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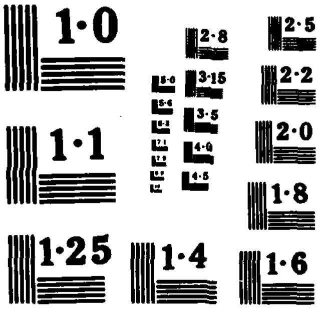
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AIR COMMAND
AND
STAFF COLLEGE

STUDENT REPORT

ROTARY-WING OPERATIONS
IN A MICROBURST ENVIRONMENT

MAJOR EUGENE E. MACE 85-1670

"insights into tomorrow"

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Microburst wind shear has been directly or indirectly involved in 28 aircraft incidents or accidents since 1964. Following the last major aircraft accident attributed to microburst wind shear in 1982, a major effort was undertaken to study the hazard. The majority of the work that has been accomplished deals with the publicity of the phenomenon to the aviation community and with acceptable methods of detecting it before it occurs. This study explores the background, detection systems and special considerations of helicopter operations in relation to microburst induced wind shear. Included are subjective hazards, aircraft response and recommended pilot actions to successfully pentrate the wind shear if inadvertently encountered. The study recommends that it be used as an interim measure to supplement existing microburst wind shear information and that additional helicopter microburst testing be conducted.

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PREFACE

The purpose of this study is to provide an interim basis of knowledge on the effects of microburst wind shear (MBWS) on helicopters until more detailed information becomes available. It was prepared for the US Army Safety Center with the idea that the information could be used to promote safety and possibly inspire additional, more scientific research. Additional copies of this study may be obtained from the Air Command and Staff College, EDCC, Maxwell Air Force Base, Alabama 36112.

The majority of the research conducted on MBWS deals with detection and formation. This research is important because if a satisfactory method of MBWS detection can be found, the threat to air traffic will be greatly reduced.

Unfortunately, a foolproof MBWS detection system does not exist. Therefore, aircraft will continue to encounter this form of wind shear without prior warning. The exact number of recent incidents is not known; however, as recently as 1982, MBWS was directly related to 158 deaths in one aircraft accident. The Federal Aviation Administration (FAA) has taken positive steps to determine the extent of the hazard, but much work remains to be done, especially involving rotary-wing operations.

The study begins with the background and history of microbursts, detailing the efforts that went into its discovery and why it is a threat to low-altitude air traffic. Much of the early work, as well as the current research, was conducted by Dr. T. Fujita, a noted meteorologist at the University of Chicago. He is credited with proving that MBWS does exist and that it is a significant hazard.

Chapter Two contains a study of the current low-level wind shear alert system (LLWSAS) which has been in operation in the United States since the mid-70s. Included is a discussion of existing wind shear detection systems that have been evaluated or are under evaluation.

Chapter Three contains information on non-electronic MBWS detection and lists the danger signals of active and impending MBWS. Also included in the chapter are examples of how helicopter crews can assist each other in avoiding microbursts while operating in remote areas by using the standardized FAA MBWS reporting procedures.

One issue which has not been resolved is why MBWS is hazardous to helicopters and exactly what those hazards are. Chapter Four contains three specific examples of helicopter operations in different microburst conditions. The examples were selected by the author using actual fixed-wing case

CONTINUED

histories of microburst encounters. The advantages and disadvantages a helicopter may have over a fixed-wing aircraft when operating in or around a microburst are also discussed.

Chapter Five is a subjective analysis of the perceptions a helicoper pilot would expect to experience upon microburst penetration, how the helicopter will likely respond, and provides suggested pilot actions to effectively handle the situation.

The final chapter summarizes the study and makes recommendations for further research into MBWS in relation to helicopter operations. It also recommends that this study be used as an interim measure to inform Army helicopter pilots about the hidden and not-so-obvious dangers of MBWS.

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EXECUTIVE SUMMARY

REPORT NUMBER 85-1670

AUTHOR(S) MAJOR EUGENE E. MACE, USA

TITLE ROTARY-WING OPERATIONS IN A MICROBURST ENVIRONMENT

I. Purpose: To provide an interim basis of knowledge on the effects of microburst wind shear on helicopters until more detailed data become available.

II. Problem: There is currently no information available concerning rotary-wing flight in microburst wind shear. How can the helicopter pilot detect/avoid microburst wind shear and what pilot techniques are recommended if it is inadvertently encountered?

III. Data: Microburst wind shear presents a hazard to low-altitude air traffic because: (1) it is almost impossible to predict when or where it will strike, and (2) because its small size makes it difficult for aircraft in critical modes of flight (landing and taking off or low level) to adjust to its wildly diverging winds. Contributing to the problem is the fact that much of the aviation community is not aware of the seriousness of the hazard. Many experts feel that an accurate detection system is important because it will preclude or significantly reduce the chances of accidents. While this is true, helicopter operations remain unprotected by land-based (because of the remote areas from which they operate) or airborne detection systems (not economically feasible). The answer for helicopter operations lies with a good, sound understanding of how and why this phenomenon occurs, how to visually recognize its danger signals, and what to do if inadvertently encountered. Its recognition is a matter of education. Answering the question of what to do if it is inadvertently encountered is somewhat more difficult. This study provides subjective data based on recent fixed-wing tests and studies but it may not tell the complete story because of the differences between the two categories of aircraft. Dedicated helicopter testing is necessary so that this segment of the aviation community can minimize the risk involved.

IV. Recommendations:

a. That action be taken to determine to what degree helicopters are affected by microburst wind shear contact.

b. Based on the information obtained above, document and publish approved pilot response actions which will best overcome the effects of microburst wind shear.

c. That an educational program be initiated within the helicopter community which stresses the hazards of microbursts and their associated danger signals.

d. That this study be made available to the helicopter community as an interim measure until more objective data are available.

Chapter One

THE BACKGROUND AND HISTORY OF MICROBURST WIND SHEAR

Low-altitude wind shear spawned by convective clouds and thunderstorms in all stages of maturity has been directly or indirectly responsible for 28 aircraft accidents or incidents since 1964 (See Table 1) (8:1-2). The majority of these accidents were similar in that the airplanes encountered wildly diverging winds while in close proximity to the ground, resulting in critical loss of altitude.

The most graphic case of a microburst wind shear accident occurred in July 1982 when a Pan Am 727 crashed at New Orleans International Airport, killing 153 persons (145 on board the airplane and eight on the ground) (8:1). Moments after takeoff, the 727 encountered a microburst two nautical miles in diameter that produced a 17-knot headwind followed by a seven foot-per-second downflow and a 31-knot tail wind (5:36). "The result of the wind shear effectively decreased the airspeed of the aircraft by 18 kts seriously degrading the aircraft's performance and resulted in the crash" (17:32).

It is important to note that the preceeding accident figures pertain to large fixed-wing aircraft accidents or incidents which were investigated by the National Transportation Safety Board and do not include statistics on general aviation aircraft (7:12). It is suspected that low-altitude wind shear does contribute to the numerous weather-related accidents in the general aviation community every year; however, the lack of detailed accident investigation data may result in the actual causes going undetected (1:1-5).

This low-altitude wind shear is actually a downflow of rapidly moving air which diverges in all directions when it encounters the earth and is called microburst wind shear (MBWS) (18:78). MBWS is the smaller of two types of downburst wind shear associated with convective weather formations and thunderstorms. The large downburst is known as a macroburst. Dr T. Fujita (5:39) of the University of Chicago describes MBWS and macroburst wind shear:

> Macroburst - A large (mesoscale) sized downburst. An intense macroburst often causes widespread, tornado-like damage. Damaging winds lasting five to twenty minutes,could reach as much as 150 MPH.
>
> Microburst - A small (misoscale) sized microburst with peak winds lasting only two to five minutes, which could reach as much as 150 MPH. A microburst induces dangerous tailwind and downflow shear which cannot always be detected by ground-level anemometers (4:Preface).

No	Year	Location	Aircraft Type	TOFF/ LDG	Fatalities/ Injuries	Wind Shear Experienced	Associated Weather
1	1964	Lake Tahoe, NV	L-1049	o LDG	85/0	During missed approach	Strong mtn wave.
2	1964	JFK, NY	B-7208	o LDG	0/0	Wind shift--headwind to cross wind	T/Storm with sharp pressure rise
3	1965	Kansas City, MO	B-727	o LDG	0/0	Wind shift on final	Unstable Moist air
4	1968	Salt Lake City,UT	B-727	o Ldg	0/1	Wind shift on final	Thunderstorm
5	1970	Naha, Okinawa	DC-8	o LDG	4/0	10-kts tailwind near threshold	Heavy rainshower 1 mile in diam.
6	1970	St. Thomas, VI	CV-640	o LDG	N/A	Landing in 20 knot wind	Lee side flow in rainshower
7	1971	LGA, NY	DC-3	o LDG	0/2	Tailwind changed into headwind	Frontal shear
8	1972	Ft. Lauderdale, FL	DC-9	o LDG	0/3	50 degrees and 8-kt windshift in 8 seconds	Heavy thunderstorm
9	1972	New Orleans, LA	B-727	o LDG	0/0	IAS dropped from 162 to 122 knots	Intense rain and Hvy thunderstorm
10	1972	JFK, NY	B-707	o LDG	0/0	42-kts tailwind at 1,500 ft to 5-kts at surface	Fog and Drizzle
11	1973	Wichita, KS	B-727	o LDG	0/0	70 dgs windshift in 9 sec	Thunderstorm
12	1973	ORD, Chicago, IL	DC-8	o LDG	0/0	Est downdraft 50 fps at 3,000 ft; 13 fps at 500 ft	Heavy rainstorm
13	1973	St. Louis, MO	FM-227B	o LDG	38/6	Up and down drafts	Outflow shear, thunderstorm
14	1973	Chattanooga, TN	DC-9	o LDG	0/42	Low-altitude windshear	Same as #13
15	1973	Boston, MA	DC-10	o LDG	0/16	Large windshifts at 500 ft continuing to surface	Frontal shear, rain and fog

