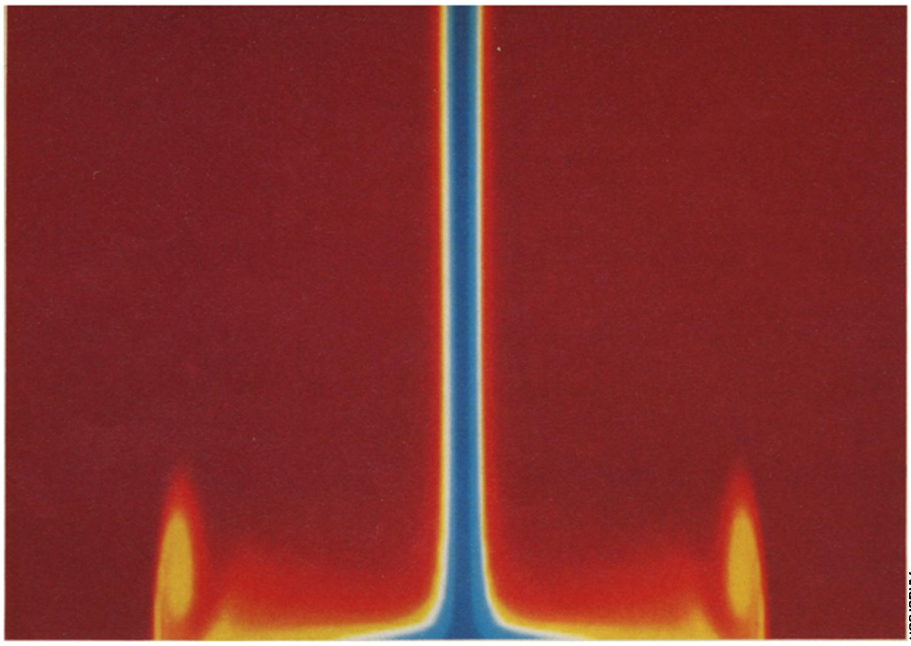
MASTERING THE MICROBURST

These elusive winds drop from clouds and sweep planes out of the sky, but scientists are developing systems to detect them



Anderson

Cross section of a computer model of a microburst color-coded for temperature, with blue representing the coldest air. As outflow spreads horizontally, vortices of wind develop at the edge. Normally circular, these vortices are distorted by the scale.

By RICHARD MONASTERSKY

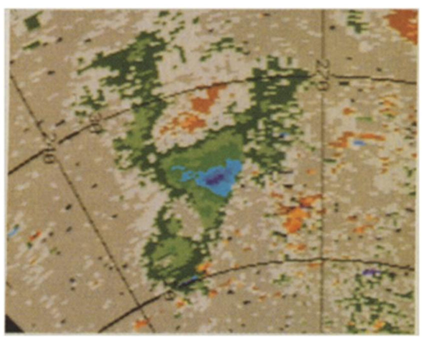
On Aug. 2, 1985, Delta flight 191 was descending through scattered thunderstorms at 6:04 p.m. on a routine approach to the Dallas-Ft. Worth Airport. At 6:06, the plane was a ball of flames, lying less than a mile from the runway. In the interim, flight 191 had flown through the treacherous winds of a microburst.

Microbursts "are the largest source of air carrier death in the United States," says John McCarthy, a meteorologist at the National Center for Atmospheric Research (NCAR) in Boulder, Colo. Over the last 12 years, this small, short-lived pattern of intense winds has been implicated in three of the most catastrophic weather-related air accidents, which were responsible for a combined total of 398 deaths.

Currently airports are ill equipped to detect these significant but infrequent threats to air travel. However, in the wake of these crashes, a concert of meteorologists, computer specialists and aerodynamic engineers is developing systems to detect microbursts and warn pilots of their deadly presence.

Last summer in Huntsville, Ala., scientists conducted the most recent in a series of large-scale field experiments designed to learn more about microbursts. These experiments indicate that a combination of Doppler radar and computers may be effective in detecting microbursts, although the widespread use of these systems is several years away.

A microburst is a wind pattern that descends from rain clouds during spring and summer months. When this stream of falling air, or downflow, hits the ground, the wind fans out horizontally into an outflow. In this way it resembles the spray pattern that water from a kitchen faucet makes when it hits the bottom of the sink. By producing a strong divergence of wind, the microburst outflow causes a condition known as wind shear, a quick change in the wind's speed or direction.

