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Meteorological and Environmental Inputs to Aviation Systems

Proceedings of the 7th annual workshop held at
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October 26–28, 1983

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Meteorological and Environmental Inputs to Aviation Systems

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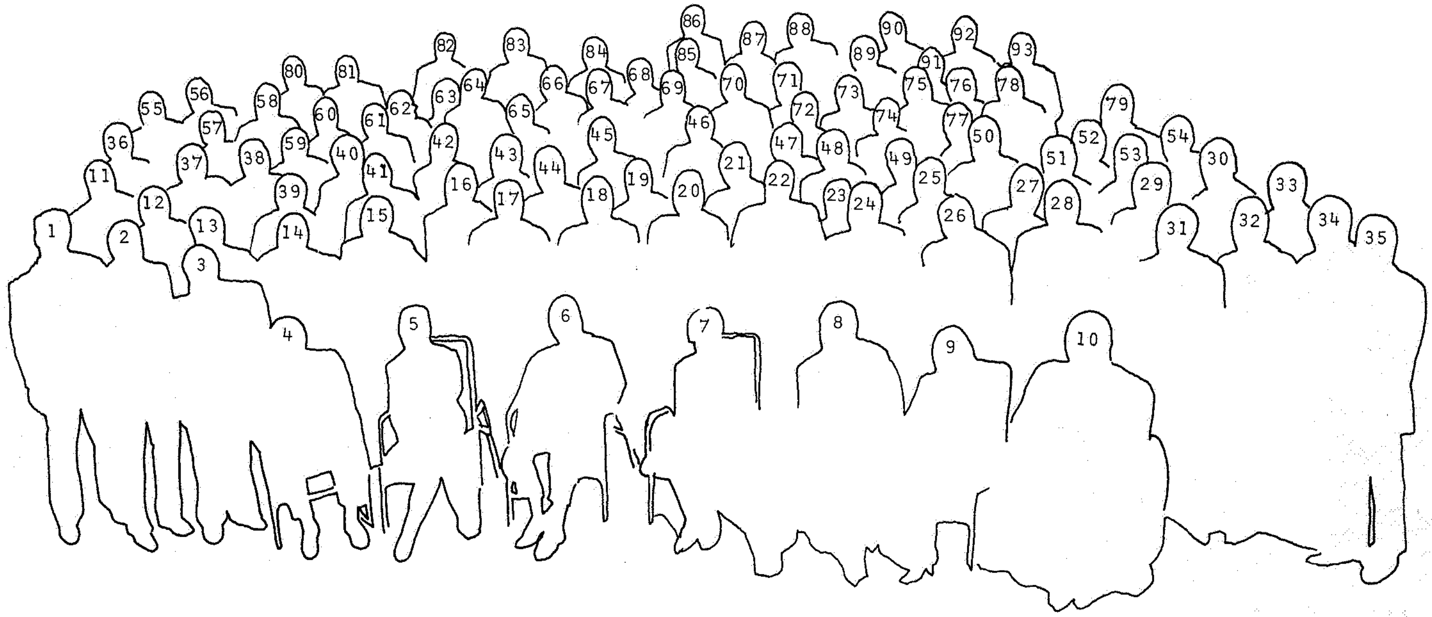

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SECTION I
EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY: Seventh Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems

26-28 October 1983, Tullahoma, Tennessee

Dennis W. Camp and Walter Frost

INTRODUCTION

There have been seven workshops, the first in March 1977 and the last in October 1983, concerning the subject of meteorological and environmental inputs to aviation systems. These workshops have served a twofold purpose for the sponsoring organizations (NASA, FAA, NOAA, DOD, and OFCM). Their first purpose was to bring together the various disciplines of the aviation community with atmospheric scientists and meteorologists in interactive discussions. From these discussions, an effort was made to establish and identify the weather needs of the community and how to satisfy these needs. Their second purpose was to use the established and identified needs to develop recommendations that serve as a basis for structuring relevant programs of the sponsoring agencies. An indication of how well the purpose of these workshops has been achieved is given in the various reports, papers, and presentations that have been made on the workshops (Camp and Frost, 1977, 1979, 1981, 1984; Frost and Camp, 1978, 1980, 1982, 1983; Frost, et al. 1979a, 1979b; and Camp, et al. 1980a, 1980b, 1981) [1-13]. Due to the coverage of the previous workshops, this article will be concerned only with the results (recommendations) of the seventh workshop.

WORKSHOP STRUCTURE AND OPERATION

The basic objective of all the workshops has been and is to satisfy the needs of the sponsoring agencies relative to such factors as: 1) Knowledge of the interaction of the atmosphere with aircraft and airport operators; 2) Better definition and implementation of meteorological services for the operators; and 3) The collection and interpretation of data for establishing operational criteria relating the total meteorological inputs from the atmospheric sciences to the operational and educational needs of the aviation community.

The specific theme of each workshop gives an insight into its particular focus. "Atmospheric Environmental Data/Communications and Applications" was the theme for the Seventh Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems. This workshop theme, coupled with the focusing of the interactive committees, according to the committee titles (Table 1), tended to direct the workshop in the desired area of effort. These interactive committee sessions are considered to be a major element contributing to the success of the annual workshops.

TABLE 1. Interactive Committees for the Seventh Workshop

Fixed Committees	Floating Committees
1. Airborne Data: In-flight and post-flight applications	1. Winds and Turbulence
2. Remote Detection/Radar, Lidar, etc. (ground-based, airborne, and satellite)	2. Icing and Frost
3. Unmanned Airfields (remote site and after-hour operations)	3. Atmospheric Electricity and Lightning
4. Engineering Analysis	4. Fog/Visibility, Ceiling, and Heavy Precipitation
5. Implementation of New Data	5. Meteorological Support within the NASP

The type of information desired from the interactive committee sessions was: What was the effect of the particular subject area (Floating Committee Title) on the operation of the various segments (Fixed Committee Title) of the aviation community? Each of the committees was asked to focus its discussion according to the committee guidelines given in Table 2.

The workshop began with a series of overview papers addressing such factors as Implementation of the National Airspace System Plan (NASP), Airspace Users' Requirements, and other related subjects that set the tempo of the interactive committee sessions. Papers on previous workshop accomplishments, interactive weather displays, and impromptu tasks were also given. These also help to set the tempo in the vein of the workshop theme, as did the banquet and dinner presentations.

The structure (program) of this workshop was very similar to previous workshops. It began with the overview presentations, followed in order by interactive committee sessions, banquet, impromptu presentations, more interactive committee sessions, dinner presentation, more interactive committee sessions, and a conclusion with a plenary session consisting of the committee chairmen presenting the results and recommendations of their committees.

COMMENTS AND RECOMMENDATIONS

At this workshop, the committee chairmen were requested to use a special procedure (form) for reporting their comments and recommendations.

Specifically, they were asked to give the results of their efforts in the following order: 1) state as concisely as possible the issue; 2) briefly summarize the discussion of the issue; 3) state recommendation action; 4) indicate who should be responsible for accomplishing any required effort; and 5) specify the priority of issues discussed.

The committees at this workshop stated 77 issues (recommendations); of these, there was an indication that 39 were in a high-priority category. These 39 recommendations could be sorted into seven classes. Some of the recommendations could

TABLE 2. Committee Guidelines

Objectives of Committee Discussions
1. What are the major problem areas with respect to the list of meteorology topics given below which exist relative to safety and operations as they pertain to the categories of aviation operations identified by the fixed committee titles (i.e., Airborne Data; Remote Detection; Unmanned Airfields; Engineering Analyses and Implementation of New Data)?
2. What current aspects of existing technology, operational procedures, or facilities cause these problems?
3. Specify what action is needed to overcome or alleviate these problems.
4. What sector of the aviation community should accept the responsibility for rectifying the problems?
5. Prioritize the action recommended in Step 3.
Meteorological Topics
A. Winds and Wind Shear
B. Turbulence
C. Fob, Visibility, and Ceiling
D. Lightning and Atmospheric Electricity
E. Icing, Frost, and Snow
F. Rain
G. Ozone, Acid Rain, and any other meteorological parameters suggested by committee members.

easily fit into two or more of the classes. Some of the recommendations are quite similar and can be combined. The ones given here should not be considered as presenting all of the high-priority recommendations, but only a sample of them. For a more in-depth discussion of the comments and recommendations, the proceedings (Camp and Frost, 1984) should be pursued.

The recommendations to be presented will be given in the format classifications as indicated above.

A. Meteorological Data and Weather Information Recommendations

ISSUE 1: To enable meteorologists and aircrews to take full advantage of the potential value of meteorological data becoming available from new automated systems based on aircraft, e.g., Aircraft/Satellite Data Relay/ARINC Communications Addressing and Reporting System (ASDAR/ ACARS).

DISCUSSION: Profile data obtained on ascent (descent) would improve terminal forecasts and warnings–thunderstorms, wind shear, turbulence, and low cloud and fog. Accurate low-level wind and temperature data at frequent heights and time intervals would improve short-range forecasting for low cloud and fog (thickness, time of onset, dissipation, etc.). Other parameters, such as humidity and liquid water content, would be available.

Profile data could also be valuable for crews of aircraft approaching the terminal if provided in concise form and in sufficient time for the crew to assess the impact and to make operational decisions. ASDAR/ACARS data obtained from cruise level are valuable for flight planning and for meteorological analysis and research. International coordination of projects is essential. Funding arrangements will vary from country to country and are yet to be resolved.

RECOMMENDED ACTION: In view of the mutual benefits, aviation and meteorological communities should cooperate to promote this type of meteorological data project and to investigate technical aspects and the processing and distribution of the data.

RESPONSIBLE AGENCIES: National Oceanic and Atmospheric Administration/National Weathe Service (NOAA/NWS); Federal Aviation Administration (FAA); International Air Transport Association (IATA); World Meteorological Organization (WMO); and International Civil Aviation Organization (ICAO).

ISSUE 2: Improved short-range terminal forecasting to enhance safety and to promote more efficient (low-cost) flight operations.

DISCUSSION: Policies and programs that lead to a reduction of complete full-scale weather observations and a lack of short-range computer forecast models to solve the forecast problem are partly responsible for forecast inaccuracies. An increase in the number, frequency, and quality of observational data, a reliable communication system to transmit and disseminate the data, and the development of a short-range objective forecast model is desired.

Computerized, objective forecast systems should be developed to assist the forecaster in the one- to six-hour projection. These systems should have the following three characteristics: 1) They should be simple enough to be run on-station on a mini-computer; 2) They should be under the control of, and interactive with, the local forecaster; and 3) They should make use of recent, local surface observations as input. Within the NWS, systems satisfying these criteria are presently being developed and should continue to be supported. The Techniques Development Laboratory of the NWS, for instance, is developing and tesing the Generalized Exponential Markov (GEM) statistical model and local AFOS-MOS Program (LAMP).

RECOMMENDED ACTION: Encourage development and implementation of systems and procedures that provide more detailed weather observations, including automated systems. Continue operational testing of GEM; make it more efficient so as to require less of the resources of AFOS (Automation of Field Operations and Services) computer configurations, and encourage more man-machine interaction techniques.

RESPONSIBLE AGENCIES: NOAA/NWS and FAA

B. Icing Recommendations

ISSUE 1: Currently there is a nearly complete lack of meaningful or adequate forecasts, or even nowcasts, for icing conditions, particularly for commuter and general aviation. This is due largely to infrequent and sparsely distributed sounding data indicative of icing conditions. To benefit the development of improved icing forecast techniques and to provide better assessments of existing icing conditions, developmental systems, such as NEXRAD (Next Generation Radar) and PROFS (Prototype Regional Observation and Forecast System) profiles should be expanded where possible to provide data related specifically to icing conditions.

DISCUSSION: NEXRAD may not be sensitive to cloud droplet diameters in the range 5 to 50 μm, which contain the liquid water content (LWC) responsible for aircraft icing, thus excluding freezing rain and droplets. In this case, NEXRAD can still be useful if it can detect the occurrence and spatial distribution of snow. Where there is snow, there is little or no LWC and, therefore, little or no engine icing, although the snow may have an effect on some engines or inlet systems. Thus, it would be valuable for nowcast purposes to have a snow recognition algorithm for NEXRAD analysis. PROFS profiler, with the inclusion of a suitable , passive microwave sounder, appears to have good potential for more direct indications of icing conditions through the detection of liquid water content (LWC) and the provision of temperature soundings. There are some inherent limitations, such as 1) the capability of indicating only the total LWC integrated over the vertical extent of the cloud(s); 2) the inability to sense cloud top or resolve multiple cloud layers; and 3) the inability to separate out the LWC that lies only above the freezing level. The basic ability to detect LWC, however, is judged to be sufficiently important to warrant development of the technique.

The MARS passive microwave radiometer/profiler technique appears promising for accomplishing the required LWC and temperature profiling referred to above in the PROFS profiler discussion.

RECOMMENDED ACTION: 1) Evaluate NEXRAD for ability to provide information on icing conditions, at least in developing algorithms for recognizing snow. 2) Develop the PROFS profiler to include meassurements of LWC and temperature profiles, especially from near-ground level to an altitude of about 20,000 feet. 3) Continue the MARS field trials with air truth comparisons from overflights.

RESPONSIBLE AGENCIES: 1) FAA and USAF [Note: 1), 2), and 3) refer to numbering in the above Recommended Action]; 2) NOAA; and 3) NOAA and USAF.

ISSUE 2: Development of an LWC instrument for use in operational service.

DISCUSSION: An LWC instrument is needed for improved forecasting and for real-time warning of icing conditions. Information from these instruments would be useful to all classes of aircraft; however, general aviation and commuters would benefit most. A low-cost and suitable "off the shelf" instrument is not available; thus, development is required. Aircraft with current down-link capability are ACARS/ASDAR-equipped transplants that require icing information the least.

RECOMMENDED ACTION: Development of an LWC instrument suitable for use in routine aircraft operations. Further, encourage (or pay for) ACARS-equipped aircraft to supply LWC data to the National Weather Service (NWS).

RESPONSIBLE AGENCIES: NASA, NWS, OFCM, and FAA.

C. Instrumentation Recommendations

ISSUE 1: There is a need for more and better weather sensors to observe surface conditions and upper-air phenomena.

DISCUSSION: More accurate and frequent measurements of weather phenomena are required to support the desired changes in forecast accuracies, forecasts of phenomena not presently forecasted, and the operational safety and efficiency of the National Airspace System (NAS). The planned increase in surface obsersvations through the implementation of automated sensing systems will significantly increase the amount and quality of surface observations data. The NEXRAD and terminal NEXRAD Program will greatly increase the upper-air information data base. However, the areas still not adequately measured are winds aloft, temperatures, and LWC.

There is more than one method to achieve some of these measurements. Development and implementation of sensors must be accompanied by trade-off analyses to determine proper balance of forecast model capability, ground-based sensors, and aircraft-based sensors.

RECOMMENDED ACTION: Development and implementation of the NEXRAD, terminal NEXRAD, and automated surface sensors should continue as a high-priority program. Development of suitable ground, air and space-based upper air winds, temperatures, and LWC sensors should be given priority. Trade-off analyses should be carried out in parallel.

RESPONSIBLE AGENCIES: NASA and NOAA

ISSUE 2: Terminal Doppler radar design.

DISCUSSION: The major unanswered questions related to ground clutter, siting, and automation because microbursts are small, short-lived, low-altitude, and sometimes weakly scattering. The optimum wavelength is an unanswered question relative to the terminal Doppler radar. We considered wavelengths from the coherent lidar area through the 10-cm radar. This is a system problem, not just a sensor problem.

RECOMMENDED ACTION: FAA should assess fully the capabilities of competing technologies and examination of JAWS (Joint Airport Weather Studies) data analysis. They should proceed with all due dispatch to develop and deploy an effective system.

RESPONSIBLE AGENCY: FAA

D. Winds, Wind Shear, and Turbulence Recommendations

ISSUE 1: Observation and forecasting of wind shear.

There is a need for airborne wind shear instrumentation. The instrumentation must meet basic requirements. It should: a) Be capable of providing the safest degree of handling a wind shear in case of inadvertent encounter, and be proven capable of safe penetration of wind shear on an approach that will be unsuccessful without its use; b) Provide the pilot with a continuous quantitative value of the significant hazard ahead, so that he can have qualitative judgment as to whether to continue or abandon the approach; c) Provide the safest performance after the decision to abandon the approach has been made; d) Assure the best means of arrival over the threshold with the proper speed upon which the pilot's runway charts are based, and give him quantitative information if the speed is unacceptable; e) Recommend continual special emphasis on wind shear related training and education to include: 1) The different types of wind shear–what to expect, what to watch for, and what to do; 2) Updating of the training information as results become available from research or other sources; 3) The use of ground speed during approach; and 4) The reaction of the flight director system to the different types of wind shear.

RECOMMENDED ACTION: Develop standard procedures approved by airlines and FAA to utilize existing ground speed information currently available on INS-equipped aircraft to avoid wind shear during takeoffs and landings. Urge development of airborne wind shear instrumentation for all aircraft.

RESPONSIBLE AGENCIES: FAA, NASA, and ATA

ISSUE 2: Effectiveness of profilers; winds, temperature, and humidity.

DISCUSSION: Mixed opinions exist on this issue. Winds are measured well, but temperatures and humidity have poor vertical resolution. General agreement exists that a hybrid system using profilers, satellites, and possibly some conventional raobs with ACARS and other aircraft-equipped sensors is likely to prove fruitful. Upper-level wind variability (time and space) is of smaller scale than now predicted or available in existing data. Winds over water are very important (Windsat).

RECOMMENDED ACTION: Conduct numerical studies to determine improvements on forecasting that will result from profiler development. Try to quantify. How good is better? What does it cost? What does it save?

RESPONSIBLE AGENCIES: NOAA, in general. FAA should examine development and cost effectiveness for winds and CAT detection along well-traveled routes.

E. Lightning Recommendations

ISSUE 1: To understand the lightning mechanism, characterization of lightning at all levels, and determine its effect on composite aircraft as well as the detection of strike potential on aircraft.

DISCUSSION: Some information is being determined by the continuing research into the characterization of lightning. The research should be focused on determining and understanding the cause of lightning. The current programs underway appear to be addressing the major issues.

The effects of lightning on composite aircraft is generally understood and basic lightning-hardening schemes have been developed. However, fleet-wide experience of aircraft with such structures in lightning-strike events is needed to fully assess their adequacy. Collection of data must be increased from the various available sources and application of this data to determine effects on composite materials and digital systems continued. Pending the assessment, pilots of composite aircraft should strive to elude lightning strikes through detection and avoidance.

RECOMMENDED ACTION: The development of suitable in-flight probability-of-strike instrument for use in reducing the number of direct strikes to composite aircraft. Continued emphasis should be placed on understanding the impact of lightning on composites and digital systems with simulation models developed to generalize lightning effects on new generation aircraft.

RESPONSIBLE AGENCIES: NASA, DOD, and FAA.

ISSUE 2: Protecting aircraft from lightning strikes.

DISCUSSION: Lightning strike incidents do not always occur where natural lightning has maximum frequency. Some cases are documented well outside of convective precipitation and in stratiform clouds. Aircraft seem to trigger lightning. Good E-field observations with penetrating aircraft and radar observations have not been made.

RECOMMENDED ACTION: Design a research program that measures frequency of hits as a function of relative location to convective cells and correlate with ground strikes, and radar reflectivity contours.

RESPONSIBLE AGENCY: NASA

F. Training Recommendations

ISSUE 1: Improve the standards of pilot and controller meteorological knowledge.

DISCUSSION: Six points were considered in the discussion, namely: a) Difficulties in implementing state-of-the-art technologies attributed to weakness in pilot/controller knowledge; b) PIREPs problems were discussed as addressed by the FAA/ NWS through the National Airspace Plan; c) En route flight weather advisory service (EFWAS); its strengths and weaknesses as a vehicle for PIREPs, forecast, en route severe weather, etc.; d) The FAA ATC controller's responsibilities and priorities as regarding the distribution of weather information; e) Current FAA pilot examinations; and f) Need for controller awareness of pilot weather data requirements.

RECOMMENDED ACTION: Require the pilot applicant to pass a specific section of meteorology as a part of the private, commercial, instrument, etc., examination. Implement ongoing meteorological instructions for controllers with special emphasis on local phenomena as applied to air operations at unmanned airfields.

RESPONSIBLE AGENCIES: FAA and NWS

ISSUE 2: Pilot training regarding low-altitude wind shear and the continuation of JAWS and other wind shear-related data analysis is necessary, as is the transfer of current information to the aviation community.

DISCUSSION: It is generally recognized that there is still a need to gather data for the characterization of low-altitude wind shear, especially the microburst phenomenon. A careful analysis of existing data is required, consisting of simulation modeling by industry and NASA. These models are necessary for flight crew training purposes and to establish standards for developing systems which require FAA certification.

There is continued recognition of the lack of industry-wide adequate training concerning the nature of wind shear, the need for complete avoidance, and the techniques for possible successful penetration of wind shear, when necessary. Most airlines appear to be addressing training well now, but the general aviation sector is significantly behind the learning curve. Finally, creative training must be continued on a long-term basis, long after the normal post-accident (Pan Am) decay of awareness.

RECOMMENDED ACTION: NASA should be funded to analyze existing JAWS data and to develop appropriate simulator models for use in real-time simulations. Distribute data in-hand to industry for purposes of incorporation into flight crew training simulators. It is also recommended that creative awareness-increasing and training techniques be explored to maintain a high degree of training in the aviation community, in all pilot sectors.

RESPONSIBLE AGENCIES: NASA, DOD, FAA, NOAA, NSF, ALPA, NCAR, industry, and universities.

G. Heavy Rain Recommendations

ISSUE 1: What are the effects of heavy rain on the flying qualities of aircraft in addition to wind shear? What are the effects on engine thrust in heavy rain? Are angle-of-attack sensor accuracies affected by heavy precipitation?

DISCUSSION: There is work yet to be done in understanding the effects that heavy precipitation has upon the flying ability of aircraft in heavy rain. It may have been a factor, along with wind shear, in the Pan Am—New Orleans crash. Leading edge high-lift devices may be adversely affected by heavy rain as well as the effect of increasing drag.

The question of how engine thrust is affected by rain was raised. Another problem may be that angle-of-attack vanes are affected by heavy rain. This would mean that pilots would not know how close to stall the airplane actually is. This, combined with the possible adverse effect on leading edge high lift-devices, could mean real trouble for penetration of heavy rain areas.

RECOMMENDED ACTION: More study is needed on the overall effect of heavy rain on airplane performance. Since the angle-of-attack indicator is necessary for stall warning devices, and stalls close to the ground are extremely dangerous, a wind tunnel study should be done, and could be done well enough, since angle-of-attack vanes can easily be placed in wind tunnels. Since two crashes, Allegheny–Philadelphia and the Jordanian aircraft, look as if they may have followed stalls, the effect on angle-of-attack accuracy should be studied first. This would seem to be the most feasible approach.

RESPONSIBLE AGENCIES: NSF, NASA, ALPA, and NCAR

CONCLUSIONS

The recommendations and comments as given in the previous section can give only a cursory look at the results and benefits of the workshop. For a more in-depth discussion, the reader should study the proceedings (Camp and Frost, 1984).

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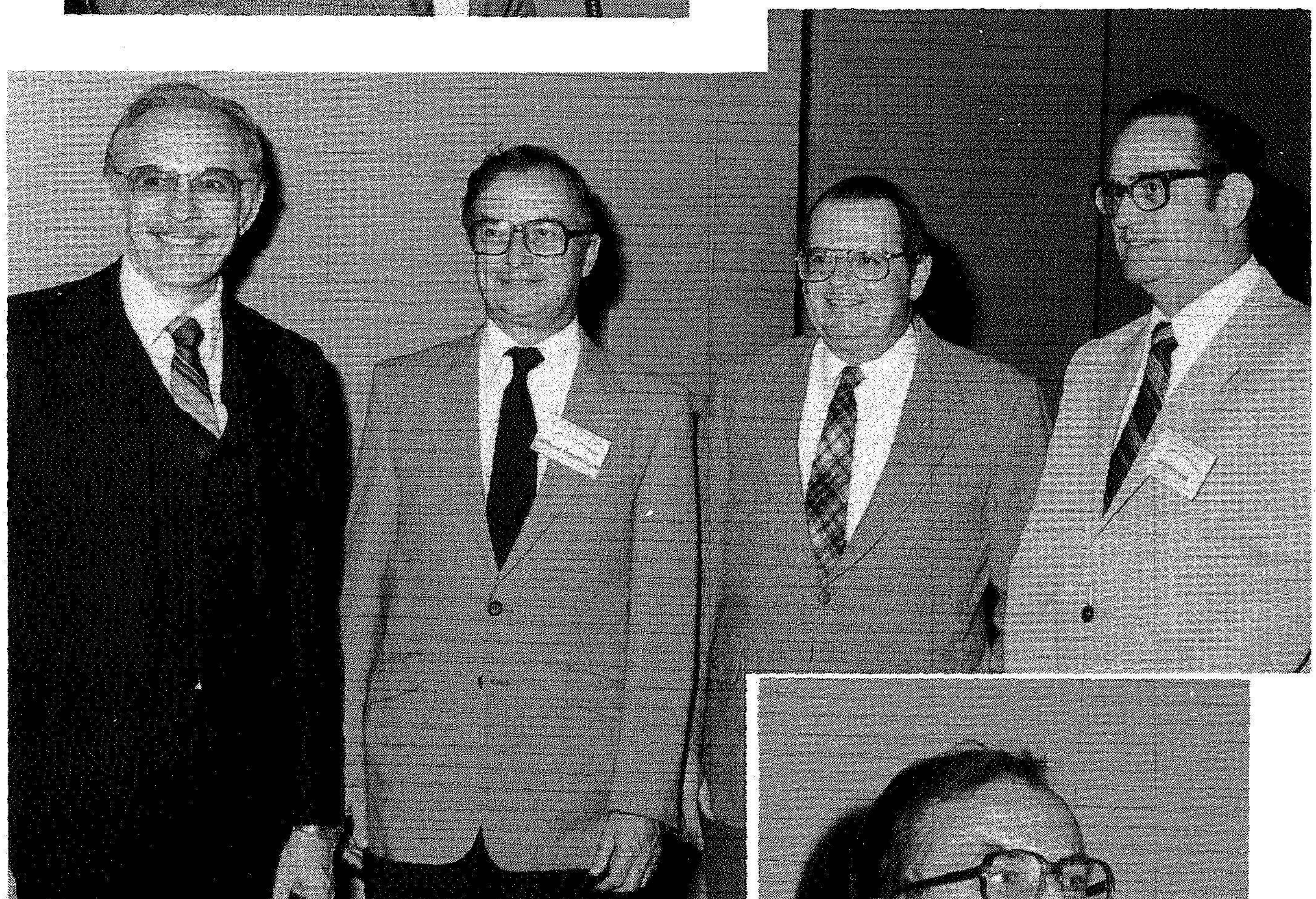
SECTION II
WELCOME REMARKS



INTRODUCTION AND WELCOME

DR. WALTER FROST

We appreciate all of you coming out to our Seventh Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems. Somehow or other we are going to have to shorten that name; however, it has been used from the onset and we don't want to change now.

To begin this morning's proceedings, we have Dr. Ken Harwell, Dean of the Space Institute, to welcome you on behalf of UTSI. Ken has been our Dean for over a year now and he has made many things happen here at the Institute. It has been a very dynamic year and I really appreciate the fact that he has time to come by this morning and address the group.

DR. KENNETH E. HARWELL

Thank you very much. It is my pleasure to welcome you this morning to this workshop. I know many of you have been here before, so the Space Institute is not new to you. I wish Walt would give me time to really tell you what has happened during the last year; but he said, "Ken, I want the short welcome this morning." Therefore, you are going to have the short welcome; but I hope during the time you are here, you will get around our campus and see some of the many things going on. If you have never been here before, this is the most beautiful campus in The University of Tennessee System. We are part of The University of Tennessee, Knoxville. At UTSI, we have a unique institution that is different from any institution in the country, in that, our graduate students and graduate study programs are really integrated with our research. To give you some idea, Deans always have to worry about money; however, we are State funded to the tune of about $ 1.6 million per year out of a total budget of about $ 10 million. Our fine faculty here then raise approximately $ 8 million per year through research contracts and grants. We have about 80 full-time research assistants who work here in some of the country's most advanced research laboratories. We are glad that you are here, because you represent an area which the Space Institute has been emphasizing for many years. Of course, Walt has done an outstanding job in the Atmospheric Science Division, and we are always glad to have this group come back. I guess I am particularly conscious of this because I am concerned with turbulence, especially in terms of the topic areas you will be addressing at this workshop. I am also a pilot. Unfortunately, I had a bad experience on a cross-country flight and made the mistake, as many neophyte pilots do, of going on a short runway too soon after a front went through. I was experiencing about a 90-degree change in wind direction within just a few minutes. However, as it turned out, to make a long story short, I really didn't know what happened. I was about ten feet above the runway, and, supposedly, had a safe descent; however, the next thing I knew I had not flaired enough and, thus, damaged a nose gear. I really don't know whether there was an updraft at the end of the runway, which was holding me up, or a sudden downdraft. By the time I contacted the tower for confirmation that it was a 180 runway, it had changed around. So, I found myself in a bad weather situation and banged up a brand new airplane. When you have an experience like this, you become more aware of the possible dangers of weather. I believe some of the present on-going research is very good for the general aviation pilot. I hope, during these working sessions, you will develop new and innovative ideas.

While you are here, try to arrange a tour to our research laboratory areas. You probably noticed the large Department of Energy facility as you entered the campus area. It is one of two national facilities for the direct conversion of electricity from coal, using magnetohydrodynamics. The next group of buildings is our own research laboratory facility. We are doing a great deal of work in laser measurements and laser diagnostics, which are key to some of the atmospheric modeling. We have 365 acres available on our campus. We currently have a high-technology industrial drive in process here. We have four small comanies in our UTSI Research Park. This year it is our goal to develop industry in this area. If any of you are looking for a location, I would be happy to talk with you about it. We have some very beneficial things to offer to industry in associtaion with the University. I think I have more than used my two minutes. My office is right next door. If you would like to have a briefing, or if you would like to have a tour of our research facilities, I will be happy to arrange either. Thank you so much for coming, and I hope that you will have a beneficial and enjoyable stay at the Space Institute.

DR. FROST

Our workshop is hosted by UTSI and NASA Marshall Space Flight Center. To welcome you on behalf of NASA Marshall, we have Dr. George McDonough, who is the Director of the Systems Dynamics Laboratory, Science and Engineering Directorate at NASA Marshall Space Flight Center. He has an Applied Mechanics PhD Degree from The University of Illinois. His research fields of interest are Systems Dynamics, Electromagnetic Effects, System Engineering, and Applications of Remote Sensing to Environmental Problems, which fits in very much with the sort of things we do. I would like to express my appreciation to Dr. McDonough for coming here to welcome you to this year's workshop.

WELCOME REMARKS: Dr. George F. McDonough

Thank you, Walt. I would like to welcome you all in the name of the NASA Marshall Space Flight Center. We are all pleased to be a part of this and to see so many people here. I trust, rather than telling you about Marshall Space Flight Center, I might spend a few minutes giving you my views of what I see in the process that is going on here. First of all, I would like to commend you for choosing a place like UTSI to have such a conference. It is a beautiful place, and very conducive to working in groups like this. The second thing is the format. Only recently, within the last year, have I had responsibility for this area of work at Marshall, and I've taken a critical look at it because one has to in such a circumstance, to see where things are going; what the goals are; what kind of people are working with it; who's using the product; where it's all going. Of course, one of the things that I was shown early on was the proceedings of the Sixth Annual Workshop. I was quite impressed; particularly, it seems that the right people are involved and limited numbers of the right people. Any of us who have been involved in meetings where we have too many people know that a lot of times the real issues become muted. So, it is very nice to see that people have thought their way through this, have small groups, and definite goals that those groups are trying to meet. The second thing that struck me about the program was that the issues being brought out seemed to be the ones of importance. I have been involved in some of these areas before, as Walt said, in Remote Sensing. I was involved in a side-issue way in the Southern Airlines 242 crash several years ago, because at that time, I was working in a program that had to do with data management. How the information on weather, etc., got promulgated to the people who used it. I got very interested in aircraft safety from that point of view and have maintained that interest. As I read the documents from the Sixth session, I was quite impressed that the problems being discussed are the ones that an outsider, as I consider myself in this business, would say are the issues that the public would like to see people with responsibility looking at, too. These are the kinds of issues that the guy sitting at the back of the airplane worries a little bit about. Are we on top of this? The airplane stories, crashes and so on, in the newspapers make them wonder about wind shears and so on...is anybody really doing something about it? Are you really getting to the bottom of this? I'm quite pleased to see that those issues are being handled in a way that I would hope they were. I just wanted to pass on those short comments to you. I am, once again, personally pleased to be involved in this program. I'm very pleased about the contribution that Marshall Space Flight Center is making... pleased that we are able to participate in these things, because I think it's an important role of NASA. We're not only space, we're also in the aviation business, and we hope to make contribution as we can. So, again, I appreciate being asked to be here. I appreciate the fact that we are able to participate, and I wish you well in the following days in your work. Thank you.

SECTION III

OVERVIEW PRESENTATIONS

"OVERVIEW OF METEOROLOGICAL INPUTS TO NASP"
James C. Dziuk

As a background for this briefing, I would like to identify the key elements of the present aviation weather system (Figure 1).

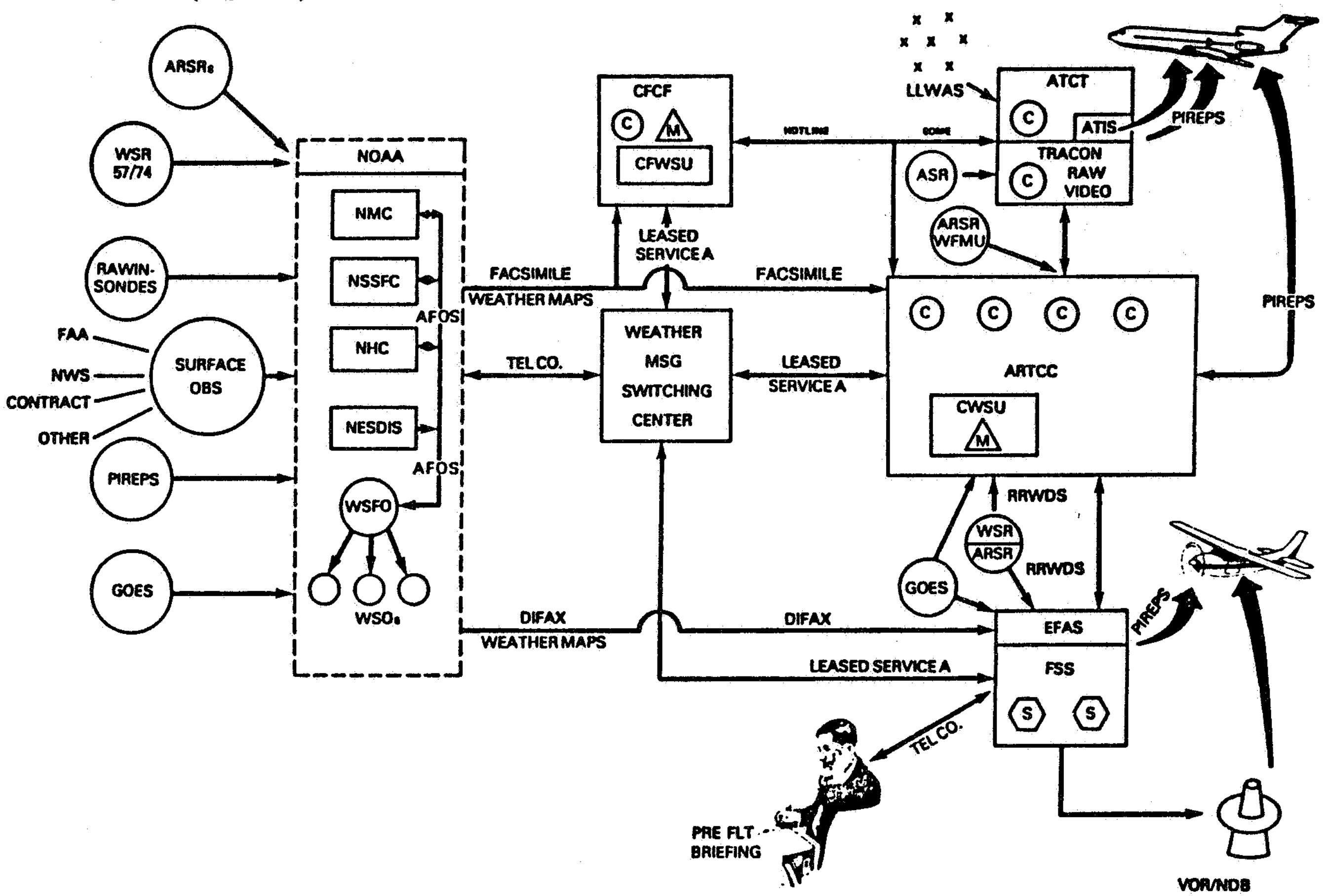


Figure 1. 1983 Aviation Weather Network

1. Surface observations are taken by several agencies, primarily NWS, FAA, DOD, and some contract observers.

2. Radar data on weather phenomena comes from weather contour circuits on our ARSR radars, the NWS WSR 57/74 series radars and from terminal ASR radars.

3. Satellite data, primarily from GOES, provides data on the CWSU and FSS facilities.

4. All forecasts and data base products are prepared by the National Weather Services and distributed to FAA and user facilities, primarily over FAA communications networks.

5. The primary focus for en route, TRACON and tower controller weather information is the CWSU staffed by NWS meteorologists. These meteorologists provide controller weather briefings, prepare and disseminate severe weather advisories and disseminate PIREPS received from controllers.

6. The weather products also go to the flight service stations for dissemination to pilots both by phone and face to face preflight briefings, and by radio for en route pilots. Current severe or hazardous weather information, is provided through the En route Flight Advisory Service (EFAS).

For the purposes of this overview briefing I have divided planned system improvements into near term and long term programs. I will also identify some unmet needs. The short term improvements are listed in Figure 2 and represent those actions which can be completed within a two to three-year time period.

- Revised pilot briefing procedures
- CWSU directive revision
- Complete Leased Service A installation
- RRWDS
- International EFAS (Miami, San Juan)
- Additional GOES (CWSU/EFAS Sites)
- High-altitude EFAS
- Hazardous In-flight Weather Advisory Service (HIWAS)
- Enhanced LLWSAS
- Automated Weather Observation System (AWOS) demonstration

Figure 2. FAA ACTIONS: Near-term program activities.

We have revised pilot briefing formats. Four types of briefings are now available to pilots. The first is the standard briefing which provides a synopsis of current weather including adverse weather, en route and destination forecasts, winds aloft observations and forecasts, and NOTAM's. The second type is an abbreviated format, designed to supplement data the pilot already has from prior briefings. The third is a briefing designed for planning purposes for flights scheduled to depart six hours or more in the future, which provides forecast data which is applicable to proposed route of flight. The fourth is an inflight briefing which corresponds to the preflight briefing, but which is given by radio. It is given by FSS briefers and is not available from EFAS positions.

The Center Weather Service Unit (CWSU) directive has been revised and is in coordination at this time. It redefines the duties and responsibilities of CWSU meterologists and the weather coordinator and it includes planned changes to improve critical weather dissemination. Other areas affecting CWSU operation include provision of Leased Service A terminals at all CWSU's which will improve PIREP distribution. The Leased Service A program will provide higher-speed communications and computer terminal equipment at all CWSU's and Flight Service Stations (FSS) by the end of 1984.

The radar remote weather display system program will equip 134 radars, 77 NWS WSR 57's and 57 FAA long range radars: The displays will provide six intensity levels in color. Implementation is scheduled for completion at all CWSU's and EFAS by December 1983, with all systems commissioned by March 1984.

International EFAS, to support over water operations in the Caribbean area, will be initiated in the Miami and San Juan IFSS's in 1984/85.

Data from geostationary orbiting environmental satellites is presently available at 20 Air Traffic Control Centers (ARTCC), 20 FSS's and the Central Flow Control Facility (CFCF). It will be available at En route Flight Advisory Service (EFAS) locations and selected level III FSS's by 1985. All 64 locations will be equipped with high resolution receivers/recorders. High altitude EFAS air-ground frequencies for high altitude EFAS will be implemented at 20 locations by 1985. A frequency allocation study is currently underway.