Table 1. Aircraft Accidents and Incidents Related to Low-Altitude Windshear (1964-1982)
Source: (14:5-6)

Table 1 Continued:

16	1974	Pago Pago, Samoa	B-707	o LDG	96/5	Decreasing headwind/downdraft in last 4 seconds	Outflow shear hvy rainshower
17	1975	JFK, NY	L-1011	● LDG	---	8 kts hd wnd to 6 kts tailwnd with 20 fps downdraft	Small downburst or microburst
18	1975	JFK, NY	B-727	o LDG	112/12	14 kts hdwnd to 1 kt hdwnd with 21 fps downdraft	Same as 17
19	1975	Denver, CO	B-727	o T/O	0/15	IAS dcreased 158 to 116 kts in 5 seconds	Same as 17 and 18
20	1975	Raleigh, NC	B-727	o LDG	0/11	10 dg wndshift, gusts up to 21 kts	3-in-per hour rainfall rate
21	1975	Greer, SC	DC-9	o LDG	0/0	200 dg change in wind direction	Light rain & fog
22	1976	Philadelphia, PA	DC-9	o LDG	0/87	65 kts hdwnd to 20 kts tailwind	Microburst,fast moving,T/Strm
23	1976	Cape May, NJ	DHC-6	o LDG	3/7	Gust to 50 kts	Frontal shear
24	1977	Tucson, AZ	B-727	o T/O	0/0	30 kts hdwnd to 30 kts tailwind	Microburst
25	1979	Atlanta, GA	B-727	● LDG	---	Strong downdraft and headwind	Microburst,T/Strm and rainshower
26	1980	Valley, NE	UNKN	o LDG	13/2	Dual engine flameout	Bow echo and heavy rain
27	1982	New Orleans, LA	B-727	o T/O	153/9	Hdwnd,tailwind and downdraft shear	Microburst with heavy rain
28	1982	LGA, NY	B-727	● LDG	0/0	Severe wind at 20 to 100 ft AGL	Strong T/Strm, gusty wind
		Totals		o 25 Accidents ● 3 Incidents		504 Fatalities 208 Injuries	

Doppler radar has revealed that microbursts have five distinct stages of development (Figure 1). The most dangerous winds occur approximately five minutes after the downburst reaches the surface and are almost completely spent five minutes later (8:5). This relatively short active period and small size are the primary differences between micro and macroburst wind shear.

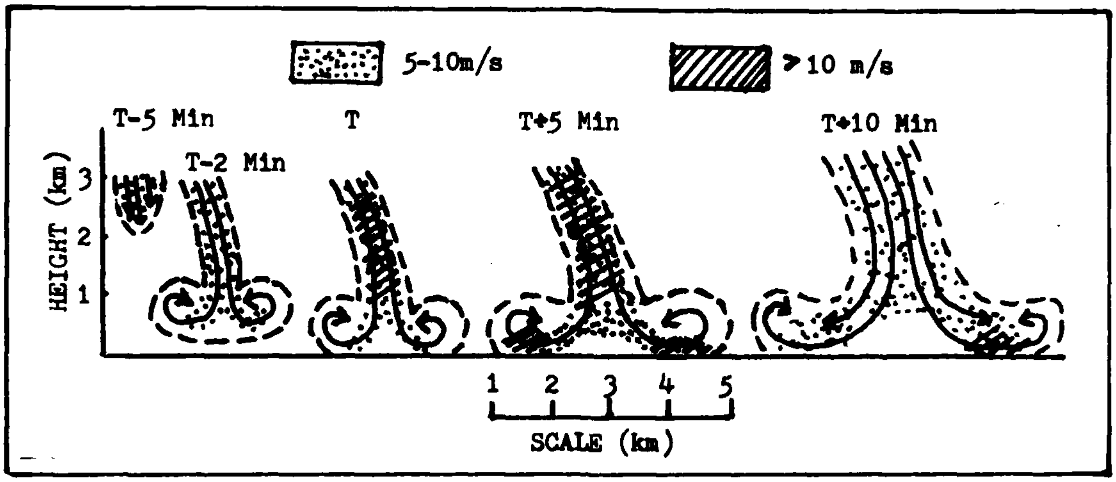

Figure 1. Five Stages of Microburst Development
Source: (8:5)

Microbursts can be further subdivided as wet or dry types depending on the amount of rain which accompanies them. If the microburst has equal to or greater than 0.01 inch of rain during the period of peak winds, it is considered wet. If it has less than 0.01 inch of rain between both the onset of high winds and the end of the microburst winds (including the calm period, if any), it is considered dry (7:22). Generally, there is no substantial difference in the severity of wet or dry microbursts. Either is fully capable of producing severe winds (5:38).

In 1975, Dr. Fujita theorized that microburst winds contributed to three weather-related accidents that occurred during that period; however, his finding was considered controversial by a large segment of the scientific community as he explained in the following quote:

> . . .the concept of the downburst (a strong downdraft which induces an outburst of damaging winds on or near the ground), which was originated after the analysis of the JFK accident on June 24, 1975, was regarded as controversial. It was because only a handful of meteorologists, at that time, could visualize that a downdraft descends to as low as 300 ft (100M) above the ground before spreading out violently. On the contrary the downdraft, as revealed by the Thunderstorm Project (1946-47), was assumed to lose its downflow speed long before it reaches the ground. Therefore, an aircraft flying beneath a downdraft should not be

affected by either downflow or strong outflow winds as long as its flight altitude remains close to the ground (5:Preface).

In 1978, during the Northern Illinois Meteorological Research on Downburst (NIMROD), Dr. Fujita used a Doppler radar to prove conclusively that microbursts did exist and did present significant hazards to low-level aircraft (18:80). It is hazardous because of its extremely small size and because meteorologists cannot yet effectively predict when it will occur. Also contributing to the problem is a general lack of knowledge in the aviation community (7:1-2).

Because a microburst is normally less than four kilometers (km) in diameter, aircraft operating at low altitudes and airspeeds experience difficulty with the sudden downshear and tailwinds. Unless the crew reacts promptly to these conditions, serious loss of lift occurs, accompanied by descent rates that are difficult to arrest (19:8-11). The aerodynamic principles involved are discussed in Chapter Four.

The conditions which spawn MBWS are thunderstorms and convective clouds, but meteorologists are unable to accurately forecast when or where they will occur. Additionally, even though MBWS is always associated with thunderstorms or convective clouds, it is important to understand that even the most benign looking clouds can cause them (14:42) and that lightning may or may not be present (7:20).

The final factor that makes MBWS so dangerous is the widespread lack of accurate knowledge within the aviation community (7:12-13). This is clearly pointed out by the literature in existence today which provides pilot recommendations for MBWS avoidance. In one specific example, an author (2:Cover) states the following as he describes how best to avoid becoming a MBWS accident statistic: ". . .in nearly every case of a thunderstorm-related air carrier accident, the aircraft penetrated a heavy rain cell during final approach... it only serves to reinforce the conclusion that taking off or landing through rain from a thunderstorm is potential suicide" (2:59-61). Although this is certainly good advice, it ignores the fact that not all MBWS has associated rain that actually reaches the surface. In fact, research conducted during project NIMROD found that of 50 microbursts detected, 18 did not have associated rain and concluded that wind shear is apparently not related to rainfall intensity (7:22). The same author also implies that downburst wind shear is always associated with thunderstorm activity which is not the case. This misconception is pointed out in the following quote by the Committee on Low-Altitude Wind Shear and Its Hazard To Aviation: "Most (microbursts) were not associated with active cumulonimbus clouds but rather occurred under streaks of evaporating precipitation (virga) from dissipating cumulonimbus or dissipating cumulus congestus clouds" (7:22).

In summary, microburst wind shear occurs when a rapidly moving downflow of air strikes the surface of the earth vertically and spreads out violently in all directions.

Microbursts are always associated with convective clouds or thunderstorms, but the clouds which spawn them can be very innocent looking and free of lightning. They also can occur with or without accompanying surface rain, and either kind is capable of producing severe winds on or near the surface.

MBWS is extremely hazardous to all low-level aviation traffic because: (1) it is extremely difficult to determine when or where it will strike, (2) it is so small and intense that aircraft experience difficulty with its diverging winds while in critical flight conditions, and (3) the aviation community, in general, does not have the knowledge to effectively avoid and/or cope with it if inadvertently encountered.

Because weather forecasters know the conditions conducive to MBWS formation, but are unable to determine when or where it will actually occur, detection is paramount. The next chapter discusses the low-level wind shear alert systems in use in the United States today and the next generation wind shear detection devices being evaluated.

Chapter Two

MICROBURST DETECTION

> Ideally, any technological solution to wind shear detection and warning must provide the following to the users, presumably controllers and pilots:
>
> (1) A high probability of detection,
> (2) A low number of false alarms,
> (3) Accurate measurement of the level of hazard,
> (4) A high degree of automation of the hazard information, and
> (5) A clear direct transfer of the hazard information to the aviation users (9:App E).

