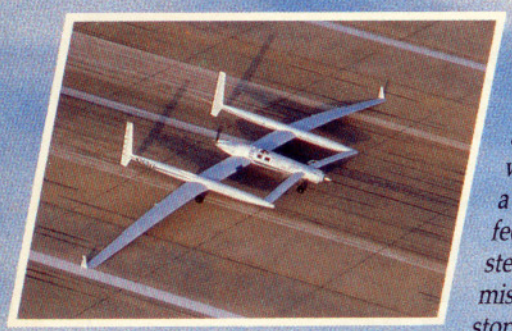
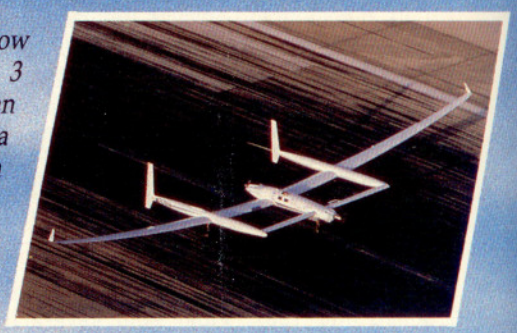
ONCE AROUND THE PATCH

Aviation has a new set of heroes

BY MARK R. TWOMBLY





THE *voyage unfolded in slow motion over 9 days 3 minutes 44 seconds. Pilots Richard G. Rutan and Jeana L. Yeager, AOPA 745893, circled a world that measures more than 25,000 miles in a world smaller than eight feet long and four feet wide. Before takeoff, Yeager maintained steadfast—some would say unrealistic—optimism about their chances of completing a nonstop, unrefueled flight around the world. Rutan was less sanguine. He rated the odds of making it on the first attempt at one in three, and only one in two no matter how many times they tried. As it turned out, he beat his own odds.*

Two days before Christmas, thousands of fans and hundreds of journalists drove through the night to witness the dawn homecoming at Edwards Air Force Base, California, on the dusty flats of Rogers Dry Lake. Members of the press were shepherded to an area directly in front of the intended landing area. The night was long, with occasional flakes of snow drifting through the air to remind everyone of the chilly temperature. A

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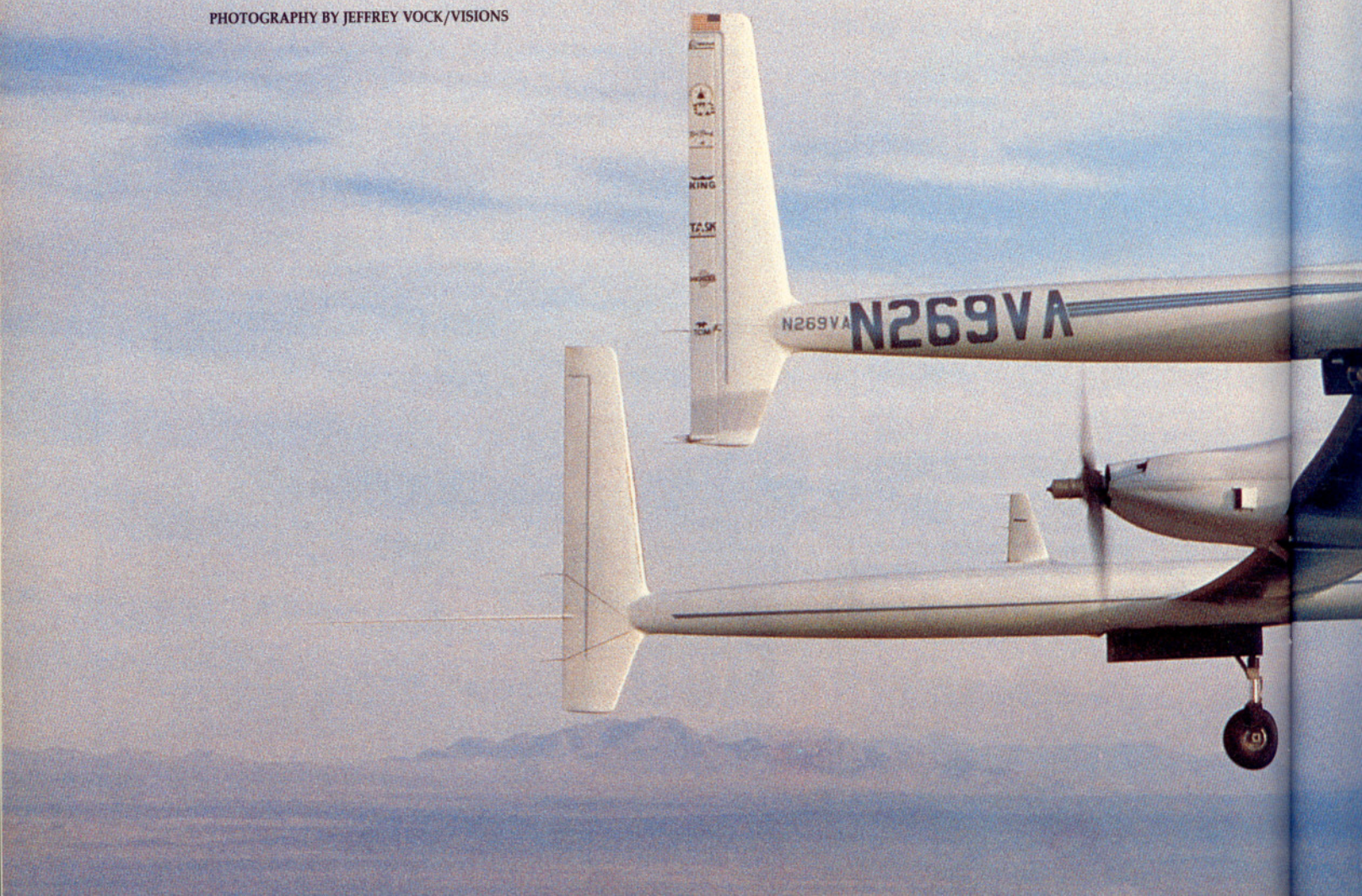



