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MICROBURST MODEL REQUIREMENTS FOR FLIGHT SIMULATION-- AN AIRFRAME MANUFACTURER'S PERSPECTIVE

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ABSTRACT

A brief outline is given of topics for presentation and discussion at this workshop. As manufacturers and certifiers of transport airplanes and associated on-board systems, we have an interest in the prevention of wind shear-related accidents and incidents. Our near-term objectives are to provide our customers technical support in the areas of training as well as to research existing and potentially improved on-board systems. In the future, we expect to be implementing many improved systems. This will require certification as well as further educational activity in the use of these new systems.

What we need to achieve our objectives is a set of wind models for design work which characterize a wide variety of real microbursts as measured during the JAWS Project. The wind models should be limited in both size and complexity to just those features which degrade aircraft performance.

INTRODUCTION

The committee on Low-Altitude Wind Shear and Its Hazard to Aviation, sponsored by the National Research Council and directed by Terms of Public Law 97-369, has recently issued its findings (reference 1).

A number of recommendations were made, two of which relate to wind shear detection and guidance systems.

1. "The FAA should sponsor a program to develop and define standardized models of wind shear based on meteorological data."
2. "On-board sensors and guidance aids should be evaluated in a systematic manner to determine their merits for future development and for possible retrofit in existing aircraft."

We, as manufacturers and certifiers of the airplane systems, need to develop a methodology for quantitatively evaluating on-board alert and guidance systems. The training community must also develop techniques to traverse wind shear encounters with the existing fleet of airplanes. This paper addresses the data requirements for the former, although it may be that similar models will be required by the training community. The need of the training community is best expressed by those individuals directly involved in pilot training.

The "theoretical wind shear model" is an important element in determining aircraft performance in a wind shear as well as designing for effective operation of on-board alert and guidance systems, autopilots, flight directors, and autothrottles. While it is important to understand the effects of aircraft behavior for a broad spectrum of meteorological phenomena; i.e., microbursts, thunderstorms, gust fronts, mountain waves, etc.), it is our opinion that the most immediate need is for data to characterize the microbursts of limited geometrical size in the take-off and landing domain, close to the ground.

Analysis results to date indicate that three parameters characterizing microbursts can be used in preliminary evaluations of airplane performance. These parameters are: 1) the shear rate in knots/mile; 2) the total shear in knots; and 3) the value of the maximum downdraft velocity. This limited characterization assumes a linear shear rate and that the maximum downdraft velocity occurs as the transition is made from a head wind to a tail wind. While this simple model may be satisfactory for airplane performance and crew training applications, it is probably not accurate enough for wind shear alert and guidance system evaluations. Three-dimensional, symmetrical models with associated turbulence need to be developed for this purpose.

<u>BOEING OBJECTIVES OF WORKSHOP PARTICIPATION</u> (Figure 1)

- <u>Microburst Mathematical Representation</u>

  - To obtain a set of theoretical microburst models which reflect characteristics of the measured data

  - To establish whether the JAWS data base represents a wide variety of wind shears by comparison with other statistical studies (references 2 and 3).

- <u>Statistical Analysis</u>

  - To reconcile microburst math modeling theory with experiment using the JAWS data base.

  - Using the three parameters--the shear rate in knots per mile, the total shear in knots, and the value of the maximum downdraft velocity--establish frequency distribution diagrams from the JAWS data base. Determine whether parameters can be combined (which might be called the "total wind shear threat").

<u>REQUIREMENTS RELATIVE TO WIND SHEAR AND TURBULENCE</u>

- <u>Summarize on-going programs requiring wind shear and turbulence data sets and models</u>

  - Our on-going requirements are best summed up by three broad aims:

    - Wind shear training.

    - Accident/incident analysis.

    - System performance evaluation in wind shear, including existing and future systems. Examples are autoland performance, alert evaluation and guidance system development.