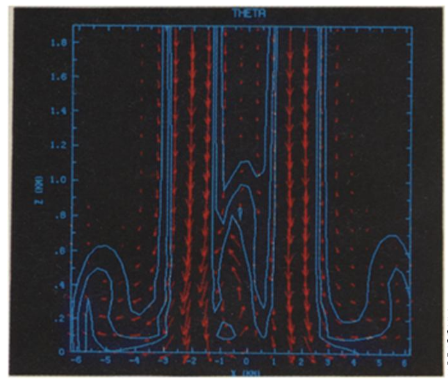


NCAR

Doppler radar signature of a microburst. Green represents airflow toward the radar, and brown represents airflow away from the radar. Proximity of these two regions indicates hazardous wind shear.

For airplanes on takeoff or landing, an intense wind shear can be particularly hazardous. When an airplane enters a microburst, it first runs into a headwind, which increases the speed of the air that is rushing over the wings and gives the plane additional lift. After the plane passes through the downdraft in the center of the microburst, it is swept by a tailwind, which robs the plane of lift.

This dramatic change from headwind to tailwind poses an insidious combination of forces. A plane on a landing approach is usually at 70 to 80 percent of



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Vertical cross section of the two-microburst system on the cover. Red arrows represent wind speed (length of arrow) and direction.

full power. Upon entering the headwind of a microburst, a pilot may mistake this for an ordinary headwind, and will not expect a sudden wind shift. "Then you are caught in a big surprise" when the airspeed drops dramatically and the plane begins to fall, says T. Theodore Fujita of the University of Chicago. It takes several seconds to reach full power, and by that time the plane may have lost too much altitude to pull out of its fall.

Fujita is generally credited as being the first to deduce the existence of microbursts, during an aerial survey of tornado damage in 1974. Instead of seeing a typical swirling pattern of fallen trees he noticed hundreds of trees blown outward like the spokes of a wheel. Since then, he and NCAR have conducted several large-scale field experiments, including the 1982 Joint Airport Weather Studies (JAWS) and last summer's Microburst and Severe Thunderstorm (MIST) project. The aim is to understand the mechanics of the microburst event and develop strategies to avert wind-shear-related air disasters.

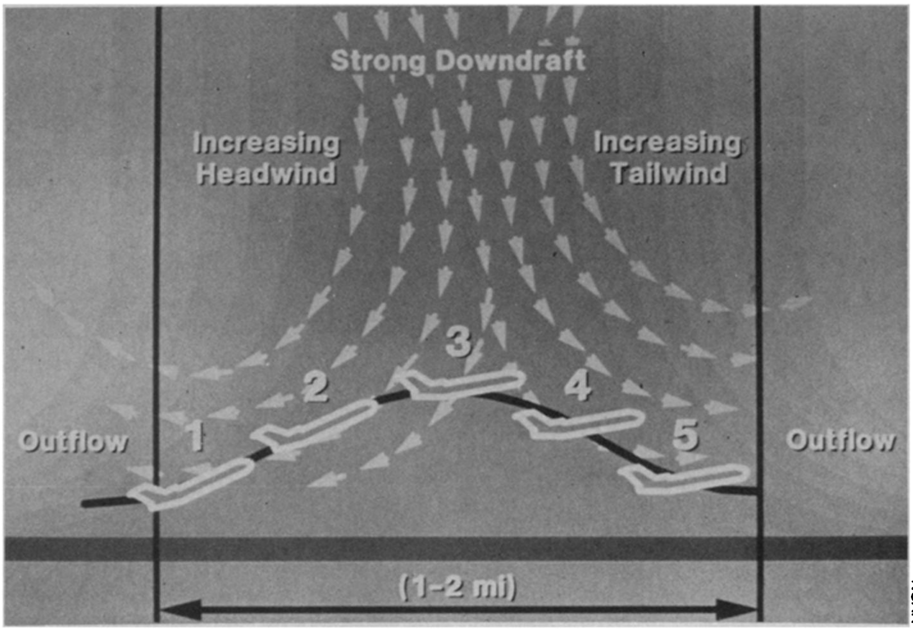
Although the mechanics are not totally

understood, says Fujita, it appears that the evaporation of raindrops is critical to the microburst formation. This evaporation cools a parcel of air, which will begin to fall as it gets heavier, thereby producing a downdraft. Humid areas like Huntsville, where the downdraft is almost always associated with rain, usually spawn the so-called wet microbursts. Dry microbursts, on the other hand, frequent more arid places like Denver, where cloud bases are higher and the precipitation will often totally evaporate before the downdraft reaches the ground.