Voyager

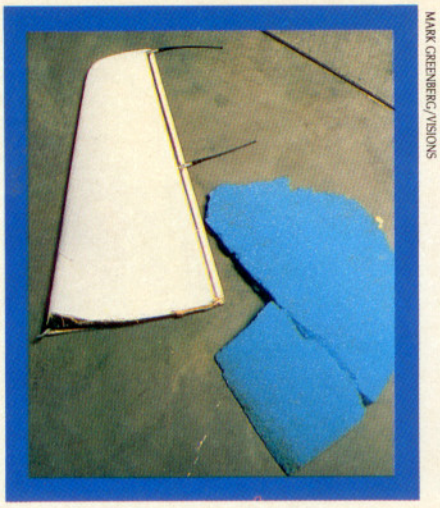
dense grove of network television microwave broadcast antennas sprouted in the dark from vans and motor homes jammed with electronic equipment.

There was concern that the aircraft might not have sufficient fuel to reach the lake bed. Spokesmen for the project elevated the tension by mentioning during live television interviews that the crew was dangerously fatigued and might not be capable of a safe landing. Those concerns evaporated when Rutan's calm, confident voice crackled over loudspeakers. "I guess I have to resign my membership in the Flat Earth Society," Rutan joked over Edwards' approach control frequency. *Voyager* was at 10,000 feet, nearing the lake bed. Eyes strained toward the southwest. Rutan reported the field in sight.

Then it appeared, accompanied by a formation of airplanes struggling to stay aloft at near stall speeds. Rutan throttled back and entered a shallow, spiraling glide over the lake bed. A Cessna 210 flying close formation carried a television cameraman hanging out of the cabin, providing live coverage of the landing. Rutan ordered the Cessna away with the explanation that *Voyager's* loyal grass-roots supporters, the thousands of people who had sustained the project by purchasing tee shirts and posters and giving cash donations, and who had driven to the high desert to see *Voyager* return, were owed a symbolic thank you. Rutan wanted to fly over the crowds at Edwards and give them an unobstructed view of the aircraft. Reporters a mile away could hear the spectators' cheering.

A few minutes later, *Voyager* drifted down to the floor of the lake bed, accompanied by a chase plane whose pilot called out height above touchdown. After a little more than 216 hours, *Voyager* seemed finally to grow weary of flying and dropped onto the runway in a small cloud of brown dust. "Not my best landing," Rutan would say later.

The two pilots were taken to the base hospital for medical examinations and a meal of fresh fruit and seafood. A few hours later, they faced a sea of reporters and their jubilant support team at a press conference held in a large hangar. Understandably, Rutan looked tired. "I'm a little wobbly," he conceded. Yeager, who lost eight pounds during the flight, had suffered some bone bruises from being tossed about the cabin in turbulence, but otherwise appeared fit. They had managed to get some rest during the flight, but not much sleep. Ninety percent of their food supply was untouched. "We had no appetite, and no time," Yeager explained.



MARK GREENBERG/VISIONS

It was an uncertain voyage from the start. Bowed wings scraped the runway on takeoff, nearly severing the winglets. Sideslips knocked them free, and the flight continued.

Rutan Aircraft Factory Model 76 Voyager
Price: $2 million (estimated)

Powerplants (rear)	Teledyne Continental liquid-cooled, four-cylinder IOL-200, 110-hp @ 2,750 rpm
(front)	Rolls-Royce Continental air-cooled VO-240, 130 hp @ 2,800 rpm
Propellers	TRW Hartzell constant speed, aluminum, two-blade, 70-in diameter
(rear)	partial-feathering
(front)	full-feathering
Fuselage length	25 ft 5 in
Boom tank length	29 ft 3 in
Height	10 ft 4 in
Canard span	33 ft 4 in
Wingspan	110 ft 7 in
Wing/canard total area	424 sq ft
Aspect ratio	33.8:1
Wing loading	31.2 lb/sq ft
Power loading	47 lb/hp
Cabin length	7 ft 6 in
Cabin width	3 ft 4 in
Cabin height	3 ft 10 in
Fuel capacity	1,489 gal (8,934 lb)
Gross weight	11,326 lb
Crew weight (including parachutes)	303 lb
Food supply	40 lb
Water supply	90 lb
Basic operating weight	2,683 lb
Takeoff weight	9,694.5 lb
Fuel load at takeoff	1,168.5 gal (7,011 lb)
Fuel load after landing	18.3 gal (109.8 lb)
Initial twin-engine cruise airspeed	113 KIAS
Final single-engine cruise airspeed	80 KIAS
Average groundspeed	100.627 kt (115.8 mph)
Flight time	216 hours 3 minutes 44 seconds
Distance	21,735 nm (25,012 sm—initial estimate)

Malvern J. Gross, a vice president of the National Aeronautic Association, presented the two with a framed citation attesting to their record-setting effort. Dick called his brother, E. L. "Burt" Rutan, AOPA 795261, *Voyager's* designer, to the stage to share the prized certificate. The two embraced, and wiped tears from their eyes.

