FAST

AIRBUS TECHNICAL DIGEST

NUMBER 6
NOVEMBER 1985

Airbus Industrie

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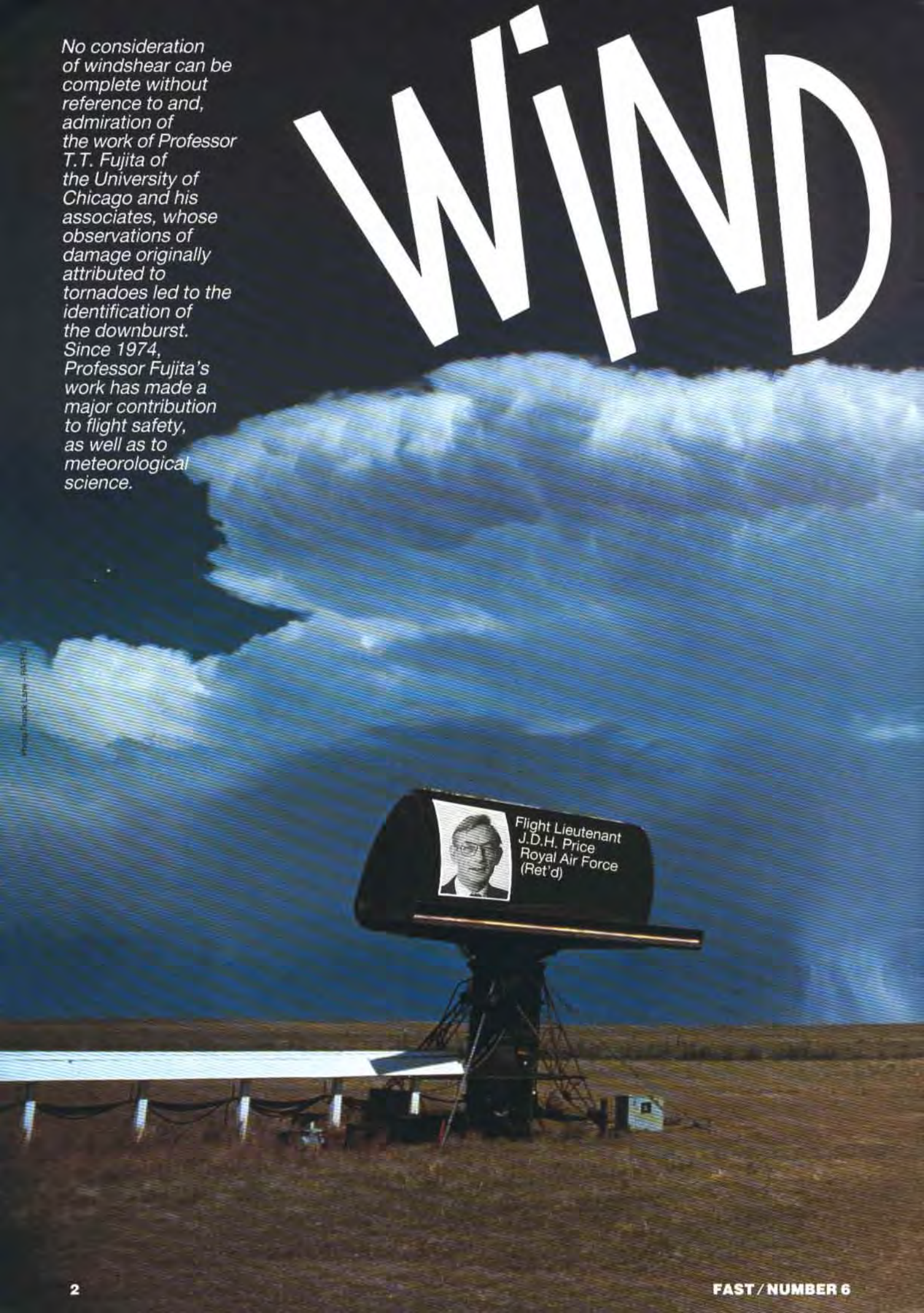
WIND

No consideration of windshear can be complete without reference to and, admiration of the work of Professor T.T. Fujita of the University of Chicago and his associates, whose observations of damage originally attributed to tornadoes led to the identification of the downburst. Since 1974, Professor Fujita's work has made a major contribution to flight safety, as well as to meteorological science.



