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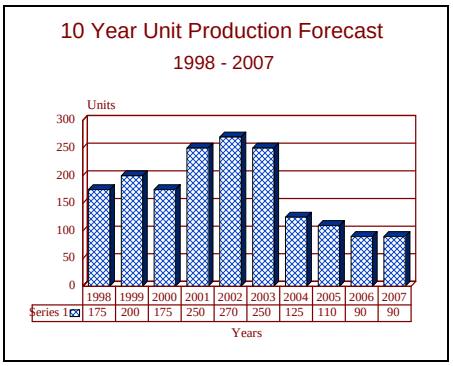
Airborne Windshear Detection Systems - Archived 8/99

Outlook

- Windshear a major cause of aircraft accidents
- Predictive radars are gaining a larger market share
- Military programs support a significant near-term market with out-year possibilities



Orientation

Description. This FAA/NASA Airborne Windshear Sensors Program is a joint cooperative effort between the US government and industry to reduce the threat of hazardous windshear to aviation.

Sponsor

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Rosemount Inc
Aerospace Division
Burnsville, Minnesota (MN)
USA
(Passive IR system, predictive system)
Safe Flight Instrument Corp
White Plains, New York (NY)
USA
(Warning and guidance)

Sextant Avionique Inc
Miami, Florida (FL)
USA
(Detection and warning)

Sundstrand Data Control Inc
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Northrop Grumman Corp
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(APN-241 predictive radar)

Status. Various receivers/sensors are in development and production.

Total Produced. Through 1997, an estimated 2,469 units of various types had been produced and installed in various airline fleets.

Application. Airborne Windshear Sensors Program are designed to warn when an aircraft is entering a windshear/microburst situation or predict impending windshear/microburst to provide up to a 60-second warning, especially during take-off and landing.

Price Range. Prices vary from system to system. Estimated ranges are given in the following two paragraphs.

Reactive Systems Safe Flight Instrument Corporation windshear detection systems range in price from US$26,000 for the Model 6501 Series analog system which provides warning only, to US$39,525 for the Model 1350 Series analog system which includes attitude guidance for non-windshear conditions. Sundstrand Data Control offers two detection systems: the Mark VII GPWS priced at US$29,619, which includes windshear detection and optional guidance for analog avionics; and the Mark V GPWS, which costs US$39,364 and provides windshear detection for digital avionics.

Predictive Systems Predictive Doppler radar windshear systems are being installed and are operational. Prices range from an estimated US$175,000 to US$450,000, depending on system and ancillary components.

Technical Data

Characteristics. Windshear detection systems are divided into two categories: reactive and predictive systems. Reactive systems provide an indication that the aircraft is actually encountering a windshear event. These systems typically rely on a variety of onboard sensors, including air data systems, inertial sensors, etc., to provide diverse information to a windshear warning computer. When threshold conditions are exceeded, the system sounds a pilot alarm; with the most advanced systems coupled to the autopilot and able to have the system execute a preprogrammed escape maneuver.

Radars look ahead of the aircraft and provide advanced warning of windshear conditions ahead of the aircraft in order to provide the pilot time to avoid entering the windshear region, or to prepare to best survive the encounter if the condition cannot be avoided. From the standpoints of both aircraft safety and passenger comfort, predictive systems are preferred. Technologically, predictive systems are more challenging and have been longer in development.

Design Features. NASA has flight-tested a range of detection technologies:

- Advanced reactive systems that sense atmospheric conditions conducive to microburst formation in order to anticipate windshear and reduce reaction time
- Datalink to the highly sensitive ground-based Terminal Doppler Weather Radar (TDWR) which is designed to detect microbursts and low-level windshear in the terminal area

- Airborne digital Doppler weather radar that gauges horizontal wind changes and windshear hazard potential by measuring raindrop velocity and direction and predicting the likely existence of windshear and microburst activity
- Passive infrared (IR) sensor that measures air temperatures and water vapor concentration ahead of the aircraft
- Ladar (laser radar) that measures the Doppler shift in pulses reflected back to the aircraft by particles suspended in the air
- CLASS (Coherent Ladar Airborne Shear Sensor) which detects winds by tracking the movement of air particles

Each of these technologies has its relative merits. Windshear-detecting radar is an extension of existing weather radar technology and can provide a 60-second warning of wet microbursts, but has limited ability to detect dry microbursts, and cannot detect clear air turbulence (CAT). Passive infrared (IR) sensors provide less warning time but can detect both wet and dry microbursts as well as CAT. The newly emerging laser radar technology can detect dry microbursts and CAT, but it is limited in detecting wet microbursts. As the technologies matured and systems went into production, the predictive radars have become the preferred system for users who can afford them.