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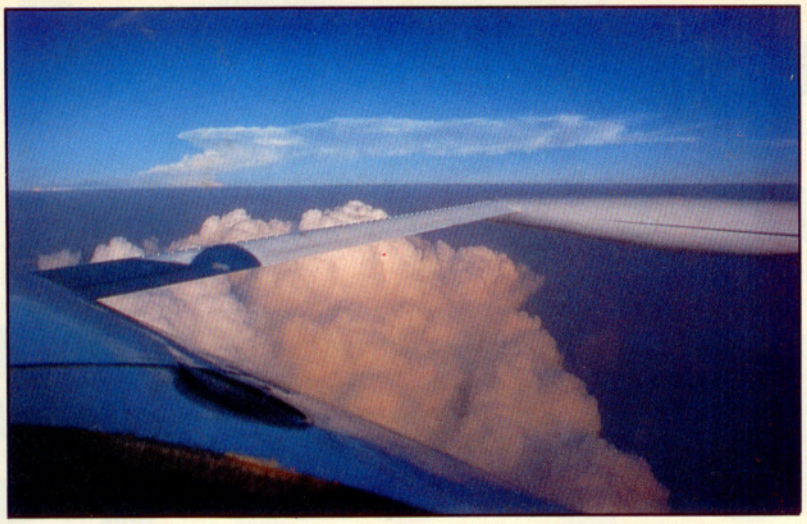
Rutan's and Yeager's odyssey began a little more than six years ago. Dick Rutan was working in Mojave as a test pilot at Rutan Aircraft Factory (RAF), a small homebuilt-aircraft design firm founded by his brother. At lunch one day, the conversation turned to the subject of a global flight. Burt speculated that recent breakthroughs in structural materials and construction techniques made it possible to build a very light, extremely strong, flying fuel depot powered by small, fuel-efficient engines with the potential to complete a nonstop circumnavigation of the globe. Dick said he wanted to build it and fly it.

Yeager was an obvious choice for copilot. The two are companions, and Yeager is a pilot who holds several speed and endurance records in RAF VariEzes and Long-EZs. She also is slim and light, important considerations in a cockpit the size of *Voyager's*. Together they formed Voyager Aircraft, Incorporated, in March 1981 to build the aircraft and undertake the record flight. *Voyager* was built in secret, beginning in the summer of 1982. It was a strange sight indeed in June 1984 when the spindly aircraft with a wingspan longer than a Boeing 727's and a cockpit smaller than a subcompact car's was gingerly rolled out of Mojave's Hangar 77, the home of Voyager Aircraft, for the first time.

For the next 30 months, Rutan and Yeager devoted 20 percent of their time to completing and testing the aircraft and 80 percent to soliciting money to keep the project going. They rejected the notion of forming a nonprofit organization, controlled by trustees, to attract donations. Rutan was fearful that a board with the power to dictate policy could force him out of the pilot's seat. Manufacturers whose products did not meet Rutan's or Yeager's personal approval were rejected. Their stubborn independence hampered fund-raising, but they felt it was the only way they could main-



RUTAN-YEAGER/VISIONS

tain control over all aspects of the project.

Most of the materials and equipment used to manufacture and outfit *Voyager* were donated, but Voyager Aircraft's operating funds came primarily from individual contributions. The Voyager's Impressive People (V.I.P.) club was established for those who gave at least $100. A computer software disk containing the names of thousands of V.I.P. members was carried aboard the aircraft during the world flight.

Rutan and Yeager found it uncomfortable, though essential, to ply the banquet circuit dressed in polyester baby-blue flight suits, in search of cash donations. Often they flew to speaking engagements in Rutan's Long-EZ or in Voyager Aircraft's Grumman Tiger. At first, they were visibly ill-at-ease in front of crowds. Rutan was stiff and formal, Yeager silent. With time and experience, they polished their presentation. "Before I begin," Rutan would say, "let me answer three questions we always are asked. First, September 14 [the planned departure date]. Second, no, Jeana is not related to Chuck Yeager. And third, we use these [fecal containment bags] and throw them overboard." When the slide presentation ended, Yeager would collect $5 and $10 bills offered by some in the audience and stuff the money into a zippered pocket in the leg of her flight suit.

Public support of their dream to capture "the last great plum in aviation" came slowly. The notion of attempting a nonstop, unrefueled global flight in an aircraft as unorthodox as *Voyager* was considered by many to be something akin to challenging Niagara Falls in a high-technology barrel: an interesting concept, but why bother? A series of delays evoked pessimism. Months of tedious testing and fine-tuning turned into a year, then two. Interest flagged. A professional public relations consultant and fund-raiser was brought aboard to seek sponsors.

I can't remember looking out and seeing ocean horizon to horizon. There was always weather, either overhead or an undercast or storms. Most of the time we could not even see water. We never had the feeling we were alone over the sea.

In July 1986, Rutan and Yeager achieved a milestone when *Voyager* orbited off the California coast for 110 hours. The 10,303.5-nm (11,857-sm) flight broke a 24-year-old world absolute record for longest closed-course distance ever flown. Skeptics began to take notice, but obstacles were still to surface.

On September 30, during a final test flight, a wooden propeller blade on the front engine failed, separating from the hub. Despite vibration severe enough to break one arm of the engine mount, Rutan landed safely. A decision was made to replace the lightweight propellers with custom-built, but heavier, metal Hartzell blades and conventional propeller governors. The engines had to be torn down and inspected, as did the avionics. More delays.

