resided at 303 Jones Street with his wife and four children. It is clear, however, that he had followed the development of airship flight in Europe with much interest, and had ambitions of his own.

Undoubtedly what inspired Dr. Greth to construct his airship was the prospect of winning prize money at the Louisiana Purchase Exposition to be held in St. Louis from April 30 through November 30, 1904. A year earlier, and on the advice of Santos-Dumont himself, who in April, 1902, came to St. Louis to act as advisor, a prize of \$100,000 was offered to the winner of an airship race three times around a 10-mile triangular course at a minimum speed of 20 mph. Santos-Dumont himself planned to enter his No. 7 racing airship, designed for a speed of 50 mph. American designers, nonetheless, felt they had a chance to win the huge prize with their own inventions.

Dr. Greth, of course, needed money, over and above his personal resources, and set up the American Aerial Navigation Company, which by October 20, 1903, had sold only 227,000 out of one million shares. One J. Ozro Brubaker, an artist, is mentioned as Greth's partner, and other stockholders not only took a lively interest in the progress of the "California Eagle," but may also have pressed Greth into making ascents with a craft he knew was technically defective. A sandy lot at 1517 Market Street was pur-

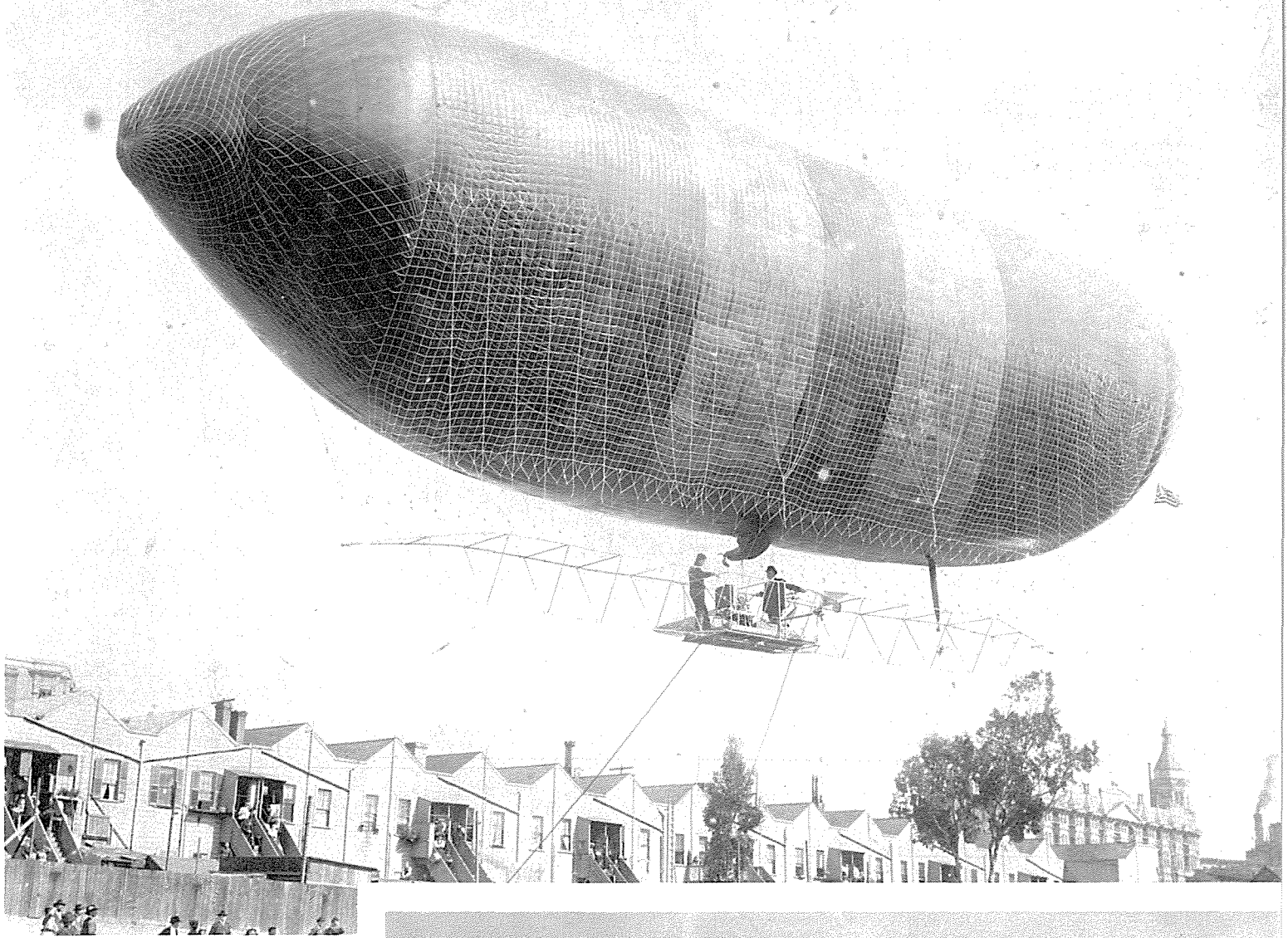


chased or leased, on which was erected a large shed with a canvas roof. With no technical experience, Greth secured the assistance of one of America's earliest astronauts. Captain Thomas S. Baldwin, who had been making hot air balloon ascents and parachute drops at country fairs since 1887, and who was later to build the first airship in America ever to return to its point of takeoff under its own power. Baldwin too had visited Europe and seen not only the work of Santos-Dumont, but also the Zeppelin establishment at Manzell on Lake Constance.

The envelope of the "California Eagle" was made of silk, presumably varnished for the San Francisco Examiner described the ship as the "yellow novelty." Eighty-two feet long and 25 feet in diameter, it could hold 29,000 cubic feet of hydrogen for a gross lift of 2,000 pounds. There was a filling sleeve or appendix at the bottom of the bag, and presumably a maneuvering valve in the top of the bag. Greth deliberately omitted the ballonnet, which most inventors felt necessary to maintain the pressure and shape of the bag, and believed in this respect that his design was superior to Santos-Dumont's:

An important improvement I have made is in the balloon part. Dumont uses a "balonnet" [*sic*] which is a small balloon inside the big one. It is filled with air and connected by hose with the motor, which continually blows air into it to keep the big balloon taut. With the expansion and contraction of the gas by changes of temperature and changes in the air pressure according to elevation some such regulation is necessary. But the "balonnet" device is cumbersome. It is heavy. It complicates matters a great deal. And it is expensive because the air gets into the gas and spoils it, so that the balloon must be frequently emptied and refilled. My balloon is so constructed with specially arranged netting that the gas is pressed towards the ends. It is as effective as it is simple. Dumont couldn't keep his balloon taut, for it buckled and doubled up, and that is what caused his mishap at Monte Carlo in January of last year.⁴

Admittedly, Santos had suffered at least three accidents when his envelopes had buckled due to loss of gas pressure, and Greth was fortunate to escape similar mishaps. It was, of course, untrue that the gas was "pressed towards the ends," and what kept the envelope from jackknifing amidships was the long steel tube girder or keel, slung under the bag and serving as an attachment point for the netting covering the entire envelope. The keel weighed 100 pounds and amidships broadened out to form the floor of the gondola, measuring seven feet long, four feet wide and four feet high. Greth told a reporter,



The photos on these pages were probably taken of the California Eagle on August 10, 1903, when the airship had a full-length keel girder, no rudder, and with the propeller shafts mounted low in the gondola.



Another thing I have done is to swing my frame only seven feet below the balloon, rendering the machine more perfectly dirigible. The other models have the frame swung twenty feet below the balloon, and this makes the framework a drag on the buoyancy of the machine, and renders the balloon hard to control. By my experiments I proved the proximity of the gasoline motor to the balloon was not a dangerous factor.⁵

Aerodynamically the good doctor was right, but with the gondola only seven feet below the hydrogen filling sleeve, Greth might well have suffered the same fiery death as Woelfert and his mechanic, if gas had escaped during an ascent with the motor running.