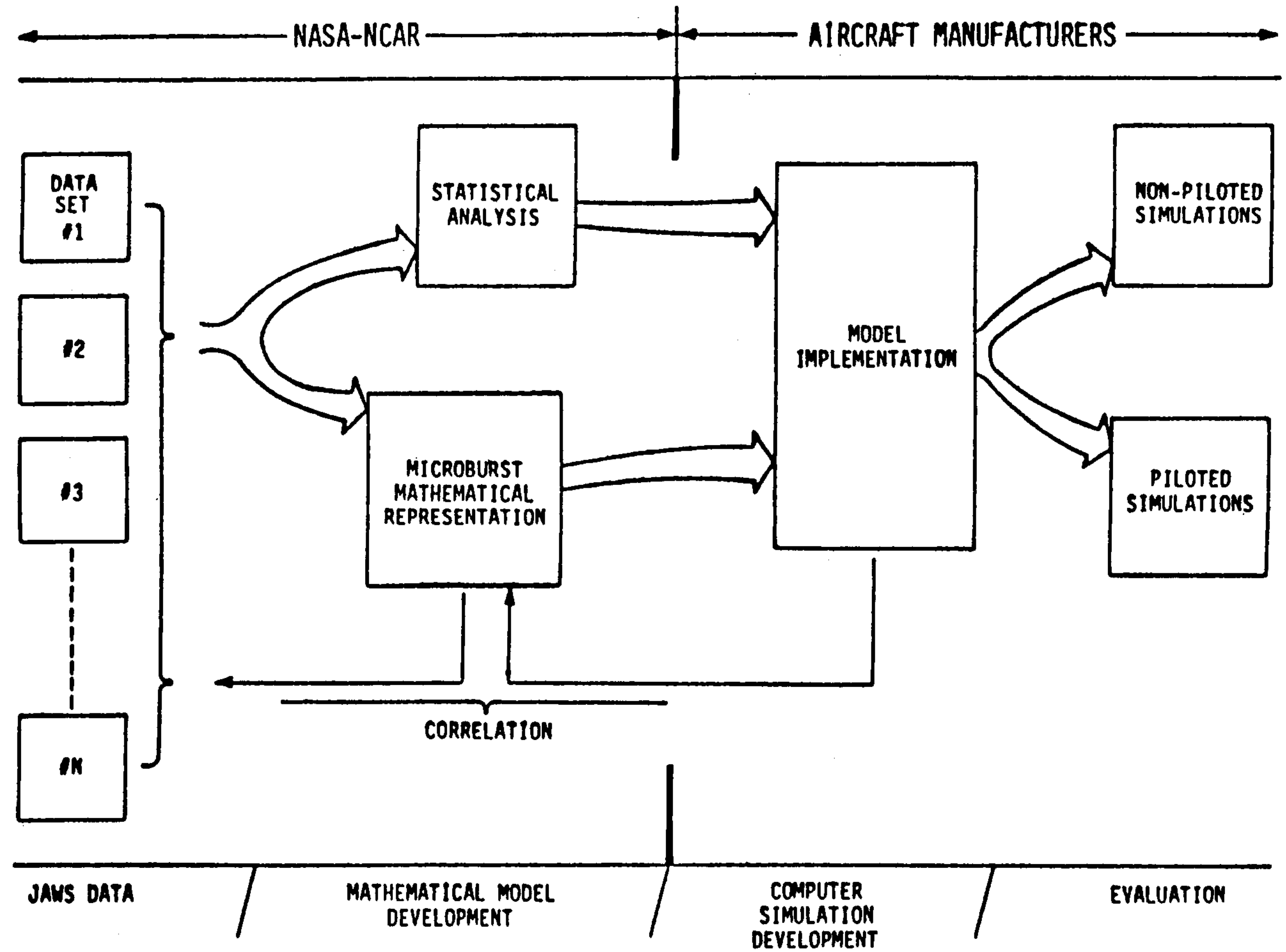


Figure 1. Microburst Modeling Studies .

- How are these requirements currently met?

  - Wind shear

    - Wind model derivations from accidents/incidents, both Boeing in-house and FAA/SRI.
      (Our concern with this form of wind model is that it is possible to derive a variety of winds from the same accident/incident which leads to differing airplane response characteristics.)
      (See Figure 2)

    - Boeing (in-house) hybrid and synthetic models (arbitrarily determined). (See Figure 3)

  - Turbulence

    - FAA/SRI (judged unrealistic, based on simulator evaluation).