SHEAR

Also since 1974 the A300, Airbus Industrie's first product, has been in service. By judiciously combining the logic of its flight control systems, its design teams had anticipated formal scientific revelation of a phenomenon and built in the maximum protection against it. For over 11 years, every Airbus Industrie product has incorporated systems which provide wind-shear identification and guidance, and in many cases automatically initiate corrective action. The A310 and A300-600 embody further advances. With the A320 another step forward is taken.

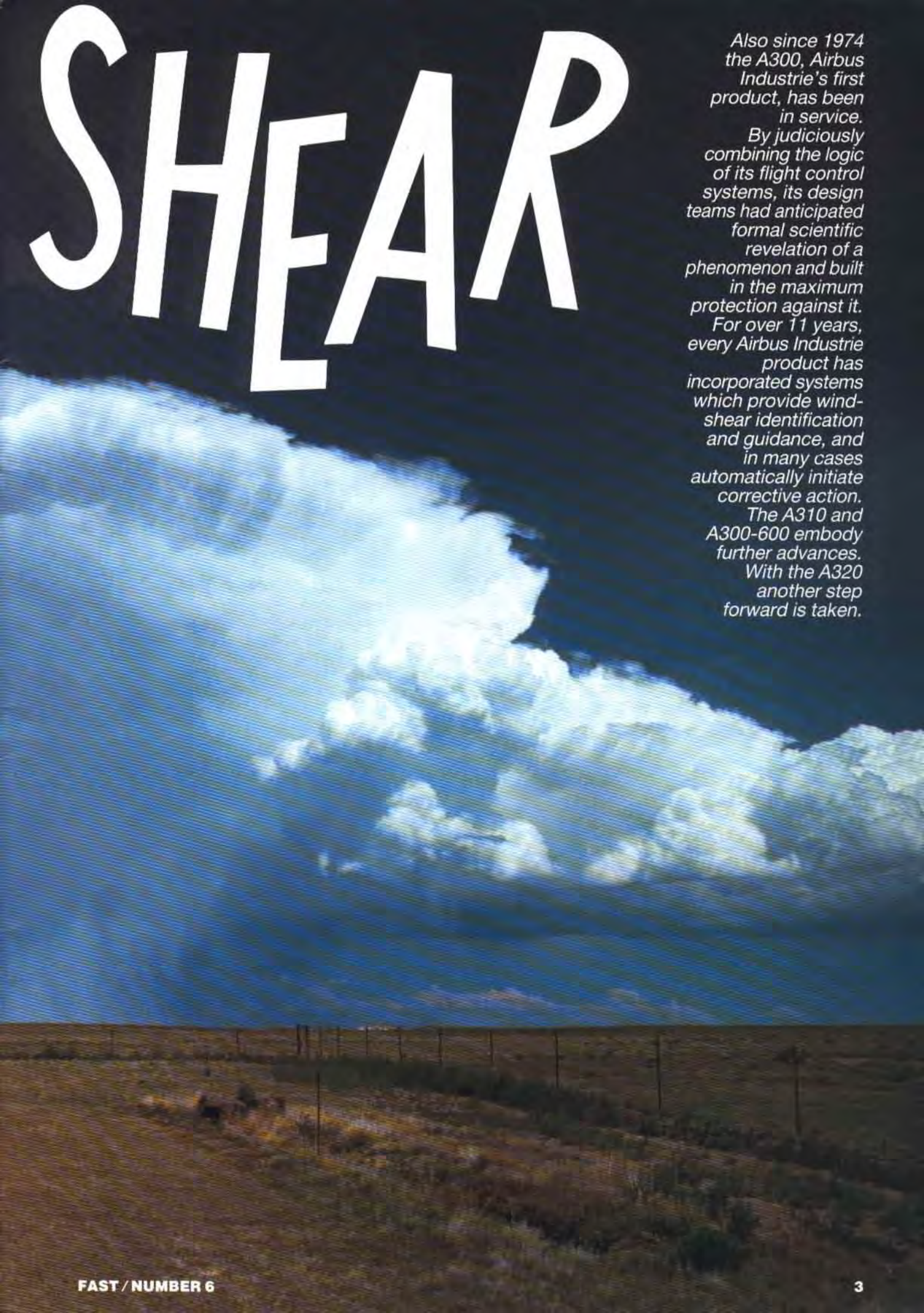
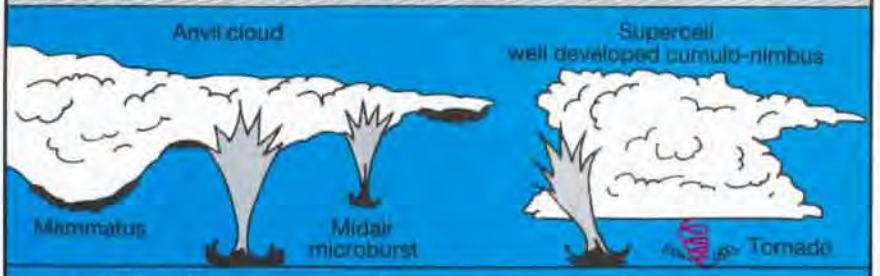