Variants/Upgrades

Advanced airborne windshear receiver/sensor technology came of age with the first FAA flight certification of a windshear warning (vs. weather-only) airborne digital Doppler radar system in September 1994.

Below is a listing of known producers and developers of airborne windshear receivers/sensors, with descriptions of their products:

AlliedSignal Aerospace. AlliedSignal Air Transport Avionics Division (formerly Bendix) received FAA certification for its RDR-4B windshear Doppler radar in September 1994. The system is an adaptation of its RDR-4A radar which is in airline service on the 767, 757, A300, MD-80, DC-10 and L-1011 aircraft in a weather detection role.

Initial tests conducted on a Convair 580 confirmed the modified radar's ability to detect microbursts, the meteorological phenomenon that produces windshear. Subsequent cooperative tests on a Continental Airline Airbus A300 demonstrated that the radar could predict windshear using its ability to determine actual horizontal wind by measuring raindrop velocity.

During flight tests, the RDR-4B system demonstrated its viability by detecting microbursts that were verified by ground-based sensors.

The RDR-4B Weather Radar System operates automatically anytime the aircraft is below 2,500 feet AGL. Although the windshear mode is selectable at any time, the screen displays weather data until a windshear hazard is detected.

Honeywell. In the spring of 1991, the FAA certified the reactive Honeywell Windshear System, MD-80, for the Lockheed retrofit of L-1011 aircraft. Approximately 100 systems were delivered to eight L-1011 operators. Honeywell also teamed up with (then) Westinghouse to produce the MODAR-3000 (MR-3000) Advanced Weather Radar. (See below.)

Lockheed Martin Missiles and Space. Lockheed Martin is presently developing a ladar system for windshear detection. While the technology is still immature compared to that of Doppler radar systems, Lockheed Martin believes such a system will be in the marketplace within two to three years. Sextant Avionique of France is a joint partner in this venture.

Rockwell-Collins. Rockwell is now offering the C and X Band WXR-700XW Doppler radar. This unit is a derivative of the WXR-700 airborne weather radar and includes a flatplate antenna designed to overcome ground clutter. Rockwell-Collins received FAA certification in June 1995. The manufacturer also indicates that windshear capability could be added to the 6,500 WXR-700s radars already in service by means of a retrofit upgrade. A militarized version of the radar, the FMR-200X, is being installed on USAF C/KC-135 aircraft as part of a major avionics upgrade.

Northrop Grumman. Northrop Grumman (formerly Westinghouse Electronic Systems) is marketing its joint Honeywell-developed MR-3000 lightweight predictive windshear weather radar system. The system uses pulse Doppler technology to detect microbursts; it should provide up to 90 seconds for in-flight windshear-avoidance corrections. FAA certification was completed in 1995. The MR-3000 modular radar is a civilian version of the militarized APN-241 radar which entered service on the USAF C-130H aircraft in November 1993. The APN-241 is being procured for

use on the C-130s in the US and international inventory.

Rosemount. Rosemount Aerospace has developed Angle-of-Attack systems that function as windshear detector transmitters and recovery indication instruments.

Safe Flight Instrument. Safe Flight Instrument Corporation offers several reactive warning systems. The Model 6501 is a computerized windshear warning system that incorporates accelerometers and uses existing air data and angle-of-attack sensors to provide visible and audible windshear indications. The Model 6502 series is similar to Model 6501 except that it develops a computed angle of attack. Model 6506 incorporates caution and warning displays, plus voice warning. Optional components include recovery guidance, attitude guidance, climb command and runway rotation guidance. Model 6580, which is standard equipment on the BAe 146, is the same as Model 6501 except that it includes a recovery guidance system. Model 6509 is also similar to Model 6501 but has an added on-stall warning system and integral recorder. As of 1993, Model 6509 was no longer appears advertised; it may have been remodeled into the new Model 1350 analog series that includes altitude guidance for non-windshear conditions.

Sextant Avionique. Part of the Sextant flight control computer system, the Windshear Guidance Display provides recovery guidance imagery on the A300-600 and A310 aircraft.

Sundstrand Data Control. The Mark V GPWS provides all ground proximity warnings plus windshear detection and warning. It is a common fit on Boeing, Airbus, MD-11, Fokker 100, and several other aircraft types. The Mark VII GPWS provides all possible ground proximity warnings. Its capabilities are extendible to include attitude call-outs and bank alerts, as well as windshear warning and recovery guidance.

