December 9, 2003, Tuesday

FLIGHT

STAYING ALOFT; What Does Keep Them Up There?

By KENNETH CHANG (NYT) 1011 words

TO those who fear flying, it is probably disconcerting that physicists and aeronautical engineers still passionately debate the fundamental issue underlying this endeavor: what keeps planes in the air?

"Here we are, 100 years after the Wright brothers, and there are people who give different answers to that question," said Dr. John D. Anderson Jr., the curator for aerodynamics at the Smithsonian National Air and Space Museum in Washington. "Some of them get to be religious fervor."

The answer, the debaters agree, is physics, and not a long rope hanging down from space. But they differ sharply over the physics, especially when explaining it to nonscientists.

"There is no simple one-liner answer to this," Dr. Anderson said.

The most common explanation goes like this: Air travels faster over the more curvaceous top surface of the wing than the flatter bottom surface. The quicker a fluid (like air) moves, the less pressure it exerts, a phenomenon known as Bernoulli's principle, which is named after its discoverer, Daniel Bernoulli, an 18th-century Swiss mathematician.

Thus, the slower moving air below the wing exerts more pressure on the wing than the faster moving air above it. This produces a net upward force called lift, which pushes the aircraft upward and balances the downward pull of gravity.

That explanation, though accurate, does not really explain why the air flowing over the wing moves faster. And that incompleteness causes much confusion.

Jef Raskin, one of the creators of the Macintosh computer, recalls arguing with a science teacher in middle school over this explanation. If lift depends on the shape of the wing, he asked his teacher, how can airplanes fly upside down? (A simplistic reversal of the Bernoulli explanation would argue that flying upside down would push the aircraft down.) And how do paper airplanes, which have perfectly flat wings, fly?

"He tried to explain first that airplanes couldn't fly upside down," Mr. Raskin said. "I said no because I had seen it." The teacher said that paper airplanes flew on a different scientific principle. "It was clear to me that what he was saying was illogical and could not be true," Mr. Raskin added. "I had evidence his argument was wrong."

Mr. Raskin said he persisted, bringing a balsa-wood model airplane to class the next day. He demonstrated that it flew when the wing was flipped upside down. Unimpressed and unconvinced, the teacher sent him to the

principal's office, where he was told to improve his behavior.

The ruminations on wings and why spinning balls curve in flight led to an article in Quantum magazine in 1994. Mr. Raskin said that Bernoulli's principle, the basic equation that describes the flows of fluids, is perfectly valid, but "it's just a bad pedagogical tool."

Instead, Mr. Raskin and others find the laws of motion of Sir Isaac Newton provide a more accessible explanation. "A wing is just a device for forcing air down," Mr. Raskin said. By Newton's third law -- for every action there is an equal and opposite reaction -- the downward force that the wing applies to the air produces an upward force of the air on the wing, or lift.

The amount of air diverted downward depends primarily on the angle of the wing as it flies through the air, the so-called angle of attack, and not the shape of the wing. (A plane can fly upside down by increasing the angle of attack to produce enough lift.)

Dr. D. Scott Eberhardt, a professor of astronautics and aeronautics at the University of Washington and a co-author of the book "Understanding Flight," said a 747 in flight diverts its weight, about 900,000 pounds, in air every second. Both Newton's laws and the Bernoulli principle are correct, but, Dr. Eberhardt said, "My experience with teaching nontechnical people, boy, Newton is a heck of a lot easier."

The simple Newtonian explanation also glosses over some of the physics, like how does a wing divert air downward? The obvious answer -- air molecules bounce off the bottom of the wing -- is only partly correct.

"That's easy to see, but it's wrong," said Dr. David F. Anderson, a retired high-energy physicist who wrote "Understanding Flight" with Dr. Eberhardt. "It's really a huge amount of air pulled down from the top. The wing bends the air down."

Air pressure and attractive forces between molecules pull air along the surface of the wing, sometimes called the Coanda effect, and because of the angle of attack, that direction is downward. The curved shape of the wing helps the air flow hug the surface. When this flow detaches from the wing surface, which occurs at steep angles, the lift disappears, and the airplane stalls and falls.

If air has to follow the wing surface, that raises one last question. If there were no attractive forces between molecules, would there be no flight? Would a wing passing through a superfluid like ultracold helium, a bizarre fluid that can flow literally without friction, produce no lift at all?

That has stumped many flight experts.

"I've asked that question to several people that understand superfluidity," Dr. Anderson, the retired physicist, said. "Alas! They don't understand flight."

CAPTIONS: Photo: AIR IN MOTION -- The downwash from the wings of a Cessna Citation VI carves a trench in a fog bank, illustrating how planes stay up by pushing air toward the ground. (Photo by P. Bowen/Cessna Aircraft Company)

Chart: "Flying Right
Wings produce lift because the pressure of air pushing up from below is greater than the pressure pushing down from above.

STANDARD DEPICTION
A common explanation overemphasizes the shape of the wing and incorrectly shows air streaming horizontally after passing the wing.

CORRECT DEPICTION

To produce lift, air flow must be diverted downward. By Newton's law, the wings downward force on the air creates an upward force. The tilt of the wing plays the dominant role in diverting the air flow.

(Sources by "Understanding Flight," by David F. Anderson and D. Scott Eberhardt)