Time was growing short. A historical study of equatorial storms and prevailing winds determined that weather along the intended route likely would turn sour by the end of November. The next available opportunity to go would be in the spring of 1987. Rutan and Yeager were anxious. They feared the loss of key sponsors if the flight was delayed into 1987. They also may have been concerned about regaining momentum that surely would have evaporated if the mission were scrubbed until spring. Yeager had cut her long, dark hair short to move more freely about *Voyager's* cabin. Both had lost weight in preparation for the flight. They had exhausted their life savings. Key people like crew chief Bruce Evans, technician Fergus C. Fay, AOPA 538087, and flight test engineer Glenn D. Maben, who had suspended careers to work full-time on the project, could be forced to return to their normal lives if the flight were put in cold storage for the winter.

November lapsed into December. The project was kept on active status. Weather along the equator was surprisingly calm, but fierce winds and cloud cover over southern California kept Rutan and Yeager grounded. During the second week in December, forecasts for local weather conditions became more optimistic. Icy winds tumbling over the Tehachapi Mountains to the west were dying. The flight was on. *Voyager* was ferried to Edwards, and the tedious chore of filling 17 tanks with 6,677 pounds of fuel began.

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At the post-arrival news conference, a television reporter asked the first question: "How was it?"

"There is a lot of weather at 8,000 feet

around this world," Rutan answered. He left much unsaid. Long ago, he had warned that the flight could fail on any of three counts: mechanical problems, physiological shortcomings or weather. All three were encountered during the flight, but weather had proved the greatest threat.

Voyager was forced to fly far north of the planned course to avoid Typhoon Marge churning in the Pacific west of the Marshall Islands. The counterclockwise rotation of the storm gave the aircraft a healthy push. Weather experts monitoring satellite images in a command post at Mojave spoke to the flight crew using high-frequency and ultra-high-frequency satellite communications. They were able to steer the aircraft between bands of the storm to take maximum advantage of tailwinds.

Turbulence and thunderstorms dogged the flight much of the way. Crossing the Malay Peninsula, Rutan and Yeager were forced to execute several 180-degree turns to avoid storms. Over Africa, they had to don lightweight nasal cannula oxygen equipment and climb to 20,000 feet to overfly convective activity. Approaching Brazil, *Voyager* penetrated a thunderstorm and was spit out in a 90-degree bank. On the final leg of the flight up the west coast of Mexico, headwinds prevailed.

During most of the trip, they were unable to fly at 8,000 feet, the optimum altitude for fuel efficiency, because of weather. Flight directors at the command post issued instructions to descend to lower altitudes—4,000 to 5,000 feet. "I got suckered into descending one time," Rutan said, "then had to restart the front engine to climb back up because of weather, so I ended up losing everything I had gained by flying lower. The weather was unbelievable."

Weather became as much of a companion as it was a threat. "I can't remember looking out the window and seeing ocean horizon to horizon," Rutan said. "I had always been concerned about overwater flight, but most of the time we couldn't even see the water. There always was weather, either overhead, or an undercast or storms. We never had the feeling we were alone over the sea."

Were they afraid?

Not afraid, but anxious, Yeager explained. "There was a challenge around every corner." The trials began the moment *Voyager* began its takeoff roll on December 14. It lumbered along for 14,000 feet of the 15,000-foot runway before the long, solid carbon-fiber spars flexed like fly rods and the heavy aircraft lifted into the air. Rutan forcibly held the stick forward to keep the aircraft from taking off prematurely, as had happened on test flights. Observers in the chase plane saw immediately that both winglets, which had scraped the runway during the takeoff roll, were attached only by the thin carbon-fiber skin on top of the wings. There was concern that the fluttering winglets could pull skin off the top of the wings, exposing fuel tanks, or that fuel vent lines routed through the winglets were plugged. A plan to shed the winglets was worked out in the air as *Voyager* slowly approached the California coastline. Burt Rutan advised his brother to perform slips to impose heavy side loads on the winglets. It worked. First the right winglet ripped free, then the left, leaving about a foot of exposed blue foam that comprised the core of the outboard wing panels. Near Lancaster, California, a woman who had been waving to the aircraft passing overhead was startled to see it respond by dropping an object—one of the winglets—into her yard.

Over the Philippines, the attitude indicator failed. Yeager squirmed beneath the instrument panel to switch a power cable over to a backup indicator. If the backup had failed, they would have had no choice but to land. The only other mechanical failures encountered during the flight were the loss of one of two electric fuel pumps used to transfer fuel between tanks and a broken bracket on an emergency hand brake used to stop the rear propeller from windmilling. The front propeller could be fully feathered to eliminate drag. The rear propeller was reversible for braking action on landing, but it could not be fully feathered.

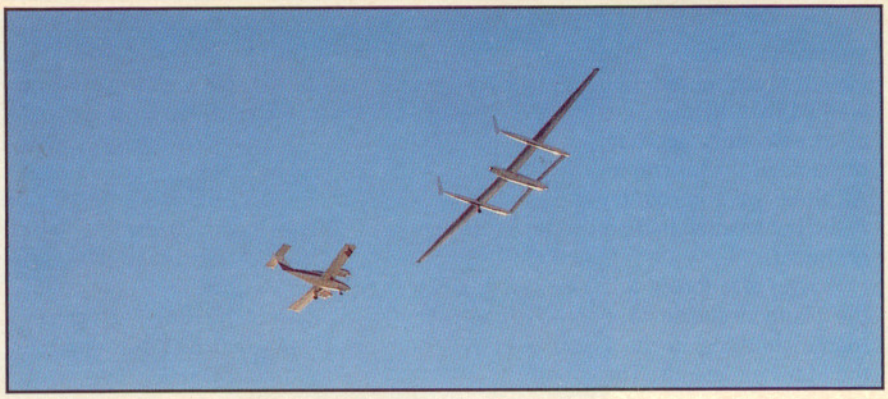
Fatigue, and at times despair, nibbled away at the crew. Rutan, concerned about turbulence, the rigors of night flying and the loss of an engine while the