The motor was the Achilles' heel of the Greth airship, and there is ample proof that the doctor would have given anything for a dependable, lightweight power plant. What he had was a Brennan automobile motor, weighing 500 pounds and rated at 12 hp, though the frustrated doctor estimated he got only five to seven hp when it could be persuaded to run. With a ratio of 71 to 100 pounds per hp, Dr. Greth was still optimistic:

It is very inferior to Santos-Dumont's which was built by De Dillon [*sic*], the famous French motor-maker. . . . Dumont's is air-cooled, weighs only 300 pounds and gives 30 actual horsepower. Santos-Dumont has every advantage in the world, so far as construction and equipment are concerned, while we have all sorts of difficulties to contend with; and yet our results on Sunday (Oct. 18, 1903) were better than anything Dumont ever achieved.⁶

The propellers and power drive arrangements, however, showed much ingenuity and sound engineering knowledge in their arrangement:

My propelling mechanism is as follows: On the rectangular frame, over the middle of the car, we have two six-foot propellers on a transverse shaft that runs in sleeves which are turned by mechanical worm and worm wheel, so as to rotate the axes of the propellers in any direction—forward, back, down or up. The plan is to have four propellers, two at each end of the frame, placed like the wheels of a wagon; but on Sunday I used only two, as there was not power enough to drive more than that. The propellers are six feet from one end to the other. Each has four blades of sheet steel $1\frac{1}{2} \times 2$ feet, set at an angle of 30 degrees. The required speed of the propellers is 400 rpm, but with the poor motor I had on Sunday I was able to get only about 120. The 400 revolutions would give a speed of twenty mph in a calm. With a thirty hp engine I can use the four propellers, which will not only give a higher speed but also much better command of the ship.⁷

The controls of the airship were rather complicated, and really required the attention of more than one man.⁸ A closeup of the "Running Platform of Greth's Dirigible Balloon" shows one of his assistants, R.B. Saxby, posed in the car:

Saxby's left hand grasps a lever that controls the propeller on the right; he has turned the blades to a horizontal position. Close to his hand is the lever that controls the position of the left propeller, shown in a vertical position. Saxby's right hand grasps the steering wheel; close to the floor is the lever actuating the clutch of the motor, which throws the propellers in and out of gear; this he works with his foot.⁹

Perhaps to give the stockholders something for their money, Dr. Greth on August 10, 1903, had the "California Eagle" brought out of its shed at 11th and Market Streets, and flying solo, made three tethered ascents. Though the San Francisco Examiner declared that the airship "poised in the air as gracefully as a bird, circling around and about, ascending and descending under perfect control,"¹⁰ it is by no means clear that the engine was running or even installed. Later the reporter found the airship ballasted with sand bags in its shed being admired by the stockholders and by Captain Baldwin, listed as one of its builders. Greth, ecstatic over the first ascent, hoped his ship would "defend the ports of the United States against invading fleets," while

he "expects to reach the North Pole and build vessels for passenger and freight service." He also spoke of his intention to fly against Santos-Dumont in St. Louis.