The Florida demonstration of the hazardous inflight advisory service was successful and national implementation is planned. Our frequncy management people are currently in the process of allocating appropriate frequencies and consideration is being given to the provision of HIWAS on some UHF frequencies. Implementation is planned during 1984.

The Low Level Wind Shear Alert System (LLWSAS) is designed to provide controllers with information of hazardous surface wind conditions (on or near the airport) that create unsafe landing or departure conditions. The system was originally developed for gust front detection at airports and has successfully detected wind shear phenomena. LLWSAS is a real-time, computer controlled, surface wind sensor system which uses telemetry as a communiation link. LLWSAS uses minicomputer processing that evaluates wind speed and direction from sensors on the airport periphery with center field wind data. A 15 knot vector difference triggers an aural and visual alarm in the airport control tower. During the time that the alert is posted, air traffic controllers provide wind shear advisories to all arriving and departing aircraft. One-hundred-ten systems have been funded, 59 systems are installed and operating, and 51 systems are scheduled for installation in 1984/85.

In response to a Congressional directive, the LLWSAS at the New Orleans airport is being expanded to improve the capability of the system to detect microburst wind shear phenomena. Five additional sensors are being added to the current sensors to provide coverage along runways. Processor and software modifications are being made that will permit comparison of wind vectors between each pair of sensors as well as the center field sensor. Facility tests are scheduled to begin in February 1984 and will run for one year. This testing could result in recommendations for enhancement of the LLWSAS'.

The Automated Weather Observation System (AWOS) is being implemented to provide efficient, reliable, and cost-effective automated weather observations at a significantly greater number of locations than are available today. It will provide automated sensing of: wind direction and velocity, barometric pressure (altimeter setting), temperature, precipitation, dew point, and visibility. The primary output is a synthesized voice broadcast. Eventually data will be output to the national weather data base and, at some manned sites, supplementary data may be added.

Currently an AWOS demonstration program is in progress. Equipment has been installed and is operating at 14 demonstration sites. These demonstrations are designed to obtain equipment reliability data, correlation between manual and automatic observations, and pilot evaluation. Demonstration results will be used in preparing the production specification to be issued in 1984.

This next set of programs (Figure 3) represent those which will be implemented in the late 1980 time period. These include next generation weather radar, terminal Doppler radar, central weather processor, Mode S data link, flight service automation system, and NADIN.

- Next Generation Weather Radar (NEXRAD)
- Terminal Doppler radar
- Central weather processor
- Mode-S data link
- Flight service automation system
- National Airspace Data Interchange Network (NADIN)

Figure 3. FAA ACTIONS: Long-term program activities.

The objective of the NEXRAD program is to develop and implement a Doppler weather radar that will meet the weather detection needs of FAA, NWS, USAF, and other Government and private organizations. A network of radars is planned that will provide weather radar coverage above 10,000 feet throughout the entire country. The aviation weather products to be provided by NEXRAD include winds, wind shear, turbulence, thunderstorm detection, storm movement prediction, precipition, hail, frontal activity, icing conditions, freezing levels, mesocyclones/tornadoes, and hurricanes. Validation phase contracts were awarded earlier this year and are scheduled for completion in July 1985. Limited production unit No. 1 is scheduled for delivery in February 1988. Production units are to be installed from October 1988 through February 1992.

As a result of the Doppler weather research that FAA and other Government agencies have sponsored over the last ten years, as well as the results of the continued analysis of the joint airport weather studies data, FAA is planning to implement terminal Doppler weather radar systems at a number of airports where wind shear conditions are prevalent. The terminal radars will have somewhat different characteristics from the en route NEXRAD systems. They will operate to shorter ranges and the radar parameters will be tuned for detection of wind shear and other clear air phenomena. FAA has examined a number of alternatives for achieving the terminal Doppler radar capability including development of "C" band weather radar, addition of a Doppler weather channel to ASR-9, modification of commercial Doppler weather radars, and a NEXRAD derivative tuned for terminal wind shear detection. A plan is currently under development for procurement of terminal Doppler radars; this concept is supported by the Tri-agency NEXRAD council.

The center weather service unit is the central facility for accumulating, processing, and disseminating weather information to the air traffic controllers. The meteorologists at these positions provide controller briefings and generate and disseminate severe weather information to the controllers in the centers, TRACON's and towers.

The central weather processor, which is to be located in the area control facility, will be the focal point for the weather system processing for the CWSU meteorologists, air traffic controllers, and pilots. The initial system capability will provide automation of the meteorologist functions, which will include the capability to overlay satellite visual and infrared images and surface radar data and to translate them into the stereographic plan used by the ATC computers. A loop capability will be provided to allow meteorologists to study storm development and aid in the generation and dissemination of severe weather advisories. A mosaic of NWS and FAA NEXRAD and terminal Doppler radars will be available to the meteorologists. This automation program will also produce a type of hazardous weather contours. These contours will be displayed on controller and FSS specialist displays and, in the future, will be available to the cockpit over the Mode-S Link.

The Mode-S system provides both improved surveillance and data link services. Terminals in the aircraft will allow the pilot to directly access the ATC system weather data base. Our schedule is to have Mode-S ground sites operational in 1988, which will provide weather data. When the advanced automation system becomes operational in the early 1990's, most clearance information can flow automatically via data link. We are also considering the down-linking of airborne sensed weather information to update weather data base information.

The flight service program provides for two stages of implementation of specialist automation. The first, called Model One, provides automation of alphanumeric products; and the second, called Model Two, adds automation of graphic products. A subsequent enhancement program will provide telephone voice response units and direct user access through Direct User Access Terminals (DUATs) and airborne Mode-S equipment.

The FAA modernization program provides for the automation of 61 flight service stations. Model 1 delivery is scheduled to start in 1984. Model 2 delivery is scheduled to occur between 1985 and 1989, and will provide alphanumeric and graphic product automation at all 61 automated flight service stations.

The objective of the national airspace data interchange network (NADIN) is to replace the current data switching systems, provide cost-effective service, and be able to expand to meet future National Airspace System (NAS) needs. The NADIN system should provide improved dissemination of weather information, replace the Aeonautical Fixed Telecommunications Network (AFTN) switch, replace service "B", replace NASNET, provide flow control communications service, provide ARINC/ airline interfaces to weather and flight plan systems, and enhance NOTAM communications. The first phase of NADIN is scheduled to become operational in 1984 with the enhanced NADIN supporting the future systems becoming operational in 1987/88.

We believe that these programs will provide substantial improvement in the observation, processing and dissemination of weather information. However, there are some areas where improved technology is needed. These unmet needs include improved accuracy of winds aloft information. Improvement in sensors for present weather, cloud height, cloud type, vertical wind shear detection and wake vortex detection. Improvement in short-term forecasts, improved icing and turbulence forecasts, and development of airborne turbulence and wind shear sensing devices. We will, undoubtedly, discuss these areas in greater depth during our technical sessions.

The upgraded system of the Post 1990 period (Figure 4) will have the following capabilities:

In the sensor area, profiler and windsat are potential providers of improved wind and other data. Weather radar data will be derived from a network of terminal and en route Doppler weather radars.

Communications of many alphanumeric and graphic weather products will flow over a NADIN system. Some information, primarily radar data, may be routed directly to system processors. Processing of weather products occurs in the NWS facilities, the FAA aviation weather processor, which formats weather data for aviation users, the Flight Service Data Processing System (FSDPS), and the Central Weather Processor (CWP). Automatic storm signature analysis will be provided and annotated hazardous weather graphic information will be automatically generated and disseminated .

Pilots will have direct preflight access to the automated weather and NOTAM data bases either by Voice Response System (VRS) or direct user access terminals (DUAT). Pilots in flight may access the ground data bases by Mode-S data link; or, if not equipped, receive automatic broadcast of severe weather information, ATIS, wind shear alerts, Automated Weather Observation Systems (AWOS), and Transcribed Weather Broadcast (TWEB) information. En route Flight Advisory Service (EFAS) will continue into this time period. The pilot will have continuous access to real-time or frequently updated weather information throughout the flight.

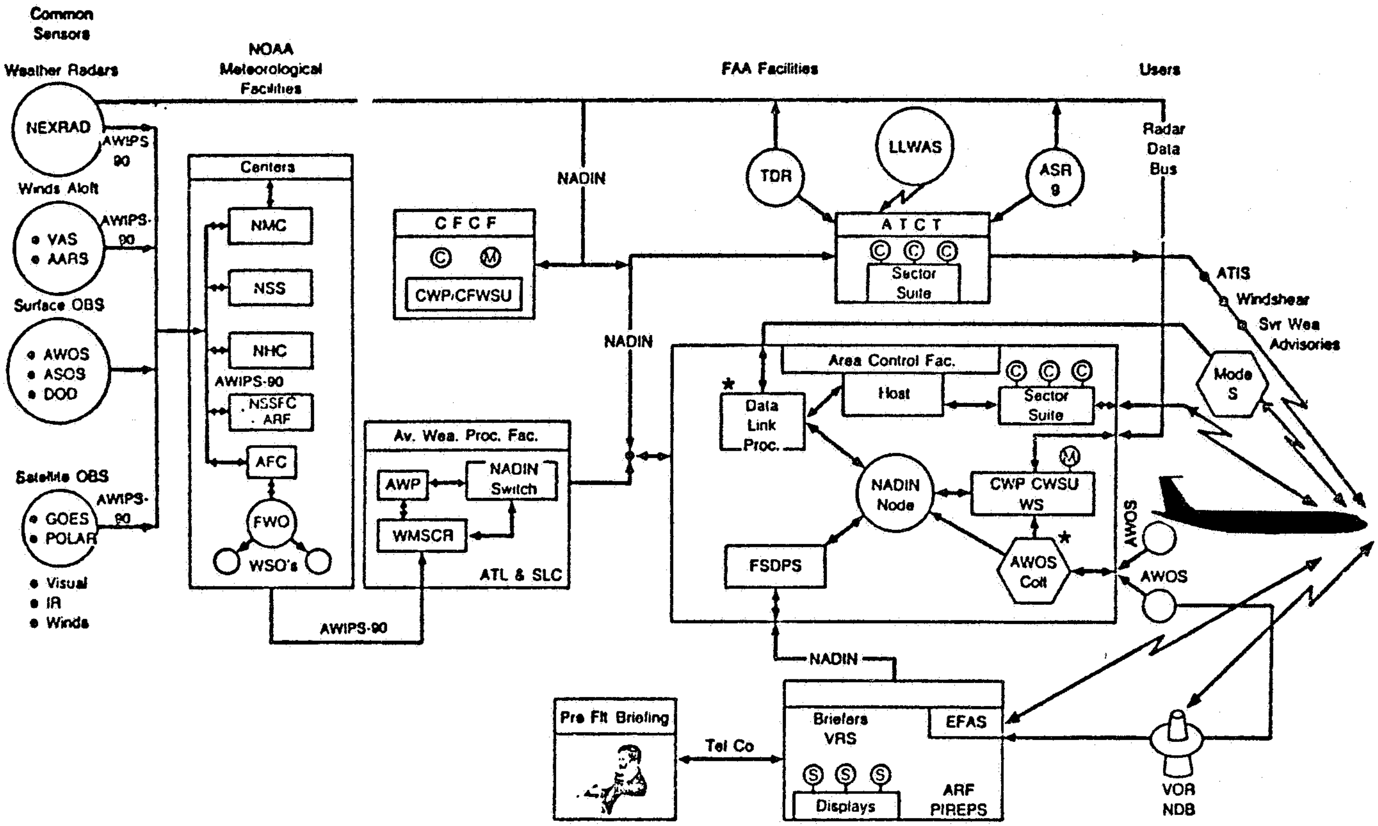


Figure 4. Aviation Weather System: 1993

procedures; mid-term program provides improvements in observations, severe weather detection, processing and dissemination; and the longer-term program is starting to define interagency activities to provide the basic technology for further enhancements in short- and long-term forecasting and improved automated observation systems. The goal is automated sensing, processing and real-time dissemination of weather products to the system users.

"AIRLINE METEOROLOGICAL REQUIREMENTS"

C. L. Chandler and John Pappas

Yesterday, as I was about ready to leave the office, the telephone rang. It was Walter asking for help. I will volunteer for anything, more or less, if it has to do with airplanes and weather. The only reason I volunteered to help is that immediately I knew in my mind who could give this paper much better than I. You don't have to twist his arm too hard. We have that man here today–Mr. John Pappas, who will present this paper; and, hopefully, both of us together can make up at least 30 % of Dan. Maybe not, but we will give it a try. Last night I asked Walter if I could give about an one-minute speech off the agenda, completely on another subject, and he said it would be all right.

Many of you may not realize that today is an historical date in aviation. Exactly 25 years ago on this date, Pan American started their transatlantic service with a 707-120 aircraft. In about T-8 hours, that 120 at Kennedy or Idlewilde, at that time, had about a 57-second ground roll; he had 6,000 pounds of water (some of you old-timers know what that water was for). My latest information tells me that tonight they are going to reenact that flight. I have not heard otherwise. They are going to take a 707 out of Kennedy to Gander to Paris with the same passenger load (I believe it was 94); they say they are going to serve the same kind of food. They found many of the members of the original flight crew and cabin attendants; and I understand they will also have about a week-long party in Paris for the invitees. I tell you that because I am proud. I was a part of that operation at that time. So was E. B. Buxton. One more thing, I would like for the aircraft manufacturers and the air traffic control people from FAA that are here today to give a little thought to what I'm about to say now.

In 1961, the schedules between Atlanta and Dallas/Fort Worth as a typical airline city pair were fifteen minutes faster than they are today, and it was real. We made it in one hour forty-five minutes in those days. It takes two hours now. We doubled the speed overnight in 1958. We went front 230 knots to 460 knots overnight; but in over 20 years, we are slowing down. Keep in mind, a passenger buys a ticket because of the fastness of the airplane in most cases. So, this is something for you people to think about. John Pappas has about 20 years in the air weather service. He was our manager at Southeast Weather in Atlanta for about five years and for the past seven years, he's been Manager of Meteorology at Western in Los Angeles. I would like to present John Pappas.

John Pappas

You heard what Chan said about being called upon to do this impromptu and how quickly he accepted. Of course, what he had in mind was making the introduction and I would make the presentation. So, welcome to the "Chan and John Show"–how do you like us so far?

The operational objectives of an airline are: Safety, convenience, comfort, and economy. Our meteorological requirements necessary to reach and maintain these objectives are many. The first thing that comes to mind is what I call "Weather Data Communication Reliability." It is not enough to develop systems that improve upon current systems. Systems that increase data storage capacities and allow us to transmit data at phenomenally faster and faster speeds are great; but meaningless unless the data that these systems provide get to the user.

From the users point of view, and the airlines are users, there is nothing more frustrating to an airline dispatcher or meteorologist who has to make a continuous wide array of decisions that require meteorological data around the clock, and the data isn't there. The data is available, and the equipment to transmit and receive it is available, but it is not getting through. Many manhours are spent on the telephone desperately trying to find someone in the communication chain that can help get that data to you. "Weather data communication reliability"–we want to confidently know that the data communication systems are reliable and we will receive data consistently.

Our other requirements are mostly traditional. Of course, we require accurate hourly observations. Moreover, they should be complete, and contain all significant elements, including remarks that amplify or enhance paraticular elements. For example, clear NW, lightning South. We're concerned that automated weather observations will not be able to provide significant remarks. For those preparing forecasts and those making operational decisions, remarks are important.

There is also a requirement for a special observaton whenever the ceiling or visibility goes above or below 2,000 feet and/or three miles. This is required to enable airlines to satisfy alternate requirements. We feel very strongly about this.

Upper-air observations are needed. We must have a system that provides accurate temperature, humidity, and pressure height data, as well as wind direction and speed. There is lots of interest in the radar-profiler today to provide upper-air data. To reiterate and emphasize, we must have pressure height data, accurate temperature and humidity information, as well as wind direction and speed.

There is a continuing requirement for radar observations. We, of course, want equipment designed specifically for weather surveillance, the NEXRAD idea. Weather satellite observations are required. A few years ago, requirements for satellite data did not exist. Today, these observations are a very important part of airline requirements and are becoming increasingly important.

We need accurate terminal forecasts, including forecasts of severe weather phenomena, low-level wind shear, icing, snow, ceilings, and visibility.

RVR forecasts are definitely something that should be provided. Moreover, forecasts that correspond to the operational ceiling/visibility categories are necessary to make aviation forecasts more meaningful. The special category for ceilings and/or visibilty of 2,000 feet and/or three miles, mentioned earlier, would permit IFR flight planning without an alternate and save millions of dollars in unnecessary expenses.

Improved upper-air forecasts have been a special requirement since the dawn of commercial aviation. It is even more significant today. Operating costs of most airlines have quadrupled during the past decade. There has been very little improvement in the forecast models that could offset some of these rising costs. We are encouraged with the work of NASA's Bob Steinberg and his MERIT program. This kind of research is encouraged by the aviation community. Some examples of the impact of upper winds on operating costs are the following:

For an airline the size of Delta, that operates approximately 1,500 flight segments per day, a change in wind that affects the flight time by as little as six <u>seconds</u> and 20 pounds of fuel adds up to approximately $ 3,900.00 per day in operating costs. This is almost $ 1.5 million per year. This kind of money is more than enough to cover the operating budget of an airline's meteorological/flight planning department. One knot of tailwind for a DC-10 operating between Los Angeles and Honolulu is worth 200 pounds of fuel. One knot! These are real numbers. Wind speeds equal to 40 percent or more of a commercial jet's true airspeed occur. Not all of the time, but they do happen, and we feel that ATC system does not consider the impact of this phenomenon. We could plan and fly great circle routes on every trip. However, we must use the wind as an energy source, a free energy source. Atmospheric winds are not constant; large variations with time, as well as vertically and horizontally, mandate that we plan and fly in order to reduce the negative impact of headwinds and increase the beneficial effect of tailwinds. Temperatures are important also but wind makes the greater impact on economy. Upper wind forecasts must be improved.

Finally, the requirement for meteorological instrumentation needs to be mentioned. Many of you in the audience probably deal with this and have a similar interest. The low-level wind shear alert system (LLWSAS) is an airline requirement - absolutely! We need further development and installation of the Doppler Radar System. These, and all other weather measurement instruments and systems, are going to be of interest to the airlines for many years to come.

This concludes our presentation on Airline Meteorological Requirements. I thank you for listening and bearing with us.

"GENERAL AVIATION'S METEOROLOGICAL REQUIREMENTS"

Dennis Newton

The theme of this year's workshop is Communication and Appplication of Atmospheric Data for Aviation Needs. One could certainly say that this theme has been implicit in all of these workshops. However, the stress on communication seems to me to be both important and appropriate, for two reasons. First, the value of weather data to aviation is often extremely perishable. It becomes quite useless if not quickly and accurately communicated to the people who need it. Furthermore, communication of weather theory and information about weather service products to pilots in an accurate and comprehensible manner is essential to flying safety in general. Probably no one needs weather knowledge more than the people who fly through it.

The specific subject of this overview paper is General Aviation's Meteorological Requirements. However, before one addresses the subject of General Aviation's requirement for anything, it is well to say something about what is meant by the term, General Aviation. In the broad view, the term can be, and often is, taken to mean all of civil aviation except the airlines. It would be virtually impossible to cover the meteorological needs of all of that in a single paper, in addition to which, one result of trying would be considerable overlap with Mr. Olcott's forthcoming paper. Therefore, I would like to limit the subject somewhat by listing some common characteristics of that portion of the broad category of General Aviation with which this paper will be concerned. The following items should not be taken as a definition, but more as a working hypothesis derived from experience of the makeup of the spectrum of weather customers, if you will, whose needs are considered here.

1) The segments of General Aviation treated here will be those which operate below an altitude of about 25,000 feet. Within that operating regime, there is a broad spectrum of aircraft types, ranging from light, single-engine airplanes to pres-

surized twins powered by turbocharged piston or small turboprop engines, and a few helicopters.

2) The operations considered are non-revenue transportation of persons and property under both the visual and instrument flight rules of FAR Part 91. Non-revenue should not be taken to necessarily imply non-business; however, as much of this transportation is business related.

3) The pilots are generally the owners or renters of the aircraft, as opposed to persons who make their living flying. They encompass a broad sepctrum of flying qualifications. Many of them are instrument-rated pilots. Some of them, praticularly pilots of higher performance aircraft, have Commercial Pilot Certificates. However, they are not often rated as Airline Transport Pilots.

4) Of the aircraft flown, only the pressurized models can generally be considered to be fully equpped for weather flying, i.e., to be equipped with weather radar and certified for flight in known icing conditions. Among the non-pressurized models, the amount of thunderstorm avoidance equipment and ice protection equipment is widely variable, down to frequently none in the fixed landing gear and in many of the retractable single-engine models. Most of these aircraft carry, at least, the basic equipment required for flight under IFR, however.

5) The financial resources of this segment of General Aviation are more limited, and more limiting, to its operations than those of, for example, a corporate flight operation. The necessity of sometimes having to cancel trips is accepted, albeit, probably reluctantly, as the price of not having some types of equipment or services available. In this regard, this segment of General Aviation is much less likely to employ a private weather service than is a corporate or commuter operator.

The above elements describe a very broad, active segment of aviation. Furthermore, it is a segment which is very dependent on the skill of its pilots in coping with weather for the safety of its flights; and on the quality of the weather services it uses, which services are almost exclusively provided by the National Weather Service (NWS) and the Federal Aviation Administration (FAA). Its aircraft do not, in general, have the performance to rapidly climb and descend through the weather. It must, therefore, frequently operate in the weather, or not at all.

It is essential to both its safety and usefulness that this segment of aviation be provided with the training to give its pilots an adequate knowledge of weather, in general; and the avoidance of hazardous weather, in particular. This done, it is then essential that these pilots have available to them weather products and services which will enable them to make intelligent decisions about routes, altitudes, times, fuel, and everything else influenced by weather down to, and including, the consideration of whether or not they should even be thinking about making this flight today. Let's think a bit about training first, and then about the products and services.

It is easy to wax hopelessly philosophical about weather training for pilots. Question: How much training is enough? Answer: Enough to be safe! Question: How much is THAT? The discussion goes rapidly downhill from there. In keeping with the function of this paper as an overview, and, hopefully, as a basis of later discussion, I would like to set forth just a few basic observations on the subject, together with a suggestion or two. First, I submit that the amount of training, which is the minimum necessary for pilots at any given skill level, is that which:

1) Instills in them a profound respect for weather which is beyond their capabilities (or the capabilities of their equipment) at whatever current stage of flying development they may be; and

2) Provides them with the knowledge required to recognize and avoid that weather.

For example, a beginning pilot, whose flying is entirely visual, must be trained in visual recognition of hazardous weather. He must also be trained in recognition of conditions conducive to reduced ceilings and visibilities which are hazardous, in themselves, at that stage. This training must also include the elements of weather briefing necessary to anticipate such conditions prior to flight. If the pilot's limitations are to expand, further weather training, to permit recognition of the new limits, is required.

Now, how much training will a pilot actually get? I submit that this is driven primarily by the requirements for weather knowledge on the FAA written tests for pilot ratings. People are most willing to invest time, effort and money in training for which there is some tangible reward, such as meeting a requirement for a license. I, therefore, suggest that, realistically, the amount of weather training which these pilots will acquire is strongly affected by the weather content of the Private Pilot and Instrument written examinations. There are, essentially, no other requirements to demonstrate weather knowledge, unless the pilot seeks an Airline Transport Pilot Certificate. These tests are, therefore, among the first things to look at if one wishes to do something which will actually have an effect on weather training of pilots. At present, weather questions constitute, roughly, 15% to 20% of the Intsrument Pilot written test. Since a passing score on the test as a whole is 70%, it is possible to miss most (or even, conceivably, all) of the weather questions and still pass the test. I can, personally, think of nothing which would be more likely to have an effect on the quality of weather training than to score this section of this test (and, perhaps, also the weather section of the Private Pilot Test) separately from the rest of the test; and to make a passing score on this section of the test, by itself, a requirement for passing the entire test.

The requirements for recurrent training of General Aviation pilots (as limited for the purposes of this paper) are, at present, minimal. There is, however, a requirement for a biennial flight review to be given by a flight instructor. There is also a much stiffer requirement for the renewal of Flight Instructor certificates biennially, which instructors can meet (among other ways) by taking a three-day refresher course. I would suggest that a refresher course for the renewal of Flight Instructor certificates devoted entirely (or nearly so) to weather and to the teaching of weather be created, and that this be accepted as satisfying the renewal requirement instead of the regular refresher course on something like an every-other-renewal basis. It would be no big trick to put together such a course, which could and should be made available to any pilot. The carrot of actually giving something tangible for taking it (i.e., the instructor revalidation) would induce far more people than would ever take an avanced weather course otherwise. What better people to take it than flight instructors? It would then be, at least, plausible to expect a general improvement in pilot weather training to take place over a period of time, and to expect that pilots might get more and better exposure to weather knowledge during Biennial Flight Reviews given by these instructors.

Turning to the subject of the weather products and services needed by General Aviation, I would like to submit some fairly specific comments for later consideration in the working sessions (including some of my own personal value judgments as to where improvements have been made and where they are needed), as follows:

1) Thunderstorm products are generally very good. Among those products of most value to pilots, I would list convective outlooks and the associated severe weather outlook charts, severe thunderstorm and tornado watches and warnings, stability charts, radar summary charts, and convective SIGMETS. I believe that little in the way of additional products is required in this area. Fast dissemination is critical to their utility, howver. This is particularly true of the convective SIGMETS and radar summary charts. In addition, the stability chart is a very valuable briefing tool and should be given much faster and wider dissemination.

2) Icing products are grossly inadequate. Despite the seriousness of the hazard, there is no long list of products like the one above relating to icing. The quality of icing forecasts has been generally conceded at these workshops to be poor. This, in my opinion, starts with the total lack of a generally accepted definition of the intensity of icing conditions in terms of forecastable physical parameters, particularly that of cloud liquid water content. I am aware that a great deal of research into this subject is underway at the present time. In the interim, however, much better use could be made of methods presently in hand. A reasonable definition of icing intensities was proposed by NACA in 1947, and a method of forecasting them has existed since 1952. They are not perfect, but they are a lot better than nothing.

3) There are many airports which have instrument approaches but no weather observations. There are also some remote locations, such as mountain passes, where observations would be very useful. Various types of automatic equipment are now being developed and installed to make such observations, which is good. I wonder, however, in these days of stuffing digital video data down wires, if remote television cameras at these sites might not be a better, and perhaps less expensive, solution. I realize that this will go against the grain of the natural deire of technical minds for quantitative data. However, the TV camera at Stampede Pass, which once provided a picture at the Seattle Flight Service Station, went out of service about six years ago and there is now a remote observation site in

its place. I have never found anyone who had used them both, myself included, who didn't prefer the picture.

4) On the subject of pictures, they are worth far more than a thousand words in a weather briefing. I refer, in this case, to the usefulness of a direct look at charts, particularly surface maps, weather depiction charts, radar summary charts, severe weather outlook charts, stability charts, constant pressure charts, and the various prognostic charts. No telephone weather briefing will ever come close to giving a pilot the information which can be had from a look at the charts. The increasing automation and consolidation of Flight Service Stations has, unfortunately, seriously reduced or eliminated the General Aviation pilot's opportunity to peruse charts in many locations. It is obviously not possible to put the system back the way it was. It was changed in the first place largely because it had become impossible to keep it the way it was. However, it seems to me that the proliferation of home and office computers may offer a good opportunity to restore pilots' access to the charts. I believe that a high priority should be given to making charts and other data, such as sequence reports and forecasts, available to those having equipment capable of displaying or printing them.

In the meantime, dissemination of weather data to General Aviation users is, and will continue to be, largely dependent on voice communication, either by telephone or radio. This, of course, is labor intensive and takes a lot of time. Due largely to these two factors, voice dissemination lends itself to the omission of items of data which are important to understanding of the weather situation. One of these items is recent past weather. It is unfortunate that most weather briefings are given as if nothing was known about what the weatherd had been from the dawn of recorded history until the phone rang; but it will probably continue to be the case simply due to time and workload constraints on the part of both pilots and briefers. Some automation of this process is possible, however, and some steps have been taken in this direction. Comments on these are as follows:

1) A system using touch-tone phones allowing pilots to obtain exactly the weather they want by following recorded instructions and entering the necessary commands has been used in a few locations. This concept is excellent and should be pursued and expanded.

2) A scheme has been implemented at the Seattle Flight Service Stations, and perhaps elsewhere by now, in which the caller receives a recorded announcement of briefings for various routes, also recorded, which can be accessed by proper keying of a touch-tone phone. Upon completion of the selected briefings, or if none are selected, a briefer answers if the caller stays on the line. This is also an excellent idea and its use should be expanded.

3) Transcribed weather broadcasts are offered over navigation frequencies throughout the country, and these can also often be listened to by dialing a telephone number listed in the local phone directory. These are good if kept current; but they are quite general, and it is often necessary to listen for a fair amount of time until the data in which one is interested comes around. In this regard, I would strongly recommend that Notices to Airmen (NOTAMS) be removed from these broadcasts. Unlike weather information, NOTAMS for airports and routes not involved in a given flight (and even some which are) are of no value whatever to a pilot in flight. There are few more aggravating wastes of time than listening to a recitation of NOTAMS, meanwhile flying an airplane, maintaining communication with air traffic control, etc., in the sometimes vain hope that the desired weather information will eventually come around. There is no way of knowing how often it happens that a pilot tunes up a TWEB for weather information, hears NOTAMS instead, and then simply turns it off and calls a briefer. I can testify that it is not uncommon. There are plenty of preflight sources of NOTAMS, and the TWEB would be a lot more useful without them.

4) Finally, the EFAS system (commonly called Flight Watch) of direct inflight pilot-to-briefer communication is an excellent service for General Aviation. It could be better if more frequencies were available for it, but functions very well otherwise.

"CORPORATE/COMMUTER AIRLINES METEOROLOGICAL REQUIREMENTS"

John W. Olcott

Thank you very much. I appreciate the opportunity to be here. I also appreciate following Dennis Newton and John Pappas, because they have very adequately covered the needs of the area that I am going to address. Corporate/executive operations are part of general aviation; but they tend to follow more the philosophy of FAR Part 121, than do the smaller operators to which Dennis Newton was referring. The commuter operators follow FAR 135, and, to a certain extent, FAR 121; so they also fall in between the type of characteristics that Dennis and John mentioned.

Within the system we call aviation weather, communications represent an element of primary importance. Man cannot influence the weather over any scale of significance to aviation. He can only observe what exists and predict what is likely to happen based upon current and historical data. To counter our inability to influence weather, we have only our ability to measure and communicate what is happening. Therefore, I add to the comments of other speakers my support for the relevance of this year's workshop theme, "Communication and Application of Atmospheric Data for Aviation Needs".

While the rapid and accurate communication of weather phenomena is important to almost everyone, nowhere is it more important than within aviation. As Mr. Newton so appropriately observed, the people who need the most knowledge about weather are those that fly through it. Furthermore, the consequences of limited, untimely or nonrelevant knowledge of weather are potentially more hazardous to the aviator than to any other group.

To provide emphasis to that last point–namely, the potential hazards of weather to aviators–, I wish to refer to the final report of an informal panel on general aviation safety, which was submitted to FAA Administrator Helms in February 1983. I served as Chairman of that panel.

Data compiled by the National Transportation Safety Board (NTSB) indicates that weather is a cause or factor in about 40 percent of fatal accidents within general aviation. Of equal significance, is the fact that the classification "pilot-inadequate preflight preparation or planning" is the leading cause or factor in nonfatal accidents (12 percent), and a cause and factor in about 13 percent of fatal accidents. Often, the specific area where preparation and planning were lacking was related to weather.

Where accidents involve weather-related causes or factors, the mishap is more likely to result in a fatality. Of the 10 leading causal citations attributed to nonfatal accidents in 1979, for example, only one — unfavorable wind conditions — explicitly referred to weather. In accidents involving fatalities, however, four of the 10 leading causal factors related directly to weather.

Low ceilings typically is a leading causal factor in fatal accidents. In 1979, for example, it was a cause or factor in 25 percent of all fatal accidents; no other causal factor was more prevalent in mishaps involving fatalities. The next most frequent citation was "pilot-contained VFR flight into adverse weather conditions" (19 percent of 1979's fatal accidents). "Weather-fog" was the fourth most-often cited causal factor (18 percent); it came right after "pilot failed to obtain/maintain flying speed" (19 percent). "Weather-rain" was the ninth of 10 leading causal factors for 1979 (7 percent). (Causal factors total more than 100 percent due to the assignment of more than one cause or factor to an accident.)

Two other top-10 causal factors in fatal accidents– "pilot-inadequate preflight preparation or planning" and "pilot-improper inflight decisions or planning"– often involve the gathering or use of weather information. In fact, six of the 10 leading causal factors for the year involved weather in some form.

Although specific data for 1979 are used here for emphasis (since 1979 was the year in which the lowest number of fatal accidents occurred for the period 1967 to 1980, the last year for which the panel had detailed breakdowns of data), the results presented do not vary appreciably from other years and are applicable for the present time.

While the data referenced by the General Aviation Safety Panel's Final Report applied to all categories of general aviation, 1979 accident data compiled by the NTSB indicates that corporate/executive and commuter operation suffer similar impact from the weather. In 1979, for example, weather was a factor in eight (57 percent) of the

14 corporate/executive fatal accidents and in five (38 percent) of the 13 commuter fatal accidents.

Returning to the theme of communications, Mr. Newton quite appropriately observed that general aviation is a broad term that encompasses all flying other than scheduled airline activity and military flying. Hence, corporate/executive and often commuter operations fall within the broad classification of general aviation.

Mr. Newton addressed the communications needs of the aviator who flies below 25,000 feet, is involved in non-revenue transportation, does not earn his living principally as a pilot (which implies a less active knowledge of aviation and a lower level of aeronautical skills for the average pilot, but such may not be the case for all nonsalaried aviators), operates aircraft that generally are less equipped for weather flying than the corporate/executive or commuter pilot, and has marginally more limited resources than pilots within corporate/executive or commuter aviation.

In many cases, however, corporate/executive and commuter operators have many of the same characteristics as the group Mr. Newton addressed. A reasonable and important percentage of corporate/executive operations occur below 25,000 feet, and most of the current schedules of commuter/executive activity is conducted in accordance with FAR Part 91, while commuters operate to FAR 135 or possibly FAR 121. But weather is insensitive to the FAA's operating regulations; there is no such thing as a FAR Part 91 thunderstorm. The more relevant regulation refers to aircraft certification (CAM Part 3, or FAR Part 25), and aircraft certificated to each of these regulations can be found in each classification of general aviation.

Thus, much of what Mr. Newton outlined and recommended in his presentation applied equally well to corporate/executive and commuter aviation. I wholeheartedly endorse his comments on weather training and feel that the concept Mr. Newton proposes applies equally well to all aviators, no matter how active. His comments concerning the adequacy of weather products, and, to a lesser extent, weather services, also apply to corporate/executive and commuter operations.

It is in the areas of recent experience, equipment flown by the larger companies and, most significantly, in communication resources, that corporate/executive and commuter operators differ from the group Mr. Newton addressed.

The average member company of the National Business Aircraft Association flies its aircraft over 600 hours per year, and over 63 percent of the NBAA fleet are turbine powered. The average member company of the Regional Airline Association flies its aircraft over 1,300 hours per year, and over 47 percent of the RAA fleet is turbine powered. These statistics differ markedly from data characterizing the typical general aviation pilot who supports his flying habit with discretionary, after-tax dollars. Such an individual probably flies less than 40 hours per year.

The corporate/executive operator typically flies an aircraft that is radar-equipped and, to an increasing extent, is also fitted with stormscope. The commuter operator flying aircraft with the capacity for nine or more passengers also employs either radar or stormscope for onboard avoidance of thunderstorms. FAR Part 25 aircraft flown by corporate/executive and commuter operators are usually equipped and certified for flight into known icing conditions. If an operator flies an aircraft not specifically approved for flight in known icing, it is usually equipped with anti-icing and deicing provisions. Thus, in terms of onboard capacity to cope with challenging weather, corporate/executive and commuter operators are better equipped than other segments of general aviation.

Aside from experience and flight hardware, the corporate/executive operator and, to a lesser extent, the commuter airline also differ from other general aviation aviators by the means they use to communicate with the providers of weather data.

Most of the larger corporate flight departments subscribe to one of the private weather services, and many use two sources of weather data other than Flight Service Stations. The FSS network typically is employed only for filing flight plans and for weather updates while en route. A typical medium-sized flight department, which operates two British Aerospace 125-700 business jets and one Beech King Air, subscribes to Universal Weather, as well as Weather Services International (WSI), and will soon install a VCR and TV system to record the aviation weather program offered by the Public Broadcast System.

Although one flight department was considering an alternate source of private weather services because its primary supplier had doubled its fees, cost is usually not a consideration. Service is the primary concern, and most corporate operators in the larger metropolitan areas feel that the FSS system is not able to provide timely service.

The commuter operator is far more cost-sensitive than his corporate brethren. Hence, he is far more likely to use the Flight Service Station as his source of weather information. But private, computer-based weather services, such as WSI and Global Weather Dynamics, are also used in this area of general aviation.

Primarily because corporate/executive and commuter operators employ experienced pilots, fly reasonably well-equipped aircraft and use alternate sources of obtaining weather data, their needs for weather data extend beyond safety considerations.

For the corporate flight department, scheduling predictability is extremely important. The corporate aircraft exists to minimize the unproductive time and hassle often associated with public travel. Provided the multi-million dollar corporate jet can move important decision makers to the places where problems need to be solved and contacts made, (all the while providing a comfortable environment that can be used for work en route or relaxation), the investment in corporate aviation is worthwhile. But, if the dispatch reliability of the aircraft is low, or if the scheduling predictability is poor for any reason, the corporate aircraft becomes a questionable investment. The boss accepts the fact that his flight department cannot change the weather, but he becomes quite upset when his crew can't make the schedule they told him they could make.

Thus, accuracy of forecasting weather is important, not only for safety consideration, but also for scheduling consideration. In fact, scheduling predictability is a particularly critical need for corporate/executive operators.

Because service is so much a part of corporate/executive activities, a need exists for current data on winds aloft and turbulence. corporate flight departments also pride themselves on the efficiency of their operations, thereby providing another need for accurate winds aloft data.

Commuter operators share with corporate/executive aviation the need for scheduling predictability, but more for the reason of avoiding the costs of diverting to an alternate or needlessly cancelling a trip than for the reason of annoying the boss because the company aircraft didn't land where the flight department said it would land. Such is not to infer that the commuter operator is disinterested in providing good service, for on-time scheduling and smooth rides are also important to this class of user. But operating costs and the impact of weather on those costs are far more important to a commuter operator than they are to the corporate flight department.

Commuter and charter operators that rely on the FSS system state that a need exists to standardize the quality of the weather briefing they receive from the FSS specialist. Perhaps, attendees at this seminar could consider the advantage of a standardized briefing format for all users. All FSS personnel would be trained to use the standard weather briefing format and would deviate from it only if requested to do so by the pilot. Such a procedure would assure a higher level of standardization and quality than currently exists.

Another common need that was expressed by corporate operators and by commuter operators who used private weather services was the ability to file flight plans via the same computer terminals they currently use for obtaining weather data. Operators want to interface directly with the FAA's computer facilities that process flight plans, and they want a computer-based confirmation that the flight plan has been received and approved. If such a system of computerized flight plan filing were possible, the popularity of private, computer-based weather services would be enhanced.

To summarize, the needs of the corporate/executive and commuter operators center principally on facilitating the communications of actual weather data, particularly data that influence schedule predictability, ride comfort, operating efficiency, and on using existing non-FSS communication facilities to input flight plan information.

"OVERVIEW OF FAA'S AIRCRAFT ICING PROGRAM"

Loni Czekalski

The Aircraft Icing Accident Summary (Figure 1) shows statistics which were taken from National Transportation Safety Board (NTSB) records and the FAA's Accident Incident Data (AID) system. If you look at the number of accidents over about the last five and one-half years, from January 1978 to June 1983, you will find that there were 280 accidents which resulted in 364 fatalities and 171 injuries. The accident injury-to-fatality ratio is about 2 to 1. It is said that if you are involved in an icing accident, you probably will not walk away from it. It is a very serious accident in which to be involved.