The preceding quote from the Interim Report of The Joint Airport Weather Study (JAWS) Project at the National Center for Atmospheric Research (NCAR) specifies what the ideal low-level wind shear alert system should be capable of. Unfortunately, the current level of detectors falls short of those goals. However, research is on-going, both to improve the current system and to devise improved methods of wind shear detection. This chapter investigates progress made to date.

Currently, there are two broad-based categories of wind shear detection systems - ground based and airborne (10:1-5).

A. Ground Based:

(1) The primary ground-based system is the FAA's low-level wind shear alert system (LLWSAS) which is in use at 59 airports across the United States and is scheduled to be installed at 51 others by 1985 (Table 2) (7:17;10:5). The LLWSAS was developed in the mid-1970s in response to the wind shear-related airline crashes (14:5-6) which occurred during that period. It was proposed by the National Oceanic and Atmospheric Adminstration's (NOAA) National Severe Storms Laboratory as a surface wind-measuring system centered on and around the airfield (9:1-5). The system consists of a series of anemometers which measure windspeed and direction. The anemometers are connected to a central anemometer that signals a central processor which produces an alert in the control tower if a shear is detected (Figure 2) (21:19).

The LLWSAS has been successful in detecting large air mass wind shears such as those associated with gust fronts but tests conducted during the JAWS Project in 1982 showed that it was not effective in detecting small microburst wind shears (9:7). The problem centered around the spacing of the sensors, the time required to process the signals, and a tendency of false reports when wind shear was not present. Additionally, the LLWSAS (since it is ground based), does not detect shears located away from the surface of the earth or vertical shears. The JAWS Interim Report further stated that the current LLWSAS is useful and that with modification should "be capable of detecting a high fraction of the dangerous wind shear conditions in the vicinity of airports including microbursts that have reached the surface" (9:App E).

(2) Dr. Al Bedard of the NOAA's Wave Propagation Laboratory in Boulder,

IN OPERATION (59 UNITS)

Albuquerque, NM
Atlanta, GA
Baltimore, MD
Birmingham, AL
Boston, MA
Buffalo, NY
Charlotte, NC
Chicago (O'Hare), IL
Cincinnati, OH
Cleveland (Hopkins), OH
Columbus, OH
Dallas/Ft. Worth, TX
Dayton, OH
Denver, CO
Des Moines, IA
Detroit (Metro.), MI
Ft. Lauderdale (Int.), FL
Houston (Int.), TX
Houston, TX

Indianapolis (Int.), IN
Jackson, MS
Jacksonville, FL
Kansas City (Int.), MO
Knoxville, TN
Las Vegas, NV
Little Rock, AR
Los Angeles, CA
Louisville, KY
Memphis (Int.), TN
Miami, FL
Milwaukee, WI
Minneapolis (Int.), MN
Mobile, AL
Nashville, TN
New Orleans, LA
New York (Kennedy) NY
New York (LaGuardia) NY
Newark (Int.), NJ
Norfolk, VA

Oklahoma City, OK
Omaha, NE
Orlando (Int.), FL
Philadelphia (Int.), PA
Phoenix, AZ
Pittsburgh (Int.), PA
Raleigh-Durham, NC
Roanoke, VA
Rochester, NY
St. Louis (Int.), MO
Salt Lake City, UT
San Antonio, TX
San Juan, PR
Sarasota, FL
Tampa, FL
Tulsa, OK
Washington (Dulles), VA
Washington (National), VA
W. Palm Beach, FL
Wichita, KS

TO BE INSTALLED (51 UNITS)

Albany, NY
Asheville, NC
Augusta, GA
Austin, TX
Baton Rouge, LA
Billings, MT
Bristol, TN
Cedar Rapids, IA
Charleston, SC
Charleston, WV
Chattanooga, TN
Colo Spgs, CO
Columbia, SC
Columbus, GA
Dallas-Love, TX
Daytona Beach, FL
El Paso, TX

Fayetteville, NC
Fort Smith, AR
Fort Myers, FL
Grand Rapids, MI
Green Bay, WI
Greensboro, NC
Greer, SC
Honolulu Oahu, HI
Huntsville, AL
Lansing, MI
Lexington, KY
Lincoln, NE
Lubbock, TX
Madison, WI
Midland, TX
Moline, IL
Monroe, LA

Montgomery, AL
Pensacola, FL
Peoria, IL
Richmond, VA
Rochester, MN
San Francisco, CA
Savannah, GA
Shreveport, LA
Sioux City, IA
Sioux Falls, SD
Springfield (Capitol), IL
Springfield, MO
Syracuse, NY
Tallahassee, FL
Toledo, OH
Tucson, AZ
Windsor Locks, CT

Table 2. Low-Level Wind Shear Alert System Locations and Proposed Locations
Source: (21:21)

Colorado, developed the second system which is called the Pressure Jump Array Detector. This system works on the theory that a wind shear results in a rise in pressure at the surface of the earth which can be detected before the shear actually strikes (9:App A). Dr. Bedard's latest findings (December 1984) indicate that the Pressure Jump System produces the best results when used in conjunction with the current anemometer systems. When used in this configuration, the number of false alarms was reduced and it was determined that up to a two minute warning could be achieved by detecting the pressure change which accompanies a microburst (22:1-2).

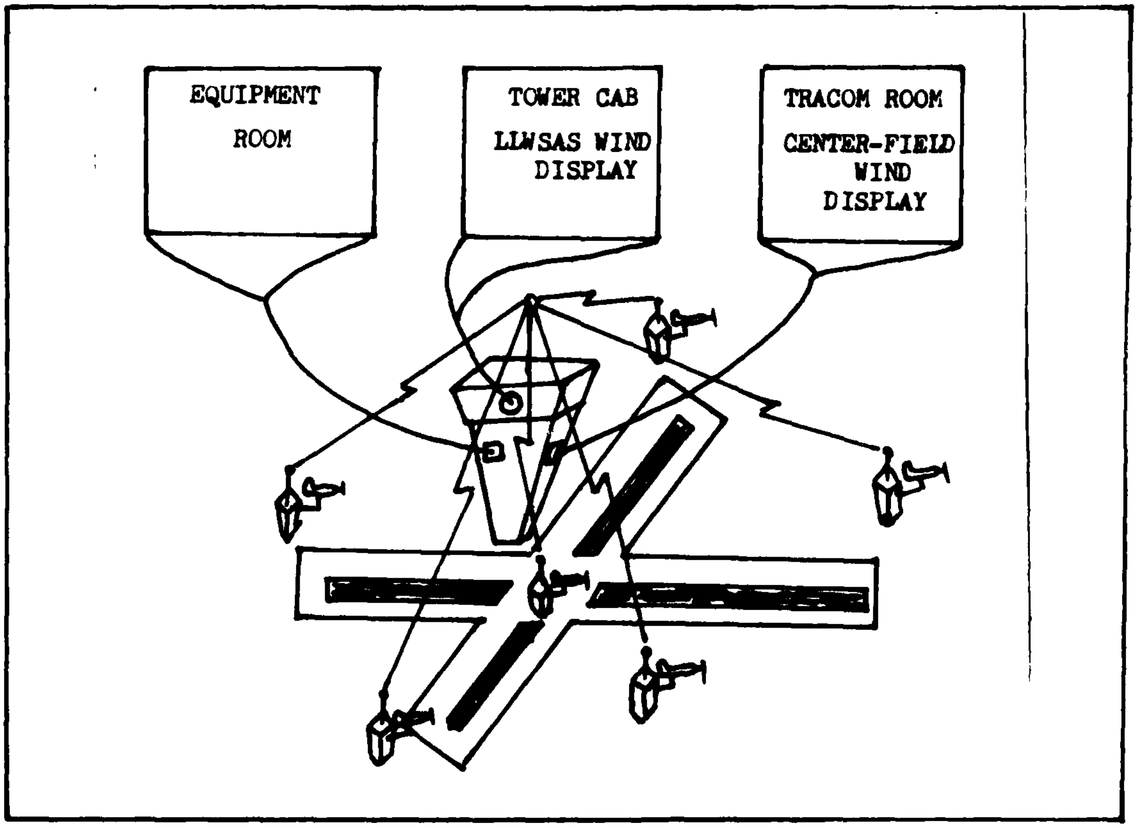

Figure 2. Typical LLWSAS Layout
Source: (21:19)

(3) The third ground-based system is Doppler radar. So far, Doppler radar has proved to be the most effective ground-based system for detecting microburst wind shear. During the JAWS experiments, Doppler radar systems were rated as impressive with approximately 60 microbursts detected "in a manner quite capable of producing accurate and timely warnings to the aviation system. . ." (10:4). Doppler radar is effective in detecting MBWS because, unlike conventional radar, it measures actual wind velocities within the air mass by detecting the shift of particles in the atmosphere (rain

drops, hail, dust, etc.) to determine the actual wind velocity and direction. Standard weather radar is unable to measure speed and direction of winds within a storm because it works on the reflectivity of the mass which indicates the degree of moisture associated with the storms and not what is actually taking place within the storm. Additionally, conventional radar cannot detect clear air turbulence or rain-free microbursts; however, Doppler radar is very effective in detecting them because it works extremely well in clear air (18:80).

Doppler radar, when used to detect MBWS, can be configured in the following three ways:

(1) Single Doppler on the airfield.
(2) Single Doppler off the airfield.
(3) Dual Doppler off the airfield.