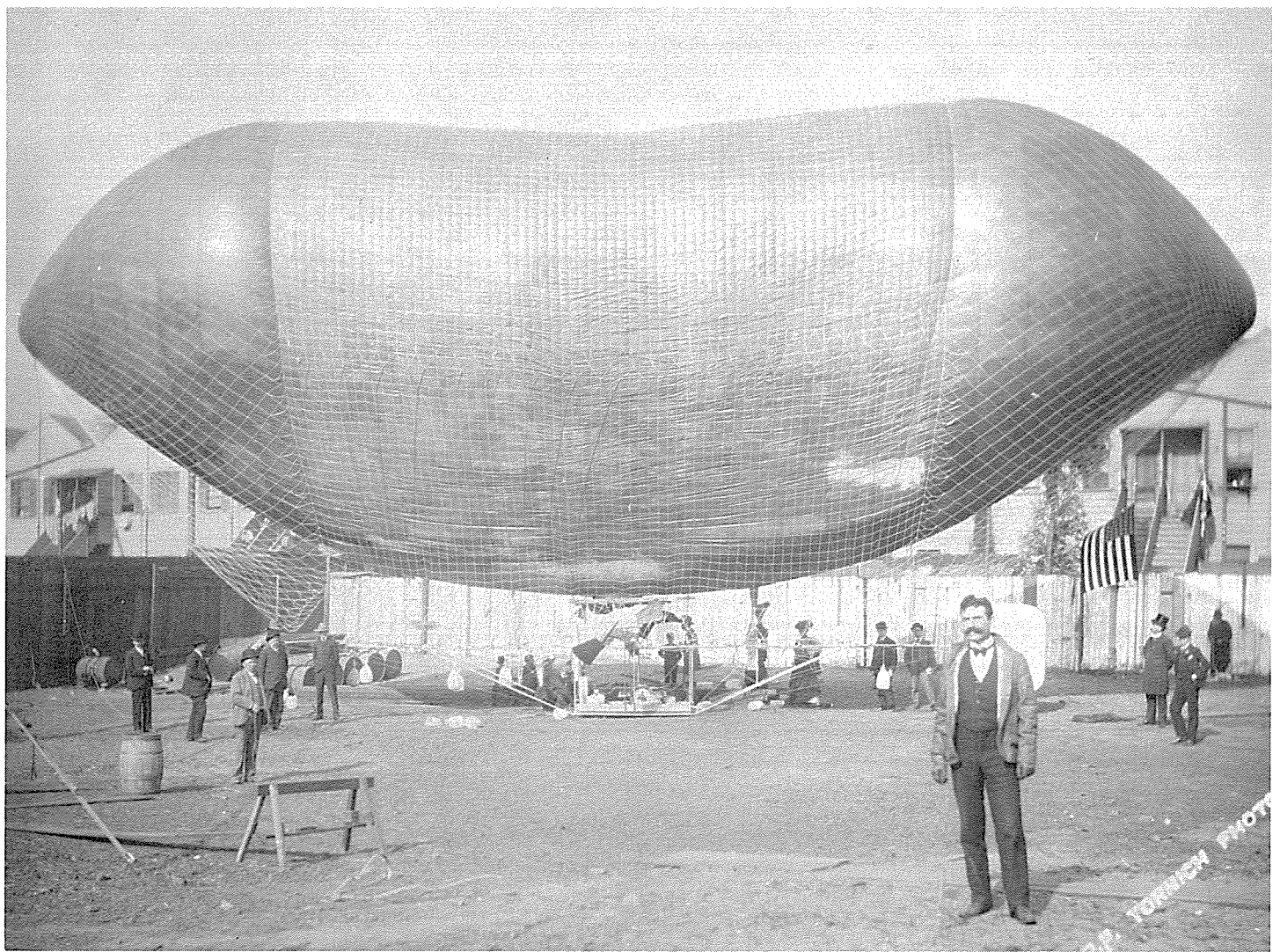
Next came the historic first airship flight in America on October 18. Excited accounts on the front pages of the local newspapers leave no doubt that Greth actually flew, but written as they were by reporters with no aeronautical knowledge, one wonders at times what really happened. The Call's reporter, for instance, wrote "At eleven o'clock a pretty turn was made directly north, and then the ship gently assumed a perpendicular position, which it held for several seconds." At 9:35 a.m., the "California Eagle" was drawn out of its shed. The envelope was not completely filled, it "sagged on top as it was necessary to leave room for the expansion of the gas as higher altitudes were attained." With the motor weighing 500 pounds, the car and fittings 500 pounds, Dr. Greth himself 200 pounds, and 260 pounds of ballast, the total weight borne aloft was 1,600 pounds (evidently including the bag and netting). While the engine was warming up, a mechanic, F.H. Hutchinson, was struck over the right eye by a propeller and knocked unconscious, Dr. Greth jumping from the car to assist him. Evidently he was not seriously injured.