1978 THROUGH JUNE 1983:	FATALITIES	INJURIES	ACCIDENTS	INCIDENTS
TRANSPORT (121)	99	5	6	10
COMMUTER (135)	19	23	30	11
GENERAL AVIATION (91)	184	95	181	63
ROTOR	(1)	(5)	(8)	(1)
OTHER/UNKNOWN	62	48	63	2
TOTALS:	364	171	280	86
AVERAGE PER YEAR:	66	31	51	16

Figure 1. Aircraft Icing Accident Summary

In a breakdown of the statistics (Figure 2), we find that 35 accidents occurred in super-cooled clouds; 31 in freezing rain and drizzle; and 39 in snow. When the FAA regulates that you must be certified for flight in known icing conditions, this certification actually certifies only for flight in super-cooled clouds. This information tells us that we have almost as many accidents in freezing rain and drizzle as in super-cooled clouds, with even a larger amount of accidents in snow.

BY WEATHER:		
CLIMB/CRUISE/DESCENT/APPROACH PHASES ONLY		
WEATHER BRIEFING:	ADEQUATE	116
	INADEQUATE	55
	NONE	4
	UNREPORTED	7
SUPER-COOLED CLOUD		35
FREEZING RAIN/DRIZZLE		31
SNOW		39
OTHER/UNKNOWN		77

Figure 2. Weather Statistics of Aircraft Icing Accident Summary

Although we do not set a criteria, our regulations tell you that you must be able to fly in both falling and blowing snow. Figure 3 outlines the current regulations relative to the certification of both small and large aircraft for ice protection. Both FAR 23 and 25 reference the FAR 25 Appendix C; but only FAR 25, which is for the large transport category aircraft, references the falling and blowing snow.

In talking to the aviation community, we have learned some very interesting things (Figure 4). As your initial operating costs have increased, the buying of aircraft has become more expensive. The operating costs to maintain that fleet, because of the increase in labor and fuel costs, have created more and more concern about fleet productivity.

SMALL AIRCRAFT:

- 23.1093 INDUCTION SYSTEM ICING PROTECTION
- 23.1419 ICE PROTECTION
  RE: FAR 25 APPENDIX C

TRANSPORT AIRCRAFT:

- 25.1093 INDUCTION SYSTEM DE-ICING & ANTI-ICING PROVISION
  RE: FAR 25 APPENDIX C
  RE: SNOW BOTH FALLING & BLOWING
- 25.1403 WING ICING DETECTION LIGHTS
- 25.1416 PNEUMATIC DE-ICER BOOT SYSTEM
- 25.1419 ICE PROTECTION
  RE: FAR 25 APPENDIX C

Figure 3. Current Airworthiness Standards

- FLEET PRODUCTIVITY
  ALL-WEATHER OR NEAR ALL-WEATHER OPERATIONS
- CERTIFICATION PROCESS
  LENGTH & COST
- ROTORCRAFT CERTIFICATION
  S-76
  PUMA/SUPER PUMA
  412/214ST
- GA AIRCRAFT
  LOW-COST, LIGHTWEIGHT ICE PROTECTION SYSTEMS
- FAR 25 APPENDIX C

Figure 4. Aviation Community Concerns

People in the avition community have told us they want all-weather or near all-weather operating conditions. The manufacturers have told us they are concerned that the length and the cost of the FAA certification process is too great.

To date, unfortunately, we have not certified any helicopters for flight in known icing conditions. The French have certified the Puma. The manufacturer for the Puma Aerospeciale has come to the United States and asked us for certification for both the Puma and the Super Puma. Bell Helicopter has started flight testing for the 412 and 214ST and intends to get an icing certification for it, as does Sakorsky for the S76. General aviation aircraft is by far the largest and most rapidly growing segment of the aviation community. They have informed us that they need low-cost, lightweight, easy-to-maintain, low-power systems for their aircraft in order for them to fly efficiently. Manufacturers have also told us some interesting things about FAR 25 Appendix C. This is a very stringent requirement. They would like to see if we could possibly relax that and give them a little relief. These are the aviation community needs. The flip side of this coin is what the FAA needs.

As noted in Figure 5, the FAA needs several different things in order to do its job efficiently. One of the things we need to do is characterize the icing atmosphere, as well as to learn things about aircraft performance in known icing conditions. As a special interest, we also want to take into consideration rotocraft needs. We would like to learn things about the use of thick fluids for deicing as is currently being done in Europe. Our

- CHARACTERIZATIONS
  - ATMOSPHERE
  - AIRCRAFT PERFORMANCE WITH SNOW/ICE ACCUMULATIONS
  - ROTORCRAFT PERFORMANCE WITH ICE ACCUMULATIONS
  - EFFECTS OF UNDER-WING FROST
  - AIRFOIL PARAMETERS SENSITIVE TO SURFACE ROUGHNESS
  - HIGHLY VISCOUS DE-ICING FLUIDS
- ANALYTICAL METHODS
  - DESIGN AND COMPLIANCE DEMONSTRATION
- SIMULATION
  - ADEQUACY OF ICE TEST FACILITIES
  - USE OF SIMULATION TECHNOLOGY
- UPDATED CERTIFICATION CRITERIA INCLUDING STANDARDS AND TEST PROCEDURES FOR:
  - ROTORCRAFT
  - TURBINE ENGINES
  - AIRCRAFT

Figure 5. Federal Aviation Administration Needs

program will also consider analytic methods to be applied in certain circumstances for certification. We also say that you can use simulation; but we really don't set any guidelines, standards, or procedures for you to follow which are acceptable to us. After we have done all these things, we need to update our standards, procedures and FARs for all of the above; i.e., rotocraft, turbine engines, and aircraft with fixed wings.

Figure 6 summarizes the recent history of the FAA Aircraft Icing Program.

2-3-83	FAA ADMINISTRATOR BRIEFING ON ATMOSPHERIC CHARACTERIZATION & LONG-RANGE PLAN.
4-21-83	AVIATION STANDARDS & REGIONAL CERTIFICATION DIRECTORATES MEETING TO REVIEW PROGRAM PLAN.
7-28-83	FAA ADMINISTRATOR BRIEFED ON ACTIVITIES CURRENTLY GOING ON IN GOVERNMENT-RELATED AIRCRAFT ICING PLAN.
9-20/22-83	NATIONAL ICING RESOURCE SPECIALISTS AND REGIONAL CERTIFICATION DIRECTORATES REVIEW REQUIREMENTS AND PRIORITIES FOR PROGRAM PLAN.
SCHEDULED 11-3-83	FAA ADMINISTRATOR, NASA ADMINISTRATOR, CHAIRMAN FEDERAL COMMITTEE FOR METEOROLOGICAL SERVICES & SUPPORTING RESEARCH, UNDER SECRETARY OF DEFENSE FOR RESEARCH & ENGINEERING WILL BE BRIEFED.

Figure 6. Aircraft Icing Program

On February 3, 1983, the FAA Administrator asked us to present him with a briefing on why we were doing atmospheric characterization. In that briefing, we also gave him the long-range plan which the FAA had developed. At that same time, the Administratór asked us to return in one year to discuss all developments which had been made within the Government dealing with aircraft icing. Within about two months, we had the Aviation Standards people and the Regional Certification Directorates at a meeting to review the program plan. We did go back in July of this year to brief the Administrator on all of the information we had (and we had researched this thoroughly) concerning all aircraft icing research and developments. In September 1983, we had a meeting of the National Resource Specialists and the Regional Certification Directorates to review the plan and set the priorities within the program plan itself. We have also scheduled a meeting between the FAA Administrator, the NASA Administrator, the Chairman for the Federal Meteorological Services and Supporting Research, and the Under Secretary of Defense, at which time they will be briefed on the same subject.

Figure 7 will show you a little about how we have organized the Aircraft Icing Program for the FAA. We have sections on Atmospheric Criteria, Procedures and Technology, and Simulation. Those three things are R & D functions which will lead to a technology base to ultimately be used in the FAA regulatory base. We intend to work very closely within the government, with all the cognizant agencies, with the academic community, and with industry, itself, to see that the program really meets your needs, as well as meeting the needs of the FAA. We also intend for the program to put forth information, guidance material, etc., as information becomes available to us. We do not want to wait five years to have it all nice and tidy for you. That would not be very good for the people in the community.

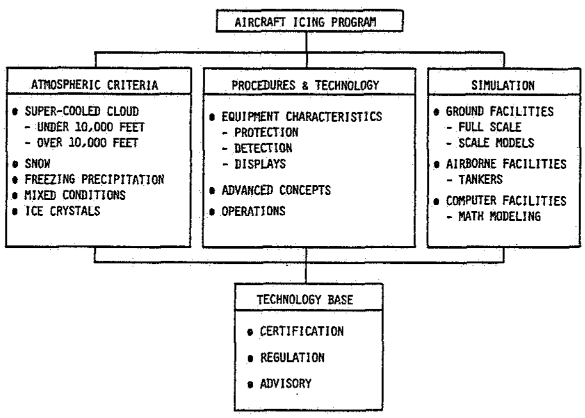


Figure 7. Aircraft Icing Research Program Functional Relationships

No program is a real program without adequate funding (Figure 8). Over the next five years, FY 84-88, the FAA plans to spend a total of $5.3 million in contracting funds to support this plan. It will also be supported with eight (8) senior specialists/scientists cognizant in their fields. As we see progress in this program, we will readjust the resources and the staffing.

FY	'83	'84	'85	'86	'87	'88
CONTRACT FUNDS ($K)	150	1500	1000	900	900	1000
STAFFING (MY)	4	8	8	8	8	8

Figure 8. Five-Year Funding Plan

The FAA Program Plan outlined in Figure 9 shows that when we characterize the atmospheric environment for icing, we are talking about super-cooled clouds above 10,000 feet. We have already completed the first phase of atmospheric characterization; i.e., super-cooled clouds below 10,000 feet. We are also going to look at snow, freezing rain, drizzle, mixed conditions with super-cooled clouds and ice crystals; then we will look at ice crystals separately. The certification directorates have told us that it is most important for us to get not only CONUS data but world-wide data as well, because our aircraft fly world-wide, and we want the FARs to be able to cover all those conditions. Therefore, if we are going to relax the FAR 25, Appendix C, we would like to know that our

- SUPER-COOLED CLOUDS OVER 10,000 FEET
- SNOW
- FREEZING RAIN AND DRIZZLE
- MIXED CONDITIONS
- ICE CRYSTALS
- INSTRUMENTATION
  - TEST
  - EVALUATION
  - OPERATIONS
- INTERNATIONAL DATA BASE

Figure 9. FAA Program Plan

planes would not fall out of the sky if they were flying over Norway.

We are also developing something that is very important–an international data base. We are going to be asking the industry as well as the departments within the government to be contributing to this. There are many places with many different sources of data, such as the Bureau of Reclamation, DOD, and NASA. We would like to combine all of this information and start an international data base to characterize the atmosphere. As we evaluate and find holes in the data, we will initiate meteorological surveys in those areas in order to complete those characterizations.

Ice protection is a very important part of the program plan. Figure 10 defines the areas into which the FAA will be looking and keeping abreast of these areas as things develop. Rather than waiting for a request to certify to come into the FAA as the manufacturers develop these systems that will be used, we would like to stay abreast of them and issue guidance material. Therefore, when some-

- ANTI-ICING
  - FREEZING POINT DEPRESSANTS
  - ICE PHOBICS
  - THERMAL
- DETECTION
- CONTROL
  - SYSTEM OPERATION
- DE-ICING
  - AIRBORNE
    - * PNEUMATIC
    - * THERMAL
    - * ELECTROMAGNETIC IMPULSE
  - GROUND
    - * THERMAL
    - * CHEMICAL
- FLIGHT TEST AND EVALUATION

Figure 10. Ice Protection System Technology

one comes to us with a need for certification on a particular type of system, we will have done our homework in advance, eliminating a long wait to get a certification. Neither will we be confused as to the requirements for certification. We think we can cut the time down to certify an aircraft or rotorcraft if we do our homework first.

We will also be publishing the guidance material as we get it. However, the FAA will really not be advancing the ice protection system technology. We will be working with you as you develop the systems so that we can be aware and can be publishing our guidance material; however, we won't be trying to advance the state-of-the-art. We have stated that simulation can be used in order to meet some certification criteria. As shown in Figures 11 and 12, one of the things that we have to do now is to correlate the airborne facilities and the ground-based facilities with nature as we discover it through our atmospheric characterization studies. We will then be issuing guidelines, standards, and procedures which can be used in order to obtain an FAA certification. We are also going to validate that those ground-based and airborne facilities do, in fact, meet the guidance that has been set forth by FAA. In the analytic method, we will hope to be reducing the cost and length of

- AIRBORNE TEST FACILITIES
  - HELICOPTER SPRAY (HISS)
  - TANKERS (OTHERS)
- GROUND-BASED FACILITIES
  - WIND TUNNEL
  - ENGINE TEST
  - LOW VELOCITY
  - ROTORCRAFT TEST RIGS (NASA TUNNEL)
    - * OSCILLATING
    - * ROTATING
- CERTIFICATION
  - RATIONALE
  - STANDARDS
  - PROCEDURES
  - GUIDELINES
- VALIDATION

Figure 11. Correlation of Airborne and Ground-Based Facilities

- DEVELOPMENT
  - MATH
  - COMPUTER MODELING
    - * ICE SHAPE PREDICTION
    - * AERODYNAMIC DEGRADATION
    - * WATER DROPLET TRAJECTORY CODES
    - * ICE ACCRETION CODES
    - * TRANSIENT HEAT CODES
    - * SOLAR RADIATION (SIMULATION)
    - * HUMIDITY EFFECTS (SIMULATION)
- APPLICATION
  - DESIGN
    - * AIRFRAME/ENGINE
  - EVALUATION
  - EXTRAPOLATION
- VALIDATION
  - AIRFOIL PERFORMANCE
  - ARTIFICIAL ICE TESTING
  - ICING SCALING LAWS
  - AIRCRAFT ICING HANDBOOK

Figure 12. Analytic Methods in the Certification Process

the certification process by using more of the analytic methods as we come to know more about them. NASA is the leader in this, as well as the academic community. They are the people who will help us learn more about analytic methods. We will also be updating things like the ADS-4, which is about 20 years old and really in need of updating. Figure 13 shows our schedule, drawing things together and putting them into perspective. The atmospheric characterizations that are seen here did not really begin until 1983. The supercooled cloud and the snow did; however, the freezing rain, drizzle, ice crystals, mixed conditions will all begin in 1984. It is planned for them to go all the way through 1988 in order for us to obtain both CONUS and world-wide data. The procedures and the technology for the ground de-icing will be updating AC 20-117 to include things like thick fluids. The initial update of the Aircraft Icing Handbook will not be a reprint but an updating of the newest, latest technology that we can find, and that ought to be out within two years.

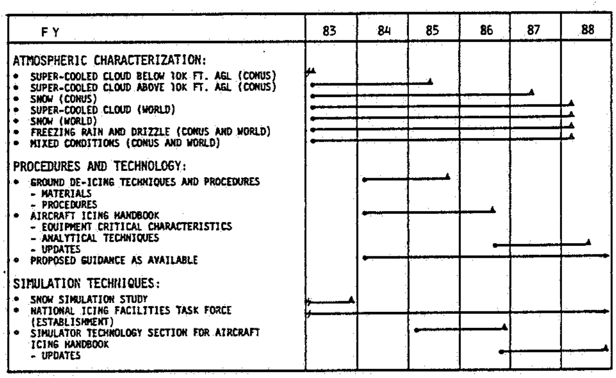


Figure 13. Aircraft Icing Program Planning Schedule

The FAA will proceed on a bi-annual update plan henceforth. We will be doing the same thing with simulation technology. We are trying to put all the information into one spot, so an internally consistent document is available.

As noted in Figure 14, the specific products with which we have promised to come forward are: 1) atmospheric characterization for supercooled clouds over 10,000 feet by June 1985 (only CONUS) 2) an update to AC 20-117 by September 1985; 3) an update of the Aircraft Icing Handbook by June 1986; 4) a simulator technology section of the handbook by September 1986.

This morning we have looked at some of the statistics that prompted the FAA to put together an icing program. We have looked at some of the history from user needs; and now we have gone into detail through the program. Please feel free to contact me with any comments or criticisms or suggestions.

• ATMOSPHERIC CHARACTERIZATIONS - SUPER-COOLED CLOUD ABOVE/BELOW 10,000 FT.	REPORT	JUNE 1985
• GROUND DE-ICING TECHNOLOGY REVIEW UPDATE AC20-117	REPORT	SEPTEMBER 1985
• AIRCRAFT ICING HANDBOOK • SIMULATOR TECHNOLOGY AIRCRAFT ICING HANDBOOK	ENGINEERING SUMMARY	JUNE 1986
• ATMOSPHERIC CHARACTERIZATION - SNOW	ENGINEERING SUMMARY	SEPTEMBER 1986
• ATMOSPHERIC CHARACTERIZATIONS - FREEZING RAIN - MIXED CONDITIONS - WORLDWIDE	REPORT	DECEMBER 1986

Figure 14. FAA Product Developments for FY 85/86

"OVERVIEW OF NASA'S PROGRAMS"

A. Richard Tobiason

I will try to give a general overview of NASA's programs and be as brief as possible. It is germane to the scope of what you will be looking at for the next few days. The good news is that we have 17 NASA representatives here from aeronautics programs within all the centers who can help you through the next few days, and they are strategically placed on all of the committees. So, if you need any follow-up on what I'm going to discuss, they are here. I will identify them as I go through the presentation this morning.

There is an aeronautics side of NASA as well as a "space" side. We are involved in things like improving planes for both the civil and military communities in areas of speed, safety, world leadership, and what the problems of flight are and how they can be fixed. That is where we start; that's why we have a charter. Our meteorology work is carried out in the Aeronautical Systems Division under the Subsonic Office. The meteorology work is really a subset of our safety program. I'm the Safety Manager with about $6 million of R & D annually. About 60 percent of that is in the areas in which you are interested, i.e., meteorology. I will spend more time on some of our programs than others because of your specific areas of interest. Our major programs are: a) severe storms with Norm Crabill at Langley; b) clear air turbulence work is being done but not on a very high scale; c) icing, which is a big problem; d) fog is a very small program, and Vernon Keller from Marshall can help you with that; and e) landing systems, which concerns itself with what happens when the runway is wet, and that is a meteorology problem. We have done some work in ozone with the Nimbus 7 Satellite in conjunction with Northwest Airlines and NASA Goddard. That was a very neat program, but it is not a topic for this conference. If someone should want to discuss it, Bill Day from Northwest, or myself, might be able to help you. The fuel savings program which John Pappas mentioned earlier is the MERIT Program with Bob Steinberg.

In the icing business, one can always understand what the objectives are: acquiring new technology; improving safety; and maintaining low operating costs. Dan Mikkelson from NASA Lewis and Jack Reinmann are involved in our icing programs. Jack is in Europe trying to figure out some things with our European friends on icing. We have a very good dialogue with everyone in the world on icing. The heart of the program is the 6 feet by 9 feet sea-level, 300 mph icing tunnel which has very limited capability in terms of temperature, water content, droplet size, etc. We were doing all right until the FAA decided they wanted to add freezing rain and drizzle. We are going to upgrade the nozzles to cover FAR 25, Appendix C, which came out of the old NACA days. If we take on this new task for the FAA, it will cause some re-thinking on our part as to whether we can duplicate those kinds of atmospheric conditions. However, we are going to spend another $3.5 million on that beautiful tunnel. It is the most heavily scheduled tunnel out at Lewis. It goes day and night, and everyone uses it. We let the Air Force use it for cruise missiles; the Army uses it for helicopters, inlet conditions, coolers, rotorblades, etc. We also have the old altitude wind tunnel from the 1940's. It is worth about $75 million sitting there doing nothing. We are going to see if we can spend about $125 million to make that a new altitude propulsion facility between 1986 and 1989. The big working section, is 20 feet in diameter and goes to Mach 1, at 50,000 feet. That's terrific, but a long-term job. Of course, we would keep the old IRT on line at the same time, because it uses the same refrigeration. If we revitalize the altitude propulsion wind tunnel for aeroelasticity, then we, the icing folk, will have a free ride.

The kinds of things we do in icing are fairly simple and straightforward. We make a better icing protection system for wings, rotorblades, inlets, and protuberances. We collect and analyze computer data; do experimental work in the tunnel; and engage in flight research to see if all the laboratory work makes sense and is reliable. The electromagnetic impulse de-icer is an example of advanced ice protection research. When ice forms on the wings, electricity induces a shock wave. There is no electrical contact with the aluminum, just a pressure which puts in a little air gap that shocks the aluminum surface, moves very quickly, and off pops the ice. We are so happy with this system that we are modifying our twin otter wings. We have qualified them through the icing tunnel and we are flying them this winter. An electrical impulse system will save about 500 or 600 lbs. on a transport airplane. They are very low-cost and low-weight.

I should mention that when we started our expanded icing program in 1978, we went out and asked people all over the world what they thought we ought to do for the short-term and long-term. We put together about 400 responses; divided it into transport airplanes, commuters, general aviation and rotorcraft. We contracted with Douglas, Rockwell, and Boeing to put all of these responses together and recommend a program. A lot of the things you are seeing us do now are things that you and your contemporaries have asked for and that are consistent with NASA ideas.

In the icing program, we want to find out if the things we learn in tunnels are really true. We want, of course, to go out and try some real ice protection systems. We would like to see how well icing instruments compare from one kind of technology to another (old to new) in natural icing conditions. We want to know what happens to airplane stability, control, and performance in icing. We also want to know what kind of meteorology data is needed to update the old data bases.

We have acquired considerable flight time with the twin otter in the last couple of winter seasons, and we are ready to start again this season. The aircraft is now equipped with new instruments. We are looking at performance degradation and icing for various meteorological conditions. We have the first airplane ever, I think, that measures all the atmopsheric conditions such as liquid water content, droplet size, humidity, and temperature. We relate these measurements to real-time history ice accretion on the wings with stereo cameras. We have a pressure belt around the wing so we can measure the change in lift, and we have a heated wake survey probe to measure the change in drag.

In discussion of PIREPs and icing, we are quantifying our instrumentation in the cockpit. Engineering test pilots are reading it back down to Cleveland Center, and it goes to the CWSU and through Service A to Kansas City, and back to the FSS. So, some poor soul who flies around where we are flying, which is Cleveland, Buffalo, and up into Canada, can get actual PIREPs which mean something, except he probably doesn't know what liquid water content is. The main thrust, however, is to get quantified information into the system. We need to find a way to take hazards and give them meaning to a particular type of airplane operation: turbulence, wind shear, rain, water, etc. We need to get some idea of quantification that is useful...not academically useful, but operationally useful.

I want to touch on Norm Crabill's program. He is Mr. Severe Storms at NASA Langley, and the biggest dollar spender in the NASA Safety Program. The objectives are given in Figure 1. There are about 25 different experiments including gas production in lightning strike areas and things like that (Figure 2). The data are being used for work being done with the Air Force, FAA, and Boeing in design of future aircraft where advanced lightning protection technology is needed. The first couple of years we did not know how to go about this research. it took a number of people a period of time to figure it out. By using ground-based weather radar, remoting that into NASA Langley, and putting WSR-57 weather radar information into the cockpit, we were able to successfully find lightning. We had to build some mesoscale models to get a better idea of where the airplane had to go to get hit by lightning. When all the strikes are added up, there are about 402 direct lightning strikes on the airplane.

In the area of wind shear and heavy rain, there has always been a problem. Despite all the improvements, there are still wind shear accidents. In the area of heavy rain, we are looking at the aerodynamics of airfoils, and experimental work is underway at the Langley 4m by 7m tunnel to look

- TO MEASURE CHARACTERISTICS OF DIRECT LIGHTNING STRIKES AT AIRCRAFT OPERATING ALTITUDES
- TO DEVELOP A DATA BASE OF LIGHTNING STRIKE CHARACTERISTICS SUITABLE FOR DEVELOPMENT OF DESIGN CRITERIA OF AIRCRAFT WITH EXTENSIVE COMPOSITE STRUCTURES AND DIGITAL CONTROL SYSTEMS
- TO DEVELOP ANALYSIS TECHNIQUES TO PERMIT THESE RESULTS TO BE APPLIED IN DESIGN OF FUTURE AIRCRAFT

Figure 1. NASA Langley Lightning Program Objectives

- OPERATE HEAVILY-INSTRUMENTED F-106 AIRCRAFT IN THUNDERSTORMS AND GET SEVERAL HUNDRED DIRECT STRIKES UP TO 50,000 FEET ALTITUDE
- STATISTICALLY ANALYZE DIRECT STRIKE RESULTS:
  - AIRPLANE RESPONSE
  - BASIC LIGHTNING CHARACTERISTICS
- DEVELOP ANALYTICAL TOOLS TO PREDICT:
  - ELECTROMAGNETIC RESPONSE OF ANY AIRPLANE
  - ELECTROMAGNETIC PULSES ON ANY WIRE IN THAT AIRPLANE
- DEVELOP "FAULT TOLERANT SOFTWARE AND HARDWARE" TO PROVIDE PROTECTION FOR THE DIGITAL DATA AGAINST THOSE LIGHTNING PULSES ON THOSE WIRES

Figure 2. NASA Langley Lightning Program Approach

at scaling effects for precipitation. This is a real tough job to handle. There are many things which are not well understood on how to scale droplets in an experiment. Changes in C_L and C_D that we found for this particular airfoil (not a transport airfoil) in heavy rain conditions are shown in Figure 3. This is some of the work that Jim Luers did for us. He suggested that we work in this area of heavy, intense rainfall rates to see what happens to lift and drag. We found there are changes in lift and drag, but we don't know that they really happen on a transport airplane wing. To keep ourselves in line, we asked Boeing and Lockheed for help. We hope someday to decide if we should go into a larger scale (40 feet by 80 feet) test facility at Ames with a scaled airplane, not just a wing. We will find out about scaling laws and sensitivity of airfoils to rain, and if the effects are real. These are some things that we must think about because, if we are telling pilots in wind shear to go to stick shakers, and if the lift and drag characteristics change enough, we could accelerate a stall. If a stick shaker goes out at 7 percent and if you knock off 12 percent C_L max, your increase in stall speed is about 6 percent, and you could get into trouble.

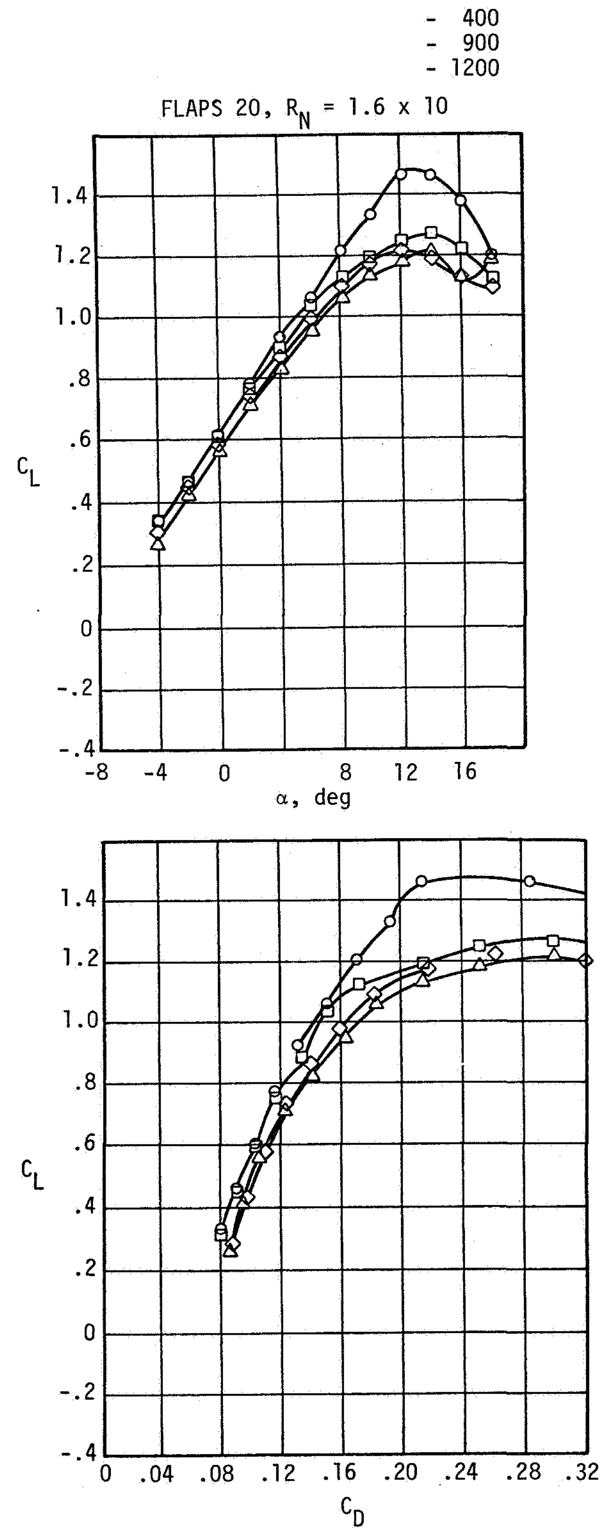


Figure 3. Effects of heavy rain on C_L and C_D

Some other very interesting things are happening with the inflow of rain to the nose radome. We find a shock wave with the T-39 radome which suggests an attenuation of the signals. We don't know enough about that yet. We are trying to quantify effects and simulate rain; and if anyone knows what the actual rainfall rate was in an accident, we would be delighted to hear from them.

Airborne Doppler Radar is an opportunity to recognize some terrific work that Norm Crabill, Leo Staton, and some other people have done in the Air Force Geophysics Laboratory on the F-106 and with some Doppler radar on the ground. We found that there is a relationship between remote Doppler-measured winds and winds measured on an airplane in the same air mass. Through a rather broad range of wind speeds measured with the F-106, we found a very good correlation with remote Doppler-measured winds. What we want to do is take this technology and use it for an airborne wind shear sensor, because then you would have all three products that a pilot needs. In cockpit weather radar today, a pilot has reflectivity; and through the new work, he has Doppler turbulence. If we add on the first moment of Doppler and take out ground clutter, aliasing, and a few other problems, we can end up with a radial wind component 20 to 30 miles ahead of the airplane. That is where we plan to go in the next two years, although we have run out of money and we are trying to find out a way to do this. It is, however, one of the major objectives of our program. We would also like to discover what winds and turbulence do to the airplane's handling qualities and performance. Since we have the F-106, and since we have Doppler, why not go to these kinds of things to find out the changes in air speed and flight controls required, control harmony, etc.? What does a pilot think about that? This is something else we would like to do, maybe through the JAWS Project. We want to look at what happens and derive some estimators of the change in air speed, altitude and controls as a function of those Doppler winds. A correlation of the Air Force Geophysics Doppler Radar, ground-based Doppler with the F-106 measured winds is shown in Figure 4.

We have a mesoscale atmospheric simulation numerical program that we have been using as an adjunct for directing the F-106 into the right piece of airspace in order to get hit by lightning. The thing that this audience wants to avoid is the thing that we want to find.

We have tried to back-cast some data for shuttle operations out of the Cape. We are also collecting the Twin Otter icing data and putting it back into

Norm's program to see if we could actually forecast icing conditions. This may prove to be very valuable.

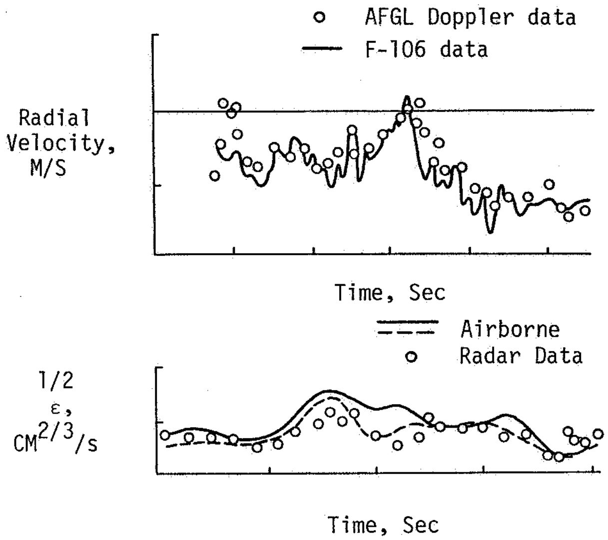


Figure 4. Example of F-106B wind measurements and ground Doppler comparisons

The NASA B-57 is instrumented to measure gust gradients in order to find the distribution of turbulence from wing tip to wing tip. Airplanes are currently designed with two-dimensional, as opposed to three-dimensional, turbulence. John Houbolt has been requesting this kind of data for years. So we instrumented the B-57. Dennis Camp from NASA Marshall is the overall Program Manager. Wen Painter manages the B-57 out of Dryden. Walter Frost is the guy who is analyzing the data off the airplane to find out what turbulence is and how to use it in design and turbulence simulations. Jack Ehernberger is involved in the research meteorology at Dryden, and is trying to help us figure out where to fly the airplane. Since we flew in the JAWS Project, we will be looking at the remote measurements of wind shear obtained by an infrared radiometer to look at the change in temperature from a few yards in front of the airplane to three miles out. We will be looking at the change in temperature over these two points. A lot of folk say that if the temperature changes, it has to be a measure of wind, especially in convective weather with the cold outflows. If the temperature farther out is getting colder than the temperature close by, there has to be something bad out there.

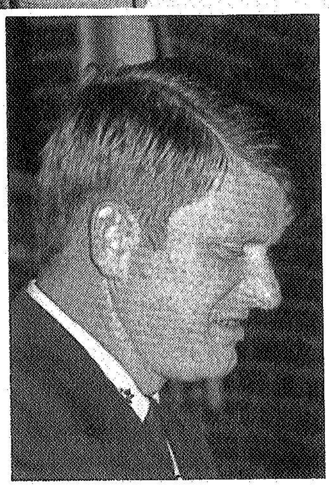
That takes us into the JAWS Project. Everyone knows what JAWS is because we have talked about it for the last couple of years–the Joint Airport Weather Studies Project. Don't fly in or near a microburst. We have helped John McCarthy and Kim Elmore in that program. Walter Frost is working with us to take JAWS data and put it into some improved simulation models for research and development. Roland Bowles from NASA Langley is doing new things in simulation meteorology. It is really an interesting area into which NASA is now embarking; but what we want to do is not only R & D but also in training. We have to get out there and help the people who need training. We scheduled a series of meetings with airplane manufacturers and airline simulation people at a big workshop in Boulder with NCAR about two months ago. Roland Bowles and Dick Bray are involved in some tasks at NASA to take this beautiful JAWS data and tailor it into a training model by simplifying the data and adding turbulence and heavy rain.

In the area of clear air turbulence (CAT), Bruce Gary at JPL has been flying a C-141 equipped with an airborne microwave radiometer (AMR) out of Ames to collect information on the variation of temperature gradients near the tropopause and on incidents of turbulence. He has a nice paper that shows what happens due to trope instability. Jack Ehernberger is also doing some work on gravity waves and mountain waves. Marshall may get involved in the next year or so in a program to look at some strange things that happen near the tropopause. It may mean an integration of Bruce's work, Jack's work and some lidar work out of Marshall.

I should talk briefly about the runway problem because heavy rain, snow, and slush on a runway can create a severe hazard. We have a program with the FAA to determine if there is a correlation between airplane tire friction and the friction you might measure from a ground device. We are trying to develop that relationship to determine if a useful and reliable ground-test vehicle is a fair estimator of the change in performance that an aircraft experiences under certain conditions. We have done some intersting work with our own Boeing 737 at NASA Langley, and we are going to try to do some more with the FAA-727. We have about 450 data runs right now at Wallops with various kinds of simulated rain. We have 400 runs from four grounhd devices and 50 runs from the airplane. It is something we think a pilot can use in an operational sense. We have a long way to go from here, but we think we can get something out of it. Since the FAA has asked us to do it, we are willing to try. The work in heavy rain will be finished next month; through the next year, we will begin our work on snow and ice in the NASA-737 and FAA-727.

We have discovered that if you run the INS data through a GOES satellite and analyze it, you can qualify the winds, temperature, altitude, longitude, and latitude and compare them to the forecast in the ASDAR. We found out that with more intelligence in real up-to-date winds and temperatures, there can be a fuel savings of 2 - 4 percent. The problem then becomes how to handle all the information the meteorologist would recover. Thus we developed the MERIT Program, where minimum routes are taken through interactive techniques to collect a whole set of different data bases, integrate these, and use them. You don't want them plotted because the whole idea of MERIT is to have the meteorologist get better weather information so flight planning can have accurate 2 - 12 hour upper-air forecasts every three hours.

SECTION IV
BANQUET PRESENTATION



"ADVERSE WEATHER IMPACT ON AVIATION SAFETY, INVESTIGATION AND OVERSIGHT"

CDR Mont J. Smith, USCG
Operations Officer
USCG Air Station
Elizabeth City, North Carolina

Good evening, ladies and gentlemen. I am deeply honored to represent the more than 5,000 dedicated young men and women who serve humanity as pilots and aircrewmen in the United States Coast Guard. I'd like to spend the next thirty minutes telling their story by borrowing on my own experiences. I hope to be able to entertain and inform you. I don't have a heavy message to impart, but I'll close my talk with a few personal observations which do not necessarily represent the official views of the United States Coast Guard.

Before I begin, let me acquaint you with a few facts about my uniform, which will help you to enjoy one of my "sea stories". I wear the naval aviator's "wings of gold", as do all Coast Guard pilots, regardless of their source of training. I also own a bunch of service ribbons, or what we call "gedunk" ribbons (expert rifle and pistol, "I was alive in '65", unit commendations, and so forth). I've never been to a shooting war. I suppose the only enemy I've ever confronted in aviation was weather. I have, on two occasions, been the recipient of the Air Medal for "meritorious achievement in aerial flight" in action against the weather enemy. In retrospect, I'm not sure the Coast Guard should decorate those who have tilted at such windmills. We may be encouraging a "Deer Hunter" mentality among these airmen.

I'll have to admit that I'm very nervous, surrounded by such an awesome assemblage of scientists, aviation industry representatives, and managers of the National Airspace System Plan. I've literally wracked by brain for a good weather joke to use as an "icebreaker", but I came up empty-handed. Instead, I thought maybe I'd relate an incident which occurred several years ago up in Alaska. It's a true story, there's a moral, and I can laugh about it...now.

Once upon a lonely mid-winter night, a U. S. fishing vessel broadcast a MAYDAY, reporting a steering casualty which seemed to indicate that within a few hours the boat would be driven onto the north shore of Unimak Island by an intense Aleutian storm. A C-130 aircraft, piloted by a close friend of mine, quickly departed from USCG Air Station Kodiak to locate the distressed vessel, stand ready to airdrop survival equipment, and act as a "pathfinder" for my helicopter.

My co-pilot and I carefully planned the 450-mile non-stop flight from Kodiak to the scene, silently thankful that the well-equipped airport at Cold Bay was within 50 miles of the vessel and would be our ultimate destination. Weather conditions and darkness combined to paint a bleak picture. After takeoff from the tiny haven of our base, the HH-3F seemed to be swallowed up by the forces of nature; we were in the belly of the whale. Our route of flight took us south of the Aleutian chain, island-hopping from Kodiak to the Trinities, past the Semidis to the Shumagins at altitudes below 1,000 feet to avoid airframe ice. A strong, northwest gusting wind produced moderate and occasionally severe turbulence. Eye fatigue encountered in scanning the flight and engine instruments prevented either of us from flying for more than a half hour at a time. Snow showers filled our radar scope and occasionally obliterated echoes from nearby land masses. A ninety-mile open ocean leg of our trackline required DR navigation, since LORAN A coverage of the area was inherently poor. It seemed like an eternity before we acquired those islands on radar.

After about two hours, I became intrigued by occasional glimpses of moonlight and stars through "holes" in the overcast. My curiosity overwhelmed me, and I asked my buddy in the "herk" what type of flight conditions he was experiencing upstairs. He said he had broken out at 6,000 feet into "VFR on top", and had established an orbit over the distressed vessel at 10,000 feet.