    - Theoretical representations of the von Karman & Dryden spectra.

- What analyses of data sets are needed to meet present requirements?

  Analysis of the JAWS data is required to validate fluid dynamic models of a standard microburst (Figures 4 and 5):

  - There is an immediate need for data to support a standard three-dimensional microburst representation within the critical range of 500 feet to the ground, including:

    - Velocity distribution laterally and vertically in the downdraft portion of the microburst.

    - Velocity distribution laterally and vertically in the outflow region.

    - The relationship between average outflow velocities and average downflow velocities.

  - Also in the near-term, analysis of the JAWS data is required to establish statistical distributions of microbursts.

    - Establish statistical properties of horizontal wind shear rate, total horizontal wind change and maximum downdraft velocity near to the ground, including an error analysis (Figure 6).

    - Combine distribution diagrams if possible to produce a "total wind shear threat" diagram (Figure 7).

    - Establish whether JAWS data statistically fits the general pattern of global wind shear events, considering the major description characteristics.

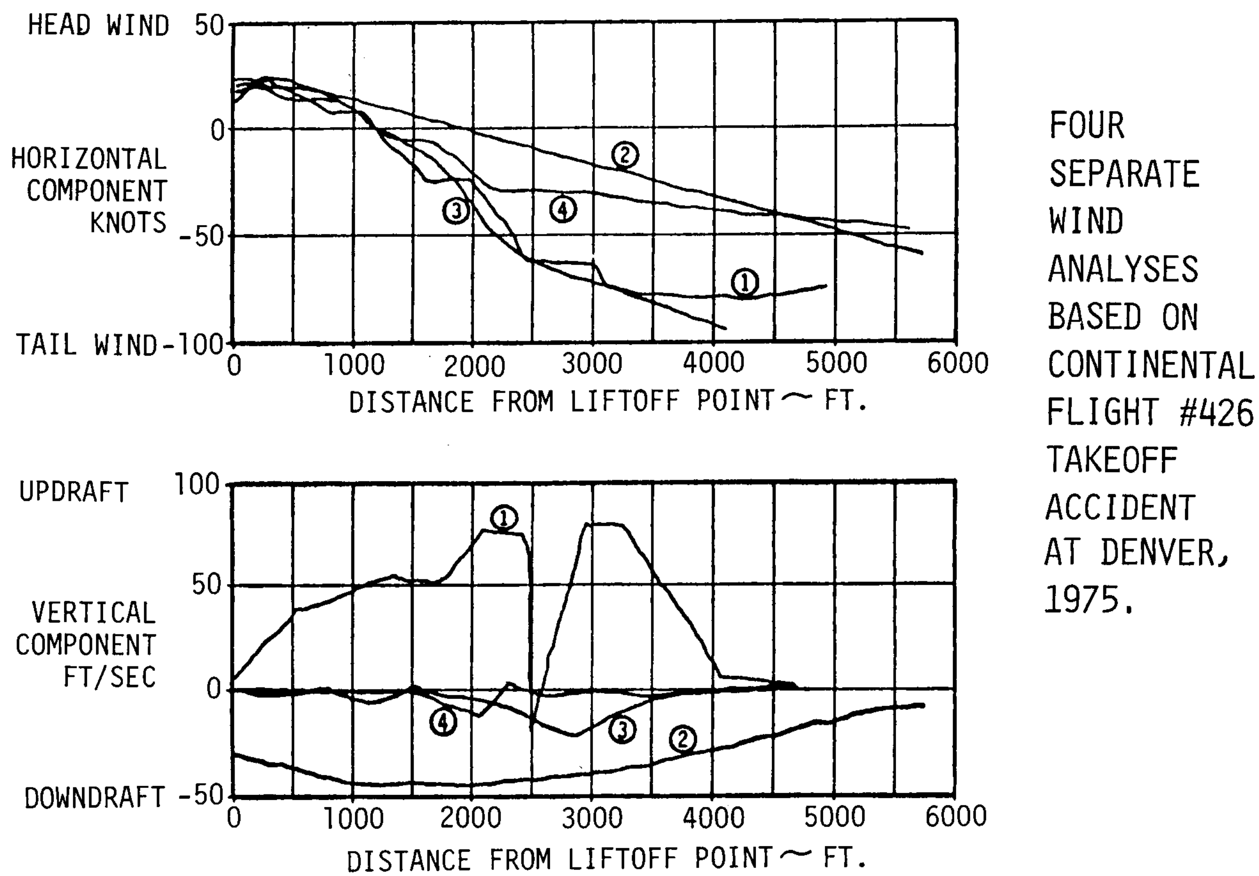


Figure 2. Currently Used Wind Shear Models--Accident/Incident Derivations.

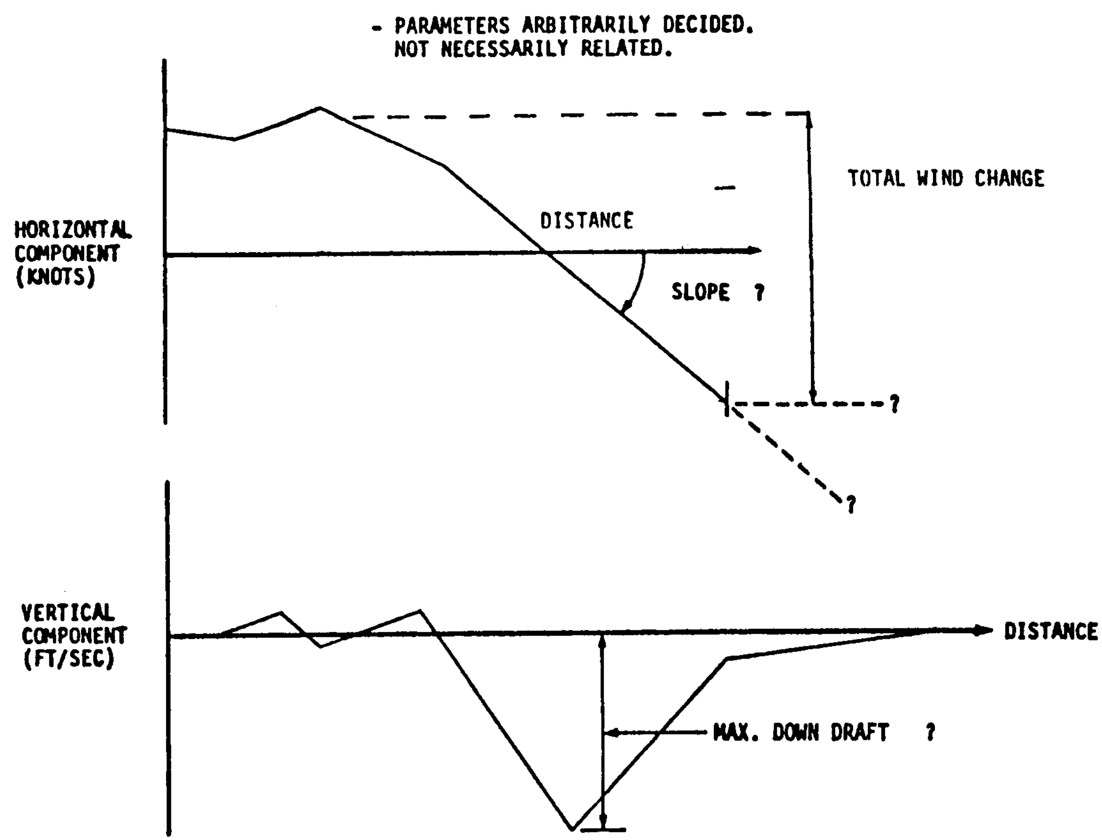


Figure 3. Currently Used Wind Shear Models--Boeing In-House Hybrid and Synthetic Models.