First, the ship rose tethered to 400 feet and with the rope slack, ascended, descended, and maneuvered before being pulled down after half an hour. "Dr. Greth was worn out by his work with the motor, which gave him much trouble."¹¹ After resting for an hour in a room on the grounds, Greth reappeared to announce, "I will make a free ascent and sail around the Call building." At 10:50 a.m., with engine running, the "California Eagle" lifted off and ascended to an altitude of perhaps 500 feet. The airship made a few circles, but the weak engine could not force it against a light southerly wind, and it drifted off north towards the Presidio. ("Another trouble . . . was that the clutch slipped constantly.") With the hot sun warming and expanding the gas, the airship was light and rose further, to an altitude of 2,000 feet. The percentage fullness of gas in the bag at takeoff is not known, but at 2,000 feet the hydrogen would have expanded by at least six percent and almost certainly the ship would have gone through pressure height, where the bag would be 100 percent full. Had the ship been fitted with a ballonet, air would have been valved at this point, but with flammable hydrogen exhausting from the filling appendix in the bottom of the bag, Dr. Greth prudently shut off the engine to prevent a fire. Valving gas from the maneuvering valve in the top of the bag, the doctor started the ship down, but found he could not restart the balky engine. Further valving brought the craft down in the bay some 300 yards off Fort Point. The life-saving crew towed the airship ashore, where it was deflated and carted back to the hangar at 11th and Market. The flight had lasted 40 minutes, and Dr. Greth boasted that he could have crossed the Golden Gate and landed in Marin County, but the cost of transporting the dismantled craft back to its base would have been prohibitive.

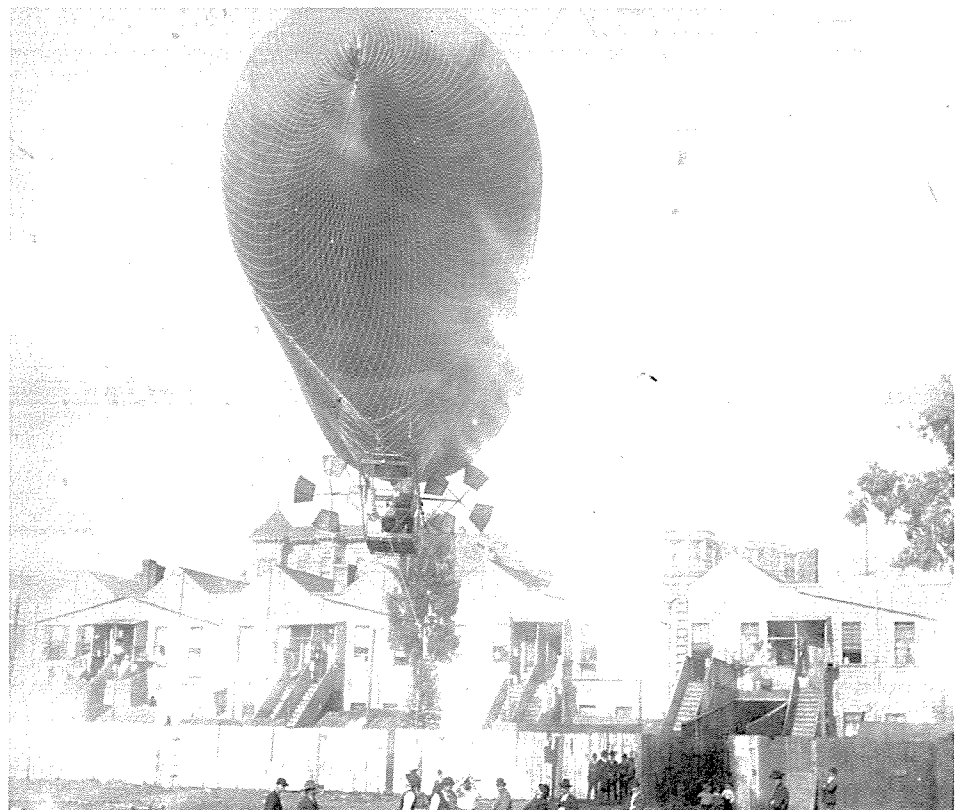
Dr. Greth's initial reaction was ecstatic:

I am going to compete for the \$100,000 prize and the gold medal to be awarded for the most successful airship . . . and I shall win the prize, too, unless I have some competition more formidable than Santos-Dumont. . . . I will sail from "The Examiner" office to the "Chicago American" building, and from there I will go to St. Louis. We will keep that \$100,000 prize in America.¹²