I felt certain that we could escape the incessant jolting by mechanical turbulence if it were possible to climb above the "lee" of the Aleutian terrain. The C-130 obtained our clearance from Anchorage Center, and with the appearance of another "hole", we started to climb.

The next few minutes were rather spooky. Both engine anti-ice caution lights illuminated, an indication that the systems which served to heat the air intake path were being thwarted by the minus 20 degree Celsius outside air temperature. Biting my lip as we passed 4,000 feet, I tried to take some consolation from the fact that the low temperature should prevent ice accretion. The fragility of our situation dawned on me with another rush of realization that we were hundreds of miles from an airport served by navigational or approach aids, thousands of feet above a hostile ocean, dodging turbulence and icing, at night, in, quite parenthetically, a helicopter.

Now, I think we all recognize that helicopters have come a long way since their inception as a collection of aircraft parts flying in close formation. The pilots who fly these machines are, however, to quote ABC news commentator Harry Reasoner, "brooding introverts, anticipators of trouble who know that if something bad has not happened yet, it is just about to." They even sit in a weird manner, all hunched over the controls and squinting in the last great act of defiance. My evening prayers used to include Sikorsky Aircraft, General Electric, and Collins Radio. It's always been hard to accept the fact that the company whose engines kept me aloft for nearly 4,000 hours could also burn my toast in the morning.

As we topped the overcast and continued the climb to 8,000 feet, a sudden brilliant flash of light reflected off of the left side of the aircraft and into the cockpit. My eyes shot toward the engine instruments and I asked the flight mechanic to view the exterior for signs of a fire. I became totally confused as our troubleshooting began to rule out problems with the aircraft. The flashes of light seemed to be originating within the atmosphere to the west of us. Lightning was an almost unheard of phenomenon in Alaska, particularly in winter, and we had never seriously considered it.

At about this time, my buddy in the C-130 called and asked if we were enjoying the show. It turned out that, in a weird coincidence, a dormant volcano on Unimak Island had begun to erupt that night, sending a huge cloud of hot gases over thirty thousand feet into the super cold Alaskan sky. The resulting "light show", featuring lightning cloud-to-cloud, was spectacular; I have never forgiven my friend for his failure to forewarn me.

I guess I'll have to finish this tale, or you will be forced to conclude that we never made it. As we endured a quartering headwind and approached Unimak Island from the east-southeast, the distressed vessel's skipper seemed to gain confidence by the minute. He devised a plan to back into the wind and sea, steering the boat with differential power from his twin screws and maintaining a safe distance offshore until the arrival of a Coast Guard vessel at daybreak.

For my part, I had abandoned all hope of proceeding directly to the scene without first stopping to refuel at Cold Bay. After four hours of bucking headwinds, our fuel remaining was becoming critical.

The Flight Service Station at Cold Bay reported "ceiling indefinite, sky obscured, visibility less than one-eighth of a mile in a blowing snow, winds northwest at 35 knots gusting to 50". As we approached Deer Island, the initial approach fix for the back course localizer approach to runway 32, my co-pilot and I discussed our options. The back course approach would be quicker to execute, in view of our fuel state, since we were conveniently near the IAF. In addition, our let-down to minimums would be into the wind, permitting a slower groundspeed as we scanned for the runway environment in conditions of minimum visibility. A significant disadvantage lie in the fact that the nonprecision back course minimums were several hundred feet higher than those prescribed for the ILS to the opposing runway. Even at 200 feet AGL at the bottom of an ILS, we were hoping for a miracle. There would be insufficient fuel for multiple approaches. We opted for the approach by Anchorage Center.

As we approached the non-directional beacon in a descent to the initial approach altitude of 2,500 feet, we re-entered the clouds and began to bounce around again in the wake of nearby Pavlov volcano, which rose over 8,000 feet. Turning outbound over the Bering Sea, I slowed our airspeed to 80 knots and timed for an interminable five minutes to anticipate the awesome tailwind which we would acquire on the inbound course. The depicted left procedure turn progressed well until turning to intercept the final approach course.

My co-pilot suddenly asserted that I was flying a heading which would not result in the desired intercept. I stifled a mental scream of panic. While scanning steering information on the flight director and cross-checking the approach plate, I recited old adages to "turn to and through to center the CDI" and "the head of the needle will fall and the tail will rise." My actions were defensible, and my co-pilot conceded a perceptual error brought on, no doubt, by terrific fatigue and stress. To this day, I admire him for verbally expressing doubt about the progress of the approach, because a healthy skepticism in the cockpit can avert disaster.

I slowed the aircraft to 50 knots as we intercepted the localizer, but judged from the rate of descent required to remain on glide slope that our groundspeed would be much higher than the no-wind 80-knot approach speeds which I had frequently practiced. At minimums, the co-pilot announced "rabbit" in sight. I looked up briefly, but did not feel that the sequential high-intensity lights would be sufficient visual reference to grope for the runway in the snow. The low-fuel lights were blinking on in both main tanks, indicating 20 minutes of fuel remaining. A missed approach was out of the question. I dismissed earlier thoughts circling into the wind after "breaking out" at minimums. This was one of those instances where you never truly "break out"...the reason why CAT II and CAT III approaches were designed.

I told my co-pilot to stay visual and be ready to take the controls while continuing to fly the localizer and descending below minimums. As the helicopter passed through 100 feet AGL, the co-pilot stated that he could see one set of runway lights going by at a time and could gain visual reference. I passed control of the aircraft to him, but stayed on the guages, ready to take control back in the event he became disoriented. I talked him down in 10-feet increments on the radar altimeter until just prior to touchdown, when something totally unanticipated happened.

At about thirty feet or one-half rotor diameter above the ground, the helicopter enters ground effect and begins to create a "cushion" of air, which is normally expelled behind the craft in an air taxi or running landing situation at speeds above translational lift. In our case, a cloud of dry, powdery snow raced <u>ahead</u> of the helicopter and created a "white-out" situation due to the tailwind.

I shifted my scan from the radar altimeter to my side window, where I could see the runway lights going by one at a time and talked the co-pilot down the final few feet to a surprisingly smooth running landing. You can imagine the relief we felt as the aircraft was braked to a stop.

We encountered tremendous difficulty in taxiing toward the parking ramp, and only succeeded by using the lights of a cross runway to establish our location, and then relying on the airport diagram and intimate knowledge of the field to move cautiously a few hundred yards.

A short conversation with the C-130 ensued. He agreed to remain overhead the distressed vessel until fuel state required that he depart scene for Kodiak. A high-frequency radio at the Flight Service Station would enable us to monitor the vessel throughout the night in case the sitution began to deteriorate and require us to hoist the fishermen from the craft. I told my buddy in the "herk" that only the most dire of circumstances could persuade me to launch from Cold Bay. I was not at all convinced we could give a repeat performance of the approach and landing which had just transpired. At this point, my young flight mechanic, who had been listening to the radio conversation, piped up on the ICS with the most astonishing statement I have ever heard. He said, and I quote, "Gee, Mr. Smith, if you can put me over that boat before daybreak, I can hoist all of those people and we'll all get the Distinguished Flying Cross." I began laughing hysterically and could barely accomplish the secure checklist. I still smile inwardly at any mention of the DFC.

The Coast Guard is a service steeped in tradition. We are the oldest <u>continuous</u> seagoing service, older even than the Navy, which was disbanded between the Revolutionary War and the War of 1812. As an amalgamation of the Revenue Cutter Service, the Lighthouse Service, and the Lifesaving Service, the Coast Guard acquired an unofficial motto which says, "You have to go out, but you don't have to come back." Pride, "can-do" attitude, mandated readiness, and a strongly perceived moral obligation have combined to present Coast Guard aviation management with an ethical dilemma over the past few years. Should we, or could we, ever say no in a situation where flight crew is likely to be subjected to the same risks as those whom we have set out to rescue? Of the many risk factors which characterize an elevated aviation accident potential, weather ranks alongside material failure as a random occurrence which cannot be programmed out through training or testing alone.

I would describe the average Coast Guard aviator as a "weather-wise" individual. Experience has taught us that weather is our greatest adversary and that we will often be called upon to fly when others do not. A sharp rise in Coast Guard aviation's accident fatality rate during the period from 1978 to and through 1981 is attributable to weather as a "factor".

For instance, one of our accident boards surmised that a night offshore helicopter crash which was fatal to all four crewmen was induced by pilot fatigue and resultant inadvertent tail rotor contact with the water during a prolonged hover over a distressed boat. You have to go back and ask yourself why the fisherman was distressed in the first place. Secondly, why had the pilot become a victim of acute short-term fatigue? The cause factor was most certainly environmental.

In another case, one of our single engine helicopters experienced an inflight engine failure during a violent gale which lashed the Pacific Northwest several years ago. The pilot successfully autorotated the aircraft to a crash landing in mountainous seas. The helicopter quickly rolled inverted, but all three crewmen egressed into the open ocean. Cast apart and driven over a mile to shore by the breakers, two of the three miraculously survived. Again, little doubt exists as to the environmental impact on this accident, although weather did not cause the engine to fail.

I would like to share with you a few of the facts surrounding a fatal aircraft accident with which I am intimately familiar. I was the member of a board which investigated the loss of an HH-3F helicopter 210 nautical miles southeast of Otis ANGB, Cape Cod, on the night of 18 February 1979. A Japanese longliner, the Kaisei Maru 18, reported a crewman suffering from head injuries and lacerations sustained during a fall earlier in the day. Medical evaluation was impeded by a troublesome language barrier and a lack of voice communications with the ship. Rescue Coordination Center Boston received CW transmission of phraseology from the International Code of Signals in morse code describing the patient's condition. After medical evacuation was decided upon, the vessel's exact position could not be established. Since the mission required that the HH-3F be flown to its maximum range, two aborted launches resulted from uncertainty over the position.

The helicopter departed the air station at 0312 local time on 18 February, arriving on scene in a hover at 0502. At approximately 0515, while engaged in an attempt to deliver a stokes litter to the Kaisei Maru 18, the helicopter suffered an apparent partial power loss and was ditched alongside the vessel. As the aircraft's rotor blades came in contact with the seas, the helicopter was wrenched violently into an inverted position. The hoist operator, who only moments before had been poised in the cabin door, was able to extricate himself from the aircraft and cling to the nosewheel until the ship pulled him aboard. The pilot, co-pilot, radioman, and medic drowned during the attempted egress.

The following weather synopsis was submitted to the board by Detachment 6, 26th Weather Squadron, Pease AFB, NH:

During the weekend of 18-19 February, a cold polar air mass was situated over New England and the adjacent coastal waters. High pressure centered over Lake Huron, coupled with a low center situated in the Canadian Maritime Provinces, were producing strong northwesterly flow from the surface up through several thousand feet. This flow resulted in the advection of cold polar air from central Canada to several hundred miles offshore.

The high centered over Lake Huron moved eastward to northern New York State over the following twelve hours. No significant intensification was noted. During the same time period, the low located in the Canadian Maritimes drifted northeastward. The surface wind pattern remained essentially constant during this period, with the flow being from between 300 and 330 degrees. Although little weather data is available in the vicinity of the accident, the synoptic pattern suggests that northwest flow existed out to at least 300 NM offshore.

Based on available coastal wind data, the winds in the vicinity of the crash site were most probably between 25 to 40 knots, gusts included. Evidence to support this velocity can be found in the attached data. Nantucket light vessel reported winds of 320 degrees at 20 knots. Winds for the same time at Matinicus Rock were reported at 30 knots. An earlier ship report in position 44-20N/66-30W gave the wind as 360 degrees at 35 knots.

Coastal stations in New England were reporting clear skies. However, low overcast cloud conditions were observed over the ocean, based on satellite information. As the cold arctic air passed over the relatively warm waters offshore, an extensive area of stratocumulus clouds developed. Past experience has shown that this type of cloud formation has bases between 1,000 feet and 2,000 feet. Satellite pictures show the tops of this extensive overcast region to be approximately 4,000 feet. The area of cloud coverage extended from just off Cape Cod to the eastward and from southwestern Nova Scotia southward to approximately 35 degrees north latitude.

Offshore surface visibilities between Cape Cod and the crash site are estimated to have been approximately 6 NM, with isolated areas having less than 1 NM in snow showers and snow squalls. Chatham (MA) radar reported a rather large area of radar echoes resulting from snow shower activity. A ship located at 44-20N/66-30W reported visibility at 1-1/4 NM in moderate snow with low overcast conditions."

As a matter of interest, this synopsis was corroborated time and again by witnesses who appeared before the board. The master of the Kaisei Maru 18 gave the following account:

The helicopter arrived in the vicinity at 0945 GMT, but actually proceeded to the location of a similar vessel approximately six miles away. (The master assumed this because he identified the helicopter as a fast-moving target on his surface radar). The wind was from the northwest at 20 knots and the seas from the same direction at 2.0 to 2.5 meters in height. The visibility varied in heavy snow showers, but the master knew that it was frequently at least two nautical miles, because later he could see the other fishing boat (to which the helicopter had originally flown) and confirmed its range on radar. The snow was of powdery consistency. Visibility was restricted by fog forming just above the sea surface. Free air temperature was measured at minus two degrees Celsius, and sea water surface temperature at 13.2 degrees Celsius. The barometer read 1040.5 millibars.

Of particular interest to the board was the pilot's decision to fill all of the helicopter's fuel tanks to the maximum before departing on the mission. With the design of the helicopter's fuel system in mind, a full fuel load would, under any set of environmental conditions, result in the aircraft being above the maximum certificated takeoff gross weight. Since the helicopter had been fueled from a JP-4 truck which had gradually "cold-soaked" to the minus fifteen degrees Celsius temperature which existed on Cape Cod, the aircraft was a whopping 1200 pounds heavier than permitted at takeoff. Although not a cause factor in the accident, this "additional finding" highlighted the importance this pilot attached to fuel sufficiency when contemplating a long offshore mission, particularly one which featured uncertainty of the vessel's position and a headwind component on the return leg.

When a few of my fellow pilots learned that I would be attending your workshop, they said, "Hey, tell them we need more information on the weather features between the sea surface and, let's say, 2,000 feet." The truth is, most Coast Guard pilots have a pretty good mental picture of what to expect at the interface between either the sea or land, given a certain set of parameters. What is needed is a graphic portrayal of these conditions for decision-makers who employ aviation resources. Why should the pilot be forced to "poke his nose in it", instead?

As stated in the book <u>Weather Flying</u>, weather is a local phenomenon. Local knowledge and experience should be combined with a detailed forecast to produce a better mental "picture" of the weather. The intent is not for the pilot or dispatcher to exploit advantages resulting from improved weather sense; on the contrary, a conservative decision can be formulated around this wariness. I remember years ago ferrying helicopters across west Texas on the "southern ferry route". Approximately 150 miles east of El Paso, commanding a view of the southernmost portion of the continental divide, is Guadelupe Pass. Even though I had never experienced turbulence in a helicopter, the "old hands" cautioned us never to cross Guadelupe if the winds at the RCO were indicating higher than 15 knots. It seemed like reasonable advice, possibly written in blood, and I would observe it today without question.

We should do away with "special VFR" for all except aircraft involved in emergency missions. I'm sorry, ladies and gentlemen, but if you don't have an instrument ticket, you shouldn't be out there flailing around in IMC. Yes, to avoid inconvenience, a great number of precision approach aids will have to be established at small airports around the country. And too, positive control will have to be exercised, if not through additional control towers, then at least remotely. All of this will tax the air traffic control system, but when the ceilings come down and visibility shrinks, we can't seriously be expected to "see and avoid" each other (and ground obstacles) while squeezed below 1,200 feet AGL.

Circling approaches are a sucker play, particularly in approach category C, D, and E aircraft. Have you ever tried to maintain circling altitude and airspeed while fighting the effects of vertigo, turbulence, precipitation, and the like without exceeding 30 degrees angle of bank? Have you really managed to keep the runway environment in sight? Can you really expect the bottom of an overcast to be perfectly constant in altitude?

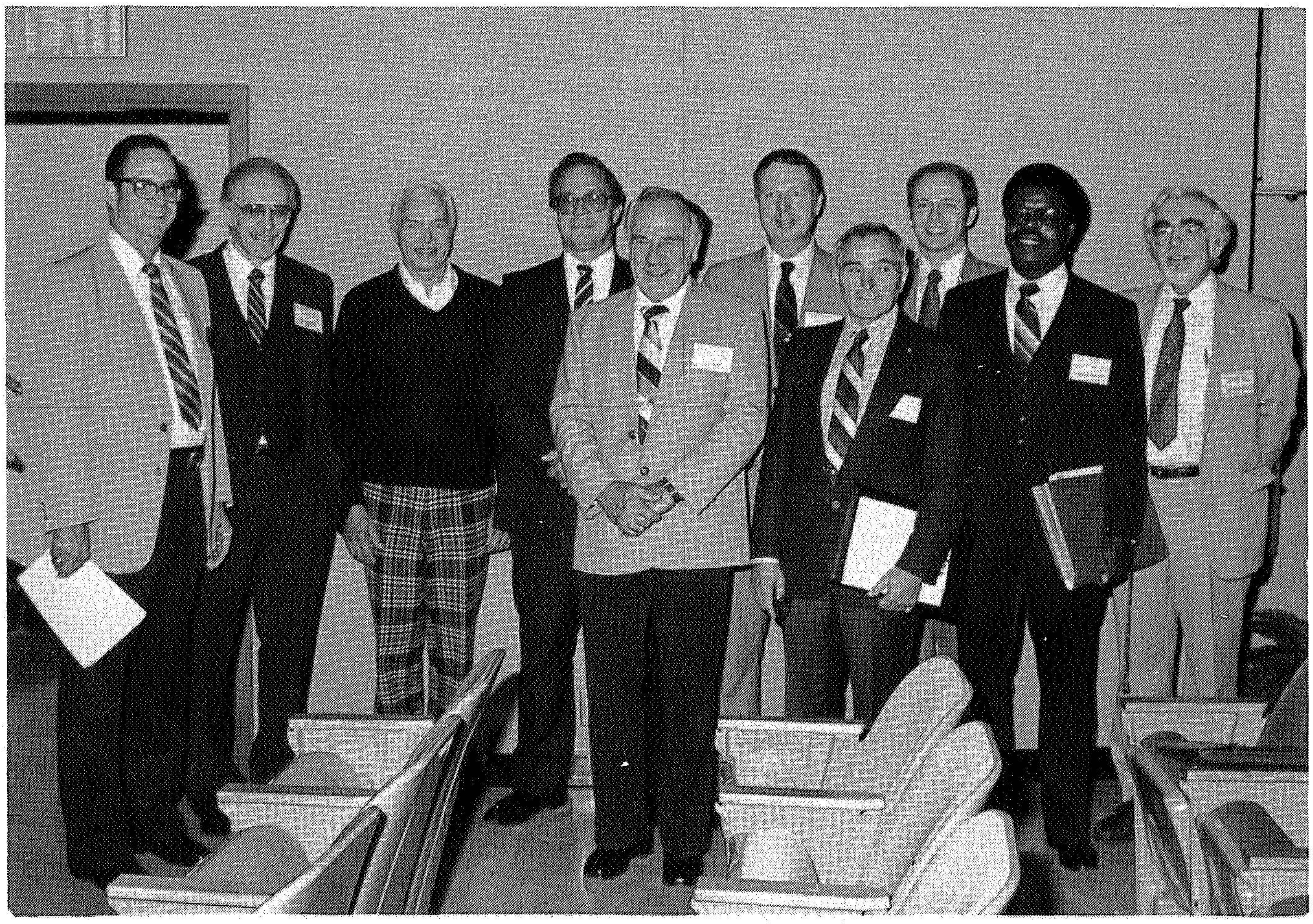
All operations should cease at an airport which is experiencing low-level wind shear. I learned my lesson over the Gulf of Alaska while penetrating "roll clouds" near the base of an imbedded thunderstorm at 500 feet. Fortunately, the aircraft encountered a severe updraft resulting in a climb of 2,000 feet per minute with collective pitch at a minimum. The aircraft yawed 180 degrees to the right with full left pedal applied. My first Operations Officer, CDR Frank Silvia, was lost on Eastern Airlines Flight 66 when it encountered LLWS years ago in the first commercial accident attributable to this phenomenon. Let's recognize it.

Pilots will never probably fully appreciate the forces of nature or the potential for destruction. Indeed, in this computer age of digital electronics, there appears to be a greater impatience with weather than ever before. Pilots want to graph it, map it, electronically disect it, display it in pulsating colors, and then top it. They surely don't want to be inconvenienced by it.

I recall launching out of Cape Cod to search for a man overboard near Boston during one of the worst summer squall lines to traverse the New England coast in years. After level-off at 1,000 feet over Cape Cod Bay, we were surrounded by lightning in all quadrants. The radar was totally useless, since the intensity of nearby cells effectively attenuated radar signals at a greater range. The best we could do was hang on. At one point, my radioman asked me what would happen if lightning struck the helicopter. I remembered hearing about a Kaman HH-43 helicopter which disintegrated after a lightning strike near MacDill AFB many years ago. I recalled also sitting through a training session where an older, more experienced, pilot described a helicopter struck by lightning as a giant arc welder. The point is, I still have absolutely no idea what happens when a helicopter is struck by lightning, but the thought is very unsettling. I give thunderstorms a wide berth for that, and many other, reasons. I told the radioman our static discharge wicks on the horizontal stabilizer could handle it. Thank you.

SECTION V

IMPROMPTU PRESENTATIONS



(FROM LEFT TO RIGHT)
DENNIS W. CAMP
WALTER FROST
JOHN HOUBOLT
CHRIS BUSCH
JOHN H. BLISS
RICHARD JECK
SEPP FROESCHL
RALPH PASS
CHARLES MASTERS
BERNARD ETKIN

"A NEW CHARACTERIZATION OF THE ICING ENVIRONMENT BELOW 10,000 FEET AGL FROM 7,000 MILES OF MEASUREMENTS IN SUPERCOOLED CLOUDS"

Richard K. Jeck

This is a report of accomplishment in response to a growing requirement over the past decade for a new assessment of aircraft icing conditions in wintertime clouds at altitudes up to about 10,000 feet. The requirement has been documented in past workshops [1-5], and comes primarily from the helicopter community which wants ice-protected rotorcraft to meet increasing demands for "all-weather" operations. Currently, only a few of the larger helicopters are equipped with certification of ice-protection devices. This is because the current FAA criteria for design and certification of ice-protection equipment results in power and payload penalties that smaller rotorcraft cannot tolerate. The FAA criteria (promulgated in the Federal Aviation Regulations, Part 25 (FAR-25), Appendix C) were actually designed for large, transport-category aircraft capable of flying to 20,000 feet or more. For this reason, there have been concerns that the current criteria may be too severe for low-performance aircraft, such as helicopters, which generally operate at altitudes below 10,000 feet.

The aircraft icing hazard comes from the fact that cloud droplets generally remain liquid even at temperatures several tens of degrees below freezing– a condition called supercooling. These droplets will freeze practically instantaneously on a passing aircraft, however, and form ice on exposed surfaces. The amount of ice depends primarily on the amount of water, or the liquid water content (LWC) of the droplets, the size of the droplets, the temperature of the aircraft surfaces, and, of course, on the horizontal extent of the supercooled clouds along the flight path. Information on the natural occurrence of these variables is obtained from research flights through subfreezing clouds.

The current FAA criteria in FAR-25 are based on research flights undertaken about 35 years ago. Recent advances in cloud physics instrumentation have, therefore, prompted calls for new measurements and for a re-evaluation of the old data for accuracy and reliability. The net requirement is for a reliable, range from ground level to 10,000 feet.

In response to this requirement, about 7,000 nautical miles (NM) of airborne measurements in supercooled clouds at altitudes up to 10,000 feet (3 km) have been computerized at the Naval Research Laboratory (NRL) to form a new data base for low-altitude, aircraft icing applications. Half of the data is from the National Advisory Committee for Aeronautics (NACA) aircraft icing studies of 1946-50 where ice accretion on rotating multicylinders was the primary measurement technique for LWC and droplet size. The other half is from recent research flights by the NRL and other organizations using optical, cloud droplet size spectrometers manufactured by Particle Measuring Systems. These measure droplet sizes, with LWC recorded droplet size distribution. A complete description of this new data base and a number of analyses of the data are contained in a report [6] to the FAA, the sponsor of the project.

The principal conclusions are:

1. The NACA and modern data generally agree in most aspects, indicating that the NACA data are accurate and reliable except possibly for indicated droplet diameters larger than 35μm.

2. The "Intermittent Maximum" and "Continuous Maximum" graphs (envelopes) in FAR-25, Appendix C, do <u>not</u> correctly describe the icing environment in the altitude range from 0 to 10,000 feet AGL. The differences are in the following items:

a) Maximum values of liquid water content.

The maximum observed LWC of 1.1 g/m^3 for layer clouds below 10,000 feet AGL is about 50% larger than the "Continuous Maximum" value of 0.8 g/m^3 (Figure 1). The maximum observed LWC of 1.7 g/m^3 for convective clouds below 10,000 feet AGL over CONUS is about half the "Intermittent Maximum" value of 2.9 g/m^3 (Figure 2).

b) Upper and lower limit to the median volume diameter (MVD) of cloud droplets.

The Continuous Maximum and Intermittent Maximum envelopes extend to MVDs of 40 and 50μm, respectively, as is indicated by a few of the NACA data points (Figure 3). However, the modern measurements show no credible MVDs larger than supercooled clouds below 10,000 feet AGL (Figures 1 and 4). The few MVDs that are reported to be larger than 35μm in the NACA data are questionable in view of the assessment by the NACA researchers themselves that large MVDs are likely to contain large positive errors due to limitations of the multicylinder technique [7]. Also, neither of the FAR-25 envelopes extend to MVDs below 15μm, although the NACA and modern measurements indicate a large fraction of MVDs between 3 and 15μm, especially for layer clouds.

In addition, the present analyses reveal temperature dependences of MVD that are not conveyed in the FAR-25 envelopes. The modern data demonstrate that the <u>upper limit</u> to MVDs in <u>layer</u> clouds decreases from about 35μm at 0° to 15μm at temperatures below -20°C (Figure 4). Both the NACA and modern CONUS data show that for convective clouds, the <u>average</u> MVD exhibits the opposite behavior and <u>increases</u> with decreasing temperature from about 15μm at 0° to about 30μm at about -17°C (Figure 5). The modern upper limit

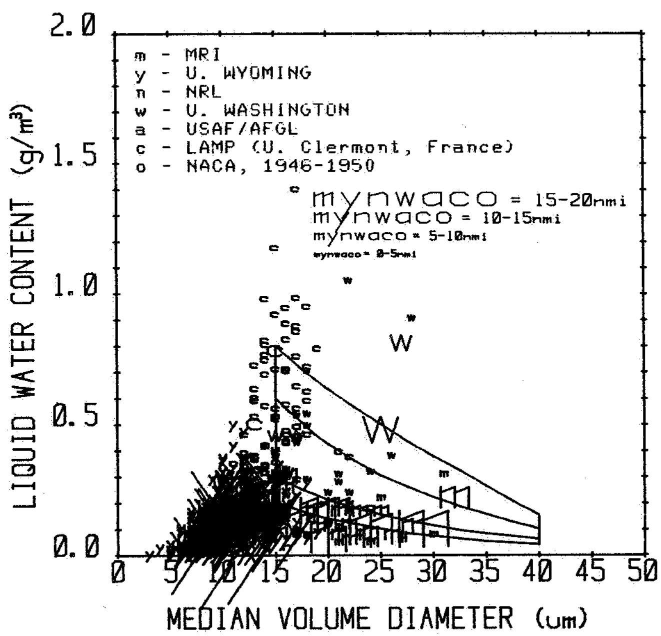


Figure 1. Scatterplot of observed LWC, MVD combinations in the modern data for supercooled layer clouds (St, Sc, Ns, As, Ac) up to 10,000 feet AGL. The various plotting symbols represent different data sources as indicated in the key. The size of each symbol is proportional to its statistical weight (i.e., the observed horizontal extent of the associated icing event) as shown by the scale above the graph. The Continuous Maximum envelope from Figure 1 of FAR 25, Appendix C, is superimposed for comparison.

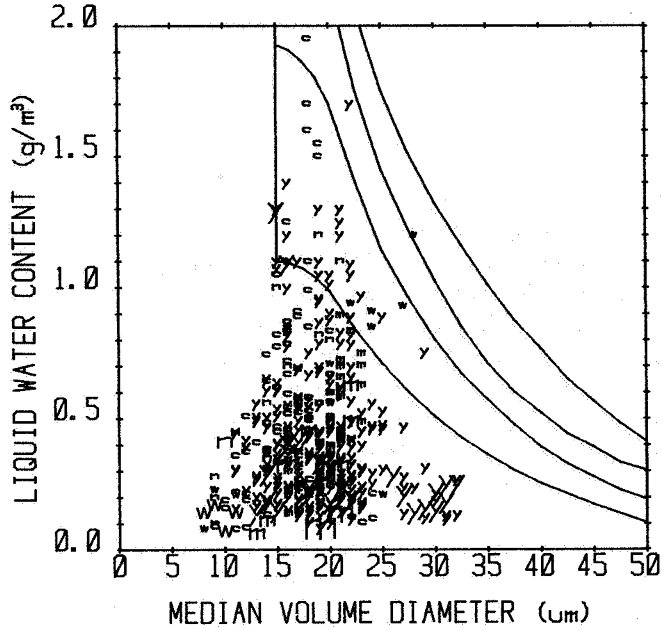


Figure 2. Scatterplot of observed LWC, MVD combinations in the modern data for supercooled convective clouds (Cu, Cb) up to 10,000 feet AGL. A total of 960 data miles is represented in this graph. The Intermittent Maximum envelope from Figure 4 of FAR 25, Appendix C is superimposed for comparison.

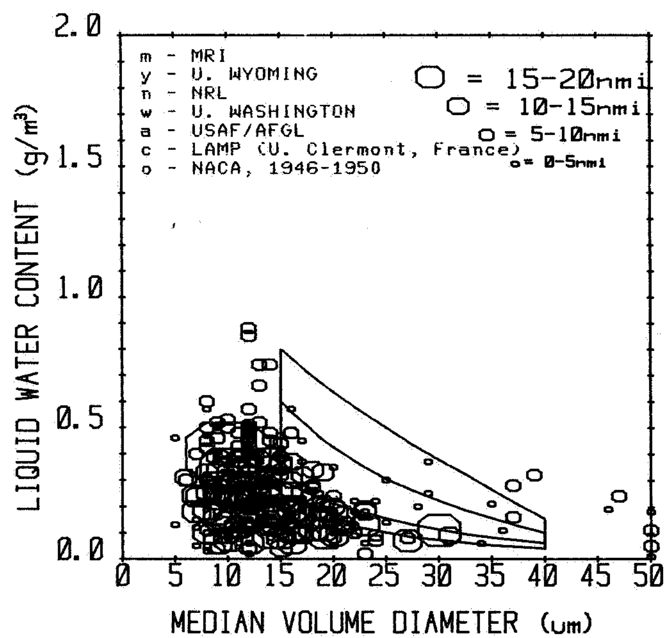


Figure 3. Scatterplot of observed LWC, MVD combinations in the NACA data for supercooled layer clouds up to 10,000 feet AGL. A total of 2565 data miles is represented in this graph.

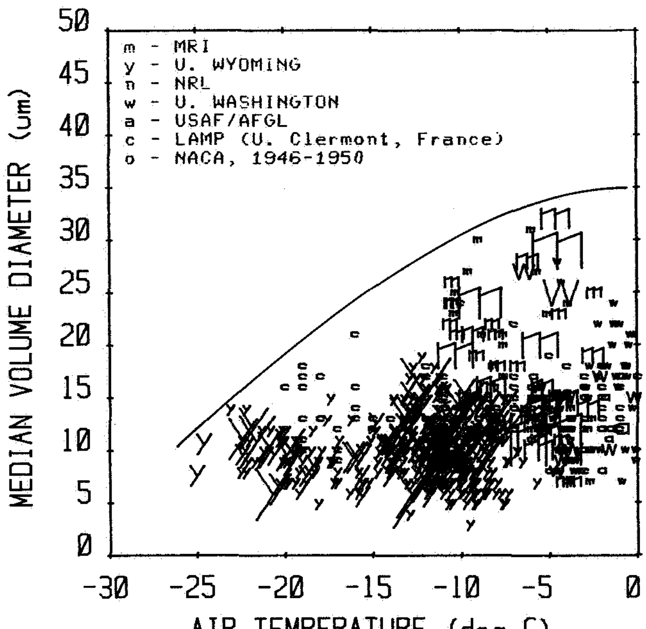


Figure 4. Scatterplot of MVD vs. OAT for modern data from supercooled layer clouds up to 10,000 feet AGL. The solid line bounding the data points represents the apparent upper limit to MVD over CONUS as a function of temperature. A total of 2565 data miles is represented in this graph.

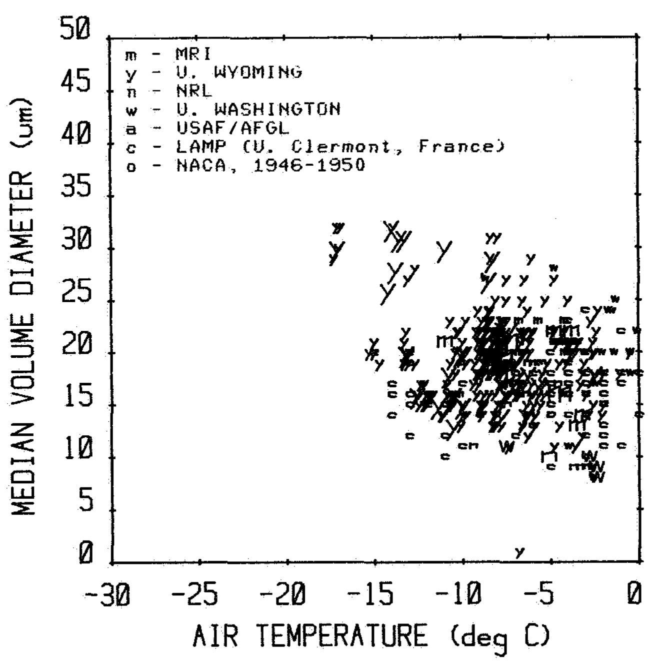


Figure 5. Scatterplot of MVD vs. OAT for modern data from supercooled convective clouds up to 10,000 feet AGL. A total of 960 data miles is represented in this graph.

to MVDs for convective clouds remains at about 35μm over the observed temperature range, however.

c) Low temperature limits.

Minimum temperatures observed in either the NACA or modern data below 10,000 feet AGL are -17°C for convective clouds (Figure 6), and -25°C for

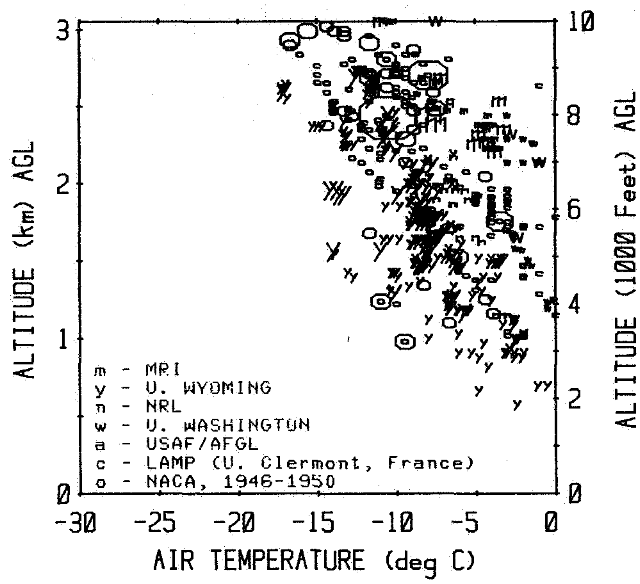


Figure 6. Scatterplot of icing event temperatures vs. altitude for NACA and modern data from supercooled convective clouds up to 10,000 feet AGL. A total of 1545 data miles is represented in this graph.

layer clouds (Figure 7). That is, convective clouds appear to be completely absent at temperatures less than about -17°C at altitudes below 10,000 feet AGL. Nearly all layer clouds with temperatures below -17°C were found in the vicinity of the Great Lakes in January. These coldest layer clouds were found at altitudes between 4,000 and 6,000 feet AGL, (i.e., all clouds sampled elsewhere at higher altitudes were all warmer).

d) Horizontal extent specifications.

A review of the literature reveals no standard definition of horizontal extent and, therefore, confusing and inconsistent usage of "horizontal extent" information occurs in practice. When horizontal extent is defined as the duration of uniform cloud intervals (icing events) as used in this study, the following results are found. Horizontal extents of up to 50 NM have been observed (in upslope cloud

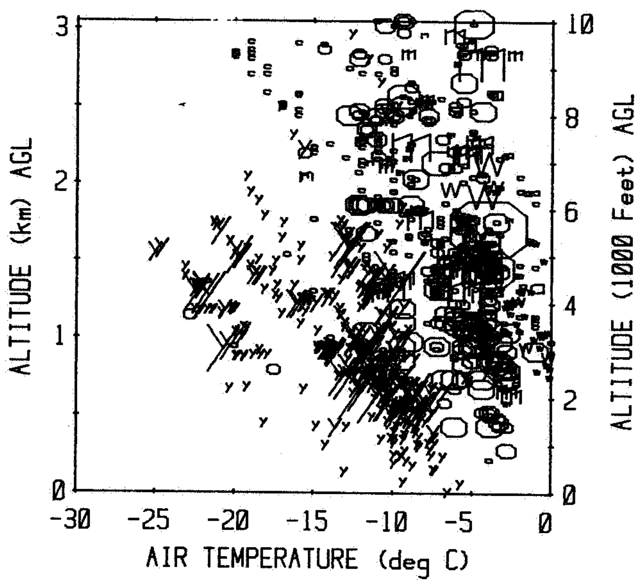


Figure 7. Scatterplot of icing event temperatures vs. altitude for NACA and modern data from supercooled layer clouds up to 10,000 feet AGL. A total of 5215 data miles is represented in this graph.

over eastern Colorado and western Kansas), but 90% of all cases are shorter than 15 NM and 50% are shorter than 5 NM. Maximum horizontal extents decrease with increasing LWC, but all values of horizontal extent up to the maximum are observed and the shorter events are most common (Figure 8).

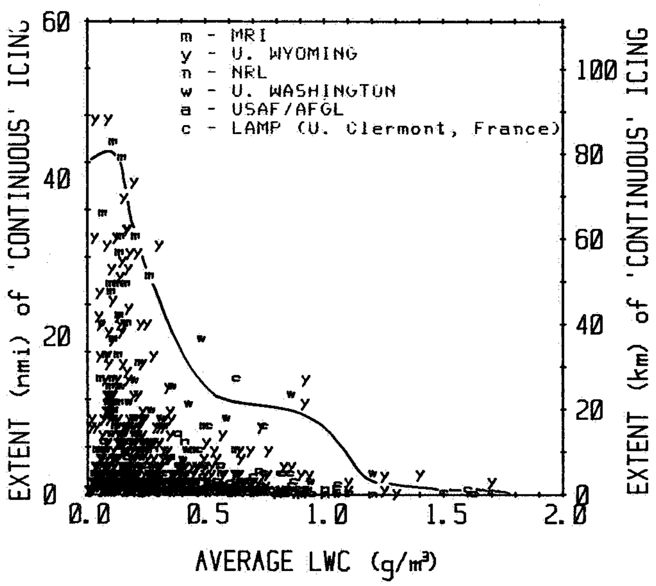


Figure 8. Scatterplot of modern observed horizontal extents of entire icing encounters vs. average LWC over the encounter. In this figure, an icing encounter is defined as a series of one or more icing events traversed consecutively until a cloud gap of 1 NM or more is reached. The horizontal extent of the encounter is the sum of the horizontal extents of the component icing events but does not include the extent of permissible cloud gaps. Data are for all supercooled cloud types at altitudes up to 10,000 feet AGL. A total of 3645 data miles is represented in this graph. The curved line is the 99th percentile of horizontal extent for these encounters as a function of average LWC.

3. A new characterization can be made to replace the FAR-25 envelopes for altitudes below 10,000 feet AGL (Figure 9).

The main features of the new characterization are:

a) Simplicity: a single set of envelopes will suffice.