These factors conspire to make the microburst a dangerously elusive phenomenon. Wet microbursts will produce a visible rain shaft, but this can often be obscured within a benign rain shaft. Conversely, without any associated precipitation, dry microbursts present almost no visual clues of their presence. Pilots and controllers hoping to spot a microburst cannot even rely on the character of the clouds for clues because both thunderheads and small, seemingly innocuous rain clouds can produce these hazardous wind shears.

From the JAWS and MIST projects, scientists have learned that microbursts are small, typically 0.6 to 1.9 miles across, and short-lived – on the order of 5 to 15 minutes. The average difference between the headwind and the tailwind is 60 miles per hour, but Fujita has documented a case with a differential in excess of 172 mph.

Presently, 90 airports across the United States are fitted with a Low-Level Wind Shear Alert System (LLWAS) – an array of 5 anemometers, or wind detectors, at the boundary of the airport surrounding an anemometer at the center field position. A processor compares differences in wind speed and direction, to determine if there is any shear within the LLWAS area.



When flying through a microburst, a plane on takeoff experiences a dangerously rapid loss of lift as it moves from headwind (1,2) to tailwind (4,5).

However, LLWAS was installed to detect gust fronts, a different weather hazard, and aviation officials have known for several years that LLWAS cannot reliably detect microbursts. False alarm rates are high, and for this reason "some pilots are very skeptical" of these wind shear warnings, says Dan Rebhun of the Federal Aviation Administration (FAA).

Furthermore, the LLWAS array is too small and too porous – microbursts can first touch down outside the LLWAS network or even between the sensors, leaving pilots unaware of the wind shear hazard. Flight 191, for example, passed though the center of the microburst over a mile and a half outside the outermost sensor. It was only several minutes after the accident that the LLWAS alarm went off, indicating that wind shear hazard was present.

The FAA is increasing the number of anemometers at the 90 airports and adding LLWAS systems to 20 others in an effort to enhance coverage, but many scientists believe that ground anemometers cannot do the job when it comes to detecting microbursts. "It's our feeling that they may be tardy in recognizing that a microburst has occurred," says Jim Evans, who is developing a computerized detection system for microbursts at MIT's Lincoln Laboratory in Lexington, Mass.

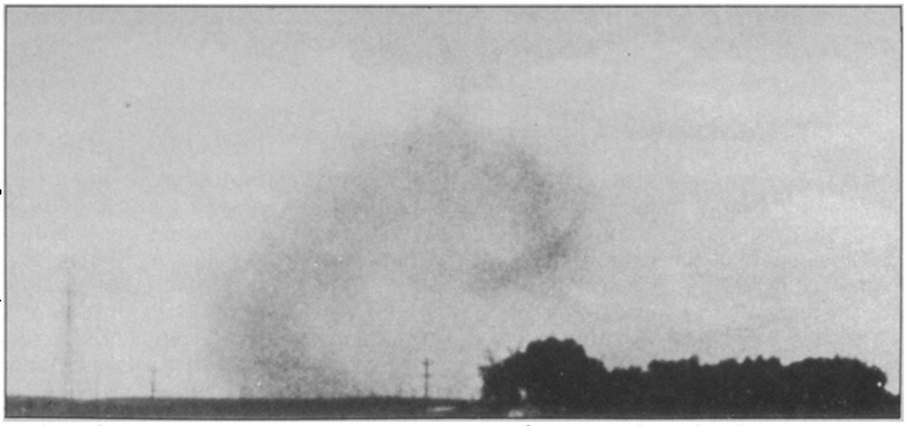
The LLWAS can only measure the outflow of the microburst. It does not register a wind shear warning until the difference between the central sensor and an outlying sensor is greater than 17 mph. This gives the microburst the chance to touch down and spread out before controllers have any warning of its presence.

Results from the MIST data give scientists even more cause for concern. The JAWS data indicated that it took at least 5 to 6 minutes from the time the downburst reached the ground to the time when the winds of the outburst had reached their highest and most dangerous speeds. However, from a preliminary study of the Huntsville data, Fujita is finding that "the wet microburst cases build up in a very short time, taking 2 to 3 minutes." Such a timescale does not give controllers enough time to warn pilots, says Fujita.

In an effort to gain more time, scientists are using a type of radar called Doppler radar to sense the microbursts before they reach the ground and develop an


Fujita

In the high plains near Denver, shown here, the precipitation associated with the downdraft often evaporates before the downdraft hits the ground. In such cases, a ring of spreading dust is sometimes the only clue that a microburst exists.