Figure 1

Types of cloud known to produce downbursts



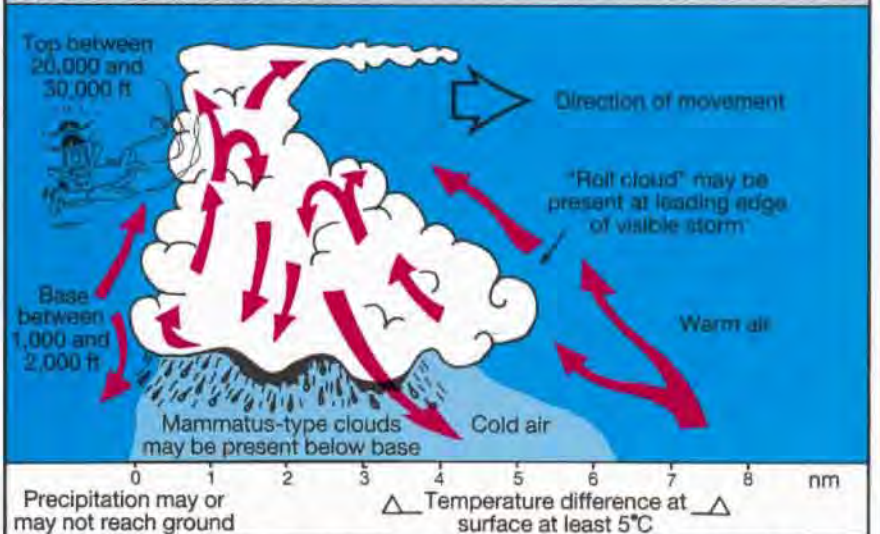
Characteristic PPI radar echo of one type of downburst-generating cloud with associated tornado.

a) Cloud retains shape during burst
b) Burst flow extends to top of shallow cut
c) Upper levels of cloud glaciated. Downburst on upwind side of cloud. Base may lower in burst reaching ground level. After burst, "anteater snout" has disappeared.

Comment by an observer : *"It was as if all the cold air in the cloud suddenly poured down all over the ground, like a leaky bladder".*

Diagrams with acknowledgements to Professor T.T. Fujita

Convection cloud circulation



Rate of advance of frontal storm may be as high as 30kts. Storm front may be limited to single cloud or consist of a line of storms. Phenomenon may be either local or affect large area

CLASSIC WINDSHEAR

Shear, in engineering terms, is a type of deformation in which parallel planes in a body remain parallel but are relatively displaced in a direction parallel to themselves (Chambers Technical Dictionary). Windshear is an abrupt change in the speed and / or direction of the wind, whether at constant height above ground or as height above ground varies. Between about 2000ft above ground level (AGL) and the surface, in the *boundary layer* between earth and air, wind-speed reduces more or less progressively, and pilots learn to take this factor into account during their training. Nevertheless, running *out of speed, height and ideas and into the undershoot* or the *long, hot float into the overshoot* are not infrequently the result of a dose of classic windshear or wind gradient effect.

AIRMANSHIP

Real awareness of weather is not necessarily impressed upon every pilot during his training : it can depend on how much his early training program was affected by weather conditions. The piston and propeller generations of pilots rarely operated above 20,000ft and were therefore always in those layers of the atmosphere where weather happens. The jet pilot however can spend over 80% of his flying time above the weather, and, unless he mainly works very short sectors, may pass less than 10% in the weather band, and for only a fraction of that 10% is he below 2000ft, where wind gradients and windshear are most serious. Simulator training and professional alertness are part of the answer to this problem.

