Real-Time defenses

BY WAYNE ROSENKRANS

Integrating data from terminal Doppler weather radar and anemometer-based wind shear alerting systems during the past 10 years has further reduced, but not eliminated, wind shear encounters by large commercial jets below 1,600 ft (500 m) as a cause of accidents. Taking the next big advance in risk reduction will require blending the technology already in place into standard operating procedures (SOPs) for airline flight crews and dispatchers and into air traffic control (ATC) procedures, says Chris Glaeser, vice president safety and security for Alaska Airlines.[1]

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Combined with on-board wind shear detection equipment, the variety of ground-based enhancements helps flight crews to avoid encounters with abrupt changes in wind speed and/or direction that cause airspeed to increase or decrease by more than 15 kt, and may include updrafts and downdrafts that cause vertical speed changes greater than 500 fpm.

Such severe low-level wind shear primarily is associated with convective clouds and thunderstorms, gust fronts, downbursts and microbursts.

Glaeser has based his call for better integration on a three-year review of international guidance, wind shear detection upgrades by the U.S. Federal Aviation Administration (FAA) and best practices obtained from eight major U.S. airlines, reflecting the FAA's 1987 *Wind Shear Training Aid* and its adaptation to current guidance by the International Civil Aviation Organization (ICAO).[2]

"Estimates of U.S. wind shear encounters — whether on-board wind shear alerts or much more serious on-board wind shear warnings requiring a full-thrust escape maneuver — range from 150 to 400 per year," Glaeser said. "More study in this area is definitely warranted. Over the past 10 years, wind shear also contributed to a number of U.S. runway excursions that did not result in accidents. These conditions can change rapidly, and benign conditions quickly can become extremely dangerous."[3]

The consensus of the best practices is that, as the best defense, flight crews should avoid operating through areas where low-level wind shear is present or suspected. Whenever multiple indicators point to possible wind shear conditions, flight crews should operate with heightened awareness; contact ATC for additional information, including delays; and request advice from airline dispatchers.

Recent wind shear events in which safe landings were conducted showed that common factors were rapidly changing conditions, microburst-generated wind shear that exceeded aircraft control capabilities and no direct feedback from ATC regarding hazardous conditions, according to Glaeser. Reviewers also analyzed two of the runway excursions, involving a Boeing 737 in 2003 and a McDonnell Douglas DC-9 in 2005.

Wind shear avoidance can reach the next level if airlines and ATC update their procedures to match current detection capabilities.

Ground-Based Upgrades

Ground-based wind shear defenses in the United States include terminal Doppler weather radar systems; integrated terminal weather systems (ITWSs) for a group of major airports that have experienced severe weather conditions;[4] weather-system processors;[5] and enhanced low-level wind shear alert systems (E-LLWAS and others).[6]

"The ITWS is a powerful tool that will make a tremendous difference if integrated into ATC procedures," Glaeser said. Although the ITWS has been a valuable tool for tower controllers, its integration into ATC arrival and departure procedures could be significantly improved, he said. Similar integrated capabilities are being deployed in other places, including Japan and Hong Kong, China. On the other hand, as of June 2005, 16 countries had filed differences with ICAO standards and recommended practices (SARPs) noting that their air traffic controllers do not issue wind shear warnings, typically because their facilities have no ground sensors or insufficient ground sensors; or they issue wind shear warnings only at one airport; or methods of communicating about wind shear vary.

The ground-based information for flight crews primarily comes in the form of an ATC *wind shear alert* in effect for about one minute or a less-urgent *wind shear advisory* in effect for 20 minutes. Controllers issue an alert to any aircraft crew that will penetrate a warning area associated with specific runways at airports equipped with ITWS. This area is a rectangle 0.5-nm (0.9-km) wide and extending 3.0 nm (5.6 km) from the approach end of a specific runway in use to 2.0 nm (3.7 km) from the departure end. This rectangle may encompass more than one runway, and warnings are only issued for specific runways with active wind shear or microburst alerts. Other runways at the same airport may continue operations when authorized by ATC when flight crews take appropriate precautions.

"Since 2000, the National Weather Service and the FAA have upgraded more than 120 airports with runway-specific wind shear alert systems," he said. "Some airports post wind shear advisories whenever gusty winds are present, however, regardless of convective activity. Standardization would reduce false warnings."