B. Waranauskas/Univ. of Chicago

A circular vortex roll of dust marks the edge of an evolving microburst.

outflow. Conventional weather radar, the kind that provides the weather maps on television, measures distance. Doppler radar, on the other hand, can measure velocity as well (police use it to catch speeders). It gauges wind speed by bouncing microwaves off objects that move with the wind, such as raindrops, ice particles and even insects.

A single Doppler radar cannot measure vertical winds, and therefore cannot directly sense the descent of the downdraft. However, through field observations and computer models, meteorologists have learned to use Doppler radar to look for indirect evidence that a downdraft is developing.

Both above and below the cloud base, wind and rain will often converge around the descending current of air, in a sense feeding into it. Another indicator of a downdraft is the rapid descent of a precipitation core. The existence of these and other precursors does not prove that a microburst is forming, but they serve as good warning signals that something may be on its way down.

In the summer of 1984, NCAR meteorologists used these precursors to provide microburst warnings for Denver's Stapleton Airport in a program called the Classify, Locate and Avoid Wind Shear (CLAWS) project. When the NCAR group spotted precursors on the radar screen, they issued an advance notice that a microburst would reach the surface within 5 minutes. Then, upon first signs of divergence at the surface, the meteorologists issued a full-scale microburst warning. On the average, they warned pilots 4 minutes before the most severe wind shear, giving the pilots enough time to avoid a hazardous encounter.

The CLAWS project demonstrated that Doppler radar can be an effective tool in microburst detection and warning. However, the project relied on expert meteorologists to continuously monitor the radar during the day – a process that is too expensive and time-consuming for widespread use. For that reason, Lincoln Laboratory is developing an automated detection algorithm, a computer program that will sift through incoming radar data for the signs of a microburst. In last summer's Huntsville experiments, researchers tested an algorithm that takes 10 seconds to detect an outflow within 6 miles of an airport.

Although this system is reliable, notes Evans, "this initial algorithm was not tremendously intelligent because it only looked at data near the surface. It didn't use any of the data aloft. Now we have some more refined algorithms, which are undergoing initial testing, that take advantage of the fact that microbursts just don't pop up on the surface. Things happen aloft that precede development." These so-called expert systems are programs that seek to imitate the reasoning that meteorologists use when searching for precursors as an advance warning of a microburst. Testing of these advanced algorithms will continue this summer in Denver.

John Anderson of the University of Wisconsin in Madison is working with Lincoln Laboratory in developing what he calls "a second-generation processing system" – computerized cloud models that can actually forecast a microburst *before* the downdraft develops. The models rely on data from Doppler weather radar. As the model goes through a simulation, radar data from the actual environment are used to update or correct the simulation. Such a combination can "make a prediction for what the cloud will look like in 10 or 15 minutes," says Anderson.

The next stage in this research, according to Anderson, "is figuring out what kinds of observations you need to update the model. . . . How good do the radars have to be?" He notes that forecasting on a larger scale has been practiced for many years, but "the idea of doing forecasts on cloud scales is really a new idea."

In another area of research, NASA Langley in Hampton, Va., is developing airborne sensor systems. Since not all airports will receive Doppler radars in the future, "the idea is to take your protection with you wherever you fly – sort of like a turtle with his shell," says NASA's Roland Bowles. They are considering equipping planes with Doppler radar or Doppler lidar, which uses laser light instead of microwaves. However, these systems as well as the forecasting models are just in their infancy.

Ground-based Doppler radar will be reaching some airports in the near future. In 1989 the FAA plans to begin deployment of 16 Doppler radars at critical airports such as Dallas-Ft. Worth, Atlanta, O'Hare, Kennedy/La Guardia, Washington National, Miami/Ft. Lauderdale and Denver.

In the meantime, the FAA and airlines are seeking to arm pilots with both the knowledge and skill to handle a microburst, in the event of an encounter. In February, a consortium of airplane manufacturers completed the framework for a pilot-training program involving meteorologic training and simulated microburst encounters. The FAA plans to require this training for all U.S. air carrier pilots, and implementation of the program should take a year or so. "When that gets transferred to the pilots, then I think we're going to be in a lot better shape," says McCarthy, who advised the consortium.

"I don't think we're going to eliminate wind shear accidents," says McCarthy, "but I think we're going to make them a 20- to 30-year phenomenon instead of a one- to two-year phenomenon." □