RUTAN-YEAGER/VISIONS

Their world. Midway through the journey, Voyager's cockpit, cabin and crew wear a look of tired experience. (Top) Tape covers failed primary attitude indicator. (Bottom) Rutan wears lightweight nasal canula oxygen system, while Yeager crouches in what euphemistically is referred to as off-duty quarters.

aircraft still was heavy with fuel, occupied the pilot's seat for the first 60 hours. He slept for only three hours, while still at the controls. Over the Atlantic, they neglected to check the oil level in the rear engine. Low oil pressure and high oil temperature readings alerted them to impending disaster. Rutan replenished the engine by hand-pumping 1.5 quarts of oil from an 18-quart reserve tank.

Approaching the halfway point, it was reported that *Voyager* apparently was burning more fuel than had been anticipated and might not have enough to complete the flight. Later, it was determined that part of the problem was an inaccurate fuel-flow meter, but the error was compounded by mistakes in the flight crew's detailed record-keeping of endless transferring of fuel between tanks to maintain the center of gravity within narrow limits. Every six hours, there was a 90-minute exchange of data between the crew and the Mojave command center. Command center controllers dictated course changes for the next six hours, recommended altitudes and throttle settings, and a 24-hour weather prognosis. Rutan and Yeager radioed their position, as computed by the onboard VLF/Omega navigator, and fuel statistics. The figures showed a 700-pound shortfall. A fuel leak was suspected. "I thought we'd have to land in Africa, and we'd never get the aircraft back," Rutan said. "You ask yourself, 'Am I going to turn around and go back? But you know damn well what the answer is." South of Nairobi, Kenya, a Beech Baron rendezvoused with *Voyager*. A visual check turned up no evidence of a fuel leak. Rutan performed single- and two-engine climb and stability tests. By comparing observed climb rates to calculated rates, it was determined that there had been no loss of fuel or excess consumption. There was indeed enough to reach California. "Boy," Rutan said, "you talk about a change in spirits."



MARK R. TWOMBLY

CAROL BERNSON/VISIONS

Just hours away from Edwards, *Voyager's* rear engine, the only one operating at the time, lost power. The fuel tank supplying the engine had run dry. Rutan, groggy from fatigue, had forgotten to switch tanks. He notified Mojave that *Voyager* was at 8,000 feet and gliding. It took a few seconds for Rutan to realize why the engine had quit and to switch tanks. As the seconds ticked away, he waited for the windmilling rear engine to start. No luck, he reported to the command center. Michael W. Melvill, an associate of the Rutans and *Voyager's* chase plane pilot, was on duty at Mojave. Melvill grabbed the microphone and yelled, "Start the *front* engine, dammit!" About 35 seconds after the rear engine had quit, fuel finally flowed to the carburetor on the front engine, and it caught. Rutan then restarted the rear engine, shut down the front, and set a course for Edwards. The aircraft had lost about 2,000 feet of altitude.

At the press conference, another reporter wondered what the crew "felt in their hearts" after landing.

"Life is an opportunity," Rutan said. "What you want to do and what you want to achieve is limited only by what you dream. This flight was the last great first in aviation, and it was done by individuals, not the military or government.

PROOF POSITIVE

After flying out of radar range off the California coast, Rutan and Yeager could have sneaked back to shore, landed at some remote desert strip and waited for Rutan to grow a scruffy beard before making a triumphant return. Even if *Voyager* did girdle the globe, how can anyone be sure they did not set down in the Philippines or Kenya or Brazil to take a shower or visit a proper bathroom or buy a little 100-octane insurance?

The National Aeronautics Association (NAA) can be sure. The NAA is the U.S. representative for the Fédération Aéronautique Internationale, which sanctions aviation records worldwide. When *Voyager* landed at Edwards Air Force Base, the first person to approach the aircraft was Richard E. Hansen, an NAA representative, who checked to see that a seal he had placed on the cockpit/fuselage seam just before the aircraft took off from Edwards nine days earlier had not been broken. There was a second piece of evidence to verify that the crew was indeed the same that departed Edwards: Rutan returned one of two Confederate ten-dollar bills that Hansen had given him just before *Voyager's* departure. Rutan kept the second bill as a memento.

Next, Hansen checked the seals he had placed on *Voyager's* fuel ports. They were intact, proving that *Voyager* had not been refueled since departing Edwards. Then he checked a sensor on the right main landing gear that recorded the number of times the gear had been raised and lowered. According to the sensor, *Voyager* had indeed stayed aloft for the duration.

Later, three sealed barographs were removed from the cabin and analyzed. The results constituted further proof that the aircraft had not descended to a landing enroute.

The NAA also was able to confirm that Rutan and Yeager actually flew the long way around the world and not the much shorter polar route of earlier long-distance voyagers. The confirmation is based on visual and radar sightings of *Voyager* at several points around the globe: just south of Hawaii; Thailand; Kenya, south of Nairobi; the island of Trinidad; Costa Rica, and just south of San Diego.