Although it is instructive to distinguish between layer and convective clouds for scientific analyses, there appears to be no compelling, practical reason to do so for icing certification or design

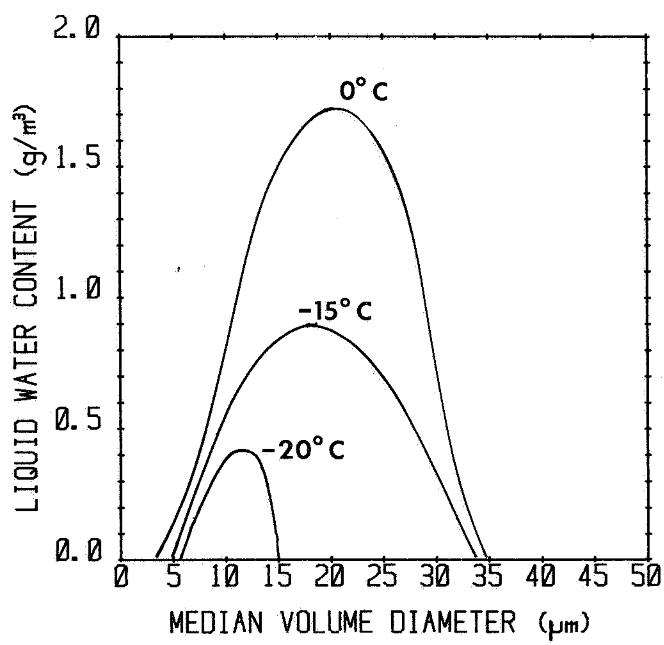


Figure 9. Approximate extreme values of LWC and MVD combinations observed in supercooled clouds at altitudes up to 10,000 feet AGL. The curved lines represent the approximate extreme values of LWC and MVD observed in any supercooled cloud icing event up to 10,000 feet AGL over CONUS and up to the temperatures indicated. The curves are based on about 7000 NM of measurements.

criteria a long as there are companion guidelines which specify horizontal extent requirements as a function of LWC. A new, single set of "icing envelopes" (i.e., temperature dependent contours of maximum LWC vs MVD) can be established as in Figure 9 for both layer and convective clouds together as a unified description of the overall icing environment for altitudes up to 10,000 feet AGL. This envelope would specify extreme LWC, MVD and temperature criteria for both design and flight test purposes, but information available elsewhere in Reference [6] would be needed to guide the selection of practical test points for in-flight certification checks. For this unified set of envelopes, the maximum LWC will range from about 1.7 g/m^3 at 0^o to about 0.4 g/m^3 at temperatures from -20^{o}C to -30^{o}C, the approximate lower limit of cloud temperatures below 10,000 feet AGL.

b) True representation of MVD extremes and their temperature dependence.

Minimum MVDs will be about 5μm at all temperatures. Maximum MVDs will be about 35μm from 0^{o}C to -20^{o}C. At -20^{o}C, the approximate temperature below which no convective clouds will be found at altitudes below 10,000 feet AGL, the maximum MVD drops abruptly to 15μm.

c) Clarify the meaning and usage of "horizontal extent."

Distance criteria should be re-defined by relating them directly to measured horizontal extents of definable icing "encounters" (i.e., series of one or more icing events separated by distances less than some specified limit, such as 1 NM, for example).

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6. *A New Data Base of Supercooled Cloud Variables for Altitudes up to 10,000 Feet AGL and the Implications for Low Altitude Aircraft Icing . R. K. Jeck, Report No. DOT/FAA/CT-83/21 and NRL Report 8738 (1983).*

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"A NEW CHARACTERIZATION OF SUPERCOOLED CLOUDS BELOW 10,000 FEET AGL"

Charles O. Masters

Introduction

The current atmospheric icing, supercooled cloud criteria for the design of U. S. civil aircraft ice protection systems and equipments is presented in Appendix C of Federal Air Regulations (FAR) Part 25 [1]. These design criteria are based upon data developed by the National Advisory Committee for Aeronautics (NACA) in the late 1940 to early 1950 time frame, and were intended primarily for large, high-performance, fixed-wing aircraft of that era. They encompass both layer and convective clouds with altitudes from 0 to 22,000 feet pressure altitude (PA), suggested temperatures as cold as -40° Celsius (° C), and liquid water contents (LWC) as high as 2.9 grams per cubic meter (gm^{-3}). Since their generation, these criteria have been exacted upon all aircraft seeking U. S. certification for flight into known icing conditions, including rotary and fixed wing, low-altitude, low- performance aircraft which typically operate below 10,000 feet. Since the phenomenon which dictates the formation of cloud water droplets and their associated LWC are dependent upon horizontal mixing and the vertical development of the cloud above the surface, icing clouds developed within 10,000 feet of the surface under convective conditions will be less severe; i.e., a lower LWC than clouds with developments extending to higher altitudes. Thus, in FY-1979, the Federal Aviation Administration (FAA) engaged the Atmospheric Physics Branch of the Naval Research Laboratory (NRL) to conduct studies and to gather data for a better characterization of the atmospheric icing environment below 10,000 feet. This effort has resulted in the data base employed in the generation of the new characterization of this presentation, and is described in the NRL Report Number DOT/FAA/CT-83/21 entitled, "A New Data Base of Supercooled Clouds Variables at Altitudes Below 10,000 Feet AGL and the Implications for Low Altitude Aircraft Icing" [2].

This presentation introduces the new characterization of supercooled clouds below 10,000 feet above ground level (AGL), and presents the rationale, data analysis, and data reduction procedures employed in the generation of the icing envelopes and other information which constitutes the new characterization. Also, potential applications of the new characterization will be discussed.

The New Characterization

The new characterization of supercooled clouds below 10,000 feet AGL is presented in Figure 1. In essence, it combines both layer and convective clouds, and encompasses three ambient temperature (Ta) dependent icing envelopes of 0 to -15° C, -15 to -20° C, and -20 to -25° C. Associated with the two colder icing envelopes are cloud horizontal extents (durations) of 20 nautical miles (NM), and for the icing envelope of the warmer temperature range, cloud horizontal extents of 50, 20, 12, and 6 NM for LWC ranges of .04 to .5, .5 to .75, .75 to 1.0, and 1.0 to 1.74 gm^{-3} , respectively. Also, associated with the 0 to -15°C temperature envelope are median volume diameters (MVD) which range from 3 to 50 microns (μm) and LWCs which range from .04 to 1.74 gm^{-3}; for the mid temperature envelope MVDs range from 5 to 38 μm and LWCs range from .04 to .66 gm^{-3} , and for the coldest temperature envelope, MVDs range from 7 to 15 μm and LWCs range from .04 to .41 gm^{-3}. The outermost edges of these envelopes and the horizontal extents represent extreme values of supercooled cloud properties determined to a probability level of exceedence of less than one part in a thousand; i.e., less than 0.001.

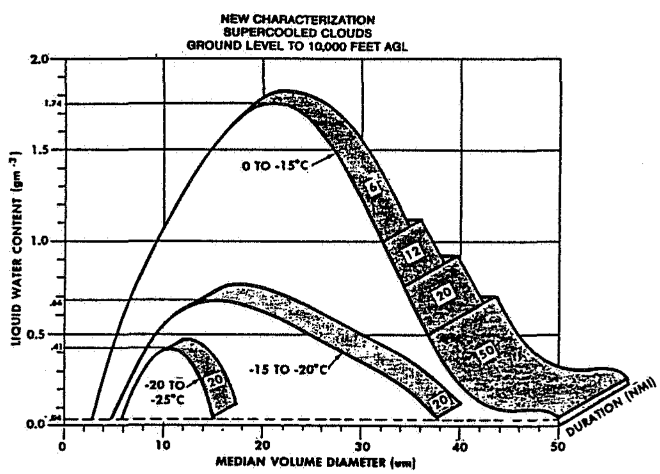

Figure 1. The new characterization of supercooled clouds from ground level to 10,000 feet AGL

General Approach

The basic approach employed in these analyses for the new characterization was to determine values of LWC, MVD, Ta, and event duration such that the probability of independently exceeding any one of these parameters would be less than one part in a thousand; i.e.,< 0.001 for all atmospheric icing conditions up to 10,000 feet AGL over the conterminous U. S. and nearby offshore areas. The initial analysis effort consisted of reviewing all icing events in raw data form in 5° C temperature increments from 0 to -25° C for each parameter of interest. These parameters were then ordered by magnitude and the 99.9 percentile selected.

Thus, values which exceeded the 99.9 percentiles would correspond to values of those paramters with a probability of exceedance less than 1 part in a thousand. Obviously, such a simplistic approach could only be employed and yield results with a high level of confidence in cases where there is a symmetrical, unimodal near-infinite data set from which to draw. However, in this case, the data base of 6,700 plus data miles representing some 1,400 icing events was deemed marginal, especially for extreme parameter values which were typified by limited data miles. Thus, realizing the possible limitation of the raw data set, a least distribution was employed to predict the extreme values. Details of this procedure are contained in the technical report noted in Reference [3].

A Combined Presentation for Layer and Convective Clouds

In FAR 25, Appendix C, the presentations of LWC, temperature, MVD, and horizontal extent (duration) are presented separately for layer clouds (continuous maximum conditions) and for convective clouds (intermittent maximum conditions). A review of the new characterization's data base in terms of layer clouds versus convective clouds indicates that the ranges of cloud properties were similar for both cloud types except for LWC's 1.0 gm^{-3} which were found only in convective clouds and, for Ta colder than -17.5° C where only layer clouds were observed. This is delineated in the matrix of Figure 2, which shows Ta versus LWC for each cloud type. A further review of the horizontal extents (icing events durations) for each cloud type revealed that combining the two cloud types into a single presentation would not be overly restrictive provided due consideration was given to the proper cloud type; e.g., the horizontal extent of 6 NM for LWC greater than 1.0 gm $^{-3}$ is based only upon convective cloud data. Thus, this was the approach taken.

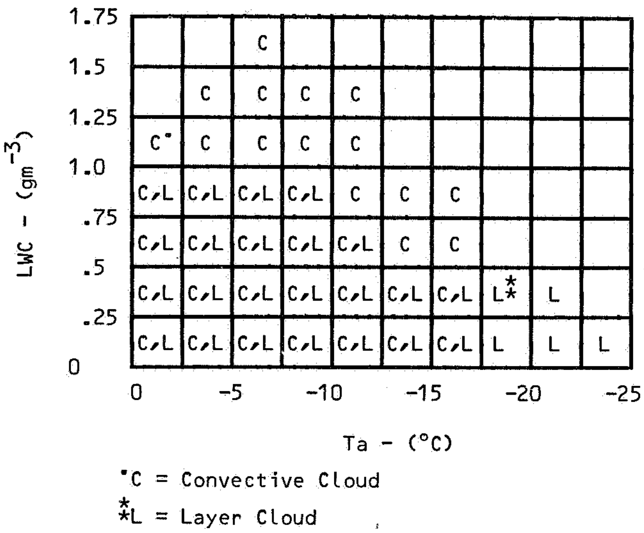

Figure 2. Matrix of LWC versus ambient temperature (Ta) for cloud types

A Consolidated Temperature Range: 0 to -15° C

Initially, raw data graphs were constructed for each of the 5° C temperature intervals between 0 and -25° C in a manner similar to the LWC versus MED graphs of FAR 25, Appendix C. The maximum observed values of LWC which occurred in each 5 μm interval of MVD was used to establish an interim envelope outline for each of the temperature ranges. The one exception is the one lone maximum data point which occurred at 22 μm at a LWC of 1.7 gm^{-3}, and a Ta of -6.5° C, which was omitted from the interim envelopes. These raw data graphs revealed very little differences between the three envelopes in the 0 to -15° C temperature interval (see Figure 3). Consequently, it was decided to combine all data in the 0 to -15° C temperature range and establish one envelope which described these parameters. Rationale for the inclusion of the one lone data point of 1.7 gm^{-3} to this temperature range could be supported if, during subsequent analysis, this point was found to lie within the Weibull 99.9 percentile. This semblance was not observed in the temperature ranges of -15 to -20° C and -20 to -25° C. Consequently, parameters in these ranges were treated separately.

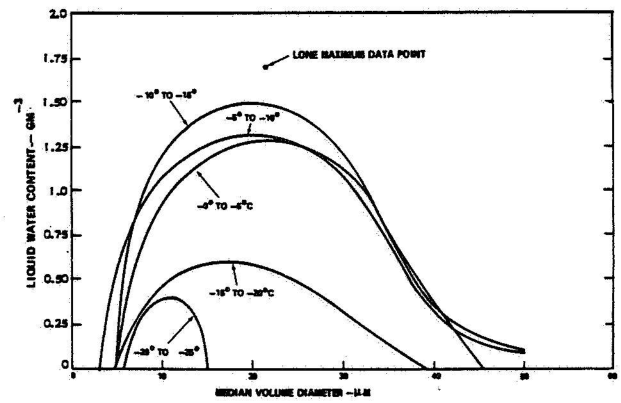

Figure 3. Similarity of icing envelope of 5°C intervals for the temperature range of 0 to -15° C.

Ambient Temperature versus Altitude AGL

An initial review of the data base indicated no appreciable altitude dependence for the cloud properties of LWC and MVD. However, icing conditions were not observed at the colder temperatures which occurred at the higher and lower altitudes; i.e., temperature in the range of -15 to -25° C which occurred between ground level and 4,000 feet AGL and between 6,000 feet and 10,000 feet AGL (Figure 4). However, this region constituted only a small portion, approximately 16 percent, of the total temperature versus altitude envelope and, for all practical purposes, could be accommodated by assuming the probable existence of supercooled clouds at all temperatures of interest and at

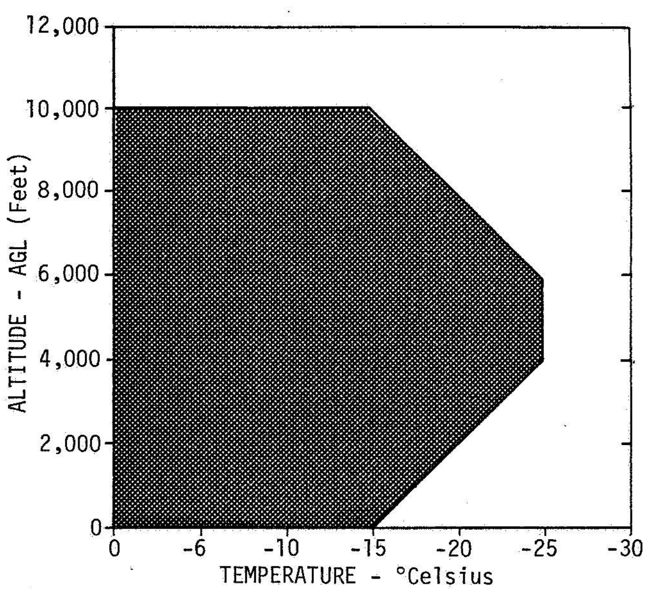

Figure 4. Ambient temperature versus altitude above ground level for observed cloud types

all altitudes up to 10,000 feet AGL. (Possibly over the northernmost portions of the U. S. during outbreaks of extreme cold polar air masses.) Consequently, the new characterization does not present a temperature versus altitude chart, whereas FAR 25, Appendix C, presents such a chart for both the continuous maximum and intermittent maximum criteria.

The Weibull Distribution

In these analyses, the Weibull distribution function was employed to predict the extreme values of the supercooled cloud properties. This function reduced to the form

$$\ell n(\xi) = \ell n \ell n(\frac{1}{1-\pi})$$

was employed to establish the coordinates of the plot of the parameter of interest: where

π = the ith percentile of an observed cloud property; i.e., 20, 50, 60, . . . 99

ξ = the value of an observed cloud property; e.g., LWC, associated wth the ith percentile.

Most extreme values of the new characterization were determined by computer; however, for illustration purposes, Figure 5 graphically depicts the procedure employed in determining the extreme value of cloud horizontal extent (duration) associated with the icing envelope of -15 to -20° C.

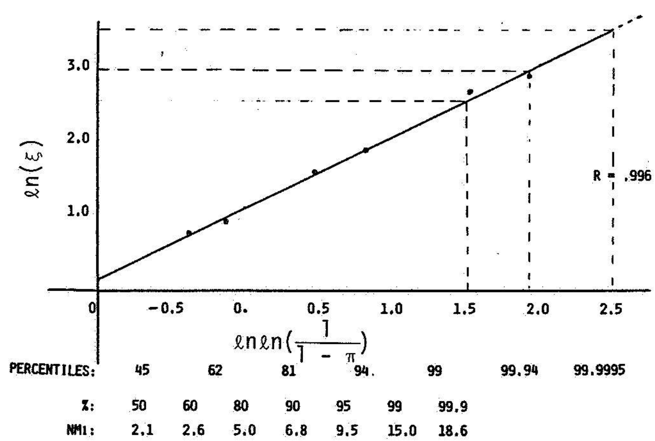

Figure 5. The determination of horizontal extent extreme: -15 °C to -20° C.

Although in this case the observed 99.9 percentile value was 18.6 NM the Weibull predicted value was found to be 20.1 NM and was subsequently rounded off to 20 NM as depicted on the new characterization (Figure 1). In a similar manner, the other extreme values of the cloud properties were determined, except that the Weibull predicted values of LWC were determined for each 5 μm MVD interval of its associated icing envelope.

A Final Comparison

Figure 6 presents a comparison of the new characterization, FAR 25, Appendix C, and the recently introduced FAA rotorcraft directorate's limited criteria. On this chart, all temperatures have been converted to Celsius, and the -40° F temperature contour line of the FAR 25, Appendix C, intermittent maximum criteria has been omitted, pri-

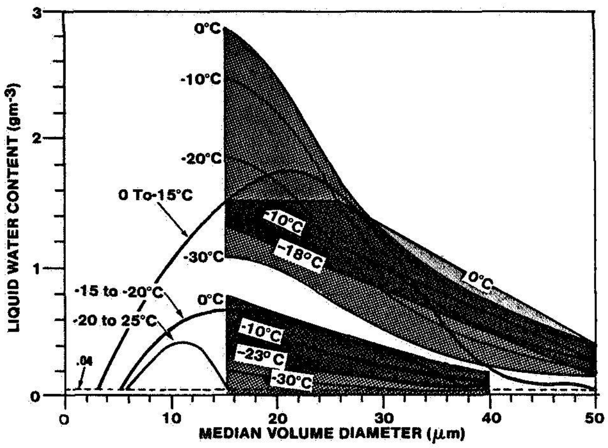

Figure 6. The new characterization superimposed on the far 25, Appendix C, and the rotorcraft directorate's limited intermittent maximum and continuous criteria.

marily for clarity. Some of the readily apparent observations/conclusions that can be drawn from this chart are:

1. The new characterization encompasses MVDs between 3 μm and 15 μm which were omitted from the FAR 25, Appendix C, and the rotorcraft directorate's limited criteria.

2. The new characterization presents a maximum LWC value of 1.74 gm^{-3} at 22 μm, whereas the FAR 25, Appendix C, criteria depicts a maximum value of 2.9 gm^{-3} at 15 μm, and the rotorcraft directorate's limited criteria depcits a maximum value of 1.5 gm^{-3}.

3. The new characterization depcits no temperature colder than -25° C, whereas the FAR 25, Appendix C, criteria presents temperatures as cold as -30° C and suggests temperatures as cold as -40° C, and the rotorcraft directorate's limited criteria coldest temperature is -23° C.

4. In the intermittent maximum criteria of both the directorate's limited criteria and the FAR 25, Appendix C, criteria, all values of LWC associated with MVD's larger than 36 μm significantly exceeds those of the new characterization and are deemed excessively conservative for altitudes below 10,000 feet AGL.

Concluding Remarks

Figure 1 depicts the final characterization of the atmosphere for supercooled clouds from ground level to 10,000 feet AGL. The envelope of each of the temperature ranges encompass values with a probability of exceedance greater than one part in a thousand, whereas the extremes of the envelopes represent exceedance probabilities less than or equal to one part in a thousand. Inherently, this characterization has parameters which may be employed in subsequent design of ice protection systems and equipments for aircraft which operate between ground level and 10,000 feet AGL. It is planned that this characterization will serve as an adjunct to the worldwide characterization of supercooled clouds currently under development.

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1. Federal Aviation Regulation Part 25 (FAR 25), *Airworthiness Standards: Transport Category Airplanes, Appendix C, Washington, D.C. 20591, Department of Transportation, Federal Aviation Administration, 1974.*

2. Jeck, R. K., A New Data Base of Supercooled Cloud Variables at Altitudes Below 10,000 Feet AGL and the Implications for Low Altitude Aircraft Icing, Department of Transportation, Federal Aviation Administration Report Number FAA-CT-83-21, 1983.

3. Masters, C. O., A New Characterization of Supercooled Clouds Below 10,000 Feet AGL, Department of Transportation/Federal Aviation Administration, Report Number FAA-CT-83-22, 1983.

"DEVELOPMENT OF A PLAN FOR IMPROVED AIRCRAFT ICING FORECASTS AND ASSOCIATED WARNING SERVICES"

Ralph Pass

I would like to describe a plan that has just recently started at the Office of the Federal Coordinator for Meteorology (OFCM). The plan was suggested by the National Transportation Safety Board (NTSB), and the goal is to provide integrated plans for improving aircraft icing forecasts. Before people panic and think we are going to come up with a new plan in a vacuum, I would like to say that I'm going to take whatever I can from various plans that already exist covering the various phases of the aircraft icing forecast problem. Yesterday, we heard a description of the FAA's plan from Loni Czekalski, which will be included in the OFCM plan. As a result, the aircraft certification part of my effort will be rather straightforward. Again, we are going to try to develop a plan that will summarize a systems view of what the Federal Government should be doing in aircraft icing and associated warning service dissemination. We have broken it down into five major areas dealing with the data collection, forecasting, dissemination, display and education, and aircraft certification.

Building on what has been said this morning, the FAA is now looking at new characterizations of clouds. The question becomes, "How do you relate that to aircraft icing?"; "Does the aircraft manufacturer have to give you a formula which says that given this droplet size and liquid water content, this is the kind of icing you can expect for a given air speed?" This might be a reasonable thing to look at. If that is the case, then the question becomes, "How do you get information to the pilot relating to liquid water content and droplet size?" Currently there are no forecast procedures for that. There is currently no way to conveniently display it; and based upon disscussions between the Icing Committee and the Remote Detection Committee, there is no way to measure it. So, this type of plan with this kind of problem needs to be addressed coherently from a systems point of view. We are going to be looking at not only what goes into each of these five areas, but also their interconnection. If the FAA would like to require liquid water, for example, as one of the parameters, the pilot needs to know it before he takes off, and we are going to have to figure out how to get it to him. That is what the plan would like to address.

I would like to give you a brief layout of what will be done. Task 1, which I have not yet addressed, is basically a literature search and interview period. Part of my reason for briefing here is to identify people to whom I should be talking in each of those areas we mentioned earlier. I certainly want to welcome anyone who would want to talk. Just let me know.

Briefly, the project schedule goes like this. We started in the first of October through the collection phase, Task 1, and it should be finished the end of this month or the first part of next month. At that point, we will start interviewing people throughout the country and throughout the various agencies interested in these areas, which will lead to a series of reports characterizing each of the individual areas we will address. We, then, have several months in order to put the report together and have it reviewed. Within approximately one year from that point, we hope to have a final copy out.

A literature search has been run at the OFCM and at TASC. Anyone who would like to make sure that certain pieces of information are included are welcome to let me know. One of the things I would like to get hold of fairly soon is the AFGL report on comparing current procedures for forecasting icing. Again, the forecast procedures are probably as conservative as the FAA characterization of clouds in the envelopes in FAR 25 Appendix C.

I would like to interview relevant individuals. If you would like to be included or know of others you would like to have interviewed, please submit your name or names of all relevant individuals. Finally, we would like to prepare a plan outline, which will be available in November at the OFCM. If you would like to see that, please contact either myself or Manny Ballenzweig, and we will see that you get a copy of it.

The first task is to see that we are pointed in the right direction. I don't intend to work in a vacuum. We would like to take the bits and pieces from the various groups and come up with a final integrated plan. Thank You.

"ADVANCE PARTICLE AND DOPPLER MEASUREMENT METHODS"

Chris Busch

I want to make just a few brief comments this morning concerning advanced diagnostic work in which various companies and government agencies are involved and which we think may have some possible application to the aircraft safety programs being addressed at this workshop. We want to point out that we have a healthy regard and respect for the measurement capabilities that are being used today. As Richard Jeck mentioned earlier, there have been a lot of improvements in the last decade which really improve the quality of data being obtained today. It is our opinion that the measurement capability is still on the upslope of the ramp, and that by implementing some of this technology, the results of the safety programs being addressed here may be enhanced.

The focus of my talk is particle environments, i.e., rain, ice, and snow particles. Two types of particles which we wish to address are: 1) the natural environment in which airplanes fly and conduct test flights; and 2) simulation environments that are encountered in ground-test facilities such as wind tunnels, ranges, etc. There are characteristics of the natural environment that one wishes to measure. The liquid water content (LWC) is the one that seems to be of most importance; size distribution may be of importance in some applications. Like snow, the shape of the particle may be an important parameter to measure. As one goes on to environment in simulated tests, additional parameters may be required such as velocity distribution, the velocity lag of the particle relative to the aerodynamic flow, and the trajectory of the particle as it goes through the aerodynamic flow and impacts on the test object.

We have been involved very much with optical implementation, laser implementation in aerodynamic tests for simulation in wind tunnels, ballistic ranges, and sleds; for example, conditions which one expects to encounter in flight. As a result of having worked on this for five or six decades, we have arrived at the point where we have very good precision at measuring the appropriate aerodynamic parameters and aerodynamic tests so that one can extrapolate from one set of flight tests to another or from ground facility tests to the flight tests. The key to that is being able to have instrumentation which can measure those appropriate properties accurately enough, so that one can transfer from one set of conditions to another.

In the area of particle measurements in icing tunnels, heavy water tests, and the like, my opinion is that we are not far advanced, as in the aerodynamic case, simply because not as much time and resources have been devoted to it. I think technology may be available that can help us along that path.

A couple of questions I think need to be answered. What data is really required for flight tests and simulation tests? For environmental characterization programs, exactly what data is needed? I do not think, if we get down to the basics of it, that those questions are really all that obvious. Another question is this. Is current instrumentation adequate? Certainly, devices that have been used extensively have made a major contribution to these program activities; but are they adequate? If not, we need to look beyond, especially when we embark on five-year terms in these technology programs.. Finally, can the new technology help? That is by no means obvious either. I think it takes some careful study and examination to answer that last question. Some candidate methods that may be considered are broken into two areas: 1) imaging methods; and 2) scattering methods.

The imaging methods are basically photography and holography. You are very familiar with the photography method which is being enhanced now by the advent of computerized image analyzer systems. This can really speed up the rate at which data can be extracted from photographs. I have had the opportunity to look at some of this data taken in the heavy rain program down at NASA Langley and good quality data is obtained. There are cases where photography cannot yield information needed; in which cases, one needs to go to holography. I do not want to get into the details of holography; but suffice it to say that it gives a three-dimensional image of the field from which one can extract high-resolution data over the whole three-dimensional volume. For example, in a wind tunnel, one could make a hologram of the particle flow and extract high-resolution data over that whole three-dimensional field. There are limitations with it which I will touch on subsequently.

In the scattering methods area, there are a couple of approaches: 1) the single particle approach; and 2) ensemble approaches. They have advantages as well as some disadvantages.

In holography, one is able to get shape information since you are dealing with an image of the particle field, and the velocity field of the particles can also be obtained. A big advantage of holography is that there has been a lot of experience with it and one is quite confident when employing holography that you will get quality data that is useful. The big disadvantage in one area is data reduction. If you get a lot of data, it is difficult to extract out of that information the subset of information which is important to you. I might point out, however, that there are programs underway at a number of centers focusing on automating the process of getting the desired information out of holographic images. The advent of computer technology, of course, is making that possible. When one makes a hologram of an object field, he then reconstructs the image field for a three-dimensional image on which the photography work can be done.

Recent applications of holography include spray characterization, coal combustion, and much work in wind tunnels. One of the early applications of holography for particle field studies was at AEDC here in Tullahoma, where it was used to characterize a particle environment in a tunnel that was laden with particulate for purposes of erosion studies. That was more than 10 years ago. There is a great deal of experience with use of this technique in wind tunnels. Rocket engines and various industrial processes are other applications.

The advantages of the single particle techniques are size and velocity information, good spatial resolution, and a big advantage is real-time data acquisition. This is based on light scattering which goes into a photo-multiplier tube, then eventually into a computer where the data is virtually all handled in real-time and managed by the computer. All of these optical techniques, of course, are nonintrusive. It is a single particle inferred LWC which can be either a disadvantage or an advantage depending on what the real mission or objective is. Quantities of interest for icing studies like LWC have to be inferred from the measurement of particle size and velocity.

Let me just summarize with a few words on ensemble measurements. Ensemble measurements are those on which one projects light into the particle field of interest and collect the scattered light off of the ensemble of particles. There are systems of that kind available and improvements are underway for them. The advantage is that those systems are inherently quite simple; the data, however, is not of as high a resolution as one can obtain by other means. They are very useful, though, depending upon the mission of the instrument.

In closing, I would again say that I think we need to clearly establish what the measurement requirements are on the various ground and flight test programs. Then, based on the voids that exist in the measurement requirements compared to what we are using today, some of the advanced methods that are underway and available may be appropriate for implementation on those programs.

"DEVELOPMENT OF A WIND SHEAR PERFORMANCE ENVELOPE"

John H. Bliss

Flying into an airmass which is moving in a new direction and/or at a different velocity may produce a large airspeed change. An increase is incidental. A significant loss, well below the bug speed in use, will severly alter the flight path and produce a large descent rate.

If there is no continuing headwind loss after such an airspeed loss, you can apply maximum power, pull the nose up, and go-around. However, a continuing headwind loss equal to or exceeding accelerative capability will prevent a successful go-around.

In a simple downdraft, altitude can be held in air which is descending as fast as the airplane can climb. Consequently, some think altitude can also be held when a headwind is diminishing at the same rate as the airplane can be accelerated.

It is quite important that the airplane performance during a continuing headwind loss be understood. This presentation is offered in recognition of this importance, and to present an aspect of performance not normally considered. Lack of consideration of this characteristic can result in assuming almost twice the performance than that which the airplane actually has during severe wind shear at high descent rates. The example data relates to the Boeing 727-200, but the characteristics are applicable to any airplane. Figure 1 portrays the characteristic of an airplane in the landing configuration, gear down, flaps 30, 100%, power, standard sea-level day, and 140,000 lbs. gross weight.

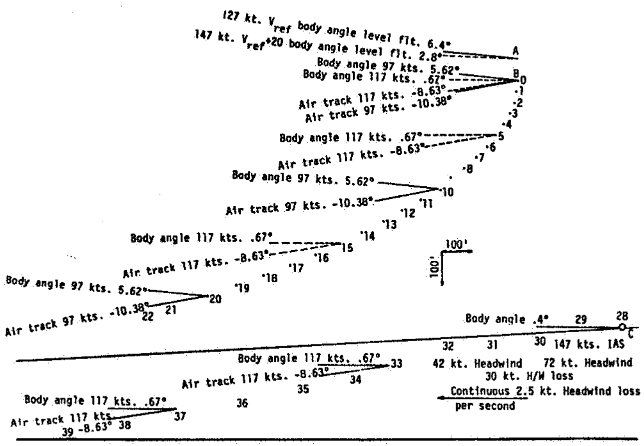


Figure 1.

We will begin with evidence of how forces are balanced during a maximum performance climb, at a Vref airspeed of 128 kts (see Figure 2). It is important to recognize that the airborne framework coincides with the inertial framework (no wind shear). I would like to draw your attention to the angles which apply. The angle, flight path to "G" direction, equals 97.31⁰.

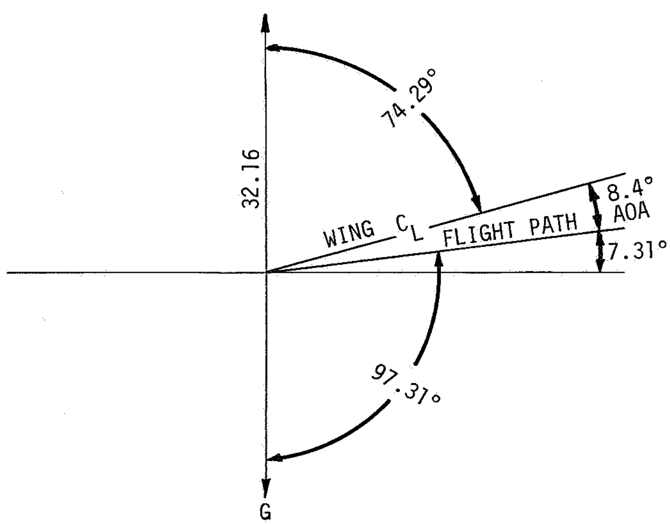


Figure 2.

A climb of 1650 fpm (27.5 fps) is achieved using maximum performance under stable air conditions. I would like to emphasize "using maximum performance".

Now consider Figure 3. We have the level flight condition, where there is an acceleration of 2.5 kps (4.222 fps). The angle between the flight path and "G" direction remains at 97.31⁰. Notice the rotation of lift by 7.31⁰ results in a slight lift deficiency which can be ignored due to its fleeting 1-second existance. Altitude is then held and airspeed increases 2.5 kts/sec.

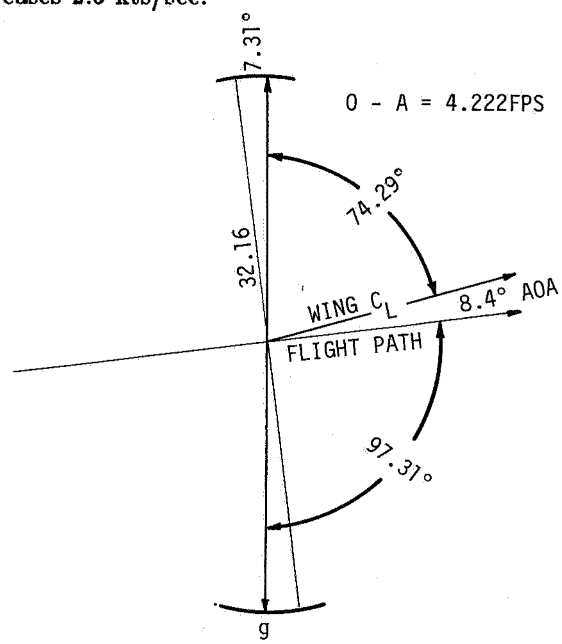


Figure 3.

Turning to Figure 4, we have the same condition as in Figure 3 except with a 2.5 kps constant headwind loss, the airspeed does not rise. The slight loss of lift in Figure 4 now becomes significant. The loss is constantly present due to no airspeed increase. The maximum flight path angle is now a tangent to the lift line represented in Figure 3, with the same airspeed. All is as balanced as the previous condition in Figure 2 as long as the 2.5 kt/sec. headwind loss endures.

Inspecting Figure 4 in comparison with Figure 3, one sees that the only difference is the 2.5 kps headwind loss in Figure 4. Surely, those of you who have observed a free-flight model in a wind tunnel will attest to the almost vertical perturbations caused by slight changes in wind velocity. The movement is near vertical because of lift change, and altitude loss has little horizontal effect on the model's movement. The acceleration/climb chart is valid in stable air where a change in flight path produces the effect of descending an inclined plane.

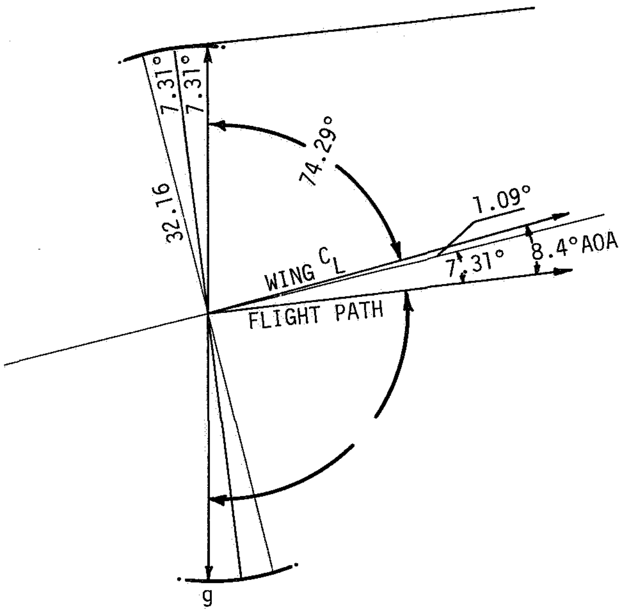


Figure 4. O-A = A-B = 4.222FPS

When a mass descends an inclined plane due to the influence of gravity (see Figure 5), its velocity will equal that acquired by a mass falling freely the height of the plane. All horizontal acceleration derived from descending the inclined plane results from the resistance to gravity provided by the plane.

As simple as this sounds, there can be complications. If you place the inclined plane on an elevator, any vertical acceleration, up or down, will affect the velocity imparted to the mass. Horizontal acceleration of the inclined plane will also affect the velocity acquired by the mass down the plane.

In an airplane, the "inclined plane" is totally formed by the geometry of the air. When the air geometry is unchanging, a solid "inclined plane" such as displayed here, and on the accelerate/climb chart (Figure 1), exists.

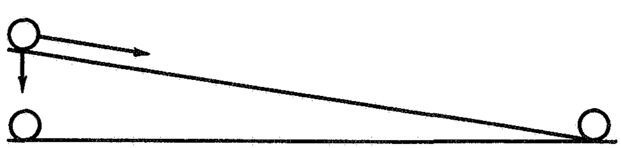


Figure 5. Display of an inclined plane

There is nothing relative to the airplane which gives any relevance to horizontal except the air geometry and gravitational ("g") force direction. When a continuing headwind loss is present, the airplane's horizontal is changed to a new direction and so is the "g", so the inclined plane is also changed. The result is altitude loss without the resultant horizontal acceleration, just as if the inclined plane were to be accelerated toward the rear at the same rate as the headwind is diminishing.

I know from experience that with no wind, a 747 can leave 39,000 feet 120 miles from destination, descend at idle power, and land 20 minutes later using power only the last 1500 feet on final. When you have a 150 knot headwind at 39,000 feet, it takes no more than 85 miles and just over 12 minutes. A much larger nose-down attitude is required to get the same airspeed during the headwind loss. There is a large altitude loss without the speed gain. This is obviously the result of a large change in the "inclined plane" and these changes are just as valid on the approach as they are at altitude. If the accelerate/climb chart values (Figure 1) were valid, at least the time for descent would be the same in either case. Obviously it is not.

Essentially, safe flight path control in the new airmass can only be assured by the use of a safe actual speed relative to the new airmass before entering. The safe speed cannot be resolved by using airspeed alone, which disregards the environment ahead.

For take-off, the best defense seems to be a pause in take-off position to scan the departure path, visually and with radar, for problem cells. If present, taxi off the runway, don't take-off.

For landing approach, where the environment ahead is known, a safe speed can be resolved for the approach. A method and instrumentation has been described here at a previous meeting. It is the airspeed/groundspeed method. This sytem automates the process and the only additionl work load is to insert the surface wind.

Presently, wind shear training (a requirement for most airlines) is like asking a student a question for which there is no answer. Conversely, the airspeed/groundspeed system gives him a tool with quantitative information from which real answers are available. Judgment can be developed which is impossible otherwise. Actual training is then possible with skills developed and enhanced.

Most importantly, true safe speeds are used on every approach regardless of headwind loss. By eliminating the need for acceleration, full climb capability is available for downdraft, even during headwind loss. With large headwind loss alone, a power reduction is required for stabilized speed. This is done, quantitatively, by using two minimum speeds. The airspeed is not allowed below normal, and groundspeed is never below the value expected over the threshold. Either speed can be normal or above, but neither below. The pilot then has full quantitative knowledge of what to expect ahead at all times, and he can expect both speeds to be normal at the threshold. If they are not, (groundspeed excessive) he can go-around and approach from the proper direction, which he can discern from his draft on the approach.

There are too many advantages to enumerate now, but no pilot will ever control wind shear without controlling actual speed. Runway overruns or undershoots cannot be controlled without controlling airplane speed relative to the runway.