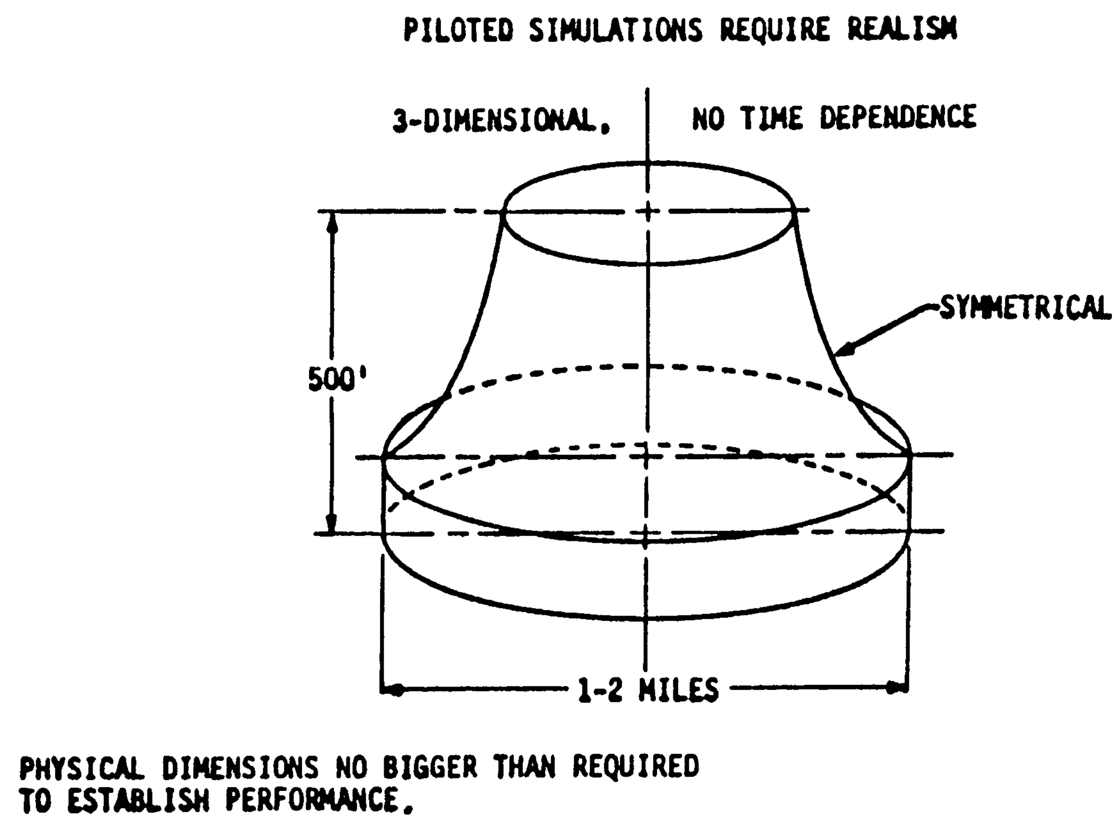