Voyager traversed 21,735 nm (25,012 sm), according to the NAA's initial estimate. Rutan believes the flight covered up to 23,028 nm (26,500 sm) and will try to have the record books reflect the longer distance. The NAA-certified distance is 45 nm (52 sm) short of doubling the previous record distance for a nonstop, unrefueled flight and 10.4 nm (12 sm) farther than the goal Rutan and Yeager had set for themselves. —*MRT*

That says a lot about this country and what freedom means. If you have an opportunity to do something like this as an individual, you just can't walk away from it."

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Six days after the landing, President Ronald W. Reagan presented Yeager and the Rutan brothers with Presidential Citizen's Medals in Los Angeles. "With all of America, Nancy and I followed the *Voyager's* progress along each leg of its fabulous flight, with alternating feelings of nervousness, and hope, and fear, and elation—but mostly an overwhelming pride in these two courageous Americans and their historic mission," the President said. "For those of us old enough to remember, the flight of the *Voyager* brought us back to the days of those magnificent men and their flying machines, and you reminded us all that aviation history is still being written by men and women with the spirit of adventure and derring-do. On December the twenty-third, 1986, the name *Voyager* joined the distinguished family of airborne technological breakthroughs that began with the *Wright Flyer* and includes the *Spirit of St. Louis* and the *Glamorous Glennis*, and three men, or new names, I should say, will be added

to the column headed 'The Right Stuff.' Along with Orville and Wilbur Wright, Charles Lindbergh and Chuck Yeager, history will now record Dick Rutan, Jeana Yeager and Burt Rutan."

The Mojave post office began delivering a box of fan mail a day to Voyager Aircraft. In early January, a staff member said that 400 people were lined up outside Hangar 77 to buy souvenirs. The proceeds will be used to pay off Voyager Aircraft's $300,000 debt. A book on the flight is due out later this year, coauthored by Rutan and Yeager.

Voyager was flown back to Mojave in January on what may have been its last flight. It has been put on public display inside Hangar 77 and eventually may reside at the Smithsonian Institution's National Air and Space Museum. Sponsors are eager to have the aircraft appear at the Paris Air Show in June. If it goes, it will have to be disassembled (by cutting off the outer wing panels), shipped and placed on static display, according to Rutan.

Burt Rutan designed *Voyager* for a single purpose: to circumnavigate the globe. The only performance specification that mattered was range, estimated to be 24,330 nm (28,000 sm) in still air. Dick Rutan, who is the only person to have flown the aircraft from takeoff to landing (Yeager is the only other person who has ever been at the controls in flight), described *Voyager's* flying characteristics as "mission adequate." Translation: ponderously slow in roll, dangerously sensitive in pitch, with terrible visibility, a tendency to porpoise on takeoff and trampoline-like behavior in turbulence. In the few times the aircraft was flown before the public, Rutan delighted in pulsing the controls to make the fuselage and wings undulate like a Slinky held between a child's outstretched arms. "Basically, it's a very dangerous airplane," he said a few days after circling the earth. "I never did like flying it." □

VOYAGER MILESTONES

What did *Voyager* accomplish? Two absolute world distance records, five world class and category records and a national speed record, for openers. The absolute records (maximum performance in any class or type of aircraft) are for the greatest straight-line distance flown without landing or refueling and, since *Voyager* returned to its departure point, the greatest closed-course distance. The latter record broke the one set by the *Voyager* crew in July. The class and category records are for straight-line and closed-course distances flown by a piston-powered airplane with a takeoff weight of at least 6,614 pounds and not more than 13,227 pounds. *Voyager's* average groundspeed of 100.627 knots (115.8 mph) also set a class and category record for a westbound global flight. The minimum distance required to qualify for a global speed record is 19,864.61 nm (22,859.79 sm), the circumference of the earth measured at the Tropic of Cancer. There is no official world record category for speed around the world on a nonstop, unrefueled flight, so a national record was bestowed.

The flight generated good will for general aviation and focused attention on a host of new technologies. The all-composite structure of the aircraft—carbon-fiber spars surrounded by foam core and an external structural skin made of Hexcel Corporation's honeycomb panels sandwiched between bonded sheets of Hercules, Incorporated's, Magnamite woven carbon-fiber cloth—withstood the stress of the fuel weight and turbulence that tossed *Voyager* into vertical banks. Burt Rutan's unorthodox aerodynamic-design philosophy, with its insistence on composites and canards, gained worldwide attention.

Teledyne Continental Motors, which donated *Voyager's* experimental IOL-200 engine, could not have conceived a better forum for demonstrating the fuel efficiency (less than 0.4 pounds of fuel per horsepower per hour) and trouble-free reliability of its new liquid-cooled engine technology. The same was true of Mobil Oil Corporation, which supplied experimental synthetic oil used for lubricating the Continental engines. King Radio Corporation designed an innovative package of communications, navigation and flight control avionics, including a KNS 660 navigation management system incorporating VLF/Omega and global positioning system receivers. Rutan and Yeager wore prototype next-generation Bose aviation headsets that feature an electronic system that duplicates ambient noise, effectively canceling noise before it reaches the pilots' ears.

CAROL BERNSON/VISIONS

Finally, the flight provided reporters with a tremendous end-of-year good-news story about a strange new machine flown by old-style heroes. Many of the press accounts drew a parallel between *Voyager's* landing at Edwards and the shuttle landings that had taken place there. It may have been less of a parallel than a contrast. The press compound at Edwards was directly in front of the National Aeronautics and Space Administration's Boeing 747 space shuttle transporter. The presence of the big Boeing served to underscore the bittersweet irony of a year that began with *Challenger's* tragedy and ended with *Voyager's* triumph. —*MRT*

SIDELIGHTS ON A LONG-RANGE FLIGHT

Mysteries of time and space

BY BARRY SCHIFF

It is said that truth is stranger and immensely more fascinating than fiction. Many pilots are tempted to draw an awkward aeronautical corollary: Fictional lore, with the passage of time, can be more convincing than the truth. This creates popular misconceptions. This article combines the bursting of a few of these fictitious bubbles with some revealing facts of flight. The recent record-breaking flight of *Voyager* can serve as a useful example for addressing a few of these fallacies.