"LABORATORY MODEL OF FLIGHT THROUGH WIND SHEAR"

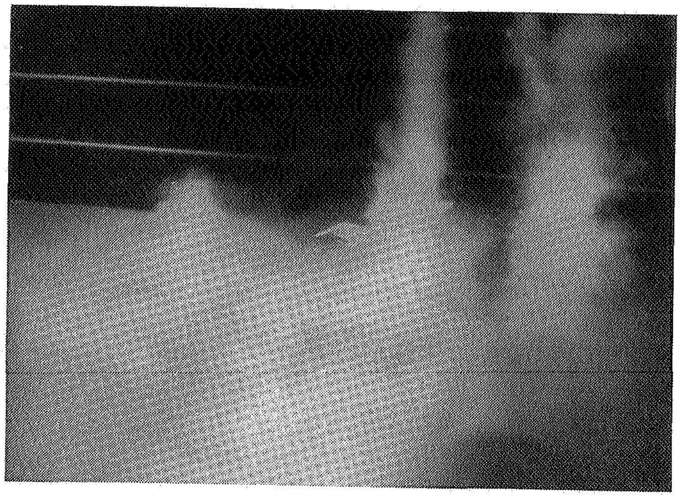
Walter Frost

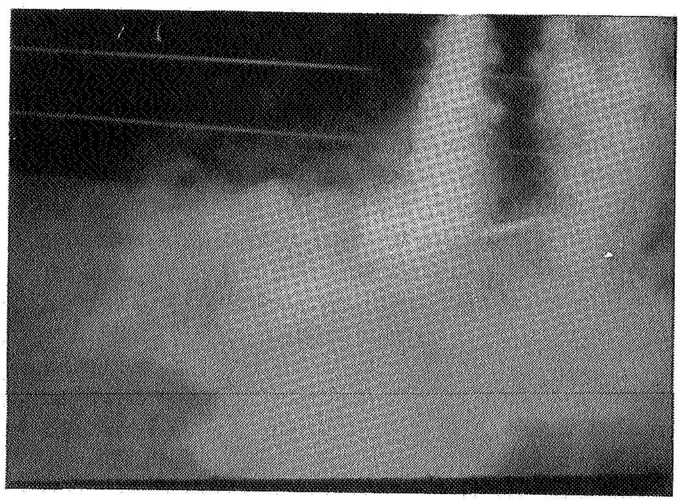
This address deals with the simulation of an airplane flying through a downdraft, or microburst. This project came to pass about this time last year, at the time when the Pan Am accident had just occurred. The television company, Alan Landsburg Productions, which produces the television show, "That's Incredible," decided they would like to do a series on wind shear. They talked to John McCarthy, Bill Melvin, and a few others. Finally, Norm Crabill at NASA Langley Research Center directed them to FWG Associates, Inc. One of the things they were insistent upon was an actual model study of an airplane flying through a microburst, and they would not be satisfied with a computer graphic simulation.

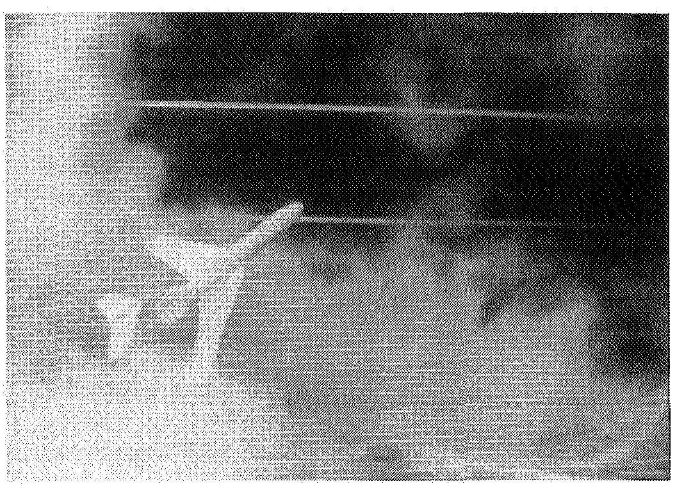
We had, roughly, two weeks to design, construct, and carry out the simulation. We decided to use a large building next door to FWG Associates, Inc., the small research and development company located in the UTSI Research Park. This building is approximately 50 feet wide, and we had to do some quick scaling laws to determine the best method of handling the project. We decided to show the takeoff because it is the easiest to do. We needed to simulate a constant take-off thrust; subsequently, we used, roughly, 100 feet of surgical tubing stretched through the door of the laboratory. This gave us an essentially constant thrust of about 2-1/2 pounds, which is what we calculated as being needed for the size of aircraft being modeled. We hung a large fan in the ceiling which had about 16,000 cubic feet, and scaled the velocity coming out of that fan relative to the velocity of the aircraft as it passed through the microburst.

Our tail was on the line because we had an agreement with Landsburg that if it indeed worked, they would pay us a relatively adequate sum of money. However, if it did not work, we were going to eat it! So, we were trying very hard and getting very anxious near the end. Nevertheless, it did work very well. We actually put a control into one of the aircraft models and learned a little about the dynamics of the aircraft. We found that if you pitched up, as Bill Melvin and others at that time were saying, when you passed through the wind shear, often times the model would come out of the wind shear and not crash. However, if you tried to put the nose down and pick up speed at all, which was the other option, the aircraft invariably crashed.

A lot of people have asked whatever became of the video results. It was supposed to go on national television; but it didn't sell, because it was competing against 60 Minutes, and the second sequel of the series which we were supposed to be in was never released. I have, however, brought a short clip that I have put together on my 1/2-inch video tape and I would like to show it to you. Incidentally, one of the airplanes which had a controlled system in it flew right into a television camera. Another of the models was glued back together so many times it was amazing that it still flew. The first part of the video was transcribed from high-speed film onto television tape, and it shows the aircraft coming out of the microburst, made visible by CO_2 fog. A series of pictures, Figure 1, show the aircraft as it flies into the wind shear, lifts, loses lift, pitches up, and hits the ground.







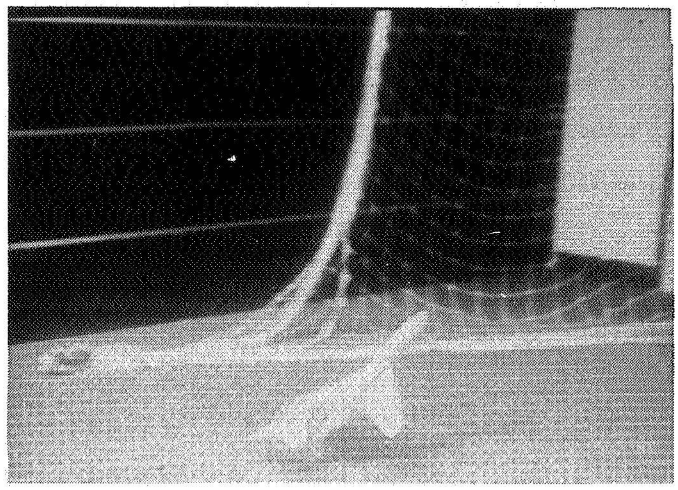


Figure 1. Sequence of aircraft trajectory through simulated microburst

When you study the downdraft phenomena, Figure 2, which has been illustrated, it shows a similarity to things we have measured with radar, suggesting that a microburst is a cold outflow moving down towards the ground and spreading out in all directions. The markers on the wall indicate a scaling of about 100 to 200 feet, respectively. If you will notice, the air jet comes out and spreads out all over the ground. It is not, however, perfectly symmetric; because we have discovered that microbursts are not perfectly symmetric.

You can see from Figure 2 how relatively shallow the outflow is once you get out of the downdraft.

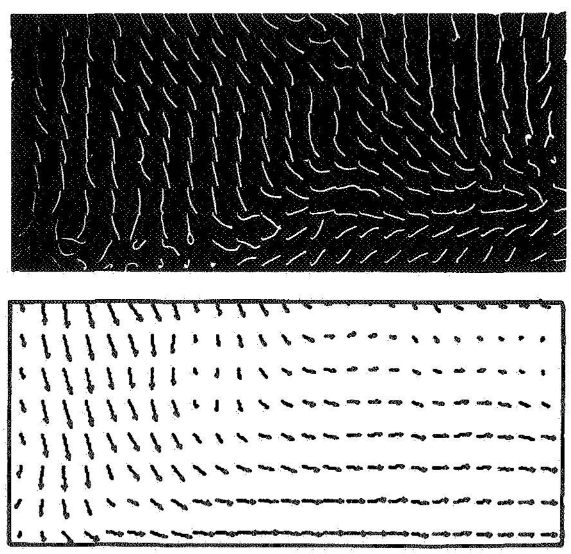


Figure 2. Comparison of laboratory microburst flow field with measured flow field from JAWS project

It took only about two seconds for the model to fly the entire length of the building, so to control it we had to be quick. However, interestingly enough, you could control it if you were on your toes. We simply had an elevator to give us pitch control.

If you are interested, there was article written about the simulation in Aviation Week and Space Technology. We have a few of the reprints of that article here if you would like to have one.

"AVIATION WEATHER OF THE 1980'S"

Sepp Froeschl

I would like to thank Walt and Dennis for giving me the opportunity to talk to you for a few minutes, because I think it is a rare, if not unique, occasion to have such a wide range of expertise to talk to. To give you a few ideas of my background which may be the reason for some rather controversial things I will say later, I am a meteorologist, and I work for the Canadian Government. I am called a Chief Analyst and Prognostician of the Quebec Weather Center. I have been a pilot for over 40 years, with a wide range of experience from military to airline flying. Over and above this, I am an enthusiast in meteorology and, particularly, aviation meteorology. As the title of my impromptu speech indicates, we are in a transition period. Our problem is that there is still a wide credibility gap between the user and the provider which is what I call the weather services. As for users, I am referring to the various components of the aviation community.

I think we have tried for too long to do everything for everybody, and I am afraid that if we carry on this trend, we might end up doing nothing for anybody. We are, due to budgetary constraints, having to cut down on personnel, and having to use more and more automation. Please do not get me wrong; I am not anti-modelling or non-automation, because my initial ideas and education are in mathematics. However, I am a realist. Since I am a user as well as a producer, I think we need a different approach. This is, I think, the weather services. They should get into measurable, quantitative configuration and move away from qualitative information. In my opinion, this is our biggest handicap. Originally, when we moved into qualitative terminology, it was a way out of the situation; but, in the last 30 years, we have not moved too far ahead. I once wrote a thesis on aircraft icing; and after hearing at the last six workshops how much is going on in icing, I went back and read the thesis. I thought to myself how new it all sounds to me; but remembered that thesis was 30 years old. In other words, we have not made good use of the new technology because it is primarily an advance in technology, not so much in real science. We should, however, make better use of this technology, especially in aviation meteorology. With the new high-speed computers we should make use of them instead of being used by them. If we make full use of them, we can really go into a quantitative description of the atmospheric conditions. By doing that, we are avoiding controversy and ambiguity. For example, I hate the term "VFR conditions", because VFR includes many things besides meteorological parameters. Over and above that, we cannot measure VFR. We can define it as something, but it cannot really be defined in quantitative parameters. We might say three miles, 1,000 feet, or whatever; but it doesn't mean anything because you can't measure or forecast that in terms of atmospheric conditions. What we should do, by going to quantitative expressions or terminology, is forecast a ceiling of 500 feet and a visibility of one-half mile and then the user can call it, or do with it, whatever he wants.

One of my theoretical specialities was icing, as I mentioned before. If we continue to talk about light to moderate rime icing in clouds with a risk of heavy mixed conditions in build-ups, we are wasting time. Every pilot knows that if he is in build-ups, convective clouds, etc., there is a danger of icing existing there. What is light to moderate? We have from a Cessna 150 up to the Space Shuttle. In the old days, there was about 150 kts speed ± 30 %, and that was everything we had. So, we could be rather generous in using those terms for everybody; but now it is completely out of range. What I would like to say, and what I would like to implant into you, is the idea that we should:

a) Aim for quantitative information; i.e., forecasts, observations, etc., and move away from qualitative.

b) Secondly, that we stop catering to users, because we should leave it to the user to take whatever is available for his personal needs. As a practical example, instead of catering to general aviation, military aviation, or airlines, we are confining ourselves to low, mid- and high-level information, then the user takes whatever he gets from a common data bank.

"THE ELEVENTH MOST SIGNIFICANT EQUATION"

John Houbolt

My impromptu remark deals with some commemorative stamps that were issued a few years ago listing the ten most significant equations of mankind. I don't mean equations to be solved, but equations that state physical reality or physical consequence. Now, somewhat with tongue in cheek, I would like to add the eleventh equation. The substance of the ten most significant equations were these elementary looking equations like $F = ma$; $E = mc^2$ and the like. In the past year, I have been continuing some studies on the response of aircraft in continuous random turbulence, and have come up with a very remarkable result. It is in remarkably simple form and seems to be quite general in nature. This equation is shown as follows:

$$\sigma = \frac{\sigma_1}{\sqrt{\alpha}}$$

To what I can see, the equation is simply stated and applies to all aircraft. The root mean square of vertical acceleration, σ, is equal to a turbulence term, σ_1, divided by the square root of the angle of attack, α, necessary to maintain level flight, and that is all it is. You do not have to include the weight of the airplane, the altitude of flight, the velocity of flight, as it is all inclusive in this one equation. Now, I should make a comment about σ_1. It is actually a combination term that involves the turbulence intensity and the turbulence scale, but it is directly deducible from turbulence data, as a combined form; and you do not have to separate out the intensity and the scale length. It is a natural combined form of the two parameters, directly deducible form turbulence data. So, I submit this as a perfectly general equation which gives you the response of airplanes to turbulence. I won't tell you at the moment how we derived it. I am in the process of writing a paper now to be given at Reno next January; and, at that meeting, if you are interested in how it is derived, I will be presenting it there. Thank you!

"A MODEL OF A DOWNBURST;" A WIND TUNNEL PROGRAM ON PLANETARY BOUNDARY LAYER;" and "AIRSHIP IN TURBULENCE."

Bernard Etkin

Ladies and Gentlemen, before I start describing to you the model of a downburst that we have recently generated, may I, since there is time, philosophize for a moment about the role of analytical models in what we are talking about at this workshop. The meteorologist, of course, has to go out and try to discover what the world is really like, such as drop size distribution; or in the JAWS Program to find the real velocity field in a real microburst. However, what the aeronautical engineering profession needs is something a little different - it needs "engineering models". We need an engineering model of turbulence at high altitude; we need an engineering model of the planetary boundary layer; we need an engineering model of microbursts. What these models must all have in common is that, firstly, they reflect reasonably well the reality of the physics. Secondly, that they have parameters in them that you can vary to adjust the models to suit various circumstances. Last but not least, they must be reasonably easy to use. With that philosophy in mind, I thought that we might be able to make a model of the microburst, or downburst that would be useful.

You have seen a number of diagrams like Figure 1 during this meeting. When you look at it, what you see, (in fact, what Dr. Frost produced in his experiment) is a vertical jet blowing against a plane surface. Well, that did not

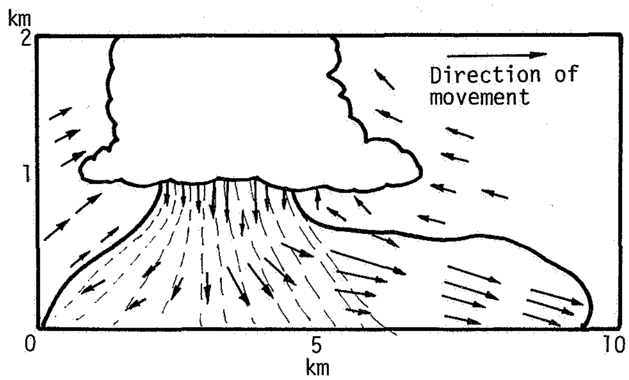


Figure 1a. Section through a thunderstorm in the mature stage

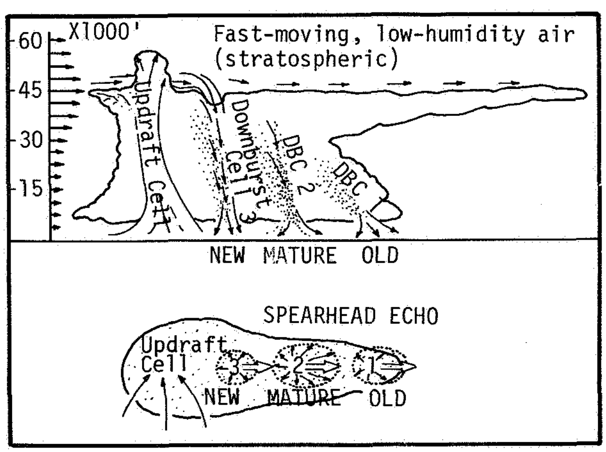


Figure 1b. Imbedded microburst storm characteristics

seem difficult to model. I thought we might try a set of doublets, a doublet surface, or perhaps ring vortices distributed in various ways to produce a flow field that looks somewhat like the downburst. Well, after a few trials, we settled on the one illustrated in Figure 2. What we have here is a circular sheet of doublets that occupies the zone A-A; and, of course, to produce symmetry about the ground plane, there is an image set down below. The figure shows streamline patterns created by such a circular doublet sheet. It

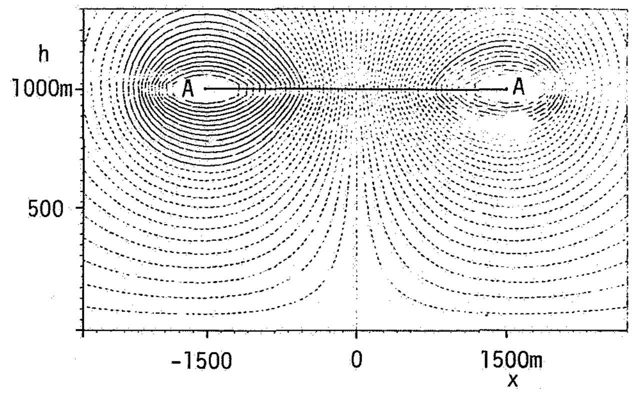


Figure 2. A typical microburst generated by a doublet sheet with cosine intensity distribution

is not a uniform-strength sheet; it has a cosine distribution of intensity. We looked at both uniform and cosine distributions. Figure 3 shows the horizontal wind, W_l, and the vertical wind, W_3, along a vertical plane through the center of the system. This figure demonstrates the main char-

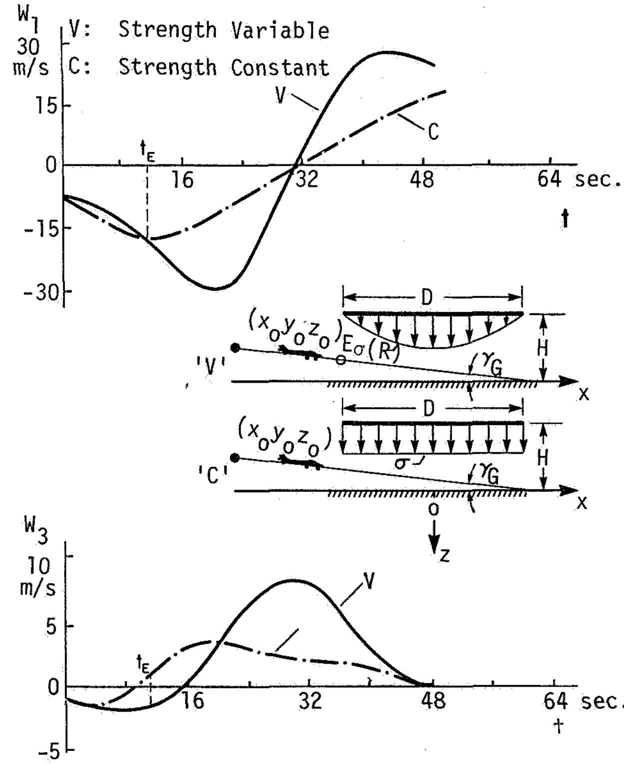


Figure 3. Comparison of 3-D model for different strength distributions:

$\sigma^V_{max} = 100$; $\sigma^C = 93.6$ ($x_0 = 2316$m;

$h_0 = 200$m; $y_0 = 0$; $D/H = 3$;

$D = 3000$m; $\gamma_G = -3°$. Comparison condition: W_1 =18.24 m/s at 'E') acteristics of the downburst. An airplane flying down the glide slope in the sketch initially experiences a head wind that later changes to a tail wind, with a fairly strong gradient. W_3 shows first an upwind, then a downwind, fairly strong to begin with, and then tapering off. One gets slightly different answers if one goes through the field horizontally. Furthermore, with this model, you can just as easily choose a track that does not go through the center, but off to one side, so that you get side wing and gradients in all three directions, simultaneously. The equations that describe such a flow field are quite simple and easy to implement for either a machine computation of flight paths or in real-time on a simulator to give pilots the exercise of flying through a microburst. You can easily change the height at which you put the doublet sheet; you can change its diameter; you can change its strength; and, if you want to, you can play games with the distribution. We ran a couple of exercises of flight through our model using a commercial jet transport (Figures 4 and 5). With fixed controls, the downburst can be seen to be quite severe. On the other hand, with an automatic control system that is tracking the glide slope, the latter is followed quite closely down to the height where a transition would occur. This is a relatively straightforward system operating on height error. That is project number one that I wanted to tell you about.

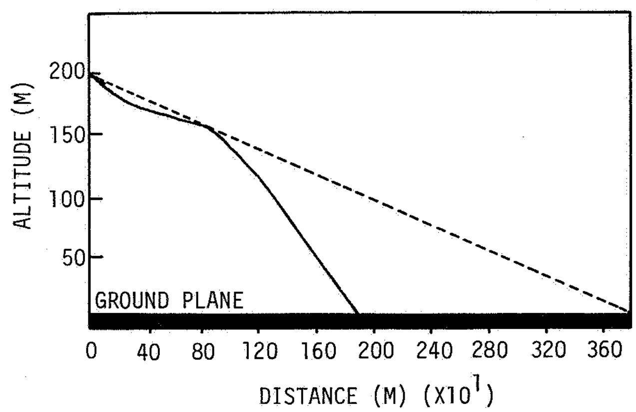


Figure 4. Response to microburst: Controls-fixed; ${}_G = -3°$; $x_{TD} = D/2$; $y = 0$; $h_0 = 200m$ (Flight Path)

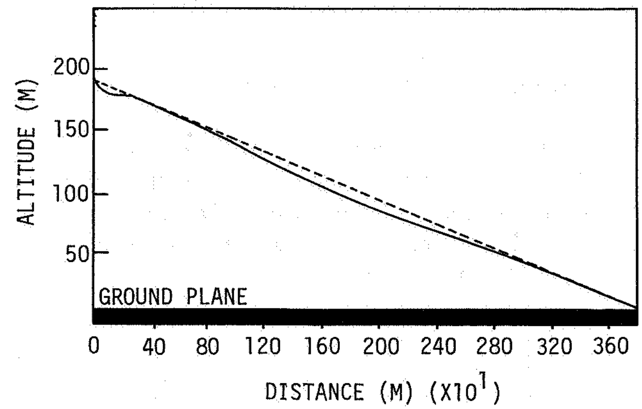


Figure 5. Response to microburst: Automatic Landing; ${}_G = -3°$; $x_{TD} = D/2$; $y = 0$; $h_0 = 200m$ (Flight Path)

The second project is a study of the landing or takeoff through the planetary boundary layer. To study this problem, we started about ten years ago with the development of a planetary-boundary-layer wind tunnel in which to simulate the shear and turbulence that exists in this situation. We, then make the necessary measurements of the appropriate time-delayed cross correlations down the glide slope, including the gradient terms (rolling gusts, pitching gusts) as well as the U, V and W gust terms. The facility itself is pictured in Figure 6. We have at the upstream end, a grid of jets in eight rows which can be individually controlled row by row and in sets of three across any row, in order to generate the desired velocity profile. We have been working essentially with power-law profiles, but you could use something different. We need a barrier and roughness on the floor in order to get turbulence intensities reasonably simulating those in the atmosphere. Figure 7 shows one particular set of measurements we have made and which have been published recently in one of our reports. It is an example of the time-delayed cross-correlation between the lateral (side) component of wind velocity at two points on the glide slope. In this particular set of experiments, hotwire anemometers were used in pairs, so it was like the NASA B-57 measuring gradients in the air. We had the equivalent measurements at two points that represent the wing tips and we were measuring cross-correlations between data at one point on the glide slope and at a lower point, time-delayed by the interval it takes the airplane to go from the upper point to the lower point. This is only one example out of many correlations. The $(\beta - \alpha)'$ seconds at the bottom is the time-delay.

We have measured the correlations of the various gust gradients, as well as individual velocities.

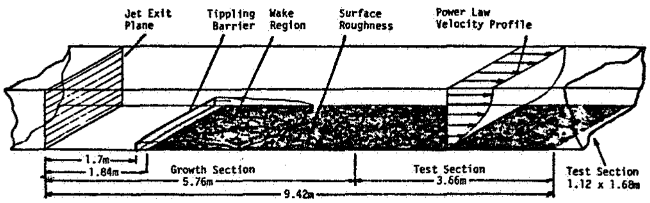


Figure 6. Boundary layer wind tunnel configuration

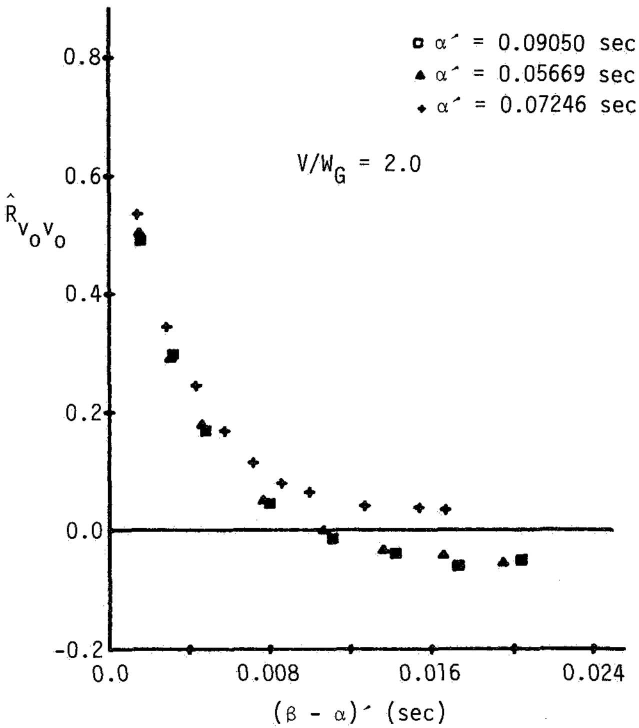


Figure 7. Flight path turbulence correlation-- $\hat{R}_{v_o v_o}$

Figure 8 shows the computed RMS response during the descent. Y_I is the lateral dispersion in an inertial frame of references and the results are for a STOL airplane descending through the boundary layer using the wind tunnel data as inputs, scaled to full scale. The RMS value is of an ensemble of flights. The figure shows how this RMS dispersion increases with distance as you come down from the starting point to the ground. The various curves show what happens when you simplify the calculation by leaving something out in the driving matrix of the system. It turns out that the biggest term is the rolling gust term Pg. If you tried to solve that problem just using side gust alone, you would not get any reasonable answer at all.

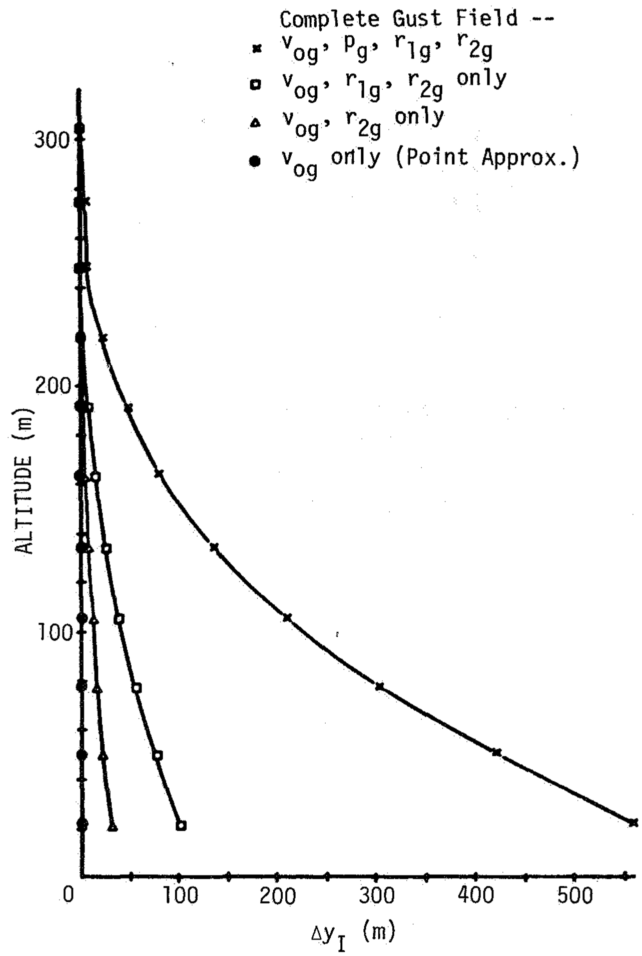


Figure 8. Aircraft RMS response -- Δy_I

I turn now to the third project, an airship in turbulence. Figure 9 shows the same wind tunnel again but set up a little differently to study a somewhat different problem. The setup here uses the grid of jets all blowing uniformly to produce an essentially constant field, and a very coarse turbulence grid to produce quasi-isotropic large-scale intense turbulence at the location of the model, which, in this case, is an airship. The aim of this investigation was to find whether the most commonly used theory for the turbulence-induced forces on a body like an airship was any good. That theory is the "slender-body/strip theory". I suspected that it wasn't much good. There doesn't exist in the literature any really good data for use in comparison, so we undertook this experiment. The model was instrumented so that it had two degrees of freedom, heave and pitch. We have two force sensors on it measuring the aerodynamic load at two positions so that through calibrations we can deduce the lift and pitching moment, which would be the same, if you rotate the system 90°, as side

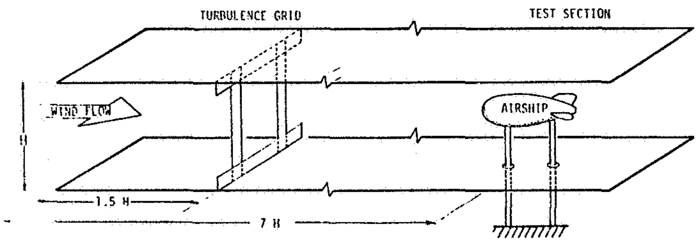


Figure 9. Wind tunnel layout for airship study

force and yawing moment, because it is axially symmetric. The main result we got is shown in Figure 10. Plotted are the transfer function from up-gust to normal force and from up-gust to pitching moment. Also shown are the corresponding predictions of the slender-body theory, and they are quite different. So, as a quantitative means of finding out what the hull contributes, the slender-body theory is certainly inadequate. We almost didn't do the experiment with fins. I told the student doing the experiment that we knew what the

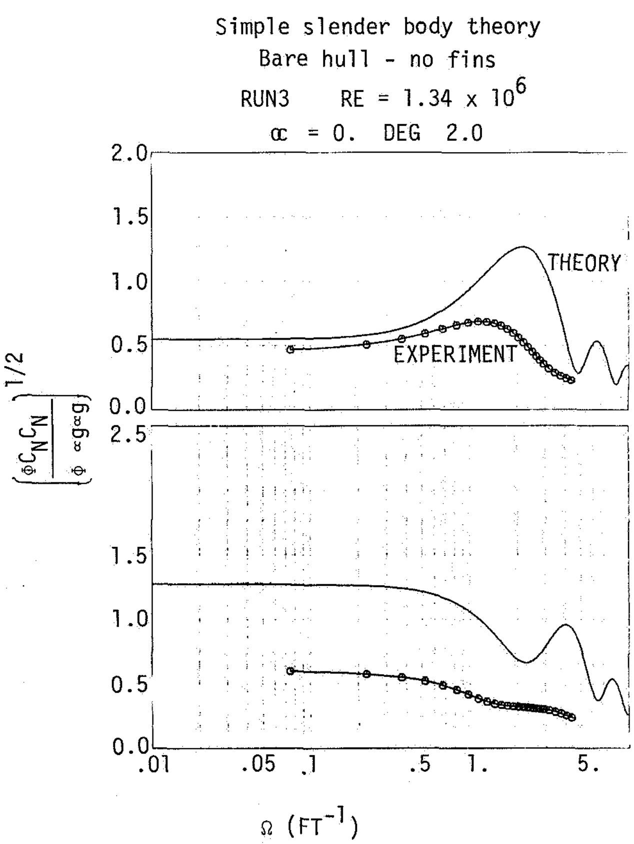


Figure 10. Experimental results vs. simulation

fins were going to do. They are just some little airfoils at the back and we can calculate that, so why should we bother to do it? The real question was the hull. It turns out that the most interesting result we got was after we put the fins on! (Figure 11)

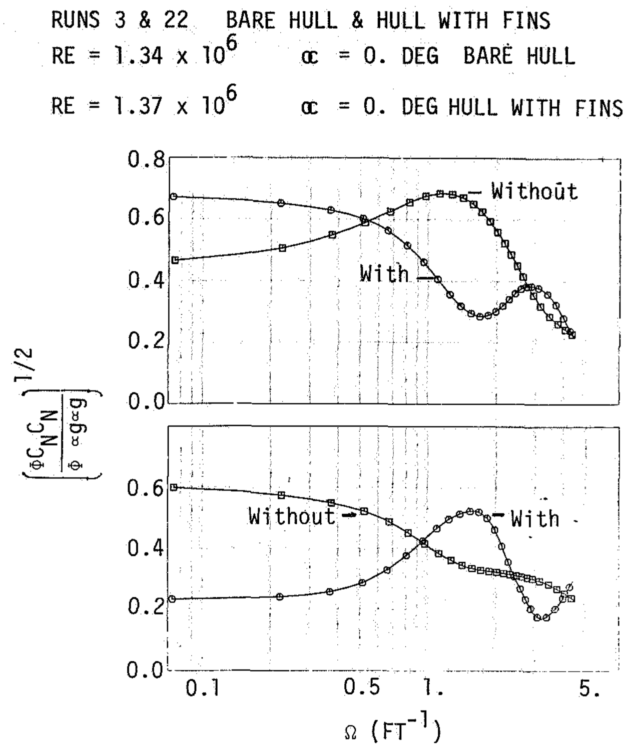


Figure 11. System gust response comparison

Figure 11 shows the transfer functions with and without fins. Now, it is perfectly obvious that at zero frequency or wave number, you have the steady state case, and adding fins must add lift. Indeed, this is what we see. However, as the frequency goes up, the effect of the fins is to diminish the lift! The maximum reduction occurs at a wavelength about twice the hull length.

With the pitching moment, we get the opposite result—when you add fins, it reduces the low-frequency value; at higher wave numbers, it goes up above the value without fins. Although the slender-body theory was quite inadequate to predict quantitatively the transfer functions of lift and moment, nevertheless, if it is used to compute the <u>phase angle</u> between the hull lift and the fin lift, it turns out that it explains this peculiar behavior very well.

That concludes my presentations of these three projects. We have done some others that relate to automatic control of vehicles on landing, and our conclusion reinforces what has already been said at this workshop - i.e. that where a microburst is concerned, or, indeed, a strong wind shear of any kind, an automatic pilot will do the right thing in terms of pitch attitude; whereas a human pilot may well be inclined to do the wrong thing, such as putting the nose down when it should come back up. What is fundamental to this is that when landing at an approach speed of 1.3 V_s, there is a 69% lift margin available. Consequently, when there is a loss of air speed, so long as you are still safely below stalling angle of attack, the correct thing to do is to pull the wheel back and compensate with additional angle of attack for the loss in lift associated with the loss in air speed. Automatic controls have no trouble doing that as you saw in Figure 1.

We did a similar study of an automatic abort system that had no trouble carrying out aborts through very strong wind shears, that included both downdrafts and horizontal shears.

Thank you for your kind attention.

GENERAL DISCUSSION SUBSEQUENT TO IMPROMPTU PRESENTATIONS

QUESTION FROM THE FLOOR:
Dr. Etkin, could you please explain the relationship of NASA's Gust Gradient Program with that of Canada's study?

ANSWER: DR. BERNARD ETKIN
As a matter of fact, I only learned about the NASA work a couple of days ago when I read the report of last year's meeting here and found that somebody had made a report on it here. There has not been an opportunity to make a comparison yet; but our data implicitly contains some things that were measured in the NASA Program. So, when we see your report and you see our report, somebody can see if the numbers come out the same. I would guess that they do. Just let me say this, because I think it is significant. The work that I reported today on this gradient data was done a couple of years ago and it was published in the Journal of Aircraft in a paper by Dr. Lloyd Reid, one of my colleagues. What Dr. Reid found, and I think this is a very important finding that somehow has been overlooked by the aeronautical engineering community, is you can use the von Karman model of turbulence in the planetary boundary layer with reasonable accuracy for these landing and takeoff problems providing you make a few empirical adjustments in choosing the correct intermediate value of L and sigma that relates to the upper and lower points. The student who did the work that I reported here intends to carry on and look at gradients and see if they fit the von Karman model. My guess is that they will probably be very close, and that the ones measured in flight by NASA will be, too.

COMMENT: DR. FROST
We have found in analyzing the NASA B-57 data for flying both near thunderstorms and doing touch-and-go's, (i.e., boundary layer turbulence) that the von Karman is generally valid. We have also looked at the data from the array of towers at NASA/MSFC; in that case, if you get too close to the ground (that is about 70 feet), you begin to get into some trouble using von Karman. However, around the top of the towers, von Karman looks pretty good.

QUESTION: K. H. HUANG, FWG ASSOCIATES, INC.
Dr. Etkin, which control laws did you use when you simulated airplane trajectory flying through your doublet wind shear?

ANSWER: DR. BERNARD ETKIN
The automatic control law used in flight through the microburst is given in detail in the report. I do not recall the exact details, but if you see me afterwards, we can look it up. I do not recall the exact algorithm we used, but I can show it to you. It basically operates on height and speed error and tracks the glide slope.

QUESTION: DR. FROST
Is it ground speed control or air speed control?

ANSWER: DR. ETKIN
It uses airspeed feedback.

QUESTION: K. H. HUANG
My second question is, "In your wind tunnel test with the airship with fins, why does the force and pitching moment first decayed and pitching up occur in high frequency?"

ANSWER: DR. ETKIN
The qualitative behavior of the normal force curve with frequency is explained by the slender-body theory. It is because of the way in which the gradient of cross-sectional area dA/dX comes into the theory. When this is positive, an updraft gives positive lift; when it is negative the updraft gives negative lift. When you work that out for sinusoidal upgusts, then you simply get the results I showed.

QUESTION: DR. ETKIN
I would like to ask Dr. Houbolt about his new Eleventh Equation that goes on humanity's list of famous equations....I presume that is for a control's fixed airplane?

ANSWER: DR. JOHN HOUBOLT
That is a controls-fixed airplane and is based upon an airplane having two degrees of freedom. The outcome is pretty general for all aircraft.

COMMENT: DR. ETKIN
Of course, when you put controls in, you change that sigma all over the place.

QUESTION: PAUL KADLEC, GLOBAL WEATHER DYNAMICS
I have a question for Dr. Etkin. Have you considered in your analysis of the downburst and the pitch-up attitude, which I certainly suscribe to in the non-rain environment, what happens in a heavy rainfall environment, like Jim Luers and the people at the University of Dayton are looking at. Do you see a difference in the pitch-up attitude of an aircraft in a heavy rainfall environment versus what you have described in a more-or-less clear air environment.

ANSWER: DR. ETKIN
Well, I think you had better ask Dr. Luers. He says that the heavy rainfall can reduce C_L max significantly. Now, if that's right, there surely is a big difference between dry and wet. I would like to think that whole thing would be explored much more fully to really settle the question; because if you do not have the lift margin, you have to use a totally different automatic control strategy. Ours was based on the lift margin still being there, so you would have to say it was a dry downburst. While we are on wet and dry downbursts, another thing we were discussing is that when the JAWS Doppler measures wet downburst, I assume the Doppler radar gets its reflections from the raindrops. So, if you want to conclude from that what the velocity field of air is, you must assume that the raindrops are good particles for tracing the air motion. If those raindrops are up to 4mm or 5mm in size, that is doubtful. We saw one picture on the video yesterday at noon of rain in a downburst, and the figure I showed, taken from a meteorological paper, showed the rainfall pattern hitting the ground with a normal component, but the air does not reach the ground with a normal component. So, it has to be wrong close to the ground if you are assuming the raindrop velocity is the air velocity, and I do not know how wrong it is as you go up from the ground. I think that really has to be looked at.