Over 60% of the accidents and incidents to aircraft occur along the path between some 15 miles on approach and a similar distance along the climb-out path. While within this zone the pilot has many preoccupations, and unless he is well conditioned to notice signs of potential shear, he may miss any warnings that may be available, and could be read in the sky. However, the downburst can come almost literally out of the blue,

CONVECTION CLOUDS

While wind gradient is a factor to be taken into account during every approach and landing, more in the mind at present is a

shear with both vertical and horizontal components known as the downburst. The circulation system inside convection clouds, whether triggered by surface heating, orographic or frontal effects, with its rising and falling currents of warmer and cooler air, has long been recognized. A convection cloud is the visible part of a system which also includes invisible up-and-down draughts beneath and outside the cloud column. We talk of *currents* and *draughts* - using words with a connotation of steady motion-but a convection cloud is not a steady-state phenomenon ; it is in constant, unsteady motion.

A landscape being heated by the sun is like the base of a saucepan of water that is approaching the boil, with bubbles forming and breaking away at irregular intervals from the heated surface. This sporadic upwards motion has as its counterpart equally sporadic downwards motion of cooler air. Every convective system in effect breathes in and out, but, unlike the human body (the heat engine with which we are most familiar) the convection cloud does not breathe in and out through a defined orifice : it does it at any point beneath or near its base, at highly irregular, even spasmodic, intervals, producing pulses of high-velocity air and / or water-vapour projected at the ground.

THE DOWNBURST

Professor Fujita describes the downburst as *a strong downdraught which induces an outburst of damaging winds on or near the ground. Damaging winds, either straight or curved, are highly divergent.* Downburst size can vary from less than a kilometre to several tens of kilometres. The terms *macroburst* and *microburst* are applied to downbursts according to the horizontal windspeed generated, and horizontal dimension. While useful for scientific precision, the pilot caught in a downburst knows only too well that there is nothing micro about the forces involved, which may indeed be beyond the recovery capacity of any aircraft (Fig. 1,2,3)

A macroburst is defined as a large downburst whose outburst winds extend over more than 4 km (2.2 nm) horizontally. Damaging winds, lasting from 5 to 30 minutes, can be as fast as 117 kts (60 m / sec).

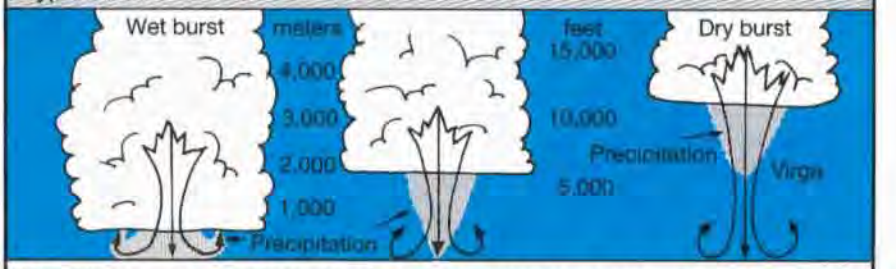
A microburst is a small down burst whose outburst of damaging winds extends over less than 4km. However, despite its small size, an intense microburst can induce damaging winds as fast as 145 kts (75 m / sec). A well-documented occurrence is that at Andrews Air Force Base on 1 August 1983 (Figure 4) :

At 1404, Air Force One with the President of the USA on board, landed on a dry runway, with a windspeed of slightly less than 20 kts. At 1409 :20, wind-speed began to increase, reaching a peak of over 120 kts, one minute and twenty-five seconds later. At 1412 :20, in the eye of the microburst, windspeed was only 2kts. One minute and ten seconds later, a second peak was reached, of 84 kts, diametrically opposed in direction to that of the first gust. At 1418 windspeed was again below 20 kts : the event had lasted about 10 minutes and substantially damaged buildings and trees on the eastern side of the base.

A case such as this is exceptional, only four microbursts with wind-speeds above 150 kts, being expected within the continental United States each year. Nevertheless, even milder occurrences can cause very close near misses to aircraft on approach or climb-out from many airports worldwide. These phenomena are neither new nor rare : line squalls and severe