Program Review

Background. Windshear as a threat to aircraft safety has been demonstrated all too well over the years. Since 1964, windshear has been implicated in the crashes of over 30 aircraft, bringing a death toll of more than 570.

Windshear is a meteorological phenomenon most often associated with cumulonimbus clouds. It consists of rapid changes in wind direction, which in turn cause significant and sudden airspeed changes, often including extremely violent downdrafts. Referred to as a microburst, the windshear phenomenon is present in most areas of the world, although more prevalent in some areas than others, depending on geographic/meteorological factors. Additionally, air-traffic volume is a contributing factor to windshear dangers; the more traffic in a given area, the higher the probability that windshear will be encountered.

Windshear is most dangerous on approach and take-off, when aircraft speed and altitude are low. While landing, a plane encountering windshear first experiences an increasing headwind which increases aircraft lift performance and also causes the pilot to instinctively reduce power in an effort to complete the approach. The increasing headwind is followed by a reverse in wind direction, resulting in a significant loss of lift and possible rapid loss of altitude, which — if it occurs too close to the ground — causes a crash.

As a result of the August 1985 Delta Air Lines windshear-related crash at Dallas-Fort Worth International Airport, the National Transportation Safety Board, as well as Congressional directives, recommended that the FAA and NASA address the threat of windshear to aviation. In 1986, the FAA initiated funding for a NASA Langley Research Center program to evaluate a variety of airborne sensors with the potential to provide advanced warning of windshear conditions. The FAA established a flight safety program and supported NASA development of advanced technologies for airborne detection of windshear.

The FAA issued a directive that some form of windshear detection be installed in all US airliners and airspace operators carrying 30 passengers or more by the end of 1993. Carriers with aircraft of fewer than 30 seats were required to train flight crews in windshear recognition and avoidance, as well as recovery techniques. Industry and airlines responded with the development and operational deployment of the previously described reactive systems. Several carriers, though, were already committed to investigating predictive radars with their obvious operational advantages; they were granted an extension until 1995.

The FAA and NASA determined that Terminal Doppler Windshear Radar (TDWR) was the most practical ground-based solution and Raytheon awarded a $373 million contract to install 47 of these ground-based systems at airports across the US. All but five systems had been installed and were operational by the end of 1997.

Windshear warning devices are required for older aircraft, but windshear predictive systems are not mandatory. Also, windshear requirements do not, as

yet, apply to foreign carriers. The FAA has previously estimated that windshear detection is required on a total of some 1,910 US aircraft.

Historically, Honeywell made a major breakthrough in 1989 when the FAA certified the company's MD-80 windshear detection, alert and guidance system. Until this point, system technology was only capable of warning pilots of windshear. Although still a reactive system, Honeywell's new feature gave the pilot the added option to choose an autopilot-controlled escape maneuver. By June 1991, Honeywell received FAA certification to retrofit all Lockheed TriStars. While not required to install windshear detection systems, several foreign carriers have bought them.

Another important milestone in the sale of reactive windshear systems occurred in September 1991, when Safe Flight Instrument Corp was granted United Kingdom Civil Aviation Authority certification for its windshear warning/recovery guidance system for the British Aerospace 146-100 and -300 aircraft. The system combines angle-of-attack inputs with flap positions, and is activated automatically during take-off and landing between ground level and 2,100 feet.

During the same period when reactive windshear warning systems were being installed on airline fleets to meet the FAA 1993 installation deadline, NASA, the FAA, industry and the airlines continued to work cooperatively to develop and certify a predictive system by the time the 1995 waiver deadline expired. Numerous tests were performed, and in the summer of 1994 the FAA worked aggressively to establish minimum operating standards (MOPS) as a prelude to flight certification activities.

This effort culminated in the September 1994 certification of the RDR-4B radar, followed by the certifications of the WXR-700XW and MR-3000 radars in the summer of 1995.

Carrier response to these certification activities has been both positive and swift. AlliedSignal reported orders for 500 RDR-4B radars; these included 300 units for Continental Airlines, to equip its fleet in 1996, with 80 percent installed by the end of 1995. Other AlliedSignal customers include Alitalia, Kuwait Airways, Northwest Airlines and United Airlines.