COMMENT: JOHN HOUBOLT
While Prof. Etkin is in the limelight, let me pursue that question about the control law. We do not want to go into detail, but I think we should at least establish that your control laws not only control your elevators but your power as well.

COMMENT: DR. ETKIN
We did control the throttle from airspeed feedback. What we found for the cases we looked at was the control of thrust didn't make very much difference. With a 4 - 6 second spool-up time on a jet engine, it helps some if you control the thrust, but the thrust is not an effective speed control.

COMMENT: DR. FROST
It does make quite a difference in our model. If you use thrust to control relative air speed, you will encounter real difficulty when the wind shears out. This is not the case when you control ground speed. In both cases, we control speed with thrust.

COMMENT: DR. ETKIN
Are you saying that the response to thrust is fast enough that you can actually get enough speed difference in those few seconds to make a difference? We didn't notice that. Maybe we were using too slow a rate of thrust increase in our model so that it did not come on fast enough to make a difference.

QUESTION: TOM GENZ, NORTHWEST AIRLINES, INC.

In trying to understand the dynamics of the microburst/downburst concept, trying to incorporate speed of motion in this, the time display, resulting in the asymmetrical parts of it, in trying to correlate that with what is coming out of JAWS and what the data is there, it is very interesting that you point out that in your opinion there is a distinction between the raindrops, particularly of a certain size, and the velocity of the wind. Could you elaborate just a little more on that, please, and tell us which way it is going, because as I am sitting here, it is not clear to me what's happening, or what you perceive is happening, especially close to the ground?

Which is moving faster, where is the inaccuracy, and what degree of inaccuracy are you thinking as a preliminary?

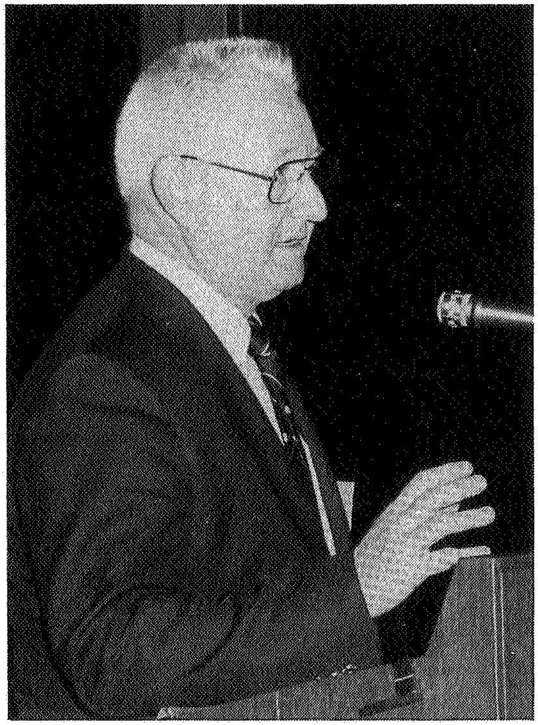
ANSWER: DR. ETKIN

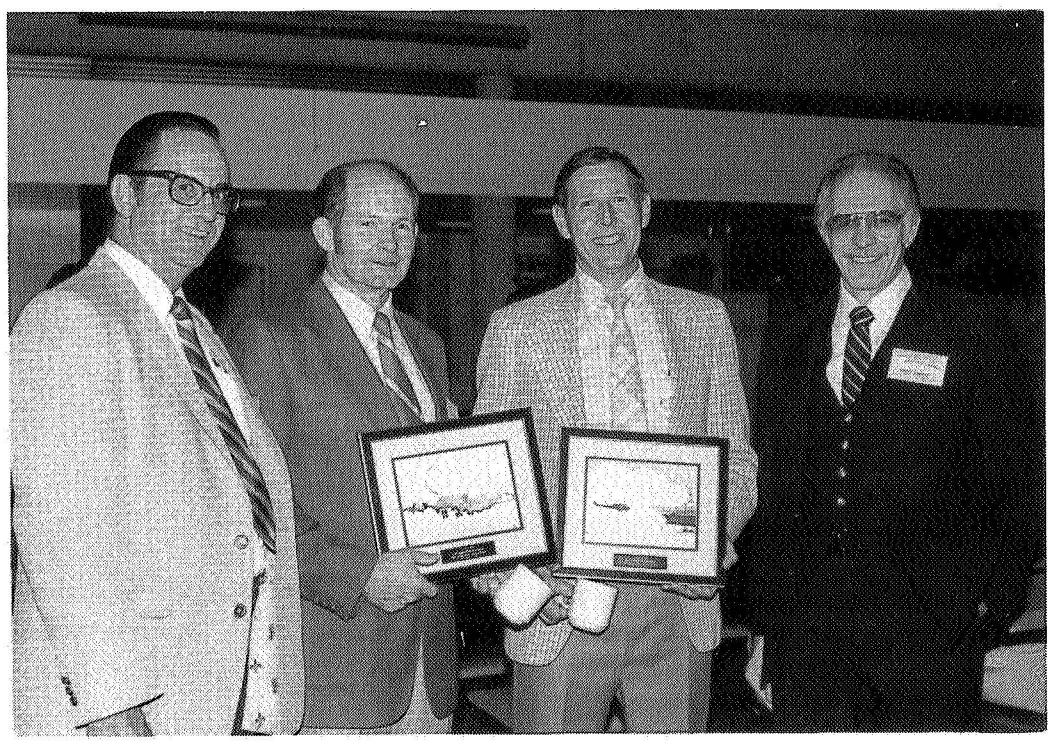
Well, I am just saying that I have recently done a lot of calculations in another connection altogether of particle trajectories in flow fields. Characteristically, particles that are very small will follow a flow field fairly closely. Particles that are larger do not follow the flow field as closely, and it strikes me, for example, that something on the order of 4mm or 5mm in size will have a reaction distance of quite a few meters, and from a standing start, such a particle might take up to 8 or 10 meters or even more to come into equilibrium with the surrounding flow. Now that means that it lags what the flow is doing, so my image of it is that a raindrop is coming vertically downwards, embedded in a flow that is coming vertically downwards. As it approaches the ground, the flow turns more and more rapidly, and the raindrop tries to follow it, but lags; so that in the end, the raindrop comes down and impinges on the ground at some angle while the flow manages to make the full 90^0 turn, the raindrop has not. If, therefore, you are measuring the horizontal component, which is what this Doppler radar does, of the velocity of the raindrop, then as you get closer and closer to the ground, what you are measuring is less and less close to the velocity of the air. Now, this is only a qualitative reaction, and all I am doing is raising the question. Someone really ought to look at it to see how faithfully the raindrops of the size that are actually present do, indeed, reflect the velocity of the surrounding air.

COMMENT: KIM ELMORE, NCAR

Dr. Etkin, the problem was addressed in a paper several years ago, and what they found, while I cannot recite to you who the authors were, was that raindrops make a very good horizontal tracer, but a very poor vertical tracer. In fact, in the process of synthesizing the three-dimensional winds from Doppler radar data, we use a reflecting estimate of the size of the particle, which will give us an estimate of its terminal velocity. The terminal velocity is removed. Now, it is true that raindrops will not follow the reaction distance you gave, which I believe, is a term they used in the paper, but you h ave to remember that a Doppler radar gathers data in pulse volumes that are a segment of a cone that is, roughly, 150 meters long, and maybe 1^0 wide, it depends on how far from the radar you are...how big this pulse volume is. The second thing is that a Doppler radar really never gives data right on the ground, although we will blithely tell you that this analysis starts at the ground level, which is not really true, that is only true for computational purposes. Most of the time, depending on the distance from the radar, the center of the beam is at least several meters off the ground, and sometimes 20 and 30 meters off the ground. It is true, that if there are any errors in our estimates of the wind speeds, the error is low. The actual air speed would be a little higher and the raindrop speed would be near the ground. The next thing you need to remember is that in many instances, JAWS microbursts were what we considered dry, which means that there was not very much rain on the ground, and that which occurred consisted mainly of small drops. Small drops are very good estimators of the wind speed. Therefore, we think that our errors are not very large.

SECTION VI
DINNER PRESENTATION





WORKSHOP REVIEW: ACCOMPLISHMENTS PAST, PRESENT AND FUTURE

Walter Frost and Dennis W. Camp

The purpose of tonight's presentation is to review the past workshops. We would like to quantify, or identify, programs which have evolved from the recommendations which you have made at previous workshops. It is difficult, however, to quantify exactly what the workshop has done. We are certain that exchange of information across interfaces of the different aviation communities has taken place at the workshops. There are also a lot of ideas you obtain here in talking with the attendees which you take home with you and put into effect in your work. Again, this is very difficult to quantify. Therefore, what we plan to do tonight is to pick out some recommendations from chairmen reports in past workshops, and have a speaker describe ongoing programs that are addressing the particular recommendation.

By way of introduction, Figure 1 shows all the proceedings which we have published through 1982. I want to call attention to the pictures on the front of each proceedings. They are original blackline drawings. I have held out for a long time against the suggestion that we should put a photograph on the cover rather than an artists' rendition. The first two covers were drawn by Roxanne Binkley, who worked with us a few years ago. The other four have been drawn by Mutt Suttles, who works with us now. I had hoped Mutt could be here, as Mutt is no small artist in his own right, and he does a very nice job of artwork. He is a member of the Tennessee Commission on Art and has been a member for two years. He has won many regional and national awards for his artwork. He has a drawing hanging in the Parthenon Art Museum in Nashville, so I emphasize that this is very good art.

The title of this presentation is Workshop Review: Accomplishments Past, Present and Future. To review and highlight the past, some of our technical editors from previous programs whom you have had a chance to work with in the past have come back to be with us tonight. Pam Parsley is here. If you recall 1979 and 1980, she was assisting me in putting on the workshops. The 1980 workshop bears her name as Technical Editor, which she did remarkably well, particularly in making sure that the spelling and grammar, as well as all transcribed mistakes, were corrected. She is an excellent English major and is back with us tonight to review past workshops. I am going to ask her to say a few words shortly.

Now, at the far end of the table, some of you may recognize my wife, DeeDee, who has been with us at every workshop. She has assisted me by having infinite patience to begin with; but she has also served us by taking your wives on safaris to exotic places in Tennessee, where they can spend your money and keep Tennessee green. More than that, however, we hope that she takes them places where they find it extremely enjoyable. Thus, they will see that Tennessee is really a great place, and they will bring you back so we can get your expertise at the workshop while they are out having fun watching Tennessee walking horses and things like that.

You all know Dennis Camp, and he will be up here in a moment. Sitting next to Dennis is Barbara Smith. Barbara is Administrative Assistant at FWG Associates, Inc., and often finds herself late at night or on weekends typing up presentations and parts of the workshop proceedings so that we can meet our schedules on time. Although Barbara does not work directly for UTSI, she has been extremely helpful in making sure the workshop comes off successfully.

Next to Barbara is Linda, whom you have all had a chance to meet. If you haven't, I'm sure she has talked to you on the phone. Linda, after Pam left, joined our group here as my assistant in putting on the workshop. The other day she said to me that she needed an assistant, and I thought about that a little bit; but I decided that she already had an assistant, and that is me! She is such a go-getter as most of you know and she really lives up to the adage, "There they go; I must hasten after them, for I am their leader." She is, in many cases, responsible for some of you being here. If she didn't twist your arm, she twisted your boss' arm, and we really appreciate all of Linda's work. She has been helping you out through the preceding days and will be helping you out tomorrow. I think she deserves a round of applause for all of her work!

One thing more before we get on with our program. I would like to introduce some of our attendees from outside the United States. We have a large contingency from Australia. We have Bob Crowder, Colin Noble and Geoff Molloy, and they are so pleased with themselves for winning the

Walter Frost
Atmospheric Science Division
University of Tennessee Space Institute
Tullahoma, Tennessee

and

Dennis W. Camp
Atmospheric Sciences Division
Systems Dynamics Laboratory
NASA Marshall Space Flight Center, Alabama

Figure 1. Workshop Review: Accomplishments Past, Present and Future

Americas Cup, that I think they are back here to see what they can win out of our aviation programs. We have two representatives from Canada: Sepp Froeschl, who has always been a friend of our workshops; and, for the first time, Bernard Etkin, who stole the show with his wind shear presentation today at our Impromptu Presentations. We do not really consider Canada a separate country; but I think when they go to exchange their money, they think probably that this is alien soil of some sort because the exchange rate if terrible nowadays. Finally, we have Nicholas Haas from England.

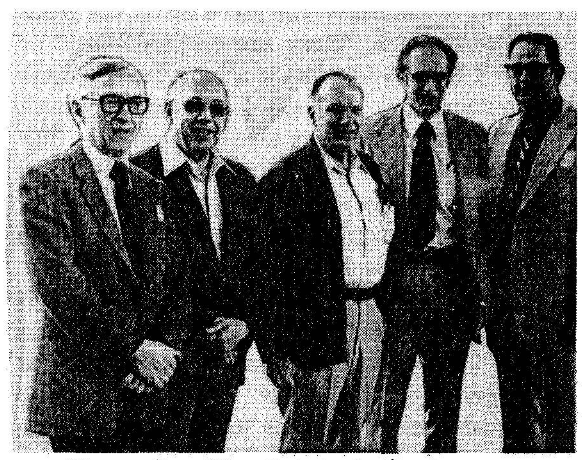


Figure 2. "The Original Five" (Organization Committee)

Now, let us consider how the workshop began. Figure 2 shows the original five members of the Organization Committee. The workshop concept originated basically between George Fichtl, Dennis Camp, Jack Enders, and myself. We, then, solicited the support of NOAA and FAA, resulting in the Organization Committee's consisting of Jack Connolly, NOAA, on the left side of the picture; Jack Enders, NASA; Joe Sowar, FAA; myself; and Dennis Camp from NASA Marshall Space Flight Center. Original sponsors of the workshop are shown in Figure 3: the Office of Aeronautics and Space Technology, NASA; National Weather Service, NOAA; and the Systems Research and Development Service of the FAA. We now have, for the first time this year, two new supporters of our program. They are: The Office of Environmental and Life Sciences, DOD, represented by Col. Paul Try; and The Office of the Federal Coordinator for Meteorology represented by Emanuel Ballenzweig. We are happy that they are supporting the program and that they will work with us to put on future workshops. The workshop is hosted by NASA Marshall Space Flight Center and by The University of Tennessee Space Institute.

The purpose of the workshop is to bring together various disciplines of the aviation community with meteorologists and atmopsheric scientists in interactive committee discussions in an effort to establish and identify the weather needs of the community, and how these needs might be satisfied (Figure 4). The workshop thus provides, on an

Office of Aeronautical and Space Technology
National Aeronautics and Space Administration

National Weather Service
National Oceanic and Amospheric Administration

Systems Research and Development Service
Federal Aviation Administration

Office of Environmental and Life Sciences
Department of Defense

Office of Federal Coordinator for Meteorology

WORKSHOP HOSTS

NASA Marshall Space Flight Center
Huntsville, Alabama

The University of Tennessee Space Institute
Tullahoma, Tennessee

Figure 3. Workshop Sponsors

The workshop was established for the purpose of bringing together a wide range and variety of disciplines of the aviation community, i.e., airlines (passenger, cargo, and commuter), general aviation, military aviation, aircraft manufacturers, safety investigations, regulators, air traffic controllers, educators, research engineers, atmospheric scientists, meteorologists, weather forecasters, etc., in interactive discussions in an effort to establish and identify the weather needs of the aviation community and how these needs might best be satisfied.

Figure 4. Purpose of the Workshop

annual basis, a collective view of aviation weather from the users, suppliers, regulators, researchers, and educators of the items listed on Figure 5. This collective view satisfies the needs of the sponsoring agency relative to 1) knowledge of the interaction of the atmosphere with aeronautical systems; 2) better definition and implementation of meteorological services; and 3) collection and interpretation of data for establishing operational criteria relating to the total meteorological inputs from the atmospheric sciences to the operational and educational needs of the aviation community.

The objective of the workshop is to provide on an annual basis a collective view of aviation weather from the users, suppliers, regulators, researchers, and educators as to:

1. Specific recommended actions relative to aviation weather needs and the agencies responsible for satisfying these needs;
2. Current status of operational procedures, design criteria, safety regulations, and training techniques;
3. Deficiencies and voids in current aviation systems and operational procedures;
4. On-going research and development; and
5. New or recurring problems and future programs to alleviate these.

Figure 5. Objective of the Workshop

The first workshop was held in 1977 (Figure 6). It was specifically designed to provide an opportunity for a mix of researchers, pilots, designers, forecasters, aircraft controllers, etc., to get together and to present their individual and collective views of weather problems to the research community. We had a small group at the first workshop, but we had some very interesting discussions. At that workshop, as has been the case at all of our workshops, there was considerable discussion about wind shear. Bill Melvin presented the first paper to us on wind shear; and in his paper, he drew the picture shown in Figure 7. This picture has been a recurring theme throughout the wind shear program. Bill Melvin was at our first workshop and has been at every workshop since; so he has a perfect attendance for all seven workshops, and Pam Parsley has a small momento to present to Bill for his participation in our workshops. Pam, please come to the podium.

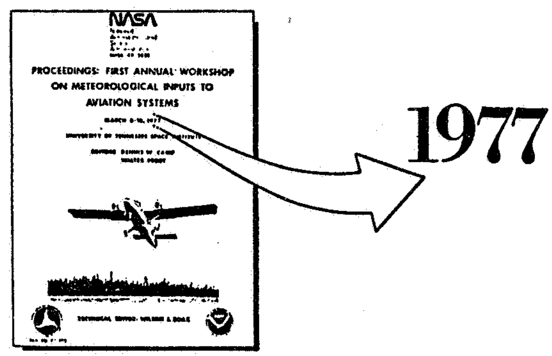


Figure 6. The first workshop provided an opportunity for a mix of researchers, pilots, designers, forecasters, air traffic personnel, weather service specialists, and airline management to express their individual and collective views on aviation systems weather problems to meteorologists, atmospheric scientists, and research engineers.

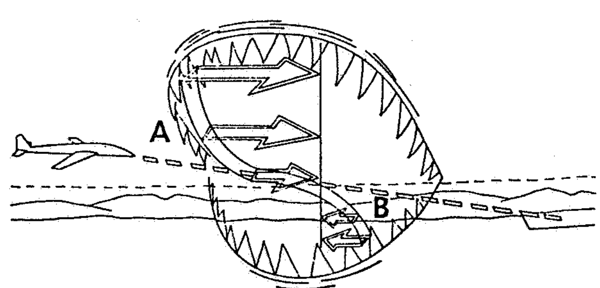


Figure 7. Bill Melvin presented this picture at the 1977 Workshop

PAM PARSLEY

Bill Melvin received his B.S. degree in Mechanical Engineering from The University of Texas in 1956, and was a member of Tau Beta Pi. He served in the United States Navy from 1956 – 1959 as a Patrol Plane Commander. After the service, Bill became an Engineer for Texas Research Associates (now TRACOR) in 1960, before beginning his commercial flying career as a co-pilot for Alaska Coastal Airways in 1960, then to Delta Airlines. Bill is presently an L-1011 Captain. he has held numerous Air Safety positions with the Air Line Pilots Association and is presently the Chairman of the Airworthiness and Performance Committee;member of Delta B-767 Evaluation Committee; ICAO WIST Study Group; IFALPA Airworthiness Study Group; and the National Academy of Science Committee on Wind Shear. He is the author of a number of technical papers on wind shear and other subjects. He is the recipient of the ALPA Annual Air Safety Award for 1977. He is also the recipient of the award from the Flight Safety Foundation for work in wind shear. He holds several patents in the field of flight instruments.

Bill, if you would be so kind as to join me up here, please, I would like to present to you this award for your contributions to and consistent attendance for seven years here at the Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems (Figure 8). We would also like for you to say a few words about what the workshop has meant to you and what you feel the workshop has accomplished. Congratulations.

BILL MELVIN

Thank you. I appreciate this award. One of the most significant things to the Air Line Pilots Association has been the dialogue that occurs at these meetings. At the workshop, we participate out of the formal atmosphere of regulatory agencies in Washington, and we come to some meeting of the minds. We have a lot of information exchange which occurs after the fact with people we meet here. We talk to them about other subjects and, in this way, we are making a lot of progress. Thank you.

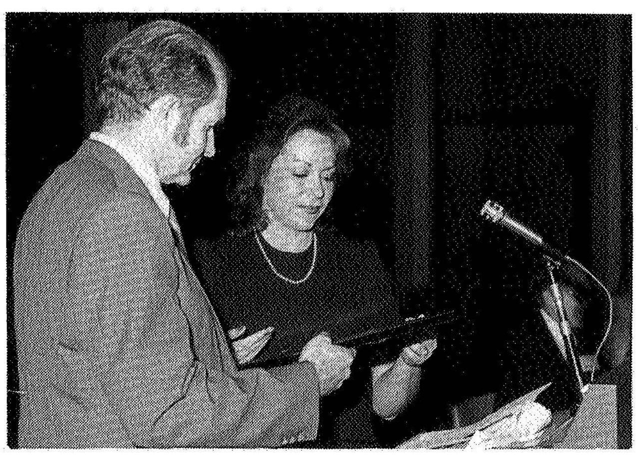


Figure 8. Bill Melvin accepts "Perfect Attendance" award from Pam Parsley

DENNIS CAMP

I represent the second half of the workshop directors and editorial team. Some of the recommendations from the first workshop related to simulation and aircraft design. Different turbulence modeling and design criteria studies were reviewed. Figure 9 summarizes some of the discussion.

The strong support of the need for a study of spanwise gradient or distributed gust velocities was a significant factor in the evolution of the RB-57 Gust Gradient Program. Figure 10 shows the airplane that we use in the Gust Gradient Program. I think many of you have seen at least a version of this picture. It is a B-57 which is presently based at the NASA Dryden Flight Research Facility. If you will notice, we have booms on each wing tip, a nose boom, and are collecting about 57 different meteorological parameters on this aircraft. We are calling this a severe storms flight program. It is a research aircraft, and we would like to talk a little bit about the man who flies this aircraft. Our ma-

Turbulence Models:

Available design methods and flight control analyses utilizing existing turbulence models are generally valid far from ground, but our understanding of the nonstationary, patchy, or intermittent nature and of the spatial distribution of turbulence near the ground, both over the airplane and along the flight path, is poor. More data are needed on eddy size, spanwise gradients, lateral gusts, cross-correlations, and other turbulence statistics. In addition to not accounting for low altitude effects, the current models have not been proven adequate for future generation aircraft designed with new concepts, e.g., composite structures with large deflections having different frequencies and modes.

Continued Research Recommended:

1. That NASA initiate a Measurement of Atmospheric Turbulence (Gust Gradient) Program to study spanwise gradients or distributed gust velocities.
2. Equal effort given to discrete gust models as is given to spectral density models; therefore, recommendation to reinstate earlier VGH programs.
3. Low altitude flight measurements along typical glide slopes with emphasis given to probing worst case conditions.
4. Further investigation to severe low altitude turbulence through tower-based measurements.
5. Research work to identify turbulence levels and location in thunderstorms using time microwave Doppler instead of instrumented aircraft.

Figure 9. Summary of discussion on turbulence

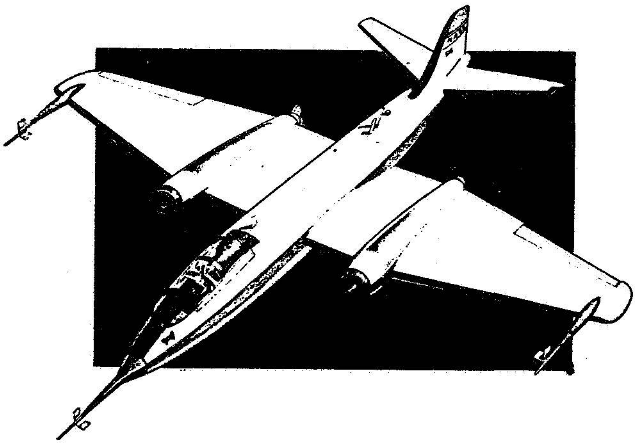


Figure 10. RB-57 Gust Gradient Airplane

jor pilot for this program is Fitz Fulton, who also has the flying responsibility for the B-747 which carries the shuttle around the country. He was part of the crew which recently carried it to Paris. We are also proud of the researchers and operators of the aircraft. Wen Painter and Jack Ehernberger operate it out of NASA Dryden, and Hal Murrow and Bob Sleeper who work the program from NASA Langley Research Center.

At this time, I would like to introduce Dr. John Houbolt of the NASA Langley Research Center , who was really one of the key people who pushed the Gust Gradient Program, and were it not for him, we may not have gotten it off the ground. He has been at Langley for a number of years as a Chief Scientist, and has been involved in aeronautics for many years. So, John, would you come forward and make a few comments about the Gust Gradient Program?

JOHN HOUBOLT

Thank you, Dennis. As I start, I would like to make this observation. Walt, no matter how you wrap it, this technical discussion is not needed at a meeting like tonight's.

All of us who have flown, whether a pilot in the aircraft or as a passenger, have noticed that often on the approach when we have severe wind conditions, especially cross winds, the airplane is suddenly rolled by at least 30 degrees or pitched violently. This simply indicates that the turbulence or gusts that are experienced during approach phase in the lower atmospheric boundary layer, or during flight through thunderstorms, or near thunderstorms, are not uniform across the span as is often assumed in theoretical study. In other words, there is a variation in turbulence intensity across the wing span. I thought that this is an idea that we haven't pursued as sufficiently as we ought to, and we should make some measurements directed toward understanding this phenomenon better. It is especially important because often, when we use simulator studies and input turbulence, the pilots will report that it just does not feel like turbulence. When you analyze the situation somewhat better, it shouldn't feel like turbulence because only one sort of input is being used and the various components of turbulence that the airplane is experiencing are not being simulated. In particular, at least three components of turbulence ought to be included in any simulator study. One, is the vertical motion which is the one most often used. The second is the roll condition, which often abruptly happens, and thirdly, is the pitch condition. That was really the motivation behind this whole program associated with the B-57. The object is to put several probes on the airplane, go through various kinds of turbulence conditions, particularly during approach, and measure the horizontal, vertical and side force turbulence at the probe positions. These can then be correlated with some of our perceived theoretical study. Dr. Etkin talked about a wind tunnel study which simulted what we are trying to do in full scale. It would be very interesting to see if some of his results correlate with the results we have obtained.

What we are trying to do is to understand the gradient in gusts across the span; what some of the distributions are; what some of the power spectral techniques or implications are. I have noticed already some of the preliminary results show that the power spectra derived do not seem to agree with our theoretical predictions; but today I have spent some time and have worked out an analytical reason why they don't. That goes back to a thing that we all should keep in mind. When you have data, be very careful how you analyze and interpret this data because the numerical aspect of your data analysis can often distort it. As an example, the cross-spectra tend to curve up at a higher frequency which theoretical predictions do not indicate. When you analyze the numerical aspects of it, the data will, indeed, be distorted. Therefore, you must correct it. Those are the things that we are looking for.

Now, we haven't looked at all the data yet, and tomorrow we are going to have, hopefully, an hour to see where we are, where we are going, and what kind of progress can be made. That is all that I want to say at the moment.

WALTER FROST

The success of our first workshop was great. We had a tremendous response. Everyone said we should do it again, and so in 1978, we proceeded to put on another workshop. This workshop focused on a detailed examination of some of the more severe weather problems which were identified in the first workshop (Figure 11). We took, basically, the same approach by putting together fixed and floating committees. However, the fixed committees were now more directed to the things we were trying to achieve. At that workshop, there was a great deal of talk about icing programs and the problem of frost on the airfoils. Jim Luers was present at that workshop. Jim is now known as Mr. Heavy Rain; but in those days, Jim was working with frost on the airfoil. The idea was that if you leave an airplane sitting outside and frost accumulates on the airfoil, then you increase the drag of the airfoil significantly which can cause trouble on takeoff In some cases, small airplanes had had accidents due to this effect. We really appreciate Jim, because, not only has he been to our first workshop, but he has also been at every workshop since. He also has a perfect attendance record, and Barbara has something to say to Jim.

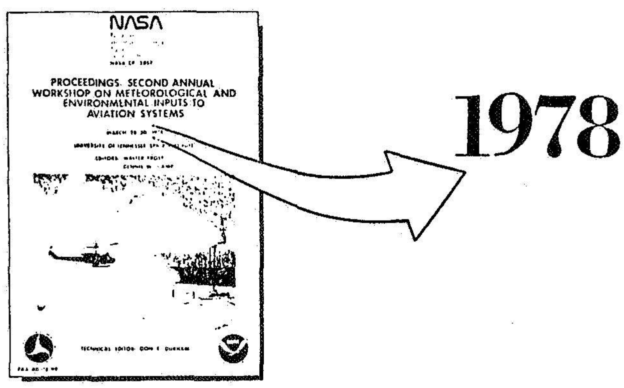


Figure 11. The second workshop focused on a detailed examination of the most severe weather problems which were identified at the first workshop with a view toward seeking consensus on appropriate public and private sector actions needed to solve these problems.

BARBARA SMITH

We have a second award to present tonight and that award is to Mr. Jim Luers. Jim received his B.S. and M.S. degrees in Mathematics from Xavier University. He is presently a Senior Research Scientist at the University of Dayton Research Institute, Group Leader for Meteorological Research at UDRI, current member of AMS, AIAA and a member of the AIAA Technical Committee on Atmospheric Environment. Jim, in his own extraordinarily non-perfunctory style says, and I quote: "I am not a) a meteorologist; b) a pilot; c) an aerodynamicist; d) a traffic controller; e) an accident investigator; or f) an employee of an airline, FAA, NTSB, NWS, NASA, etc." Jim, would you please come up and stand here with me (Figure 12). It is certainly my pleasure to present this award to you for having a perfect attendance since 1977 at our workshops, and would you please give us a few words about how the workshop has benefited participants, like yourself, over the past seven years?

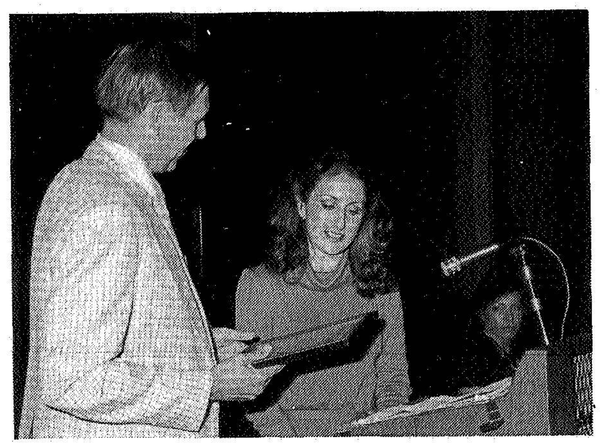


Figure 12. "Perfect Attendance" award presented to Jim Luers by Barbara Smith

JIM LUERS

Thank you. After listening to the accolades of Bill Melvin, with all the awards and the wonderful things he has done, I only wish that Walt had given me a little more time to write down all my credentials, qualifications, and awards. I forgot to mention the one most dear to my heart. Just two weeks ago, our team received a trophy for finishing in 2nd place in the Hamilton Merchants Horseshoe Pitching League. In all seriousness, though, I really appreciate and want to thank Walt, Dennis and all the other members of the Organization Committees who have invited me back here year after year. I am a researcher and I find this workshop extremely beneficial and challenging in outlining the various areas where research is needed, and in keeping me up-to-date with what's going on in the research community. That is really what we researchers try to do. This workshop offers a unique opportunity to stay abreast of the needs of meteorology for all segments of the aviation community. As a researcher, this affords me the opportunity to interact with both the user groups that need the meteorological data, as well as the government agencies whose charter it is to address these needs (and give us some funding). There is, however, a talent to maintaining longevity in the research business. What is foremost in addressing a research problem is to never really solve the research problem; but, instead, to uncover some new research area. If you solve the problem, you don't have a job. Having successfully survived in this environment for many years now, I feel safe in letting you in on one of my secrets. I try to invent new research areas. Participation in the workshop helps me do this.

DENNIS CAMP

At this second workshop, as Dr. Frost mentioned, the icing program was discussed to a great extent. A concentrated effort was focused on the recurring problems of icing. Helicopters, in particular, were having problems and still are, as well as the commuter, air taxi and general aviation aircraft. The committee laid out a detailed plan for a possible way to attack this. As a result of this plan, there were many recommendations made, such as icing research, flight tests, certification, and operational usage instruments needed to make the necessary measurements. Figure 13 summarizes some of these recommendations. Many of these have been discussed this year and will be discussed at the next workshop. We have comments on simulation facilities. These are necessary because natural testing for icing certification purposes is very costly, time-consuming and uncertain. We heard, not only at the workshop, but also in our retreat in the early part of the week, comments on how we may attack some of these icing problems.

We also have a problem with the meterological data on icing and how we analyze it, as well as severity levels below 1500 feet. In our impromptu presentations today, we had talks on icing and problems below 10,000 feet AGL. In Figure 13, we see forecasting of icing conditions, in which we still have problems. In fact, I think we should try to narrow our icing forecasts down from a one- or two- state area to perhaps a 50 - 100 mile area.

We have design criteria problems and I might mention that shortly after this 1978 workshop, people at NASA Headquarters and NASA Lewis got together and decided to have an icing workshop at NASA Lewis Research Center. Many problems were discussed there, and many of the things taking place today at Lewis were established at that workshop which was based on issues discussed at this UTSI workshop. I might point out that we have a gentleman with us tonight, Mr. Dan Mikkelson, from the Lewis Center who will give us a talk on icing. He heads up the NASA Icing Program at Lewis. Dan, would you come up and give us a few comments on that program?

DAN MIKKELSON

Thank you, Dennis. The workshop here has been quite instrumental in fostering our aircraft icing research program. Back in 1977, there really wasn't any program, and since then, we have grown at NASA to about a $1.5 million a year program. There is a growing FAA program, too. There

<u>For Icing Research, Certification Flight Tests and Operational Usage, Instruments are Needed to Measure</u>:

- Cloud liquid water content
- Droplet size
- Outside air temperature
- Cloud ice crystal content

<u>Facilities</u>:

- Simulation facilities are necessary because natural testing for icing certification purposes is very costly, time-consuming, and uncertain
- Improvement of existing simulation facilities and development of new simulation facilities is recommended
- NASA, FAA, and the military services should determine the proper mix of simulation facilities
- Development of modeling techniques to supplement or reduce facility requirements is needed

<u>Meteorological Data</u>:

- Meteorological data base is considered inadequate for real-time and flight planning determination of:
  - Frequency of occurrence
  - Severity levels below 1500 feet
  - Forecast modeling
- NOAA and the Air Weather Service should determine the most cost effective method of filling the data needs and implementing the necessary programs

<u>Forecasting of Icing Conditions</u>:

- Improvement in the capability to forecast icing conditions is urgently needed
- Additional effort should be devoted to the application of forecast models
- Ice severity level should be stated in quantitative rather than subjective terms
- Installation of icing severity indication systems on an aircraft fleet would benefit in acquiring needed data for improvement of icing forecasts

Figure 13. Recommendations relative to icing, frost, and snow

are a number of activities underway. Models have been tested in our Icing Research Tunnel at Lewis, and we have some activity ongoing to improve the productivity of that tunnel and its ability to simulate natural icing. These tunnel improvements will be completed under a $3.6 million construction of facility program. Dick Tobiason mentioned that we are proposing to rehabilitate a large wind tunnel at Lewis called the Altitude Wind Tunnel (AWT), and create a large propulsion and icing facility which would greatly enhance the nation's ground simulation capability. We have a Twin Otter aircraft that we fly out of Lewis to obtain natural icing data for comparison with our tunnel results. Also, we are developing a number of analytical tools to predict ice build-ups and the resulting aircraft performance penalties, as well as codes to predict the performance of both old and new ice protection systems. We are working on improved modeling and test techniques that go along with verifying our analytical codes. In the area of icing instrumentation, we are evaluating both old and modern instruments in-flight on our Twin Otter and comparing them to some measurements we have made in our icing tunnel. This work should lead to improved measurement techniques and enhanced instruments that can more accurately measure icing conditions.

In the area of measuring and forecasting icing, there is still room for improvement. There has been some activity, however, like the MARS system that was evaluated last winter in the Buffalo, New York, area. There are several mesoscale models that may have the capability to predict icing conditions. Langley has used one of these models to predict conditions for a few of our Twin Otter flight icing encounters. The results of this comparison so far are encouraging. In the area of design criteria, the FAA has funded some activity which we have participated in to look at characterizing the atmosphere at altitudes below 10,000 feet, where helicopters operate. You have heard about some of those results a little earlier in the meeting. It did turn out that maximum liquid water contents below 10,000 feet are considerably lower than the current FAR 25, Appendix C, requirements. That work is going to be expanded by the FAA in the future to other altitudes and conditions. We are looking at more streamlined ways of certifying aircraft. This activity will include both better ground simulation capability and enhanced prediction tools. Overall, the workshop here has been quite instrumental and we are closely following the recommendations of the previous workshops. Thank you.

DR. WALTER FROST

What we are trying to point out, as Dan mentioned, is that your discussions here and your recommendations are not being made in vain. We are not saying that the workshop is directly responsible for programs such as the icing program, but that it has provided the impetus to get some of these programs going. However, we have always had time to have a little fun at the workshops. Figure 14 shows an impression from Lauren Spencer of the FAA who has been to some of our workshops. In 1978, there was a cry for all types of instrumentation and warning systems for aircraft. So, Lauren put together this little aircraft to illustrate the weather committee's version of a well-instrumented weather aircraft. If you will notice around the tail, there are all types of antennae to get the FSS informtaion, EFOS information, ARTAC information, etc. If you will look at the wing on your right hand side, you will see that it is well equipped for frost sensing, liquid water content, droplet size measurement, and IF icing. You will notice on the boom there is a wind shear warning and detection system, a cross wind component system, and behind the cockpit, you will see a downblast detection device. So, it is well-equipped in terms of wind shear. Also notice at the front there is a runway visible range sensor for landing in difficult visibility situations. It has also a lightning strike probability detection and all of the instrumentation to monitor those sensors. So, it ends up that the pilot is sitting down in the corner flying from outside the aircraft. That was their version of a well-instrumented airplane.

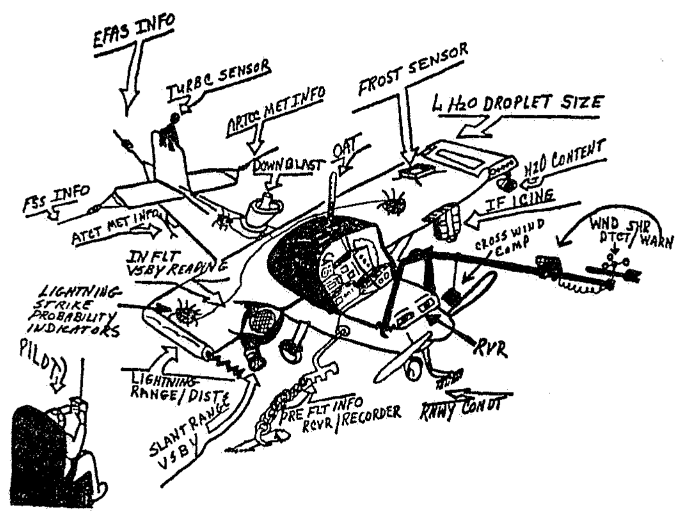


Figure 14. Weather Service Committee's version of a well-equipped weather-instrumented aircraft

That brought us on to 1979 (Figure 15); and by then, the workshop was beginning to take on an annual status, as this was our third in the series. It became apparent during the previous workshops that there was a need for training and education throughout, so we put together a workshop to address those topics. In terms of trying to identify how recommendations on training and education have evolved. I would have to say that this is one area where we cannot point to any strong programs. Whether we are not talking to the right people or what, I am not sure. At that workshop, there were other recommendations. We had, now, grown to 84 participants (Figure 16), and standing boldly at the front of that group you will see a man named Andy Yates. Andy had been to our previous workshops and has been to every workshop since. Therefore, Andy also has a perfect attendance record. Andy has always been the kind of guy who would fill in wherever he was needed. When we need a chairman, Andy does that; and if we need anything else, we ask Andy and he does it. He has been a tremendous help to our workshop. Linda has something to say to Andy.