Advisories may be received via the airborne communications addressing and reporting system (ACARS) or automatic terminal information service (ATIS), telling flight crews that a wind shear or microburst has occurred within the past 20 minutes. Common to E-LLWAS or other upgraded LLWAS, the weather-system processor and terminal Doppler weather radar in airport control towers is a ribbon display that visually and audibly draws controllers' attention to any automated wind shear alert, showing the effect in terms of airspeed gain/loss and the specific runway(s) affected. Tower controllers are required to communicate these alerts to flight crews by radio. One example of phraseology would be, "Runway 34R arrival, microburst alert, airspeed loss of 35 kt on one-mile [1.9-km] final." Other controllers are not required to issue these alerts, which may reduce significantly the time available for the flight crew to take evasive action, Glaeser said.

"The gust front is a huge hazard to aircraft during takeoff and landing, but is … ignored in ATC procedures, and somewhat unrecognized in industry training programs."

An ITWS display of a gust front and its movement (Figure 1) enables controllers or dispatchers to advise flight crews about the real-time situation. On this display, the runway complex — shown by black lines — is centered, the current position of the gust front is shown as a solid line, and future gust-front positions are shown by dashed lines representing 10 minutes later and 20 minutes later. "Notice how far the gust front is projected to move in only 10 minutes," Glaeser said. "Use of this display should be integrated into ATC procedures, at both approach control and tower facilities, and into operators' dispatch offices. In this case, a 15-minute delay allowed time for all of the hazardous weather to leave the airport area. The gust front is a huge hazard to aircraft during takeoff and landing, but is a very transitory phenomenon ignored in ATC procedures, and somewhat unrecognized in industry training programs."

Airline Best Practices

Several recommendations emerged from comparing the best practices. One is that SOPs should specify that "takeoffs and approaches and landings are not authorized when runway-specific wind shear alerts or microburst alerts have been issued by ATC." Another is that if a takeoff is in progress, and one or more wind shear indications are encountered, the captain immediately should decide either that the takeoff can be completed safely and continue, or reject the takeoff. If wind shear is encountered during approach and landing, a full-thrust wind shear escape/recovery maneuver is mandatory. An immediate go-around or missed approach should be conducted if any degraded aircraft performance is experienced below 1,000 ft above ground level, an airspeed loss greater than 15 kt occurs, ATC issues a wind shear alert or the airborne wind shear warning system activates.

Similar to the ICAO guidance, the eight airlines that use these best practices also manage the risk of encounters with academic training on how to evaluate severe low-level wind shear probability given a set of current conditions. Recommendations from the review were that flight crews especially need to be vigilant for any runway-specific wind shear alert or microburst alert — which normally indicate the highest probability of a wind shear encounter — and to interpret this alert as an unmistakable indication that takeoff or landing cannot be conducted safely.

The following events would indicate a high probability of a wind shear encounter: a runway-specific wind shear alert within the previous 10 minutes — for the flight crew's own aircraft or another aircraft approaching the same runway — even though the alert is no longer active; a severe thunderstorm cell less than 5.0 nm (9.3 km) from the airport and moving toward the airport; a gust front approaching the airport, indicated by rapid changes in wind speed and/or direction; a pilot report (PIREP) of an airspeed loss or gain of more than 15 kt within the previous 10 minutes in a similar or larger aircraft; a wind shear warning from an airborne system (aboard the flight crew's own aircraft or another aircraft); heavy rain showers along the flight path; airborne weather radar returns showing heavy precipitation; reports of blowing dust, roll clouds, wall clouds or cloud rotation approaching the airport;

large changes of autothrust or manual thrust required to maintain airspeed; and/or large changes in pitch required to maintain the glideslope.