The JAWS experiment revealed that the most preferable configuration was the dual Doppler system because every aspect of the wind shear could be detected. The dual Doppler should be located approximately 14 km from the airfield and situated 90 degrees to each other (Figure 3). Unfortunately, this system is

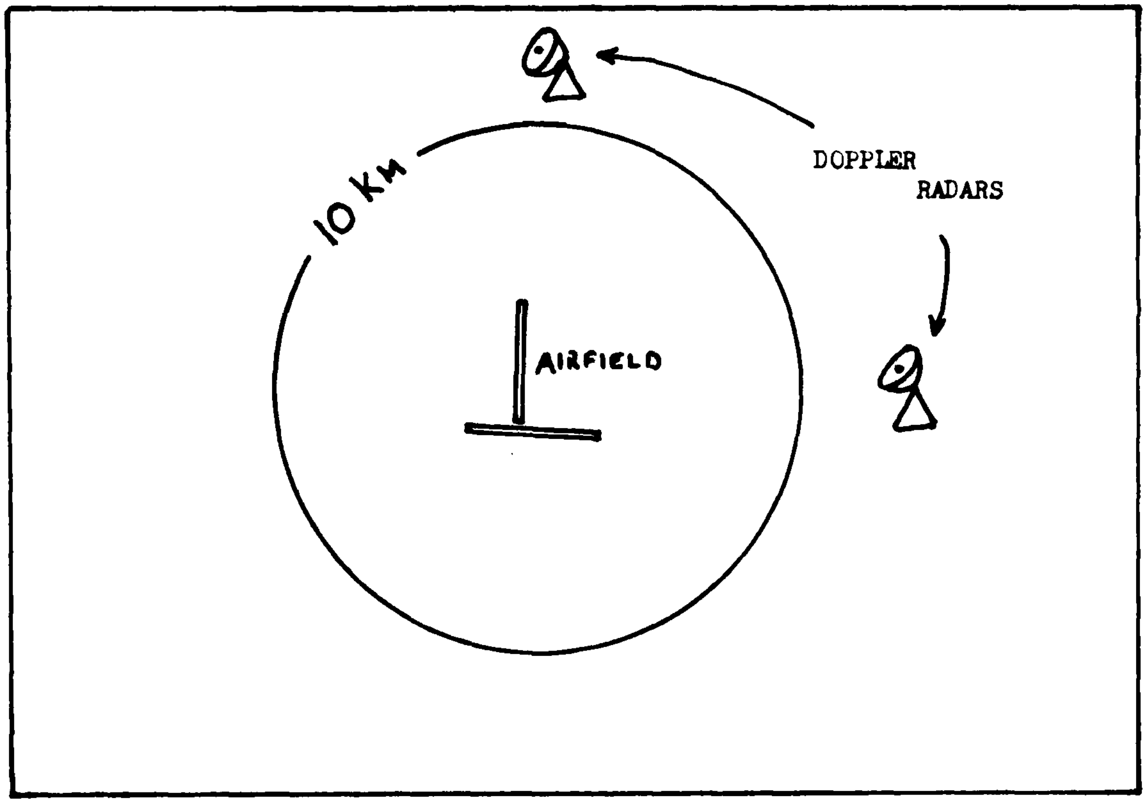

Figure 3. Dual Doppler Configuration
Source: (13:907)

at least twice as expensive as single Doppler systems and requires more time because data from both radars must be integrated for usable information (13:898-914).

B. Airborne Systems: There are four basic microburst airborne detection systems available today in various stages of development and in use within the European and US communities. During the JAWS Project, three systems were tested on a Hawker-Siddiley 125 (HS125) test bed belonging to the United Kingdom's Royal Aircraft Establishment (RAE) and two systems were tested on a Beechcraft King Air belonging to the University of Wyoming. The RAE participated in the JAWS Project as an addendum to MBWS testing currently being conducted in the United Kingdom. Results from the airborne tests will be reported in both countries when the data become available (9:App A).

The four airborne systems, the theory behind them, and their relative value in MBWS detection are discussed below:

(1) The Airspeed and Groundspeed System. The Airspeed and Groundspeed system detects subtle decreases in aircraft groundspeed which could indicate that the aircraft is beginning to penetrate the outflow segment of a microburst. It then signals the pilot to add power in anticipation of the downflow and tailwind component that will follow initial penetration of the microburst. Essentially, this system provides the pilot with an advanced warning (over actual pilot perception) of impending wind shear so that corrective action can be initiated in a timely manner (9:App E).

(2) The Laser True-Airspeed (LATAS) System. The LATSAS closely resembles the Airspeed and Groundspeed System except that it incorporates a Doppler radar in the nose of the aircraft. The radar measures the windspeed and direction approximately 250 meters ahead of the aircraft and alerts the pilot of potentially hazardous conditions before the aircraft actually reaches the wind shear. Minutes of the American Institute of Aeronautics and Astronautics (AIAA) 21st Aerospace Sciences Meeting revealed that the LATSAS System provided wind shear data two to three seconds faster than the Airspeed and Groundspeed System and "when both systems are coupled together provided a substantial advantage with regard to anticipation of wind" (9:App A).

(3) The Velocity/Energy Rate System. The Velocity/Energy system is similar to the first system in that it "senses" the initial beginnings of wind shear rather than detecting it ahead of the aircraft. The vertical velocity system works on the principle that once an aircraft has stabilized in a particular regime of flight (such as final approach or during climbout), any changes induced by different wind components will produce vertical accelerations on the airframe. These vertical accelerations are then transferred to the pilot who adds power, as needed, to fly through the wind shear (9:App A).

(4) Modified Weather Radar. The fourth system is a modification of the standard airborne weather radar to incorporate storm scope information. This system, being developed by the Bendix Corporation, converts the electrical energy associated with wind shear turbulence into the overall weather radar picture. This electrical charge is not lightning (which is the discharge of atmospheric electricity) but rather the electrical charge resulting from

atmospheric friction caused by the turbulence. The system is currently under production; however, operational results are not available (23:1-2).

Advanced warning, rather than actual penetration of MBWS, is preferred because the shear can be avoided. In this regard, systems two and four have an advantage over one and three since they both detect the microburst ahead of the aircraft.

It is interesting to note that one US commercial carrier and one foreign aircraft manufacturer have already altered their current airborne weather radars to incorporate a Doppler feature designed to spot turbulence in what may otherwise seem to be a smooth area (20:196). Although MBWS was not specifically mentioned, the radar should be invaluable in the detection of MBWS.

Since 1982, wind shear detection and avoidance have received considerable attention and resulted in numerous studies to determine the extent of the problem and how best to cope with it. One particular segment of the aviation system which has not benefited as much as the others is the rotary-wing community because of the different ways in which this category of aircraft is operated.

Helicopters routinely operate in areas not covered by any type of wind shear detection system. Also, they are usually not equipped with sophisticated electronic detection equipment. As a result, it is imperative that this segment of the aviation community be educated in the recognition of visual clues which signal potential and/or existing microburst conditions. The next chapter discusses non-electronic detection/avoidance of microburst wind shear.

Chapter Three

NON-ELECTRONIC DETECTION/AVOIDANCE OF MICROBURST WIND SHEAR

For years, pilots have been warned to steer clear of thunderstorms and other convective clouds because of associated hazards such as turbulence, heavy rain, lightning, hail, and gusting winds (7:11). With Dr. Fujita's confirmation of the existence of MBWS, another known hazard is added to low-level aircraft traffic. Though MBWS is not new to nature, it is new in a relative sense in that it has only been a short time since it was proved to be a significant hazard.

Unfortunately, little work has been done to aid the pilot who operates in remote areas or who does not possess the sophisticated on-board equipment to detect MBWS (7:2). The helicopter segment of the aviation system (both military and civilian) routinely operates below 1,000 feet above ground level (AGL) and often below 500 feet AGL, and as such, probably faces a far greater exposure to MBWS.

Even though the accident statistics do not reflect any kind of a pattern for MBWS-induced helicopter accidents, it is important to remember that the same aggressive, detailed investigation which goes into air carrier accidents generally is not applied to general aviation accidents. Many accidents credited to weather may, in all actuality, have occurred because of MBWS (7:12). Regardless of the history of helicopter accidents directly related to MBWS, it is now recognized as an extreme hazard to all air traffic, including helicopters (7:51).

Given the seriousness of MBWS and the lack of sophisticated electronic detection equipment available to helicopters (either on-board or ground based), it is imperative that the helicopter community be educated on visual detection of MBWS. Accordingly, the following list of conditions signals the potential for, or the existence of, MBWS:

A. Conditions which indicate the existence of MBWS.

(1). Due to the nature of MBWS, it is extremely limited in the area that it covers (four km or less in diameter) and therefore produces very localized winds. Any isolated gusty conditions indicated by swaying trees, blowing dust, or the surface disturbances of a body of water may signal an active microburst. Though the conditions may seem innocuous, it is important to remember that the "average" microburst may produce wind divergences of 35 to 40 knots and is always accompanied by a core of down-rushing air. Additionally, the portion of the MBWS that actually reaches the surface may be relatively small or even mild when compared with the conditions that may exist somewhere above the surface and not visible to the naked eye (21:21).