When the *Voyager* made its historic globe-girdling flight last December, pilots Richard G. Rutan and Jeana Yeager were uncertain how much fuel remained available as they neared the halfway point of their incredible journey. Knowing that stall speed and climb performance vary with gross weight, they performed a series of flight tests over East Africa. The results of the tests enabled them to calculate the approximate gross weight of the spindly craft. Once gross weight was determined, it was a simple matter for them to estimate the weight of fuel on board.

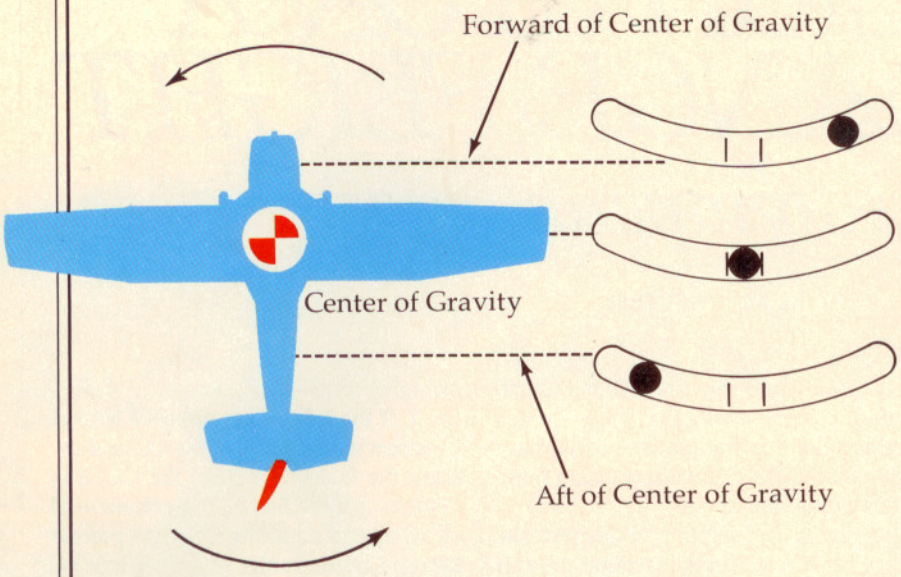
Suppose, however, that Rutan and Yeager had wanted to determine the location of *Voyager's* center of gravity. Without knowing the amount of fuel in each of the 17 fuel tanks, CG location certainly could not have been calculated. Is there a way that they—or any other pilot, for that matter—could have pinpointed the CG without using numbers or mathematics?

A clue to the solution of this perplexing problem lays in the fact that the axes of motion of an airplane pass through the center of gravity. Bringing the control wheel aft, for example, results in the aircraft's pitching about a lateral axis that passes precisely through the CG. In other words, that portion of the aircraft ahead of the CG pitches up while that portion of the structure aft of the CG rotates downward. All that is required to determine CG location, therefore, is something that accurately senses aircraft movement about any of the three axes (lateral, longitudinal or vertical). One item that does this quite nicely is a hand-held slip-skid ball (inclinometer), the instrument normally associated with a turn indicator or coordinator.

Figure 1 shows how the slip-skid ball behaves during a left skid. As expected, the ball responds to left-rudder deflection by sliding to the right. This movement of the ball, however, occurs only when the instrument is forward of the center of gravity. If the instrument was aft of the CG during a left skid, the ball would move left (in response to the tail swinging to the right), as shown in Figure 1. If the ball moves opposite to skid direction when ahead of the CG and toward the skid when aft of the CG, it is obvious that the ball would not move at all when placed at the CG. The precise location of the center of gravity can be determined, therefore, by holding a slip-skid instrument in your hand and moving it fore and aft until it fails to respond to gentle rudder deflection (in either direction).

Locating the CG in this manner and during different loading conditions is a fascinating, easily performed experiment that allows a pilot to visualize a principle of flight that ordinarily is accepted only on blind faith. Assume that a pilot determines—for a given load distribution—that the CG of his aircraft is exactly midway between the front and rear seats. Does this mean that all passengers would be equally jostled when flying through turbulence, or would the aft passengers be affected differently from those riding in front? During a skid, for instance, it would appear from our previous experiment with the slip-skid ball that ride quality worsens as distance from the CG increases. After all, the passengers are subjected to the same forces that move the ball in its glass tube. In this case, then, it would appear

FIGURE 1



that those in front are affected as much by turbulence as those in back. (Passengers seated at the center of gravity do get the most comfortable ride.) But all is not always as it appears because the movement of the slip-skid ball—as shown in Figure 1—reveals only part of the story.

As left rudder is applied (or the aircraft yaws left because of a gust from the side), the slip-skid ball aft of the CG slides left because of the ball's inertia; as the tail swings right, the ball "attempts" to remain in position by moving left in the glass tube. Eventually, though, the centrifugal force developed during a left skid overcomes the ball's inertia and forces the ball to the right. In other words, the ball ahead of the CG moves only one way (to the right) during a left skid entry, but the ball aft of the CG moves left and then right. Similarly, those seated aft of the CG get shoved twice, first toward one side and then the other. This is why, for any given distance from the CG, rear-seat passengers are treated twice as harshly as those in front, something that pilots often fail to consider when gauging the effect of turbulence on their passengers. This explains also why those seated in the rear are most prone to airsickness. It also explains why Jeana Yeager, who spent most of the flight in the aft of the passenger compartment, received many severe bruises.