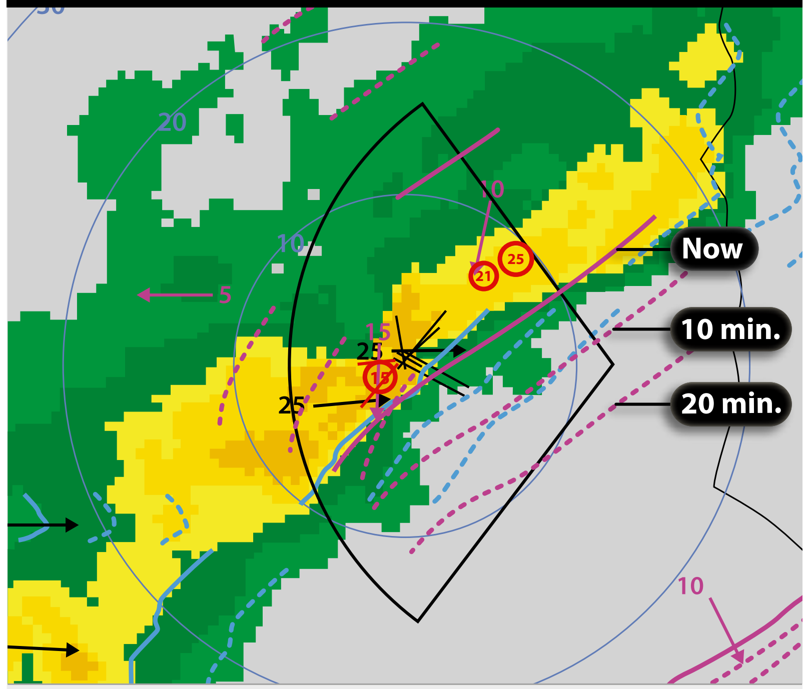
Faced with high-probability events, the flight crew should use caution and consider holding until the weather phenomenon no longer affects the approach/departure path, Glaeser said. The flight crew should divert if the safety of flight is adversely affected by the fuel state or weather. In any event, the pilot monitoring must be vigilant for degradations in either aircraft performance or weather conditions. Crews also should consider each environmental factor as cumulative. "If more than one is observed, the probability of a hazardous weather encounter is increased," Glaeser said. "The flight crew then should consider alternate routings or runways; consider holding or diverting; brief the wind shear escape maneuver; and utilize all wind shear precautions." Review of the two runway excursions, which he called "near accidents," found multiple high-probability events, he said.

Another best practice used by the eight airlines is to present, for periodic review, possible current conditions, wind shear probabilities, departure precautions, approach/landing precautions and appropriate flight crew actions in a flow chart in the quick reference handbook. In either the departure phase or the approach and landing phase, the flow chart's precautions should require specific decisions/actions for thrust setting, runway selection, flap selection, operational considerations, engine ignition and response to wind shear warnings. For example, precautions for takeoff call for using maximum thrust; using the full length of the longest compatible runway that avoids convective activity; soliciting PIREPs; using the maximum takeoff flap setting in accordance with the aircraft flight manual; being prepared to reject the takeoff by watching for signs of stagnated acceleration; and adding a factor to the normally computed rotation airspeed.[7]

Examples of precautions for approach and landing are: do not approach or land on a runway if an ATC wind shear/microburst alert is active; conduct a stabilized approach as a mandatory requirement; do not make aggressive reductions of thrust due to sudden changes in indicated airspeed (IAS) or allow the autothrust system to significantly reduce thrust — instead, the pilot flying should accept increases and expect corresponding rapid drops while gradually correcting IAS; and consider disconnecting autothrust or otherwise minimizing thrust reductions by not allowing autothrust to make inappropriate reductions. "The first precaution is the most important but, unlike the others, requires ATC involvement," Glaeser noted.

More precautions for approach and landing include: wait 10 minutes after the flight crew of a similar or larger aircraft reports a loss of IAS greater than 15 kt; conduct an immediate go-around in response to a loss of IAS greater than 15 kt; select an approach procedure that provides

FAA ITWS Display of Gust Front and Wind Shear



(21) Low-level wind shear with predicted change of airplane velocity in knots
Current gust front position
Projected gust front position in minutes
Boundary for wind shear detection by terminal Doppler weather radar and other FAA/NWS sensors

FAA = U.S. Federal Aviation Administration   ITWS = Integrated terminal weather system
NWS = National Weather Service

Note: ITWS primarily is a tool for air traffic controllers and airline dispatchers, showing the airport runway complex at the center of the display and the surrounding area to 60 nm (111 km). The FAA's prime contractor is Raytheon Air Traffic Management Systems.

Source: Chris Glaeser

Figure 1

a glideslope when possible; increase the approach speed by up to 15 kt to correspond to any anticipated loss of IAS; be sensitive to large changes in pitch — five degrees — or in vertical speed — 500 fpm — and go around if excessive changes occur; use continuous engine ignition; and go around if any airborne wind shear warnings occur.

