MAKING THE SKIES SAFE FROM WINDSHEAR
Langley Develops Sensors To Warn Pilots Of Deadly Downdrafts

By Michael Finneran

The thunderhead lay directly ahead of the 737 jet, a mountain of black pounding down a steady stream of rain and wind. Lightning flashed and the plane's windows blinked like static-stricken TV screens. Storm cells like this can knock a plane to the ground, but instead of veering away, the jet shot straight toward it.

"Looks like a good one," a voice crackled over the intercom.

The cabin went dark and rain lashed the windows as the plane bounded through the heart of a white-knuckle flyer's worst nightmare. Half a minute later it slipped out—then banked sharply for another stab at the storm.

For the crew of NASA Langley Research Center's "flying laboratory," the encounter 900 feet above Orlando, Fla., last August was just what they wanted: a one-on-one with a sometimes deadly weather condition known as a microburst windshear. The payoff: a chance to test sensors designed to warn pilots of what's ahead so they can prepare to ride it out or steer clear.

Saving lives

The windshear team has spent the last six years developing the technology that soon will give pilots the tools to fight one of the major causes of airliner crashes during takeoff and landing.

"Windshear microbursts can be extremely intense and they can be lethal," said Dr. Roland L. Bowles, manager of Langley's Wind Shear Program Office. "The aviation industry considers them to be a major safety issue."

Windshear was a factor in 27 aircraft accidents involving more than 500 deaths and 200 injuries between 1964 and 1985. Between 1975 and 1985, windshear figured in about half of all crashes.

Bowles and his crew, which has flown through more than 50 microbursts, hope to make those numbers a thing of the past. "This is going to save lives," he said. "If you and your family are flying on a commercial airliner after 1995, there will be windshear detection technology aboard as a result of this NASA program."

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The program began with a more than $20 million NASA and Federal Aviation Administration (FAA) agreement signed in 1986 at the urging of Congress, the National Transportation Safety Board and the National Resource Council. Under a 1988 FAA directive, so-called “reactive” windshear detection devices are to be installed on airplanes to meet a year-end 1993 deadline.

Reactive systems, however, do not detect microbursts until a plane already has entered it—which may be too late to prevent a crash. By contrast, Langley is developing sensors to detect microbursts 20 to 40 seconds in advance, which will give pilots time to react.

“NASA studies have shown that every second of advance warning pays big dividends in terms of survivability,” Bowles said. “It’s the old adage—an ounce of prevention is worth a pound of cure.”

Airlines that elect an advance-warning system must install them by December 1995, according to the FAA directive.

“We have to be able to develop systems that pilots will have high confidence in,” Bowles said. “That really frames the technological challenge for us. The key is to put the information at the pilot’s fingertips so he can believe in it and so it becomes part of the routine.”

In harm’s way

As part of the program’s final phase, Langley’s 737 test-flew three sensors—a laser, a microwave radar and an infrared radiometer—on a total of four deployments in 1991 and 1992. The two- to three-week trips were split each year between airports in Denver, Colo., and Orlando and took place in the summer, when thunderstorms are most plentiful.

Not all thunderstorms conceal dangerous microbursts. But those that do can generate winds of more than 80 miles an hour. And the shifting direction of those winds is just as treacherous as their speed. As a microburst pours from a cloud, it hits the ground and spreads out like an upside-down mushroom, producing first a headwind, then a downdraft and finally a tailwind for a plane passing through.

These swift wind changes can result in the following fatal scenario during takeoff or landing, when a plane’s speed is low and there’s little room—or time—to maneuver:

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• As the plane encounters first the headwind, it is lifted up. The pilot maintains flight path by cutting power and dropping the nose.

• The wind shifts quickly to a tailwind. If the pilot had foreseen this, he would not have cut power and lowered the nose. But it's too late—the tailwind and the earlier power reduction combine to force the plane down.

It can be risky business flying into such weather, but Langley's 737 took few chances. The plane was even flown back to the haven of Langley when Hurricane Andrew smashed across South Florida last August (it returned to continue its mission after the threat had passed).

"It sounds dangerous but really it's well orchestrated," said Dick Yenni, safety captain aboard the 737. "If we decide it doesn't look good we don't go into it. We just don't take unnecessary risks."

To give it a safety margin, the plane never entered a microburst at less than 750 feet above the ground or slower than 240 miles per hour. Most windshear-related crashes have occurred because aircraft were flying too "low and slow" to escape the microbursts. And if sensors showed the microburst exceeded a predetermined hazard level, the pilots steered away.

**Team effort**

The Langley team spent long hours each day to pull off the deployments. Besides pilots and managers, the crew included technicians, engineers and scientists from four Langley directorates, and contractors representing the companies that are helping develop the sensors—in all, more than 50 people.