(2). Many of the dry microbursts recorded during the JAWS Project at Denver Stapleton Airport had accompanying virga (precipitation that evaporates before it reaches the ground). If at all possible, low-level flight through or near virga should be avoided. The microburst downdraft that accompanies virga is actually created by the momentum of the falling rain. In an article published in a recent US Army Aviation Digest, personnel of the US Army Safety Center stated that "virga virtually assures that a fast moving downdraft exists" (21:19).

(3). Dr. Fujita specifically states that "localized showers, either heavy or very light, may induce microburst winds" (4:37). It is also important to remember that the showers do not have to be associated with active thunderstorms, and that even relatively mild-looking clouds can result in microburst activity.

(4). Due to the mechanics of a microburst, it produces horizontal winds radiating 360 degrees from the core of down-rushing air. As an aircraft encounters the fringes of the horizontal wind, it will pitch up momentarily and the indicated airspeed will increase relative to the wind velocity. If the aircraft encounters the microburst off-center, the cockpit indication may be a smaller increase in airspeed and altitude accompanied by a "crab" angle to maintain the desired ground track, or the aircraft may actually lose altitude (7:61-62;6:38-40).

(5). Probably the most effective means of detecting/avoiding microburst wind shear is via the pilot-to-pilot or pilot-to-controller route. It has always been mandatory for pilots to report unusual or unforecast weather conditions but due to the uniqueness of MBWS, often it is not reported. The FAA, in an attempt to standardize wind shear terminology, now specifies the terminology to be used by aircraft to report encounters with wind shear. The current Airman's Information Manual (AIM) contains the format to be used. The report basically requests that the effects of the wind shear on the aircraft be reported in terms of loss or increase in airspeed and the altitude at which it occurred. If the pilot is unable to give specific terms for airspeed and altitude, the actions taken to overcome the shear should be stated (16:525).

These reports at major airfields are invaluable. However, this again reveals a disadvantage for the rotary-wing pilot who is not operating from an improved area. Although the AIM's request for microburst pilot weather reports (PIREPs) is not mandatory, the rotary-wing community should adopt it as standard practice. This would increase the emphasis on microburst detection and would aid in early detection and/or avoidance. Specific examples of instances where MBWS PIREPs may be valuable to helicopter operations are:

(1) While flying in light rain, the lead element of a two-ship, nap-of-the-earth (NOE) mission (separated by several minutes) encounters a very mild MBWS easily traversed and requiring power settings only slightly more than normal to maintain altitude. Knowing the dynamics of MBWS formation, the pilot realizes that his encounter may well have been only the initial stage of

the wind shear. Therefore, he is able to warn the trail aircraft of its presence.

(2) During terrain flight, the crews' attentions are directed to the immediate tasks of obstruction avoidance and navigation and in many instances, the horizon and airspace above the aircraft are not within the crews' field of vision. Because of this, important microburst danger signals (such as virga) may not be noticed. A PIREP from another ship within the area or from a safety or cover aircraft could alert the crew to the danger.

B. Conditions conducive to the formation of microburst wind shear.

As stated previously, MBWS is spawned by either thunderstorms or convective clouds. In many instances, the same conditions which produce tornados are also favorable for the formation of downburst activity.

> Using a doppler radar during the JAWS project, scientists were able to identify three types of microbursts: (1) A divergent outflow associated with a mature convective cell which had a rain core reaching the surface (wet microburst) (2) a smaller scale divergent outflow embedded within a larger scale outflow from a mature convective storm (embedded microburst), and (3) a divergent outflow associated with smaller convective cells where significant rain is not reaching the surface (dry microburst) (11:5).

The preceeding quote (taken from the report Research from the JAWS Project at NCAR) categorizes the three types of detected microbursts. It is highly unlikely that the microburst occurrences could be seen without radar; however, the conditions which caused them are recognizable. It would be, however, incorrect to state that only the most dangerous-looking clouds were potential hazards because the reverse is often true (4:37).

The dry microbursts observed in the Denver area during the JAWS Project that were not associated with active thunderstorms would have been virtually impossible for a pilot to detect because there were often only very mild cloud formations from which they originated. Meteorologists do have a theory as to what synoptic (large scale) conditions can produce microbursts but actual prediction remains somewhat sketchy. They do know that dry microbursts are the result of evaporating precipitation (virga), and that its negative buoyancy actually produces the vertical velocity of the microburst (12:537-542). Because of the innocuous conditions which produce some dry microbursts, only a trained weather forecaster could reveal potentially hazardous conditions. On the positive side, it is important to remember that virga virtually always accompany dry microbursts, making visual detection, in some cases, possible.

In summary, helicopter operations in remote areas are probably devoid of any kind of electronic wind shear detection equipment, making visual detection very important. A pilot should ensure that preflight planning includes a thorough microburst briefing and that the conditions favorable for microburst formation are known. Localized dust clouds, virga, or sudden increases/ decreases in performance are signals which may indicate the presence of active microbursts. Very often, the only microburst warning in a remote area will be via PIREP. Pilots should make it policy to report any occurrence, no matter how slight, so that all aircraft within the area can be warned.

The next chapter provides an in-depth discussion of the hazards associated with helicopter flight in or around microbursts.

Chapter Four

THE HAZARDS OF ROTARY-WING FLIGHT IN A MICROBURST ENVIRONMENT

Microburst wind shear is hazardous to helicopters for basically the same reasons that it is hazardous to fixed-wing aircraft. It affects both by a systematic loss of lift which occurs following downdrafts and tailwind conditions which are undetected by the crew until the aircraft has penetrated the wind shear. The majority of the MBWS could be handled by most aircraft at altitude (above 1,000 feet); however, encounters below 500 AGL can pose a significant hazard to any kind of aircraft, including helicopters (7:4).

Admittedly, no documented research has been conducted which deals specifically with helicopters and microburst wind shear but its potential hazards are well documented by the FAA and weather scientists who have devoted many hours to the study of wind shear. This fact is evidenced by the following statement taken from the report issued by the Committee On Low-Altitude Wind Shear And Its Hazard To Aviation; "wind shear represents a hazard to all aircraft,* ranging from small general aviation aircraft to swept-wing jet transports" (7:4). The committee also summarized that some microburst wind shear recorded during the JAWS Project was so intense that no aircraft could have safety penetrated it below 300-500 feet AGL during takeoff or landing (7:1-4).

Dr. Fujita has similarly recorded or studied microbursts that were so violent that safe penetration was highly improbable at any altitude. In one particular instance at Andrews Air Force Base in 1983, he recorded a microburst that generated wind in excess of 130 knots followed by a short calm period with a sudden wind reversal that measured 82 knots. The microburst was "spawned by a small thunderstorm, the top of which was located three nautical miles northwest of Andrews Air Force Base when the microburst hit the runway area. The thunderstorm moved toward the east-north-east, but the microburst shot out of the cloud toward the east-southeast 30 - 40 degrees to the right of the thunderstorm motion" (4:36). The preceding quote taken from Dr. Fujita's conclusions after he studied the Andrews microburst dramatically sums up the threat which MBWS presents to all air traffic, including helicopters. Dr. Fujita feels so strongly about microburst wind shear that he recommended that "the helicopter route from Andrews AFB to the White House be monitored by doppler radar" (4:36).

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*In its summary, the Committee specifically defined the term aircraft as commercial transports, general aviation aircraft, helicopters, and airships (17:1).

The only reported incident that directly involved a helicopter encountering a microburst was recorded in 1975 by Dr. Fujita during investigations involving a B-727 that crashed while landing in heavy rain. The helicopter was in cruise flight at 1,200 feet when it encountered a localized heavy rain shower, causing it to rapidly lose 600 feet even though the crew held maximum continuous power. Once the aircraft flew through the rain, the conditions returned to normal (6:32). Dr. Fujita attributed the loss of altitude to the rapidly flowing column of air of a descending microburst. Fortunately, the helicopter had sufficient altitude to arrest the descent; however, the example does reinforce the hazards to helicopters, particularly those engaged in terrain flight.

The remainder of the chapter will use the known effects of microbursts on airplanes to subjectively analyze how a similar wind shear would affect a helicopter. And, although the effects would not be identical, they should be similar, since both move airfoils through the atmosphere to create lift and both have the same three axes of motion (pitch, roll, and yaw) (15:3-1).

The most critical aspect of loss-of-lift situations involving fixed-wing aircraft is a sudden degradation of airspeed which corresponds to a drastic loss of lift and altitude. This fact is exemplified by the fact that lift varies as the square of the velocity (15:2-10). Consequently, any decrease in airspeed, such as that experienced in a sudden tail wind condition, results in a corresponding loss of lift if all other values remain constant (7:61). Helicopters are similarly affected by tailwinds, especially if they are at or near their power limits. This statement is brought out very clearly in the following quote from an early book on helicopter aerodynamics;

> The marginal hovering performance of many present-day helicopters has resulted in the loss of several machines in the hands of inexperienced pilots. When flying close to the ground there is a tendency to fly by ground speed rather than according to the airspeed indicator. If winds are involved a "downwind turn" may result in zero airspeed, so that the machine will settle to the ground. Again the helicopter may be hovering in a wind above some obstacle, such as a row of trees. When the helicopter drops below the trees, where the wind is decreased, it is unable to hover and settles to the ground (1:39-40).

In addition to the loss of lift that accompanies the tailwind condition, the downflow in the center of the microburst also contributes to the overall loss of lift. This occurs because as the aircraft enters the downflow, it pitches over which decreases the angle of attack (7:61).