Figure 2

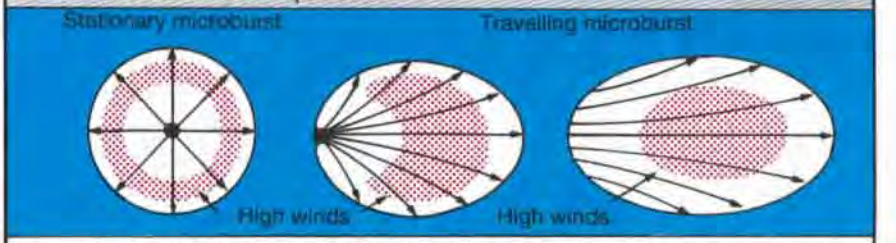
Types of microbursts



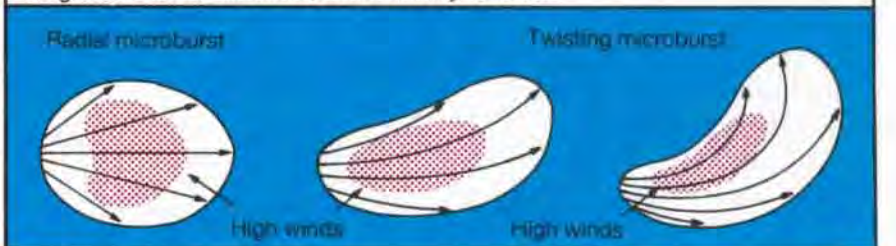
Wet microbursts occur in the humid regions, while dry microbursts are common in more arid regions with high-based convection clouds. Thus, rain does not invariably accompany a downburst. Downburst may be embedded in frontal activity or originate from isolated convection clouds.

Figure 3

Downburst surface wind patterns



Depending on its duration, a burst may produce a symmetrical wind-pattern at the surface, or a pattern asymmetric along the direction of movement of the air-mass from which it originates. The longer the downburst time and forward movement, the greater the coriolis effect, and tendency to rotate.



A "twisting burst" can develop cyclonic tendencies like an incipient tornado or localised cyclonic storm, which itself may, when fully developed, contain or trigger off further downburst activity.

Table 1

Loss of lift

Angle of attack	0°	5°	10°	15°	20°
Loss of lift by tailwind	1.3%	1.3%	1.3% per knot	1.3%	1.3%
Loss of lift by downflow	13.2%	4.5%	2.5% per knot	1.3%	0.5%

thunderstorms are classic downburst generators and have been flattening crops and woods, and knocking down ships for millenia. They are as old as weather. They happen all over the world (Figure 5). What is new is that there are many more airfields than there were, and traffic intensity at these airports is increasing. Results of a trial at Denver suggest that on average an aircraft will encounter a downburst below 500 ft AGL once every four and a half days in the Denver area.

In the Andrews downburst, horizontal windshear reached 5.3 kts/sec. This is a rate of change of speed of 8.95 ft/sec/sec which, if produced by an aircraft, would be 0.28 g in the horizontal plane. As a comparison of the effect of such an event with aircraft performance, the deceleration experienced during A300-600 certification brake-testing averaged 0.33 g (touchdown at 166 tonnes, 178 kts., time to stop 28 sec.).

The effects on aircraft performance are made dramatically clear by Professor Fujita in table 1 correlating the effects of tailwind and downflow on lift at various angles of attack and 150 kts indicated air speed (IAS) :

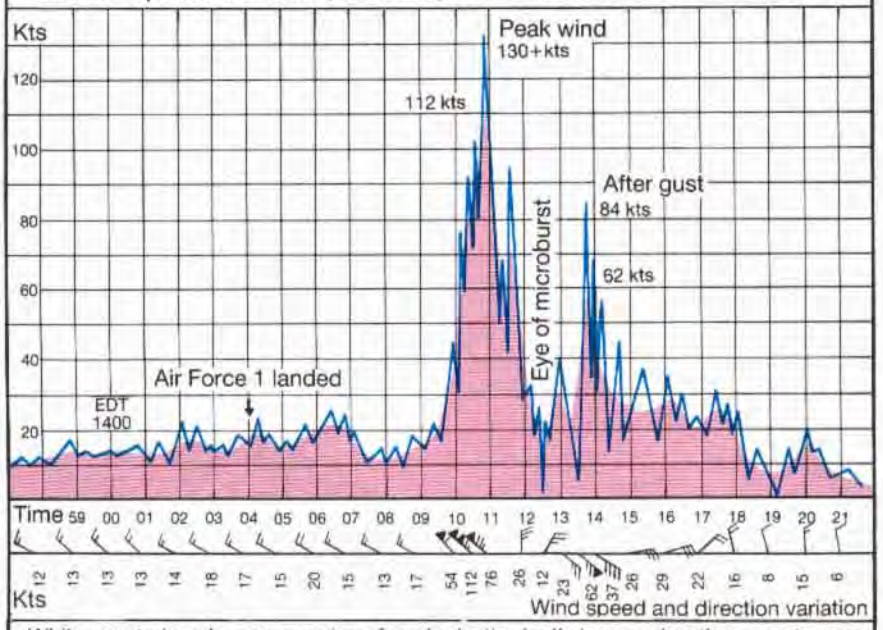
Thus, an aircraft taking off at 150 kts with an angle of attack of 15° and experiencing a 20 kt tailwind where zero wind-speed had been forecast would experience a 26% reduction in lift. If it also experienced a 20kt downflow (2,000 ft / min. - a not uncommon rate from a moderate downburst), it would experience a further 26% decrease in lift. Rates of descent of 7000 ft / min have been measured, which would cause a lift reduction of almost 90% at the same IAS and angle of attack. An aircraft on approach at 150 kts and 5° angle of attack, meeting a purely vertical downflow of 2000 ft / min would also experience a 90% reduction in lift.