But six days later the San Francisco Bulletin told its readers that "Dr. Greth will make no more experiments until he gets lighter and more powerful machinery." The article added that the treacherous Brennan "was considerably damaged by the ducking it got when the balloon fell into the bay and it will not be used again in the experiments." Greth's stated ambition was to obtain an engine similar to Santos-Dumont's, "and should he get one installed to propel his airship he claims he will be able to have his balloon under perfect control at all times."¹³ Certainly, with a reliable, lightweight and more powerful engine, the "California Eagle" would have been a quite different airship. But the new engine never materialized, probably because the stockholders feared they would be throwing good money after bad.



Further photos of the California Eagle reveal changes made in the keel girder and position of propeller shafts. These photos were probably made October 18, 1903 at the time of the final flight that was of 40 minutes duration.



Thus, the reconditioned Brennan powered the "California Eagle" on its last two ascents. Dr. Greth's friend and colleague, Thomas S. Baldwin, was in charge when the airship ascended from 11th and Market at 9:30 a.m. on April 23, 1904. An unnamed engineer was to give his full attention to the temperamental Brennan, said to be "lighter and somewhat improved," but after takeoff, Baldwin found the lifting force was inadequate, and commanded the engineer to jump overboard from an altitude of five feet. Initially the airship made a few turns, then the engine broke down and could not be restarted. The remainder of the hour and a half flight, during which the craft ascended to 3,500 feet, was as a free balloon, and the airship landed at the California Chemical Works on the San Bruno road. The flight did not inspire confidence in the airship's chances at the St. Louis Exposition, and the San Francisco Examiner said that

The dream and hope of Dr. Greth, the inventor and promoter, lacked entire realization. Mr. Baldwin, the balloon man, failed to properly work the engine. He says the fault was with the machinery, while Dr. Greth says the fault was with Baldwin. There may be some truth to both of these assertions, for Baldwin admits he did not know much about the machinery, and it was apparent to everybody that the motor, which had been taken from a \$2,400 automobile, was not a very good one for the purpose.¹⁴

On the last recorded flight on May 2, 1904, Dr. Greth was in charge, accompanied by Frederick Belcher, engineer. Instead of flying to Chicago, Dr. Greth had decided on a more modest goal—San Jose, located about 45 miles southeast of San Francisco. Telling reporters, "I am confident that I can do what I like when I get up, and to show you what I can do and what this machine will do, I will make the trip to San Jose," the doctor left the lot at 11th and Market Streets at 8:30 a.m. For a time he made progress against a light southerly wind, when "suddenly a valve got out of order." Probably the "California Eagle" had become light, either from the sun warming the gas or from consumption of fuel, and when Greth opened the valve in the top of the bag, it had stuck open. Again he descended on the San Bruno road just south of the county line, "between the Five Mile House and Blanken's."¹⁵

The "California Eagle" never had another chance to show what she could do, and never made it to the St. Louis Exposition. The sensation of the meet was Greth's former colleague, Thomas Baldwin. With his "California Arrow," an airship with a bag 54 feet long by 17 feet in width and equipped with an efficient motor constructed by Glenn Curtiss (then an unknown motorcycle builder), which developed 10 hp for a weight of 60 pounds, Baldwin made a first flight on July 29, 1904, at Idora Park in Oakland. On August 2 the "California Arrow" made a longer flight, for the first time in the United States returning under her own power to the point of departure. It was the Baldwin airship that outshone all others at St. Louis in the fall, though it failed to meet the stringent conditions for the award of the \$100,000 prize.

Like many of his townsmen, Dr. Greth lost everything in the great San Francisco earthquake and fire of April 18, 1906. This included the deflated "California Eagle," which according to his family, he had never succeeded in insuring. He moved to Los Angeles, and a photograph of him posing with Thomas Baldwin in the hangar at 11th and Market Streets appeared in the June 7, 1908 Los Angeles Sunday Times in an article featuring aeronautical experimenters in the Los Angeles area. But he never got back to his first love, aviation, and died in Los Angeles in 1938.