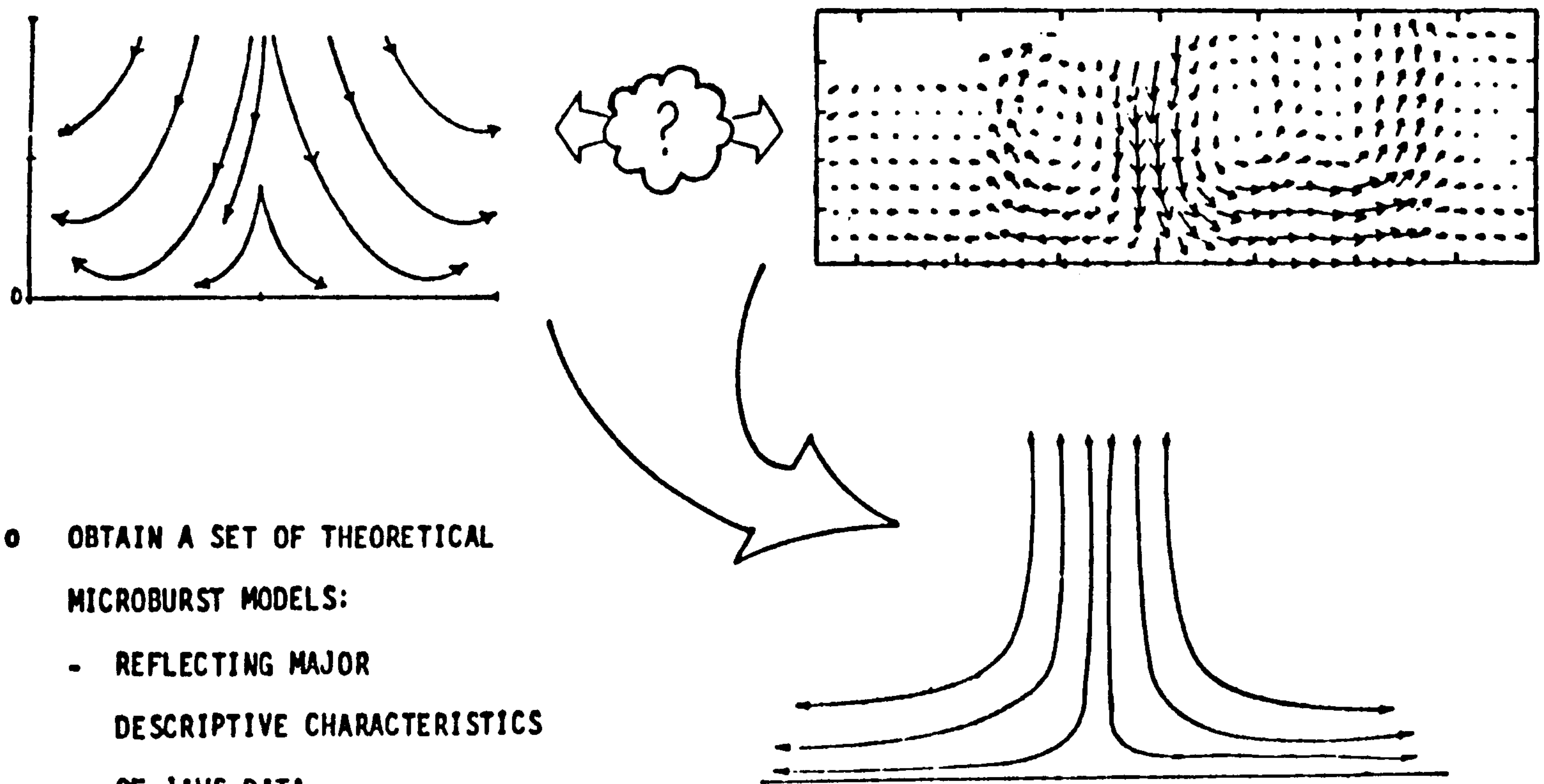