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Circumnavigating the globe is more than a 25,000-mile flight around the pattern. It also is a tortuous marathon that crosses 24 time zones, or so most people think. There actually are 25 time zones. (The zone containing the International Date Line is divided into two half-zones; although the local time is the same in each, the date is different.) For identification purposes, each time zone is assigned an alphabetical appellation. The zone containing the Greenwich, or Prime, Meridian is designated as the Z zone, which explains why Coordinated Universal Time (abbreviated UTC—nee Greenwich Mean Time, or GMT) is referred to as Z, or Zulu, time. There is no J zone (don't ask me why), but New York, Kansas, New Mexico and California are in the Romeo, Sierra, Tango and Uniform time zones, respectively.

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Another significant element of flight is wind, the vagaries of which can foil even the most meticulous planning. It blows one way when we expect it to blow the other and seems to take capricious glee in its whimsical, unpredictable nature. For the pilots of the *Voyager*, taking advantage of favorable winds aloft was critical to the success of the mission. Given the unpredictability of the winds over such a long course and the suddenness with which ocean storms can form, the *Voyager* team faced many meteorological unknowns.

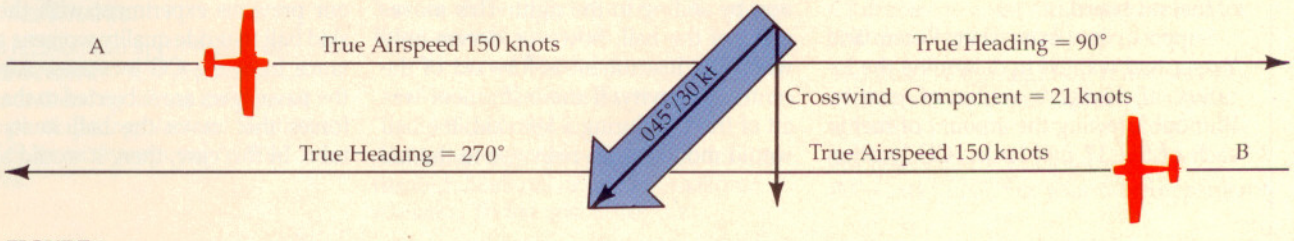

FIGURE 2

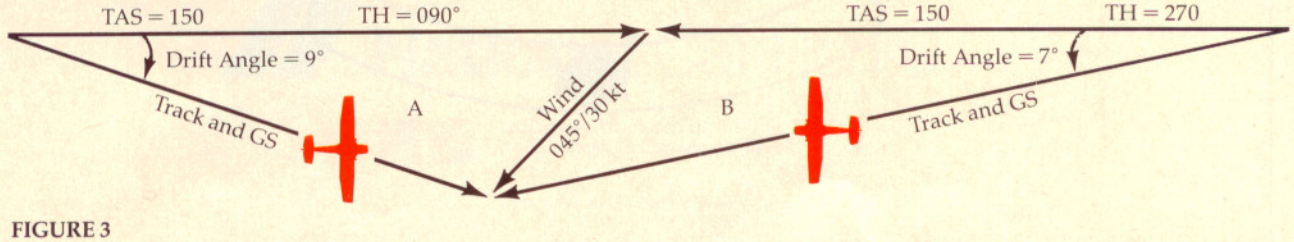

FIGURE 3

Even when the wind blows steadily, pilots do not always comprehend its effect. One would assume, for instance, that a round trip made under the influence of a steady wind would take no longer than the same round trip conducted during no-wind conditions, but we learn early in our flying careers that the total time required to fly outbound with a 20-knot tailwind and return with a 20-knot headwind does indeed take longer than if there was no wind at all. This is because more time is spent fighting the headwind than is spent taking advantage of the tailwind.

If this principle seems easy enough to understand, then let's try a sample problem. Aircraft A in Figure 2 is cruising at 150 knots on a true heading of 090 degrees; Aircraft B is heading in the opposite direction (270 degrees) at the same airspeed. Each aircraft encounters the same wind, which is from the northeast at 30 knots, and, therefore, is affected by the same 21-knot crosswind component. Does this mean that each aircraft has the same drift angle? The obvious answer is "yes," but the obvious is not always correct, as in this case. Figure 3 shows the wind triangles applicable to the flights of Aircraft A and B. Although each aircraft drifts the same distance south at the end of one hour (21 miles), the drift angles are different. The aircraft flying into the quartering headwind drifts nine degrees right while the other drifts seven degrees left. In other words, a quartering headwind causes a larger drift angle than a quartering tailwind (everything else being equal).

The reason for this is that the aircraft with the least groundspeed covers less ground in a given period of time. Therefore, it must have a larger drift angle for it to drift off course as many miles as an aircraft with more groundspeed. Some might believe that such knowledge has only trivial value, but that is not true.

Rutan and Yeager took advantage of this navigational rule by cheating—they flew their round-robin flight heading in essentially the same direction. As a point of interest, had Rutan and Yeager looped *Voyager* as they passed over Edwards Air Force Base at the end of their around-the-world marathon, they could have laid claim to the largest figure eight ever performed in an airplane. On the other hand, they did perform an outside loop of global proportions. □

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