Since 1962 windshear has been held responsible for at least 30 accidents involving over 680 deaths and 260 injuries. An equal number of incidents has been reported that narrowly - some literally by inches - escaped becoming accidents.

Figure 4

"Andrews" downburst

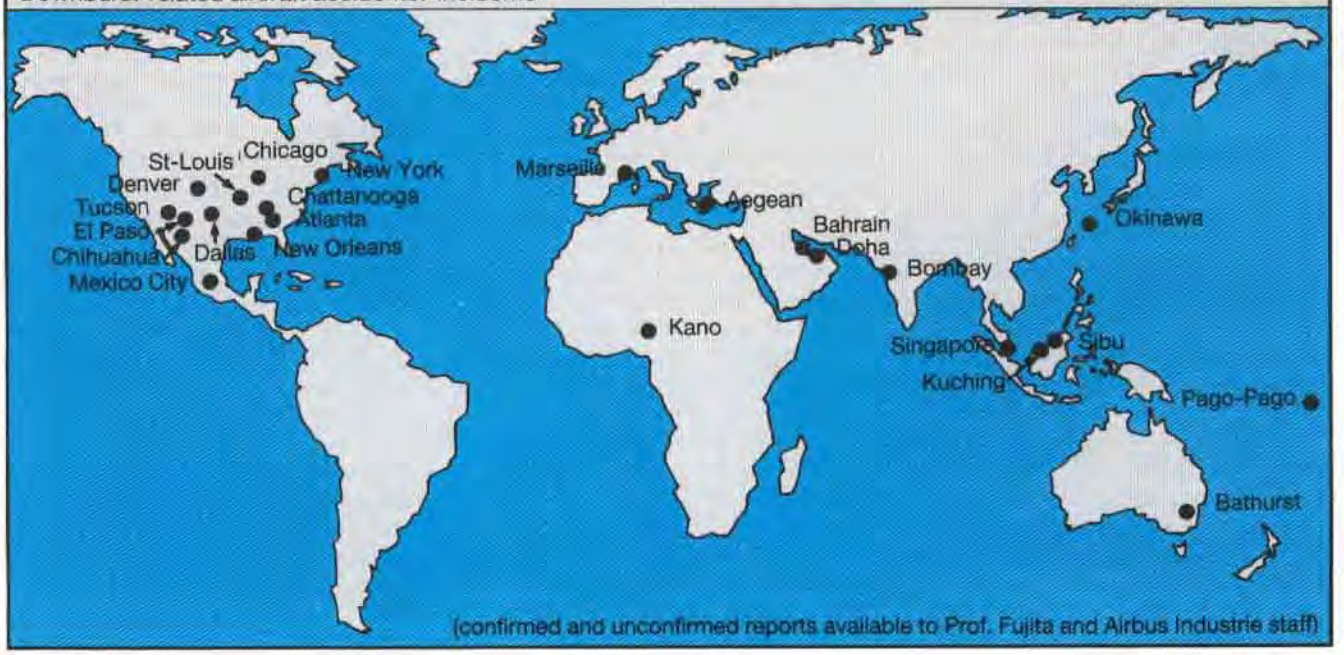
Recorded speed/time trace, 01.08.83, 1357-1422 local time



While most downbursts consist of a single "pulse", longer duration events can include several pulses, with a notable reduction of windspeed between them. This "eye" effect, in these relatively small-scale events, geographically speaking, is another similarity with cyclone/typhoon/tornado structures, which remain to be investigated.

DETECTION AND WARNING

By nature transitory, windshear is hard to detect and harder to forecast. Intense downburst activity has been encountered that hardly showed up on radar. Low Level Windshear Alerting Systems (LLWAS), developed by the FAA, have been installed at some 60 airports in the USA and are to be installed at 50 more. The system consists of an airport-centered array of anemometers separated by about

Figure 5

Downburst-related aircraft accidents/incidents