"This was a very complex operation," said Bowles. "It was amazing that we could take this many people, move them and the aircraft around the country and make it work."

Each morning crew members left their hotel rooms and drove to the airport, where the 737 waited on the runway apron outside the charter operation where it was based for the deployment. The wait for "weather" began in earnest after a midday briefing.
When word came to fly, everyone scrambled to the plane—off in search of yet another encounter.

The alerts to fly came from a ground-based system called Terminal Doppler Weather Radar (TDWR) operated by the Massachusetts Institute of Technology's Lincoln Laboratory. The experimental radar can detect and measure the strength of microbursts around an airport. In fact, the presence of TDWR at the Orlando and Denver airports was a main reason Langley managers chose those sites for the flight tests.

More than 40 TDWRs are to be installed at airports around the country by mid-1994. But while the system will be an important aid for searching out microbursts, advance warning sensors are still needed, Bowles said. For one thing, he said, not every airport will get a TDWR. For another, onboard sensors will give an inflight view ahead of the plane that a ground-based radar can't.

"The aircraft needs to be like the turtle and its shell: You carry your protection with you," said Bowles. "Wherever you go, it's always there."

The 'flying laboratory'

Langley's 737 resembles a commercial airliner only in shape and size. The plane—the first 737 made by Boeing—has been extensively refitted since Langley bought the 25-year-old craft in 1974. Its most striking feature is a second cockpit for research where the first-class seats would have been.

"The airplane is flown, for the most part, from the research cockpit," said Michael S. Lewis, deputy manager of Langley's windshear program.

Once in the air, the 737's advance-warning sensors squinted ahead, working in tandem with the TDWR to locate and prepared to fly into microbursts. Chatter from five intercom and radio channels crackled through the headsets as the plane snaked through the sky in a 30-mile radius around the airport. In the research cockpit, crew members monitored numerous displays as the plane maneuvered to microbursts, which were depicted as color-coded ovals with numbers to indicate predicted hazard levels.
The idea was to detect the deadly downdrafts using the advance warning sensors, then fly through them for reactive sensors to take an actual reading. The measure of how well the advance-warning sensors worked was how closely it matched the recording of the reactive instruments.

"The Doppler sensors generally worked extremely well," said Lewis. "What we were seeing was, in most cases, what we actually got."

The rear of the jet is crammed with data-collection instruments, many of which are permanently part of the plane, which has been used for numerous experiments apart from the windshear program.

Some 30 people were seated amid the electronic wizardry every time the "flying laboratory" took off.

But the action wasn't limited to the sky. On the ground, a Langley radar van collected data and monitored the weather. Nearby, other Langley personnel gathered more data and tracked the plane on a monitor during its one- to three-hour flight. And the work didn't stop when the plane touched down. After a post-flight briefing, many of the researchers and technicians stayed behind to tweak systems, work data and prepare the aircraft for its next flight.

**Looking ahead**

Bowles said the next step is to analyze the wealth of data from two years of flight tests and make it available to the FAA and industry.

"We have collected very good data that will have lasting scientific value long after this program is finished," he said. "But our job is not to package this technology or to impose it on the industry. Our major role is to provide the industry with information so they can come up with the sensors that can be installed on aircraft."

And when that happens, he added, "we will put this problem behind us."

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KEY ACCIDENTS
Several airliner crashes were key to recognizing windshear as a major hazard and spurring NASA and the FAA take action:
- In 1975, 113 passengers were killed when an Eastern Boeing 727 crashed in at the airport in Dallas-Forth Worth.
- In 1982, A Pan Am 727 crashed in New Orleans, killing 124 passengers.
- In 1985, 145 passengers were killed when a Delta L-1011 went down at JFK International Airport in New York City.

ABOUT THE SENSORS
Langley is developing three types of forward-looking systems:
- A laser-based system, called Doppler "LIDAR" (light detecting and ranging) measures the speed of aerosols—minute particles in the air, such as dust—as an indicator of changes in the wind. It works best detecting "dry" microbursts, which are those with little rain in them. Langley flight-tested this system for the first time last summer. It is mounted on the belly of the 737.
- Another system, in the nose of the aircraft, uses microwave radar to locate microbursts by measuring sudden, large changes in the speed of raindrops in storm cells ahead of the plane. This system works best to detect "wet" microbursts—those accompanied by rain.
- Another system uses an infrared light sensor, which detects microbursts by measuring air temperature differences ahead of the aircraft. Typically, a microburst is characterized by a cooler column of air. The sensor is mounted on the side of the plane.

Gowles and his crew, which has flown through more than 50 microbursts, hope to make those numbers a thing of the past. "This is going to save lives," he said. "If you and your family are flying on a commercial airliner after 1995, there will be windshear detection technology aboard as a result of this NASA program."