The following step-by-step discussion of an airplane penetrating a microburst while on final approach and immediately after takeoff will help in understanding exactly what happens and why it happens, and will provide a basis for understanding how the same principles apply to a helicopter under the same conditions:

1. <u>Encounter on final approach.</u> Refer to Figure 4.

As the airplane approaches the initial outflow of the microburst an uncommanded increase in airspeed and angle of attack initially causes the plane to pitch up and climb (a). In response, the pilot reduces power and angle of attack to remain on his approach path. Those descent rates are now aggravated as the airplane encounters the downdraft portion of the microburst which further reduces the angle of attack and increases the descent rate (b). The aircraft now encounters the tailwind outflow segment which again decreases the angle of attack and effectively reduces the indicated airspeed, causing a further reduction in lift (c) (7:61;6:39). At this point, depending on the altitude, the only hope for recovery is to add maximum power and increase the angle of attack to the maximum lift condition (12:10-11). Unfortunately, a common mistake made by pilots at (c) is to lower the nose of the aircraft to regain the reference airspeed which may, depending on the aircraft altitude, make recovery not possible.

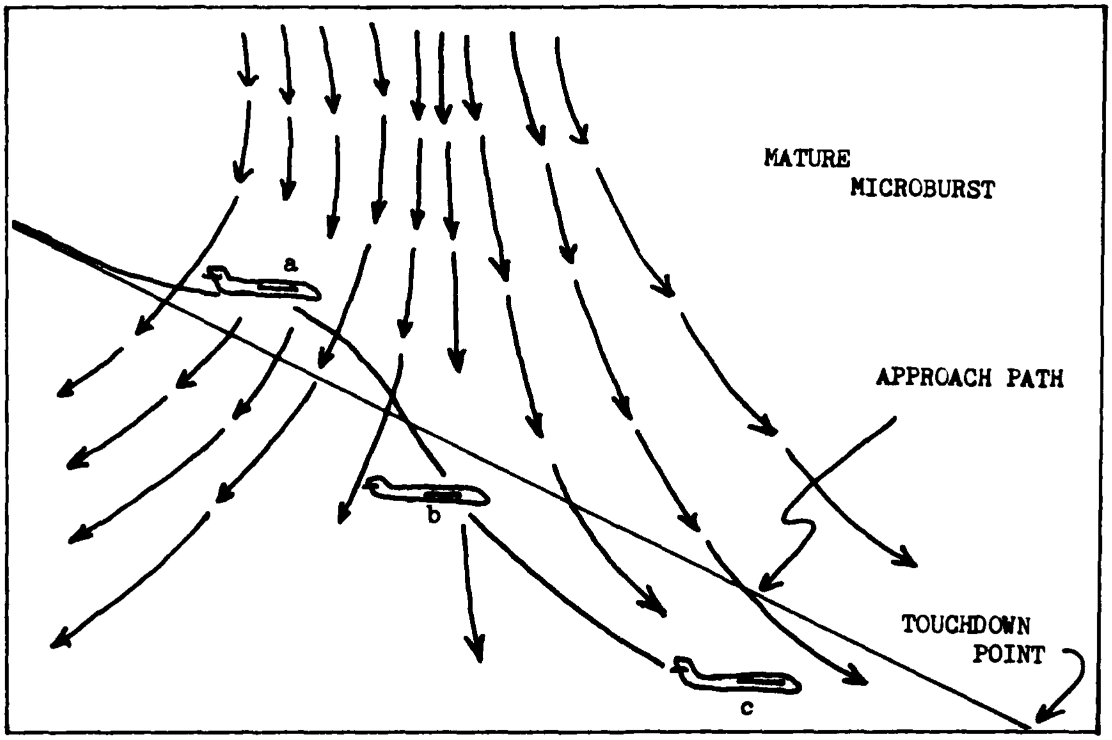

Figure 4. Microburst Encounter on Final Approach
Source: (3:11)

2. <u>Encounter immediately after takeoff.</u> Refer to Figure 5.

Immediately after takeoff, an airplane's power and angle of attack are much closer to the maximum limits than in the previous situation. For this reason, a severe microburst may be more than the airplane can overcome as was the case of the 727 at New Orleans in 1982. In the following situation, the airplane has just taken off and encounters the downburst segment of the microburst (a). As in the previous example, the airplane will lose lift due to a decreased angle of attack followed by a further reduction of lift caused by a loss of airspeed as the aircraft passes through the center of the microburst into the tailwind outflow segment (b). Depending on the actual altitude that the airplane encounters the microburst and the height of the terrain and obstacles, the pilot's only chance for recovery rests with an immediate recognition of the problem at or before (a). This was graphically portrayed in the New Orleans accident when the 727 encountered the shear approximately six seconds after takeoff at 163 feet. In a matter of seconds the 727 lost 110 feet of altitude and the airspeed decreased from a maximum of 162 knots 47 seconds after takeoff down to 144 knots 54 seconds after takeoff. Even though the 727 was climbing at approximately 361 feet per minute when it first impacted a 52-foot tree, it was descending in excess of 1,200 feet per minute just five seconds before the first impact. In his investigation of the accident, Dr. Fujita determined that "the loss of altitude inside the microburst was attributed two thirds to the tailwind and one third to the downflow" (5:36).

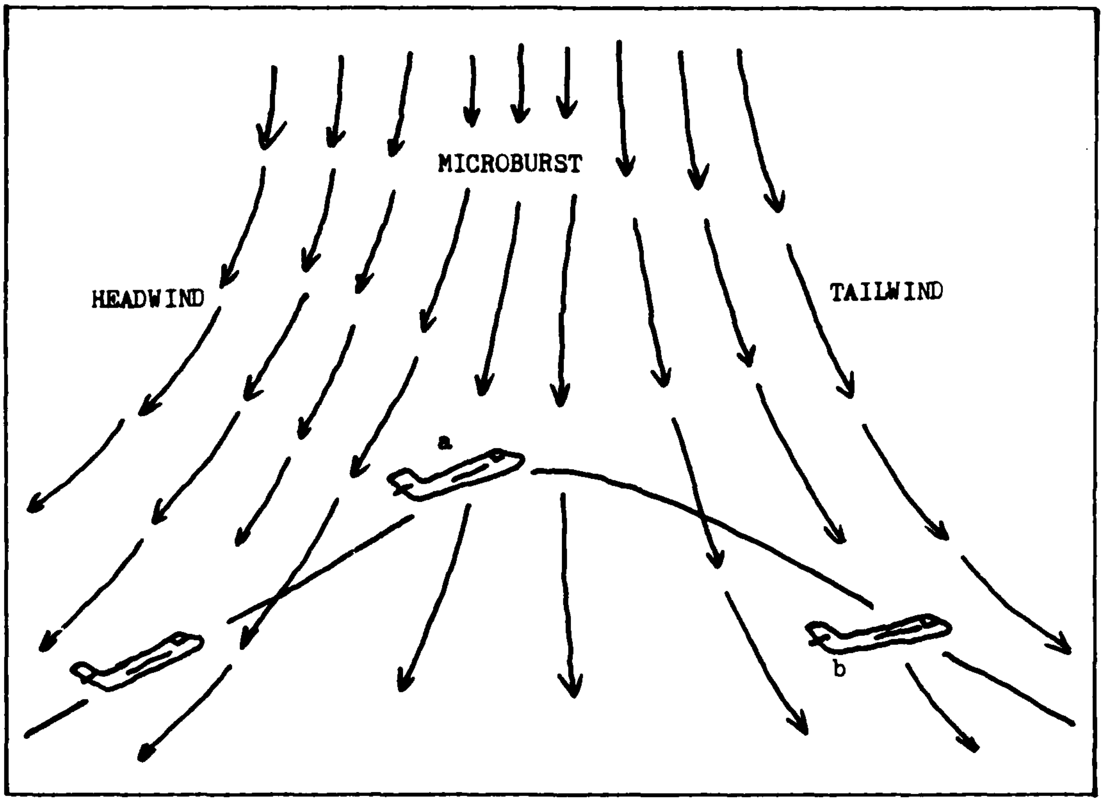

Figure 5. Microburst Encounter Immediately After Takeoff.
Source: (3:11)

In either of the two previous conditions, a helicopter would be affected in a similar manner because the same basic aerodynamic principles apply. What is not known is to what degree the same microbursts would have affected a helicopter.

When comparing the effects of microburst wind shear on the two different categories of aircraft, the following factors, as a minimum, should be considered: stability, power application response time, stall characteristics, and typical mission profiles. The remainder of this chapter examines each of the preceding factors:

1. Stability. In the case of non-stability-equipped airplanes and helicopters, the airplane would tend to be affected the least by microburst conditions due to inherent stability. However, many modern helicopters are equipped with stability augmented systems capable of providing artificial dynamic stability. These systems, along with built-in design factors, reduce helicopter crew work loads to approximately the same as those experienced by airplane pilots. For this reason, microburst conditions would have approximately the same effect on both categories of aircraft.

2. Power application response time. Some airplanes, particularly those powered by jet engines, have a very apparent lag time from throttle movement to engine response. In the case of a microburst encounter at traffic pattern altitudes, this lag time may be critical. Helicopters, on the other hand, are operated at full throttle (governor controlled) throughout the normal flight envelope with power linked directly to the rotor blades (angle of attack). In other words, when a helicopter pilot adds or decreases collective pitch to change the rotor blades angle of attack, the engine power (torque) is reset at the same time. In most situations, power applications up to maximum limits cause no perceivable engine droop and response is almost instantaneous with collective movement. As a result, the helicopter, with all other conditions equal, would seem to have an advantage over fixed-wing aircraft.