Even before its certification, Rockwell-Collins announced first sales of the WXR-700XW radar to three major customers. Following its certification, the company reports, deliveries are under way to 14 customers of the system, which they also call the Forward Looking Windshear Radar. International Lease Finance Company (ILFC) and Air Mauritius chose to outfit their fleets of Airbus A340 aircraft, and China Northwest Airlines chose similarly to equip its Airbus A300-600 fleet with this unit.

Douglas aircraft also indicated that it planned to deliver MD-90 aircraft equipped with a predictive windshear system starting in March 1996. The company also plans to offer predictive windshear systems as an option in its MD-80 and MD-11 aircraft. The supplier(s) has not been specified.

Lockheed Martin Missiles and Space is presently developing a ladar system capable of windshear detection. While this technology is still immature compared to that of Doppler radar systems, Lockheed Martin believes such a system could enter the marketplace within two to three years. Sextant Avionique is a partner in this venture.

It should also be noted that NASA continues to sponsor the development of a new laser sensor, designated the Coherent Ladar Airborne Shear Sensor (CLASS), which will be able to detect winds by tracking the movement of dry air particles. Because it is free of ground clutter, this scanning technique has the potential to yield extremely accurate readings. Other applications for CLASS include detecting volcanic ash, wake vortexes, and jetstream locations for head and tail winds.

Funding

Funding is from platform acquisition/upgrade accounts and not broken out separately.

Recent Contracts

Specific contract information in relationship to individual airlines is not available.

Timetable

Month	Year	Major Development
Jun	1986	FAA and NASA began joint sponsorship of windshear program
Jul	1989	Honeywell received FAA certification for its warning and avoidance system
Dec	1993	FAA deadline for installation of windshear detection
Sept	1994	FAA certification of first predictive Doppler radar windshear system
Dec	1995	Extension deadline for predictive windshear detection installation
Dec	1998	Ladar windshear detection predicted to be available

Worldwide Distribution

While non-US airspace operators are not required to install windshear detection systems, several international carriers have bought them. Honeywell alone has sold over 100 systems to several operators, including Delta, American Trans Air, All Nippon, Hawaiian, LTU, Royal Jordanian, Gulf Air, Trans World Airlines, and British West Indian Airlines. Rockwell-Collins, Northrop Grumman, and AlliedSignal are capturing a significant share of both the domestic and international markets as the result the certification of predictive warning Doppler radar systems.

Forecast Rationale

Considering the elusive nature of the windshear phenomenon, as well as the high costs and lengthy R&D periods involved in developing reactive systems, reactive and predictive windshear detection systems will be made to complement each other in the near term. Windshear-predictive systems will eventually replace reactive sensors throughout the airline industry.

While many carriers are equipping or retrofitting their aircraft with newly certified windshear-predictive systems, they are not necessarily eliminating the older reactive systems. Because of the upgradable nature of many of the existing reactive systems, the predictive systems may not fully edge the reactive systems out of the market as quickly as previously thought.

The three major predictive Doppler systems on the market are advanced versions of weather radars already in airline service. Two of these suppliers (AlliedSignal and Rockwell-Collins) have stated that a predictive windshear capability can be achieved by a retrofit upgrade of these systems. This has two important ramifications: a precapture of a portion of the market, and a limitation in total value since the cost of a retrofit kit is estimated to be one-fourth to one-fifth that of a completely new equipment set.

After much experimentation, the FAA and NASA determined that Terminal Doppler Windshear Radar (TDWR) was the most viable ground-based solution, and Raytheon was awarded a US$373 million contract to install 47 of these systems at airports across the US.

In the worldwide market for windshear detection devices, the United States carriers are purchasing most of the advanced units, because of the FAA mandate. Outside the US, the technology is just beginning to enter the market. Many foreign governments and airlines are beginning to take a serious interest in the windshear detection technology (as they have with collision avoidance equipment in recent years), and may soon be initiating mandates of their own as more of the world recognizes the serious danger of windshear.

The 10-year forecast has been updated to reflect the predictive radar market, including contracts for military aircraft. The market reflects a near-term retrofit effort. An added market potential is a replacement radar for the APN-59 common on military aircraft in the US and around the world. This system will be required to have a predictive capability, and will probably be one of the systems procured by the Department of Defense. Installations may begin around the turn of the century and be spread over many years.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

			High Confidence Level			Good Confidence Level				Speculative			
Designation	Application	thru 97	98	99	00	01	02	03	04	05	06	07	Total 98-07
AIRBORNE WINDSHEAR DETECT	(VARIOUS)	2469	175	200	175	250	270	250	125	110	90	90	1735