Figure 4. Wind Model Selection Criteria.

o CLOSE THE LOOP BETWEEN THEORETICAL REPRESENTATIONS AND THE JAWS DATA



o OBTAIN A SET OF THEORETICAL MICROBURST MODELS:

- REFLECTING MAJOR DESCRIPTIVE CHARACTERISTICS OF JAWS DATA

- WITHIN STATISTICAL BOUNDS DETERMINED FOR DESIGN WORK

Figure 5. Required Analysis of JAWS Data--Theoretical Representation.

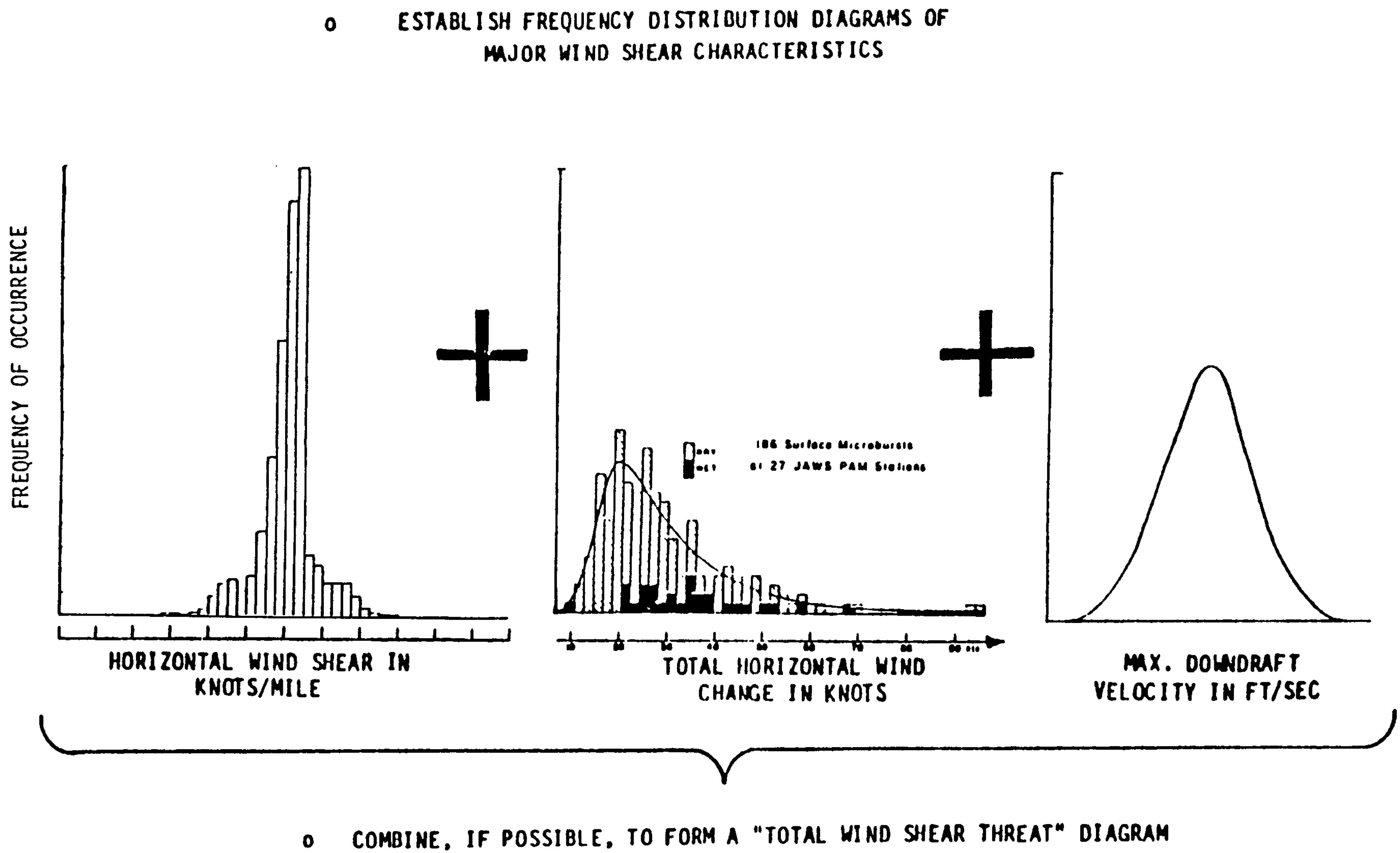
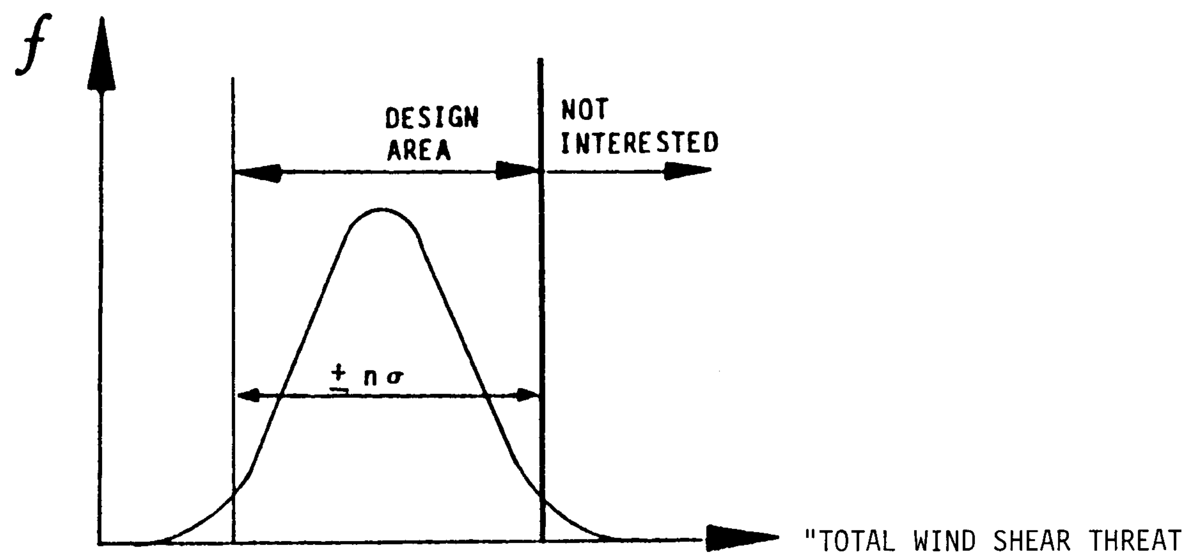