Primitive indeed was the "California Eagle," though it embodied ingenious ideas showing Dr. Greth's engineering talent. Ridiculous, perhaps, to his contemporaries was the 40-minute flight of October 18, 1903, with its ignominious end in the waters of San Francisco Bay. Yet this California physician dared to lead the way in an era when aeronauts were thought to be of unsound mind. To Dr. August Greth must go the credit for making the first airship flight in the United States, and with a light and efficient motor, which he sought in vain, he instead of Thomas Baldwin might have flown the first aircraft in the United States to return under its own power to the point of departure.

REFERENCES

1. H.L. Scamehorn, "Balloons to Jets" (Henry Regnery Co., Chicago, 1957), p. 15.
2. This might seem to show Stevens flying Thomas Baldwin's "California Arrow" at Coney Island on July 4, 1905. C.R. Rosebery, "Glenn Curtiss; Pioneer of Flight" (Doubleday, N.Y., 1972), p. 44.
3. Scamehorn, op. cit.
4. San Francisco Examiner, Oct. 20, 1903. Actually it was on February 14, 1902, that Santos fell in the sea at Monaco because his No. 6 airship, the Deutsch prize winner, was not fully inflated with hydrogen and the envelope buckled, causing it to slide stern first into the sea.
5. San Francisco Call, Oct. 19, 1903.
6. San Francisco Examiner, Oct. 20, 1903. The figures given here do not coincide with those for any motor in any of Santos-Dumont's airships. His No. 5 had a 4 cyl. air cooled Buchet developing 15 hp and weighing 180 lbs.
7. Ibid.
8. Why did Dr. Greth make the important flight of Oct. 18, 1903, without an assistant? Probably the "California Eagle" was still inflated with the same hydrogen with which she had been filled for the August 10 tethered flight, and after two months, this would have been contaminated by air diffusing in through the envelope, degrading its lifting ability. To make a fresh 29,000 cu. ft. of hydrogen from sulfuric acid and iron filings would have been an expensive proposition.
9. San Francisco Examiner, Oct. 20, 1903.
10. San Francisco Examiner, Aug. 11, 1903.
11. San Francisco Call, October 19, 1903.
12. San Francisco Examiner, Oct. 20, 1903.
13. San Francisco Bulletin, Oct. 26, 1903.
14. San Francisco Examiner, April 24, 1904.
15. The Evening Post, May 2, 1904.

ACKNOWLEDGMENTS

I am deeply grateful to Dr. Greth's daughter, Mrs. Vera Louthier, and to his grandson, Mr. Milton G. Canfield, for their assistance in providing information about the Greth airship, particularly from newspapers, articles and photographs in their possession. I am indebted to Dr. A.D. Topping of the Lighter Than Air Society for advice about other early airship experimenters in the United States.

BIBLIOGRAPHY

- A. Santos-Dumont, "My Airships" (Grant Richards, London, 1904).
 L.T.C. Rolt, "The Aeronauts, A History of Ballooning 1783-1903" (Longmans, London, 1966).
 C.R. Rosebery, "Glenn Curtiss, Pioneer of Flight" (Doubleday, New York, 1972).
 H.L. Scamehorn, "Balloons to Jets" (Henry Regnery Co., Chicago, 1957).
 Peter Wykeham, "Santos-Dumont, A Study in Obsession" (Harcourt, Brace & World, New York, 1962).
 Kenneth M. Johnson, "Aerial California" (Dawson's Book Shop, Los Angeles, 1961).



ABOUT THE AUTHOR

Dr. Douglas H. Robinson is a physician practicing in Trenton, N.J., who has been contributing articles to the Journal since 1959. He is an authority on lighter-than-air, with two major books on the subject, "The Zeppelin in Combat," and "Giants in the Sky." Also published under his name are: "The Dangerous Sky," a history of aviation medicine, "Hindenburg" and "The B-58 Hustler." Dr. Robinson's recent articles in the Journal are, "The Effectiveness of the Dirigible in Military Operations" (Volume 19, Number 4) and "The First Aerial Voyage in America" (Volume 21, Number 21). Despite a busy practice and writing stints, Dr. Robinson finds time to fly his Cessna 170B and Schweizer sailplane.