3. Stall characteristics. The helicopter, by virture of its whirling rotor blades which are maintained at a constant velocity by a governor, is capable of reducing its forward speed to zero without stalling. This ability to vary airspeed across a much wider spectrum enables a helicopter to convert airspeed to altitude to a larger degree than an airplane without risking a stall. This capability gives the helicopter pilot greater flexibility when faced with an inadvertent microburst encounter.

4. Typical mission profiles. The most unique characteristic of a helicopter is its ability to hover. As such, the hover mission serves as the mainstay of helicopter operations. Typical hover missions include terrain flight (including NOE), pinnacle and confined-area operations, sling loads, and various rescue missions. Since most of these missions occur at relatively low altitudes (below 200 feet AGL) and in close proximity to terrain and obstacles, microburst encounters are extremely critical. In addition to reduced reaction times because of the low altitude, available engine power is also a problem. A helicopter operating at a hover or below effective translational

lift (ETL)* is operating much closer to its maximum allowable power limits and therefore has less of a margin of power to allow it to fly out of critical conditions.

One other factor that could impact on helicopter missions to a greater degree than many airplane missions is the remote areas from which helicopters typically operate. These areas are usually devoid of modern pilot aids such as radar, wind shear indicators, or even weather observations.

In summary, the aerodynamic principles for fixed and rotary-wing aircraft are similar in that both generate lift by propelling airfoils through the atmosphere. Consequently, many of the hazards of MBWS which affect airplanes also apply to helicopters. However, in forward flight above ETL, the helicopter may have an advantage over the airplane because of its reduced engine response time and its ability to rapidly convert airspeed to altitude without the danger of a stall. On the other hand, the helicopter's hover capability places it in low-level altitudes where it faces a greater risk of being affected by the hazards of microburst wind hazards.

Since the extent of helicopter vulnerability is subjective at this time, additional research should be conducted to determine the exact nature of the hazard so that helicopter crews can be educated and prepared to deal with the problem.

The next chapter is a subjective analysis of the perceptions and cockpit indications of a MBWS penetration by a helicopter and appropriate pilot actions.

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*ETL is an airspeed (16-24 knots) at which the helicopter flys into air free of its rotor vortexes thus improving the efficiency of the rotor system. This enables the helicopter to maintain altitude at power settings somewhat lower than those required to hover (15:3-9).

Chapter Five

PILOT PERCEPTIONS, AIRCRAFT RESPONSE, AND SUGGESTED PILOT ACTIONS IF MICROBURST WIND SHEAR IS INADVERTENTLY ENCOUNTERED

This chapter will examine the predicted pilot perceptions and aircraft response upon penetration of a microburst. The microburst dynamics used in the situations were taken from actual case histories of documented fixed-wing microburst encounters and were adopted by the author for use in this project (3:13,21). Also provided will be recommended pilot response actions for each of the following microburst encounters:

(1) During final approach.
(2) During takeoff.
(3) During flight below ETL.

Situation 1, Encounter on final approach. Refer to Figure 6. This situation involves a helicopter on a final approach. The microburst is located 0.5 mile from the approach end of the runway and is centered along the approach path. As the helicopter proceeds on final, the initial phases of the approach are normal. The first indication of impending problems occurs when the helicopter enters heavy rain at approximately 400 feet. The initial outburst winds of 25-30 knots will cause the nose to pitch up, along with a corresponding increase in indicated airspeed (IAS), and the established descent rate for holding the glide path will either lessen or the helicopter will actually begin climbing (a). At this point, without prior warning that microbursts were in the area, or without a Doppler radar warning from the ground, it would be highly improbable that any pilot would be able to correctly determine that the initial stages of microburst penetration were beginning. Normal pilot responses would consist of a power reduction and a re-established pitch attitude so as to regain the approach airspeed and glide path. As the helicopter approaches 300 feet, it passes through the initial outburst and enters the core of the downflowing microburst (b) which would be perceived by the pilot by a noticeable sinking sensation, with a corresponding descent indication on the vertical speed indicator (VSI). A very apparent pitch-over would also probably occur as the helicopter entered the downflow segment. Once the helicopter passes through the core of the microburst and into the tailwind outflow (c), a drop in indicated airspeed would occur, further aggravating the descent and making recovery exceedingly difficult. The combined negative lift effects produced by the downflow and the tailwinds are sometimes too much to overcome as in the case from which this example was taken. Specifically, a 727 was unable to overcome a sudden headwind to tailwind condition which reduced its IAS by 16 knots in seven seconds, combined with a 22 foot-per-minute (FPM) downdraft which caused it to crash 2,400 feet short of the runway. In another instance, a L-1011 initiated a missed approach at 400 feet because of the same microburst conditions and it descended to within 60 feet of the ground before it began climbing (3:13). For these reasons, it is imperative that the microburst conditions (sudden increases or decreases in airspeed with corresponding changes in performance) be recognized as early in the approach as possible so that a timely recovery (missed approach) can be conducted. The recovery should consist of maximum power at best rate-of-climb attitude until clear of the downburst conditions.

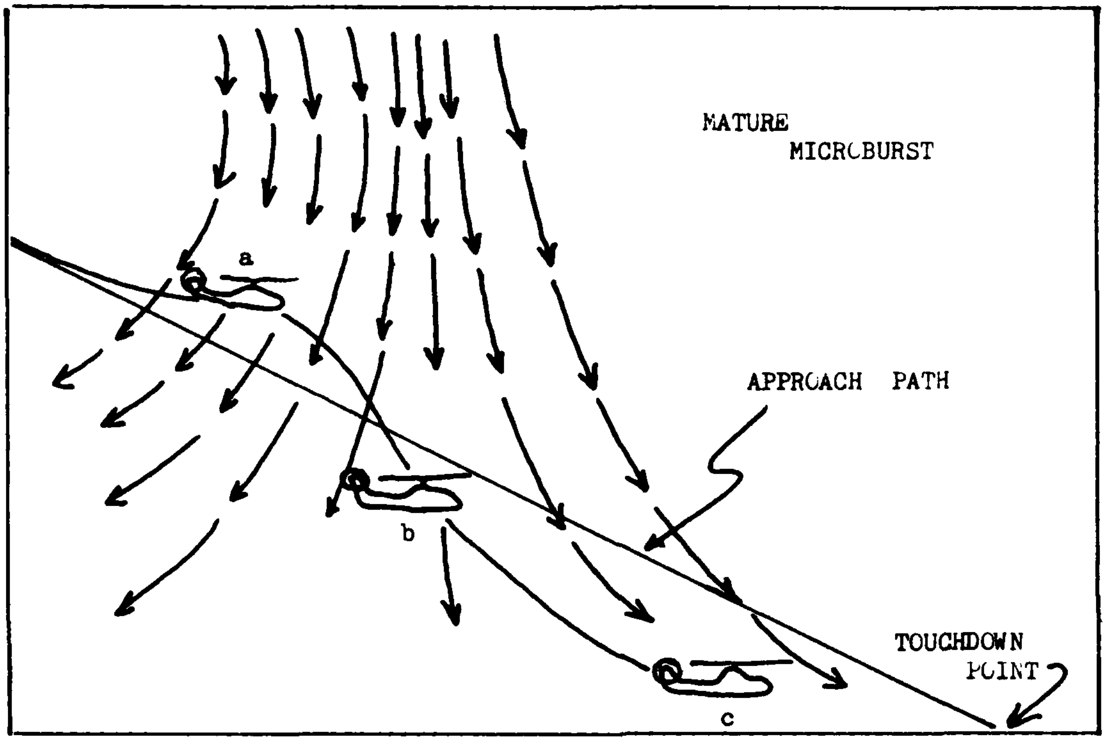

Figure 6. Microburst Encounter On Final Approach
Source: (3:11)

<u>Situation 2, Encounter immediately after takeoff</u>. Refer to Figure 7. This situation involves a helicopter engaged in a sling load mission. The takeoff (a) is made in visual flight rules conditions. At approximately 100 feet, the helicopter encounters rain which necessitates the use of the windshield wipers (b) but does not enter instrument meteorological conditions. At approximately the same moment, the indicated airspeed suddenly drops from 80 to 40 knots in approximately five seconds along with a noticeable sinking sensation with a corresponding descent on the VSI (c). Concerned with the loss of airspeed, the normal pilot response is to lower the nose to regain the lost airspeed. As in the first situation, the recommended pilot response is to apply maximum power and set the pitch attitude on maximum climb attitude regardless of IAS (7:69;19:10-11). In the case of flight-director-equipped helicopters, the go-around mode would be invaluable since it could be selected for immediate pitch

attitude reference. If the descent can not be arrested, the load should be jettisoned without hesitation. In this situation, the normal headwind, and to some degree the downburst portion of the microburst, were not a factor because the microburst occurred adjacent to the takeoff point rather than directly in line with the flight path (3:20).