Figure 6. Required Analysis of JAWS Data to Establish Statistical Properties of a Microburst.

- MANUFACTURERS TO DECIDE HOW TO LIMIT MICROBURST CHARACTERISTICS ON "TOTAL WIND SHEAR THREAT" DIAGRAM



- CHECK CORRELATION OF JAWS STATISTICS STUDY WITH STATISTICS OF OTHER WIND SHEAR DATA BASES TO ASSURE DATA IS REPRESENTATIVE WORLDWIDE.

Figure 7. Required Analysis of JAWS Data--Statistical Analysis: To Produce a "Total Wind Shear Threat".

- What are the factors involved in the selection criteria for candidate mathematical representations?

  a. Should be representative of the real world in terms of major descriptive characteristic.

  b. Should be bounded for practical purposes to be no more than 1-2 miles wide and 500 feet high.

  c. Would have to decide where to cut off the frequency distribution diagram (number of standard deviations, $n\sigma$) for design work on the "total wind shear threat" diagram.

  d. Wind model would have to be 3-dimensional and symmetrical; i.e., stationary with respect to time.

IMPLEMENTATION OF WIND SHEAR AND TURBULENCE DATA SETS AND MODELS

- All wind and turbulence effects enter the simulation model through aerodynamic effects, primarily angle of attack and sideslip, and the related rate terms.

- The coefficients for the angle of attack and sideslip rate terms presently produce inconsistent results. This problem is under investigation.

- Rotational components of wind shear are not presently included. It is planned to include these components when a fluid dynamic downburst model is implemented. These effects need careful study as the airplane shows selective sensitivity to the wind gradient components, which may be combined to produce a rotation.

WHAT WIND SHEAR AND TURBULENCE DATA AND MODELS DO YOU ENVISION WILL BE REQUIRED TO MEET YOUR FUTURE PROGRAM OBJECTIVES?

- There is a longer term need to answer more general questions to provide a better understanding of the microburst phenomenon, including:

  - Considering the microburst events to be a superposition of a steady wind and a microburst, what was the range of values of the steady wind component?

  - What range of altitudes characterizes the starting point of the downdraft?

  - How does the size of the microburst vary as a function of time?

  - What was the range of downflow and outflow velocities?

  - Based on B-57B data, what spanwise gradients were measured in the vicinity of microburst extremities?

- The interrelationship between turbulence and wind shear.
- The pressure distribution within the microburst.
- Other characteristics of the microburst that may affect the aircraft system performance.

QUESTION:

In the interrelationships between turbulence and wind shear, will you also include the interrelationships of reflectivity in that data set?

RESPONSE:

Yes. We are very interested in what can be done with airborne radars, and we would like to understand what reflectivity information is available.

REFERENCES

1. Low-Altitude Wind Shear and Its Hazard to Aviation. National Academy Press, Washington, DC, 1983.
2. Usry, J.W.; and Dunham, R.E.: Low-altitude wind shear statistics derived from measured and FAA proposed standard wind profiles. AIAA-84-0114, 1984
3. Woodfield, A.A.; and Woods, J.F.: Worldwide experience of wind shear during 1981-1982. Flight Mechanics and System Design Lessons From Operational Experience, AGARD-CP-347, 1983.