One resource that Glaeser highlights is terminal weather information for pilots (TWIP), which enables automated wind shear/microburst advisories and alerts to be uplinked via the ARINC network to ACARS displays. Like digital ATIS text messages, the ACARS message from TWIP for a wind shear advisory will continue for 20 minutes after any wind shear/microburst alert has been issued. "A number of U.S. operators take advantage of this automated service, which is destination-specific," Glaeser said. "To determine if a wind shear/microburst alert is active, however, a flight crew must contact the tower even though a wind shear advisory is in effect."

Each ACARS message (Figure 2) indicates the source of the message, such as ITWS. Only one advisory per airport is current at a time; recurring alerts do not result in multiple advisory messages, and any advisory can be superseded.

"Tremendous recent advances have occurred in U.S. wind shear detection technologies, with good progress in nationwide installation and 100-percent upgrades of LLWAS," Glaeser said. "But ATC and ICAO documents should be updated — and accident risk can be greatly reduced by air carriers' widespread incorporation of these procedures and best practices. The FAA also should adopt the ICAO term 'warning' in place of 'alert' in controller-pilot radio communication as it is much clearer in required flight crew actions." ●

Example of TWIP Message on ACARS

1. DFW
2. *MICROBURST Advisory
   40KT LOSS BEGAN 1816Z
   –STORM AT ARPRT MOD PRECIP
   1NM E HAIL
   MOVG W AT 15KT
   BEGIN 1822Z
3. VALID 1816 TO 1836Z
4. CANCEL NONE-TWIP

ITWS TERMINAL WX INFO

ACARS = Airborne communications addressing and reporting system
DFW = Dallas/Fort Worth International Airport
ITWS = Integrated terminal weather system
TWIP = Terminal weather information for pilots

Source: Chris Glaeser

Figure 2

Notes

1. Glaeser, Chris. "Windshear Risk Reduction: Integrating New Technologies Into Aircrew and ATC Procedures." A presentation to the Flight Safety Foundation International Air Safety Seminar in Paris. Oct. 23–26, 2006.
2. International Civil Aviation Organization. *Annex 3 — Meteorological Service for International Air Navigation.* 2005. Document 9817, *Manual on Low-level Wind Shear.* 2005.
3. Estimates were based on extrapolating deidentified aviation safety action program (ASAP) data — voluntary reports submitted by U.S. airline pilots — after noting that flight operational quality assurance (FOQA) programs show that only 10–15 percent of wind shear events downloaded from aircraft quick-access recorders were reported via ASAP, and that approximately 20 percent of reports were full-thrust escape maneuvers, Glaeser said.
4. Integrated terminal weather service (ITWS) primarily provides automated weather information for use by air traffic controllers and supervisors in airport terminal airspace 60 nm (111 km) around the airport. The system was designed for wide use without meteorological interpretation. ITWS provides information about the current weather and forecasts for 30 minutes through integration of data from sensors such as terminal Doppler weather radar, next-generation weather radar, airport surveillance radar, low-level wind shear alert system (LLWAS), automated weather and surface observing systems, lightning-detection systems, weather models and weather sensors aboard some airliners.
5. The ATC facilities equipped with a weather-system processor have an enhanced weather channel on their ASR-9 traffic surveillance radar, warning controllers and pilots of hazardous wind shear and microburst events near runways; predicting the arrival of gust fronts; and tracking/predicting thunderstorm movement. It is used when facilities do not have terminal Doppler weather radar.
6. As of early 2007, U.S. airports had four LLWAS generations in operation. The most advanced — called *network expansion* — integrates wind speed and wind direction data from as many as 32 anemometers to increase the probability of microburst detection compared with four to six sensors in the legacy *LLWAS-2* generation. The *relocation* generation improved LLWAS-2 performance by relocating or replacing anemometer masts to overcome sensor-shielding or sensor-sheltering. The *sustainment* generation extended the service life of LLWAS at airports that do not have terminal Doppler weather radar or the weather-system processor.
7. According to U.S. Federal Aviation Administration Advisory Circular 00-54, *Pilot Windshear Guide*, to apply the wind shear additive for takeoff, the flight crew essentially calculates the normal takeoff airspeeds for the actual aircraft gross weight and flap setting; sets these speeds with the indicated-airspeed bugs; determines the runway maximum weight capability for the same conditions; determines the takeoff speeds for this maximum weight; and, during takeoff, delays aircraft rotation until the higher speeds — to a maximum additive of 20 kt — are reached. Some operators specify 15 kt, Glaeser said.