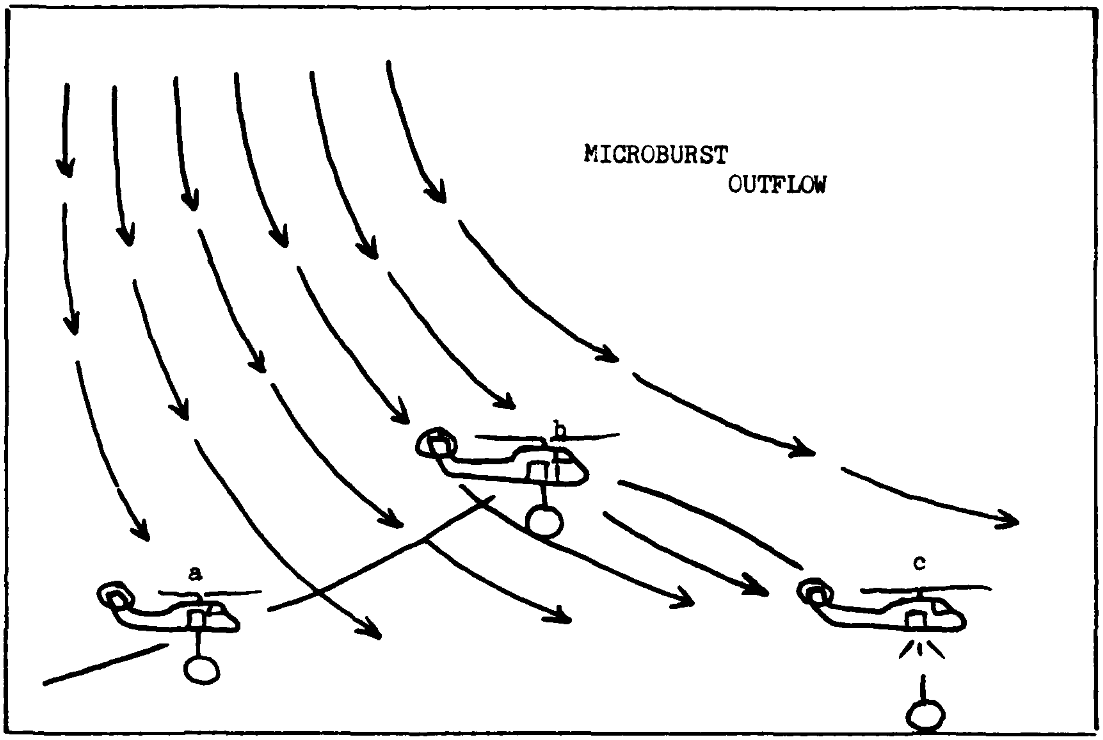

Figure 7. Microburst Encounter During Takeoff
Source: (3:11)

Situation 3. Encounter during NOE flight.

This situation involves a helicopter engaged in NOE flight. As stated previously in Chapter Four, the effects of a microburst on a hovering helicopter are probably more severe than if the helicopter were in forward flight above ETL. The first indication of the impending microburst is a dust cloud approximately one mile to the front, followed immediately by a gusty disturbance in the trees surrounding the helicopter. During the initial outburst portion of the microburst, the helicopter will derive increased lift due to the greater efficiency of the rotor system interacting with the outburst winds. The hovering helicopter's IAS will increase in response to the outflow and, depending on the magnitude of the microburst, may pass through ETL while at a hover. This will necessitate a substantial power reduction in order to maintain a constant altitude and may not be a problem unless the helicopter's flight path continues through the remainder of the microburst. Probably the safest maneuver, at this point of the penetration, is to land and remain at operating revolutions per minute until the disturbance ceases. If a landing cannot be made due to the terrain, an abrupt course change may be best to avoid the core of the microburst. Care should be taken not to expose the helicopter to critical wind azimuths, especially below ETL. The least desirable action would be to attempt to climb out through or along a path parallel to the microburst. This action would unnecessarily expose the helicopter to the full intensity of the wind shear.

Though highly speculative in nature, this chapter attempted to describe probable sequences of events with different microburst encounters. In all three encounter situations, early detection of the microburst is important if a successful penetration or avoidance is to be made. Crews should be especially alert for any danger signal (Chapter Three) that may provide clues as early as possible. Once microburst contact is suspected (whether on final or during takeoff), maximum power should be applied along with a pitch attitude that provides best rate of climb. In the hover situation, flight through or near the center of a microburst would, in all likelihood, be extremely difficult to cope with due to the relative close proximity of the terrain. As in the other two situations, early recognition of microburst danger signals increases the pilot's odds of coping with the wind shear or successfully avoiding it. If a microburst is contacted during a hover, every effort should be made to land. If a landing is not possible, the center of the microburst should be identified and avoided. No attempt should be made to climb out through the center of the microburst.

The next and final chapter summarizes this study and provides recommendations for future, more detailed research involving rotary-wing operations in a microburst environment.

Chapter Six

SUMMARY AND RECOMMENDATIONS

1. Summary.

Since the New Orleans crash which resulted in 153 fatalities, MBWS has received enormous amounts of public attention. As a result, several major studies were sponsored by the US Government to determine the exact nature of the phenomenon and what could be done in the future to prevent similar disasters.

MBWS presents a hazard to low-altitude traffic because: (1) it is almost impossible to predict when or where it will strike, even though the conditions favorable to its formation are known, and (2) because its small size makes it difficult for aircraft in critical modes of flight (landing and taking off) to adjust to its wildly diverging winds. Contributing to the problem is the fact that much of the aviation community is not aware of the seriousness of the hazard.

Many experts feel that an accurate microburst detection system is important because it will preclude or significantly reduce the chances of MBWS related accidents. The FAA's low-level wind shear alert system (currently in use at 59 airfields) was evaluated during the JAWS Project. Results of the study indicated that the LLWSAS was not effective in detecting MBWS primarily because the surface sensors were spaced too far apart, allowing the small, highly transient microburst to occur without being detected. Improvements to the system have been recommended. The system is scheduled to be installed at 51 additional airfields across the United States.

A number of other ground and airborne detection systems, including Doppler radar, were tested and have shown promising results. Doppler radar has the capability to detect developing microbursts which is far superior to the other systems which are activated upon an actual microburst occurrence. This advantage makes Doppler radar the best detection system but its high cost makes it an unlikely candidate for implementation at a large number of airfields in the near future. It has also proved to be effective when used in conjunction with existing airborne weather radar, and as a result, is being installed and used by several air carriers.

Unfortunately, the progress that has been made in detecting microbursts does not apply evenly to helicopter operations. This is true because of the helicopter's unique capabilities which allow it to fly like a fixed-wing aircraft or perform low-speed, low-altitude missions in remote, uncontrolled areas. Little or no emphasis has been placed on the visual, non-electronic detection of microbursts even though a significant segment of the total air traffic routinely operates in areas completely devoid of any type of microburst detection systems.

There are a number of visual danger signals which could indicate the presence or impending occurrence of microbursts: isolated gusty conditions, virga, localized rain showers, and unusual aircraft and/or instrument deviations.

The FAA has standardized its procedures for reporting MBWS. This is a good source of wind shear data and should be used by the helicopter community, even in remote, unimproved areas.

Both airplanes and helicopters are aerodynamically affected by MBWS in a similar manner because both derive lift by interaction of airfoils in the atmosphere. The primary problem is a rapid decay in IAS causing a sudden loss of lift. This is a well-documented problem among large aircraft maneuvering near the ground during landing and takeoff operations. And, although it has not been documented, the same principles should apply to small aircraft and helicopters.

It is important to recognize MBWS in its earliest stages so that prompt action can be taken to overcome its effects. This applies to helicopters as well as airplanes. Complete avoidance is the best way to be completely free of microburst effects, but since that is not always possible, a working knowledge of the effects on the aircraft is necessary to successfully overcome the hazards of MBWS.

The helicopter does appear to have two advantages over the airplane in that the helicopter has a much faster engine response time and is capable of trading airspeed for altitude without as much of a stall risk. On the other hand, the hovering helicopter would appear to be especially vulnerable to MBWS due to the greater demand for engine power and the closeness of the terrain.

Pilot perceptions and recommended pilot responses for microburst penetration by a helicopter are probably very similar to those experienced by fixed-wing pilots. These data were originally to have been derived using the Fort Rucker, Alabama, flight simulators programmed with a National Aeronautics and Space Administration (NASA) three-dimensional microburst math model; however, the degree of work involved to program the simulators was beyond the scope of this study.

The subjective analyses provided in this study were based on actual histories of fixed-wing encounters with microbursts except in the case of hover flight. In this instance, no data could be found to substantiate the subjective analysis; therefore, the scenario is based on the author's opinion.

In both takeoff or landing situations, aircraft response and pilot perception for microburst penetration are significant gain or loss of airspeed, and as the aircraft passes through the downburst portion of the wind shear, a noticeable sinking sensation. In either case, prompt reaction to the microburst conditions greatly improves the chances of recovery. The pilot should select maximum power and a pitch attitude that derive best rate of climb. During hover flight, escape from a mature microburst would be doubtful, making strict avoidance essential. If the initial stages of a microburst are detected, the pilot should land the helicopter or depart the hazard area as quickly as possible.

2. Recommendations.

a. That action be taken to determine to what degree helicopters are affected by microburst contact. In the past two years, microburst simulation testing has been conducted involving fixed-wing aircraft; however, none has been completed on helicopters. A program using established wind shear models and modern helicopter simulators would be a logical first step in determining microburst effect on helicopters.

b. Based on the information obtained above, document and publish approved pilot response actions to best overcome the effects of MBWS.

c. That an educational program within the rotary-wing community be initiated which stresses the hazards of microburst windshear and its associated danger signals so that any future incidents can be avoided. Ideally, the best solution would be to equip all helicopters with modified weather radars that incorporated a doppler or storm scope feature (23:2).

d. That this study be made available to the helicopter community as an interim measure until more objective data are available.

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