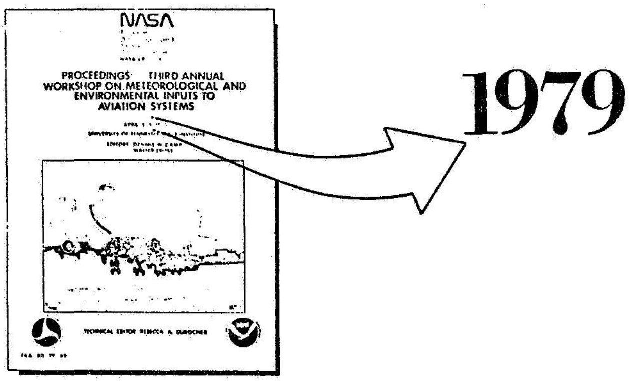


Figure 15. The third workshop was organized to explore the training and educational questions resulting from the first two workshops. It became apparent during the first two workshops that training and education throughout the community were important to achieving a better understanding of weather hazards and weather-tolerant designs and operations.

LINDA HERSHMAN

Andy was born, <u>reared</u>, and educated in Virginia. He is married and has six children. He served in the Marine Corps as a pilot during World War II. He retired from the Marine Corps Reserve subsequent to that. On December 9, 1949, Andy joined Capital Airlines and served in the capacities of pilot, instructor, check airman, and designated FAA

Figure 16. 1979 Workshop group photograph (84 participants)

Examiner for Airline Transport Pilot Certificates until Capital's merger with United in 1961. At that time, Andy returned to flying the line with the new United Airlines and has been with them from that time to the present. In 1964, he became active in accident investigation, and his special areas of interest include flight data recorders and cockpit voice recorders. Among other things, on his own time, Andy was involved in Scouting, and he was a Scout Master for seven years, during which time, he organized the Air Explorer Post, which taught young men how to fly. Andy is a member of the International Society of Air Safety Investigators, the Aerospace Medical Association, the Survival and Equipment Association, as well as having been a faithful participant of this annual workshop for seven years in a row. I would like to ask Andy at this time to join me at the podium (Figure 17). I understand that in August 1984, Andy will retire from United. I don't know how Andy has had time to fit all of his activities into his busy schedule; but, Andy, would you please tell us what accomplishments you feel have been made here at the workshops?

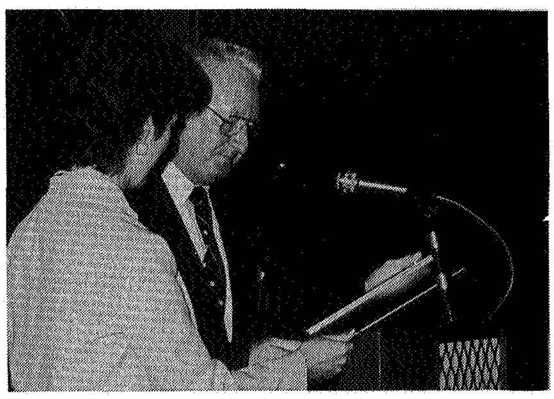


Figure 17. Andy Yates receives "Perfect Attendance" award from Linda Hershman

ANDY YATES

The accomplishments at the workshop are so numerous that it would be hard for me to tell you all the ones that I feel, personally, have come out of here. However, one of the greatest things that has happened to me with regard to my attendance here is the fact that I have been able to associate with some of the greatest minds in aviation. We have people like John Houbolt, Charlie Sprinkle, Dick Tobiason, Walter Frost, Dennis Camp, Bud Laynor, Joe Stickle, all of these people who are absolutely outstanding in their fields, along with many others I don't have time to mention. I, personally, hope that a little bit of their brilliance has rubbed off on me; but I'm sure it has been very little because it is pretty hard for me to absorb things sometimes. I have learned a great deal from these men, however. Some of the accomplishments that I believe I may have helped to achieve were changes in the FARs, even though we have nothing specifically to do with meteorology or the environmental inputs to aviation systems. That is what is so great about the workshop. You have the opportunity to deal with people on a basis which would not be possible otherwise. I have seen other evidence of things coming out of the workshop, and I am pleased to have had the opportunity to be in attendance here. As Linda said, 288 days from today I am going to retire from United, but I am still going to continue to participate here as long as I am welcome and invited. Thank you very much.

DENNIS CAMP

It was at this 1979 workshop that we had considerable discussion about atmospheric electricity and lightning. We see many recommendations (Figures 18 and 19) relative to atmospheric electricity and lightning: forecasting, developing lightning forecasts, basic concern and timeliness of reporting, standardization, and quantity of information required. We might also say quality as well as quantity. We need a better data base; more research into the definition of airborne lightning; theoretical and experimental strike models. There was a great deal of discussion about the models needed. Instrumentation was a prime concern at that workshop, as well as training and simulation efforts. Design is still a problem with atmospheric electricity and lightning, especially aircraft composites which are now here and will be more prevalent. More work is needed in this area. The workshop was not responsible for the F-106 Lightning Program; but it has been discussed at these workshops and has received substantial support from the user, as well as the research, community. I would like to invite Norm Crabill from the NASA Langley Research Center, who is responsible for the F-106 Program, to tell us about this program.

NORM CRABILL

NASA is flying a highly instrumented F-106B aircraft (Figure 20) into thunderstorms to characterize the lightning hazard to future aircraft with composite structures and digital controls. We have been flying every summer, starting in 1980, and have accumulated over 400 direct strikes to the aircraft, mostly above 25,000 feet. The remaining

Forecasting: Those developing lightning forecasts need to address four basic concerns:

1. Timeliness of reporting (real-time versus delayed reporting).
2. Standardization of communication (terminology).
3. Quantity of information required.
4. Accessibility of information to general aviation.

Data Base: A central data base must be established in order to track lightning strikes to aircraft. In the area of accident investigation, a recording system is needed to provide lightning strike evidence.

Research: Research into the definition of airborne lightning theoretical and experimental strike models is needed.

Instrumentation: Ground-based and airborne instrumentation to measure electrical fields for the purpose of lightning probability prediction and lightning strike avoidance should be developed. Also, development of on-board instruments to detect lightning strike current path on the aircraft is needed.

Training: Pilots of all aircraft need a better understanding of the conditions under which lightning strikes can occur and of the effects they may have on their aircraft. Users should be trained in the interpretation of electrical field-measuring devices, lightning detectors, and Doppler and weather radar. There is a need for education concerning the lightning/precipitation static (p-static) environment and its effect on systems.

Simulators: For simulators there is a need to be able to simulate the lightning flash and the effects of upset to electronic systems or to electrical systems. Also, flame-outs associated with lightning hits should be simulated in conjunction with realistic lightning flashes.

Design: Positive hardening techniques to protect modern flight control and avionic systems must be designed since total avoidance of lightning strikes or near strikes is not a realistic expectation.

Figure 18. Atmospheric electricity and lightning research areas

task is to obtain 50 to 100 strikes below 25,000 feet. We plan to try that in 1984.

We use ground-based radar and lightning locators to find areas of thunderstorm activity within 150 miles of Langley. Then we launch. On the way, I keep track of the storm development and the aircraft's position and "vector" the aircraft to the desired position (Figure 21). The pilot, using his own observations, including an airborne radar and lightning mapper, and radar data sent up from the ground, modifies my plan as he sees fit. Then, he goes in, and usually gets struck!

The aircraft often gets struck on the nose, with a discharge emanating usually from the wing tip and vertical fin. If the pilot or crew were to look back over their left shoulder (Figure 22), this is what they would see. Note the two main channels, their reflections on the wing and rudder, and the streamers from the main channels. These two main channels are actually flowing straight back from the aircraft, and are parallel. Their apparent convergence is due to the camera optics.

	1	2	3	4	5	6	7	8
NEED	In-flight data on lightning electrical parameters • direct strikes • nearby strikes • static electricity	Technology base and design guidelines for protection of advanced aircraft systems and structures	Improved test techniques for: • induced effects • blast effects	Analysis techniques for predicting induced effects	More lightning strike incident data from general aviation	Lightning detection systems	Obtain pilot reports of lightning strikes to aircraft	Better training in lightning awareness for pilots of all aircraft
NATURE OF PROBLEM	Lack of data	Lack of design data, R & D	R & D	R & D	Operational	R & D	Operational and procedural	Operational and procedural
TIME REQUIRED	2 - 4 years	2 - 6 years	2 years	3 years	1 year	2 years	3 years	---
IMPACT OF PROBLEM	Uncertain test and design parameters	Increased Safety hazards; decreased use of advanced technology	Increased hazards; decreased efficiency	More cut-and-dry	Decreased reliability	Continued hazard to air/ground personnel and operations	Increased strikes	---
COST BENEFIT	Increased flight safety, especially under IFR conditions; quicker and more confident introduction of new technologies.							
EFFORT REQUIRED	New effort	Some knowledge in hand and major new effort required	Continued effort	Some new effort	Additional reporting effort	Some new effort	In hand; education needed	New
PARTICIPANTS	Major role: government Supporting role: Contractors	Government/ contractors; improved data base airframe manufacturers; specific applications	Government and industry	Government and industry	General aviation industry	Government and industry	Operators	All

Figure 19. Needs of the aviation community relative to lightning

Figure 20. Lightning Research F-106 Aircraft

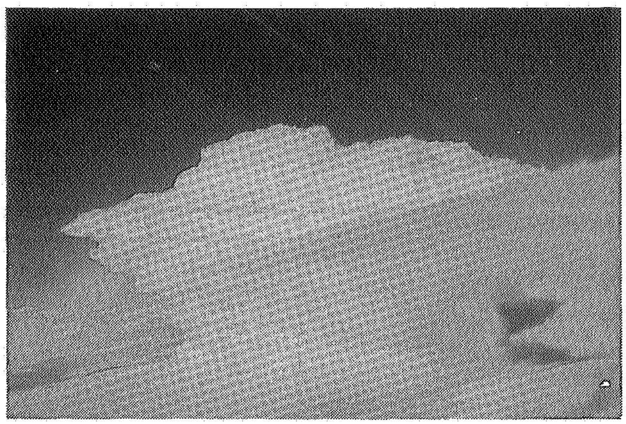


Figure 21.

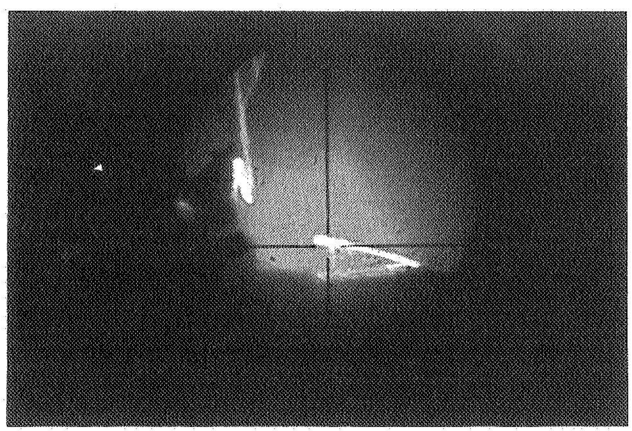


Figure 22.

In each successive frame (Figures 23 through 28) taken 1/14th of a second apart, the channels get longer and longer until they "go out". Then in

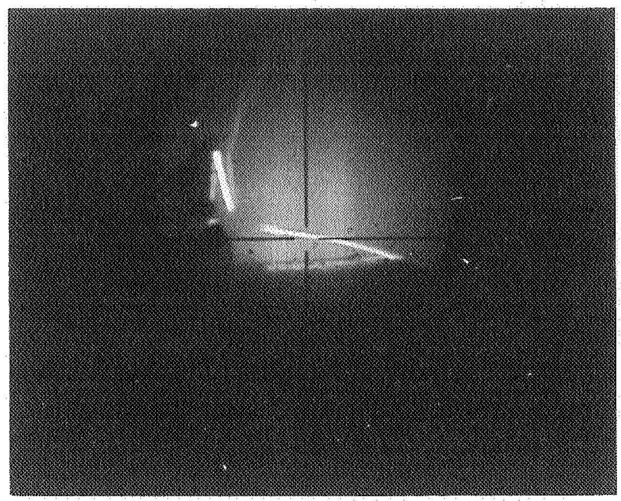


Figure 23.

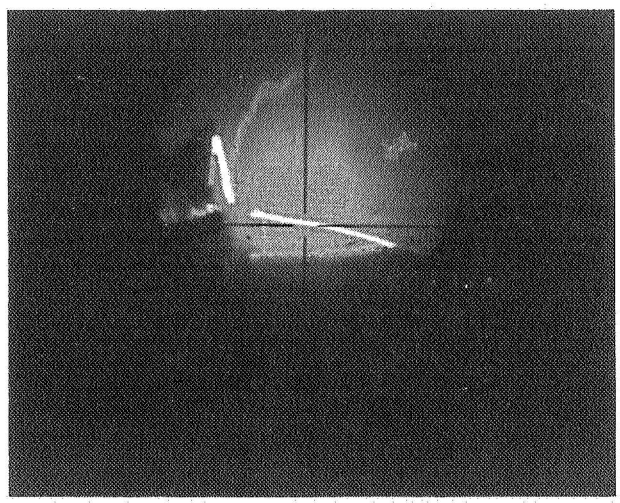


Figure 24.

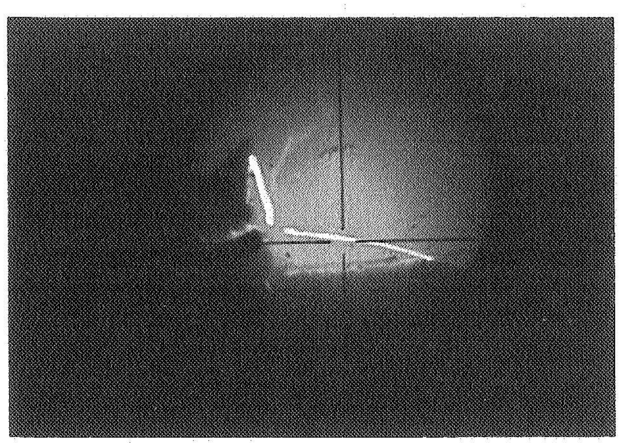


Figure 25.

Figure 28 you can see the channel light up again by a reflash. The 90 degree bend or kink in the channel is the point that the aircraft flew through the flash. The flash is not always directly visible. Sometimes it appears only as a glow (Figures 29, 30, and 31) in the clouds. Then a visible strike appears to hit the jet engine exhaust.

Analysis of ground-based radar data taken during the strikes indicates that at least for the high-altitude strikes, the lightning channel originates at the radar target that is the airplane, and moves away very rapidly. This indicates the airplane "triggers" the strike. We will attempt to find out if this is true for all direct strikes to airplanes in subsequent flights in 1984. This program is supported

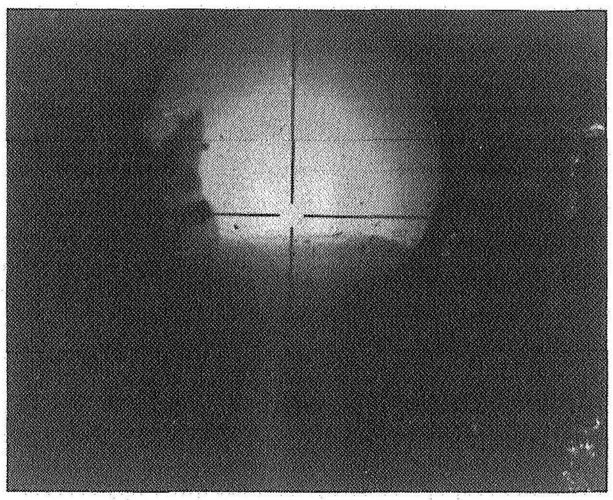


Figure 26.

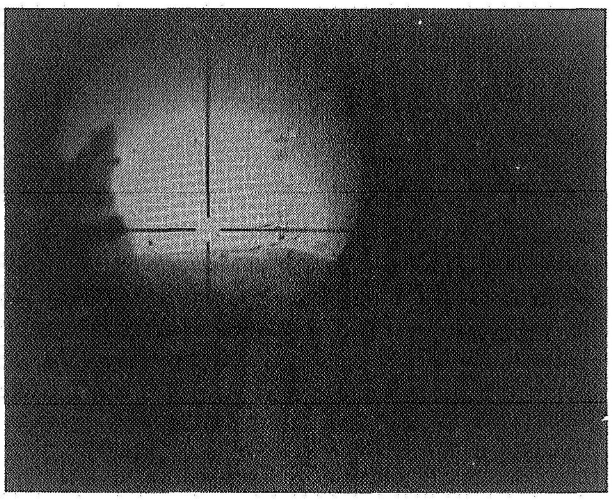


Figure 27.

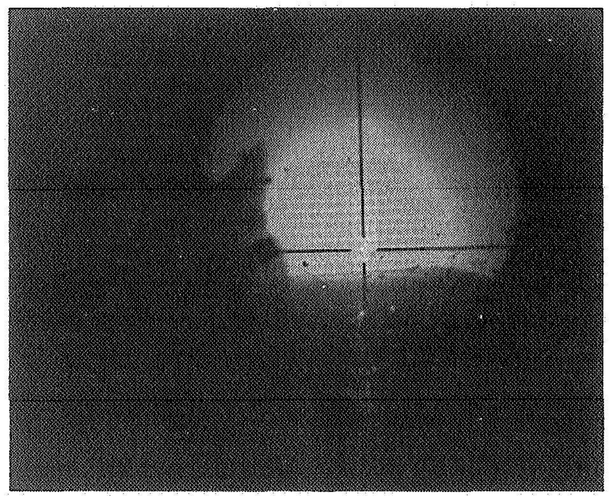


Figure 29.

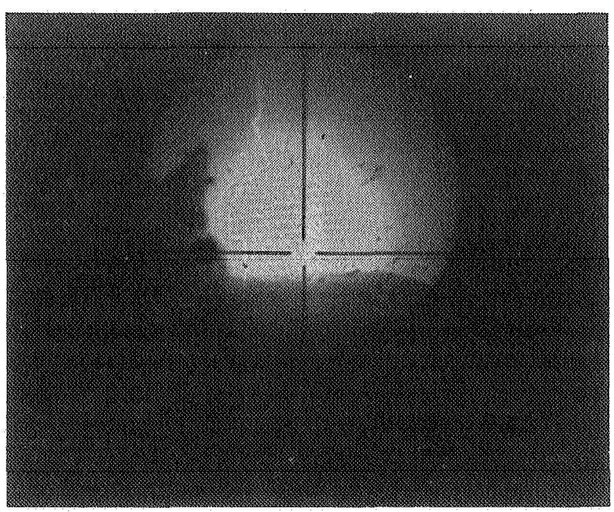


Figure 28.

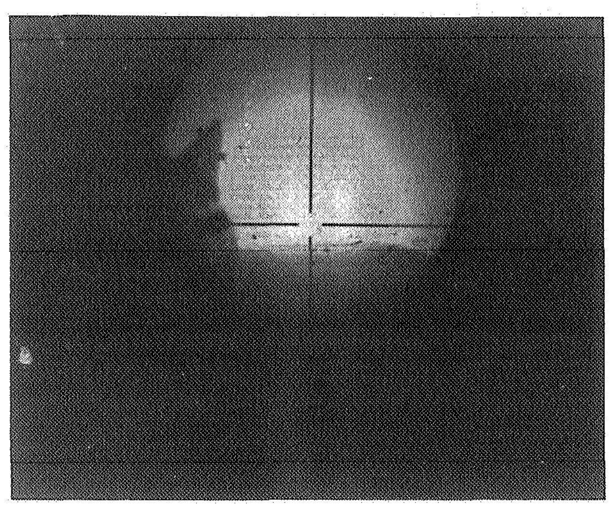


Figure 30.

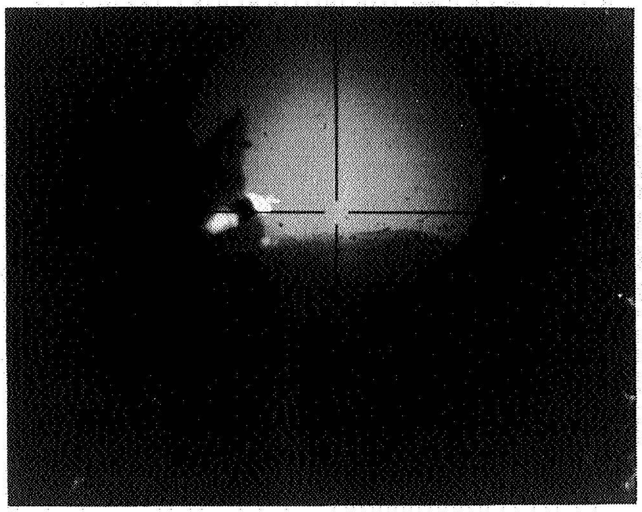


Figure 31.

by NASA, USAF, and the FAA. Thank you.

DR. FROST

So, we proceed to 1980 (Figure 32) by which time the workshop was beginning to gather not only a national, but an international, reputation. I think that it was at this workshop that the Congressional Oversight and Accident Investigations Committee in Washington canceled their meeting because all of the experts were here in Tullahoma. So, we were beginning to be heard. For the fourth workshop, we decided to look at measuring weather for aviation safety in the 1980's. We looked at instrumentation and equipment and on-going research relative to these systems. We also looked at identifying future work and programs necessary to bring the instrumentation and equipment up to the standards required for present and future aviation safety and operations. At that workshop, we numbered 77 participants. We had a very effective and strong working group.

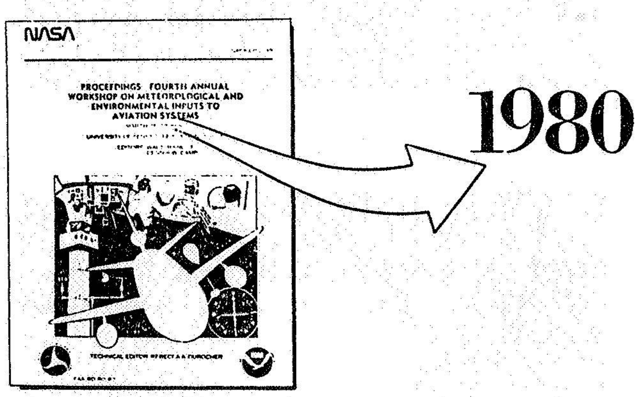


Figure 32. Through an evolutionary process, the theme for the fourth workshop became "Measuring Weather for Aviation Safety in the 1980's". This workshop took an in-depth look at the status of instrumentation and equipment systems currently in use, describing on-going research relative to improving these systems and identifying future works and programs necessary to bring the instrumentation and equipment up to the standards required for present and future aviation safety and operations.

Throughout all workshops, there has been one topic that has always excited the committees. It has always generated active and boisterous discussion; this topic is wind shear (Figure 33). The committees have always agreed, both prior to 1980 and thereafter, that wind shear affects the terminal area and will continue to be a dominant weather hazard until an effective solution is found. There have been discussions and recommendations relative to the detection of wind shear. At the 1980 meeting, it was felt that the application of ground-based microwave Doppler radar was a real possibility for measuring wind shear. There was some doubt as to whether the wind anemometer array system would work; and it was always agreed that, at best, it was an interim system. A cry came out of 1980 that we needed to identify procedures after detection of wind shear, and we have seen the evolution of certain techniques for flying out of wind shear; but there is still disagreement as to whether to go to stick shaker, minimum drag, or what exact way to fly out of wind shear.

There is also the problem of measuring wind shear with Doppler radar in that the question is raised as to what signal we look for and how to measure severity. The air traffic controllers do not want us to tell them what the wind gradient is; they want a numerical value. They would also like to know how different aircraft are affected by wind shear so that they can reschedule aircraft when there is a possibility of impending wind shear.

There is a big problem now for training in wind shear. Do you train pilots to fly through killer wind shears or do you train them to avoid wind shear at all costs? We don't want to give them the impression that they can fly through wind shear. There is a need for standard terminology. Again, there is air crew training, not only in terms of simulators, but in terms of whether you teach them theory or specifically what you teach realtive to wind shear. There has always

Seriousness of the Problem: Wind shear effects in the terminal area continues to be one of the most dominant topics of discussion.

Detection of Wind Shear: The application of ground based, pulsed microwave Doppler radar which is located at or near the terminal to provide detection capabilities of wind shear along approach and departure paths is strongly supported. The wind anemometer array which has always been considered by the committees an interim solution at best should be used to its fullest; however, until a better system is available, evaluating the array system for its effectiveness and recording the data is a recommendation voiced by many committees.

Procedures After Detection: When wind shear detection systems have been developed and installed at major airports, manufacturers as well as the FAA must determine specific actions to be taken after wind shear has been detected. Data uplink of Doppler radar-derived information on winds and wind shear directly to an aircraft is feasible. Develop systems to automatically detect hazardous weather phenomena through signature recognition algorithms and through automatic data linking of alert messages to pilots and controllers. A human factors study should be conducted to assure that pilots and controllers are not being provided more information than can be absorbed in a given time.

Air Traffic Control: Research should continue to determine the intensity of wind shear which an aircraft, categorized as to type, can withstand if actually penetrating a system. They noted that wind shear intensity should be reduced to a numerical value.

Training for Wind Shear: Teaching of wind shear should include interpretation of severe weather reports and should educate users as to the availability of these reports within the National Airspace Systems (NAS).

Standard Terminology: Development of an International Civil Aviation Organization (ICAO) standard terminology for describing the effects of wind shear on flight performance should be pursued.

Aircrew Training: Aircrews' understanding and training relative to meteorological conditions which may create a low-level wind shear hazard should be continuously updated. Equal emphasis should be given to both the cold air outflow region of a thunderstorm and the gust front conditions. Also, frontal zones and low-level jet stream conditions should not be neglected. It was recommended that creating the impressions to the pilots in training programs that any wind shear can be penetrated using the correct technique should be strongly avoided.

Figure 33. Summary of discussion relative to wind shear

been the claim that we should not get too carried away with only microbursts and downdrafts because there are other kinds of wind shear, i.e., thunderstorms and gust fronts, frontal zones and low-level jets. So, the discussion goes on; but we have come a long way from the beginning as to understanding wind shear. One of the people who is very responsible for information coming to light is John McCarthy. John has been pushing the wind shear program for a long time. When FAA had concluded that wind shear had been solved with airborne systems and the low-level wind shear alert system, John said it had not been solved. By his perseverance, he put together the JAWS Project. He was the chief scientist with Ted Fujita and Jim Wilson, and that program, as all of you know, was extremely successful. It was carried out in July 1982. John has participated in our workshops many times, and I am happy that he is with us tonight in order that he may tell you where we are in JAWS, and what is left to be done.

JOHN McCARTHY

Well, thanks a lot, Walt. I won't take much of your time because we have been talking about wind shear for the last two days, as usual, in the group that I'm in. I think the first workshop I attended was in 1978; I missed the first one. I have been here talking about how to deal with this problem from the onset. Many of you have been involved in the discussions that brought about the need for a definitive experiment, which we call JAWS (Joint Airport Weather Studies). I wasn't aware of Bill Melvin's first slide, which is really amazing. Ted Fujita from Chicago, Jim Wilson and myself from NCAR, and many other people were involved in executing a project that fundamentally addressed the nature of wind shear in an applied sense. Bob Serafin from NCAR has been very instrumental in it; Ed Blick, who was at a much earlier workshop from the University of Oklahoma; Frank Coons, who is not here tonight; Jean Lee was involved in our early discussions at Oklahoma at the Severe Storms Lab; and most particularly Walt Frost in our long attempt to try to get something going. With regard to where we stand today in JAWS, major programs are in progress to improve pilot and controller awareness. You saw the film we produced, which is just the beginning of that process. Other films and papers have come from the program to educate very experienced pilots who still say that they can feel a wind shear just by sitting there, and say that they can go through any wind shear we can find. We have tried to deal with that in a very forthright program. We are still working on flight training procedures, not only in techniques once you encounter wind shear, but in techniques in the simulator.

We have a very definitive program with NASA, FAA, and industry, to design much better wind shear simulation profile models. We felt all along that the low-level wind shear alert system (LLWSAS), which was designed primarily as a gust front detector, was an interim solution. We are working intimately with FAA to upgrade and substantially improve the LLWSAS. This will, with improvements, in my opinion, be a long-term important addition to the whole detection of wind shear.

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I think the bottom line is that in the area of wind shear, most of the recommendations made are now major initiatives within and on the outside of government. I believe that the applications part of the wind shear project came from this workshop. Fujita was approaching it from basic studies; I was looking at it from aircraft performance; and Wilson, Doppler radar. However, I look to the evolution of the kinds of discussions that we continue today as being fundamental to pulling this program off, so I think everyone here now and at all the previous workshops has been very important. It is very exciting to see it evolve. We have developed some very close working relationships, the closest of which has been with Walt, who has been very important to me throughout this evolution. Many thanks also go to NASA, with Dennis in his early support, and Dick Tobiason at NASA; FAA has also been with us very strongly. Thank you very much.

DENNIS CAMP

Moving on to 1981 (Figure 34), many things were discussed at this workshop, including ASDAR (Figure 35). About 80 participants were present at this workshop. The discussion on the committees was aimed at fuel economy, forecasting that would be of benefit to the airlines, trying to make it a more economical system. A lot of data was collected from airlines which participated in programs with the different government agencies, NASA, FAA, etc. Committees recommended that data collected by the airlines through ARINC should be made available to all users. Rick Decker is here from NOAA who has had some direct responsibility for this type of program, so I would like to ask Rick to come forward and make a comment or two on this.

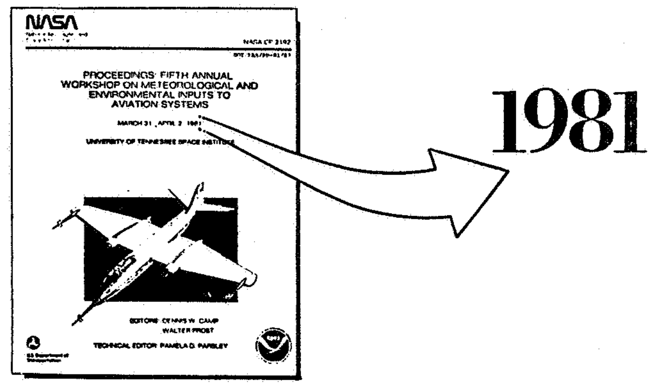


Figure 34. The theme of the 1981 Workshop was "The Impact of Meteorology on Future Aviation Efficiency, Operations, Design, and Safety."

<u>Fuel Economy</u>: Better forecasting of winds aloft is required.

<u>Forecasting</u>: A denser observation network with a data link to inertial navigation system (INS) equipped aircraft is recommended time and time again by all committees.

<u>Data Collected by Aircraft</u>: The committees recommend that the data collected by airlines through AIRINC should be made available to all users. A common winds and temperatures aloft data base and improved collection of such data either through additional reporting or by automatically reporting with automated sensors on aircraft should be studied as to cost benefits. The committee felt that an operational Aircraft/Satellite Data Relay (ASDAR) or at least that kind of capability be encouraged or even demanded.

Figure 35. ASDAR/ACARS related needs

RICHARDSON DECKER

Automated aircraft reporting systems on commercial airliners really got started as a part of First GARP Global Experiment (FGGE). The First GARP Global Experiment, or FGGE, was a meteorological experiment conducted during the years 1979 and 1980 to gather large quantities of data globally for use in developing atmospheric numerical models. The Aircraft to Satellite Data Relay (ASDAR) was one of the new observing systems employed. During the experiment, it was shown through the use of ASDAR how the frequency, accuracy, and timeliness of aircraft reports of wind and temperature could be greatly enhanced. NASA and NOAA jointly funded the development of 17 prototype

ASDAR units on widebodied aircraft of several international carriers. These prototype ASDAR units demonstrated to the meteorological community beyond any doubt a valuable new source of upper air data.

At the 1981, and subsequent workshops, support was given to the development of an operational ASDAR system for worldwide deployment. These endorsements were most helpful in focusing on the need to have operational hardware developed and to have the prototype units continue in service after the completion of FGGE. Despite the early endorsements, a critical mass could not seem to be brought together at that time. Several budget initiatives were undertaken. The first year we put a package together called ASDAR. That did not work, so the next year we renamed it AARS. Then, later, it became GARS, and then AMDAR. Even with thes various repackaging shcemes, the carrot of full program funding was always just beyond our reach.

Finally, in 1981 and 1982, international attention was focused on ASDAR's operatonal potential. Led by the U. S., an international consortium was formed in April 1982. The Consortium for ASDAR Development (CAD) now has eight member states including Australia, Canada, Federal Republic of Germany, Netherlands, New Zealand, Saudi Arabia, the United Kingdom, the United States and others. The purpose of the CAD is to raise funds for and manage the development of preproduction ASDAR units. In 1982, an RFP was issued by the CAD under the auspices of the World Meteorological Organization (WMO).

Last month (on September 13), the Secretary General of the WMO and the Chairman of the CAD signed a contract with GEC McMichael of Great Britain. By late in 1985, McMichael will have built six (6) preproduction ASDAR units that will be certified both here and in Britain. Beginning in 1986, the first production units will start being deployed on aircraft of several international carriers. We believe that widespread deployment of ASDAR-equipped aircraft over data-sparse ocean and land areas will provide the observations needed for improved global aviation wind and temperature forecasts.

While ASDAR will be particularly helpful on international routes, I also want to say a few words about another automated aircraft reporting system that will be beneficial to aviation interests in the U. S. The ARINC Communications Addressing and Reporting System (ACARS) per se is designed primarily for VHF radio down-linking of aircraft operational and performance data into Aeronautical Radio's (ARINC) communications system. Meteorological observing and reporting components "piggy-back" onto the ACARS system. In a similar manner to ASDAR, the wind and temperature is observed once every seven (7) minutes; and when six (6) observations have accumulated, a report containing them is transmitted via VHF radio link to an ARINC ground station. Many U. S. airlines are now equipping their aircraft with ACARS. While only a relatively few have the required meteorological reporting equipment, their number is steadily increasing. In fact, within two to four years, we believe there may be as many as 200 ACARS-equipped aircraft that will be transmitting down meteorological information over the U. S.. Also like ASDAR, both vertical profile as well as flight level data will be available to improve wind and temperature forecasts.

From the recommendations offered at this workshop, I can see there is substantial interest in the capabilities offered by automated aircraft reporting systems like ASDAR and ACARS. We appreciate your endorsements and believe the progress that is being made is in part the result of your focusing attention on the need for such systems.

DR. FROST

Well, we are almost there—1982 (Figure 36). The theme at this workshop was Satellites and Other Aviation Weather Facilities. The make-up of the fixed committees indicates the theme and what we were trying to achieve at the 1982 workshop. We wanted to see what satellites could do for aviation weather, and very active and viable discussions took place. We wanted to know how we could improve communication facilities, forecasting facilities, training and simulation facilities, and how we could improve operations and airport facilities. We were now growing. We were up to 106 participants. From the workshops throughout the years, a recommendation was continuously made, and that was there is an urgent requirement for weather information at many general aviation airports (Figure 37). In 1977, an automatic weather observing station was discussed as a possible long-term solution. In 1979, it was determined that emphasis should be placed on the establishment of weather for observation at general aviation airports, particularly where an instrument approach exists. In 1980, there was a recommendation that a justifiable requirement exists for an ALWOS, which will measure ceiling and visibility since 1,000 airports in the United States have IRF approaches, with little or no weather observation data. To those of you who do not know what ALWOS means, it is Automatic Low-cost Weather Observing Systems; and because there has always been a need for these, it has been repeated throughout the workshops. Dan Bellay is here to tell us a little bit about the status of ALWOS. Dan is still on active duty with the Navy; but he has been assigned to FAA, and he works directly with Neal Blake in terms of the FAA's weather program. He will tell you about the status of the ALWOS, at this time.

DAN BELLAY

Thank you. The status of the AWOS (Automated Weather Observing Systems) is that we now have 14 demonstration sites in place throughout the United States. For example, we have them in Alabama, Alaska, etc. We will be continuing this demonstration program for one year until the end of Summer 1984. What we had hoped to learn from this is the good and bad of the systems we have in the field, and take recommendations from

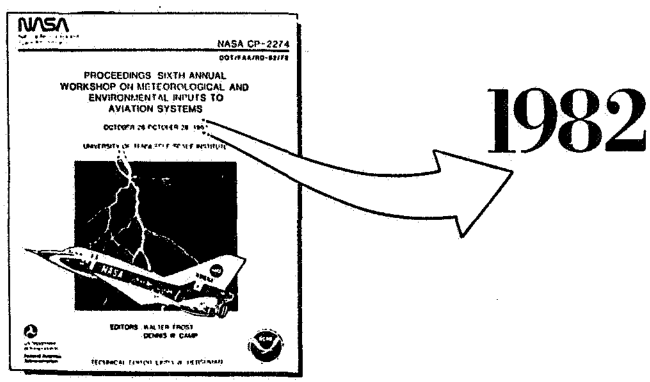


Figure 36. The theme of the 1982 Workshop was "Satellites and Other Aviation Weather Facilities."

There is an urgent requirement for weather information at many general aviation airports; an automatic weather observation station is a possible long-term solution.

Emphasis be placed on the establishment of weather observations at general aviation airports, particularly where an instrument approach exists.

There is a justifiable requirement for an ALWOS which will measure ceiling and visibility, since some 1,000 airports in the United States have approved IFR approaches but little or no weather observation data.

Automatic observing and reporting stations need to be time-coordinated and identified. Data collected from these stations needs to be retained for some specified time in a retrievable manner.

Figure 37. Automatic Low-Cost Weather Observation System (ALWOS)

the users. We will then build a specification for production. We hope to have this specification written by the end of 1984, with a production contract in early 1985, and the first of a thousand systems out as early as 1986.

DENNIS CAMP

Thank you, Dan. We are nearing the end of our presentation; but we would like to hear from the man who has been, in many ways, responsible for the workshops and what we do in them. He is the man that looks after me and keeps me on the straight and narrow. He is from NASA Headquarters and is responsible for aviation safety at Headquarters, and the meteorological programs relative to aviation. So, I would like to ask this man, Mr. Dick Tobiason, to come and give us a few comments on the future of our workshops here and the way Headquarters views them.

DICK TOBIASON

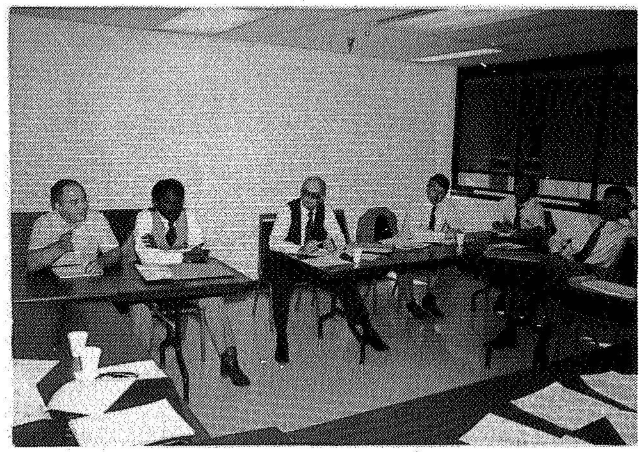
Watching the interaction of the committees here at the workshop is fantastic. There are some who have done an outstanding job. We, however, need to decide what we want to do in the future, and the idea is to keep a good thing going, as we intend to do. Therefore, we should all be back down here next October. The other thing we wanted to do was to see how the government puts its act together before it gets to this kind of an organization; also, what the other civil users and DOD users of the system do. We tried an experiment here and I wouldn't say that it was extraordinarily successful, and that was to try to get the various sponsors of meteorological work together for a couple of days and rehearse before we met with you, the users, in the regular workshop. This is the first time we have put the so-called Government Retreat back to back with the workshop. I think it had its pluses and minuses. We had some ideas of things that we wanted to see happen in the workshkop and I think all of those have happened; but next year, I think we will try something a little different. We would like to bring into the workshop in the future a little better idea of what we are doing in major programs and how the workshop has influenced the government. You have had a big influence on us. Thank you very much.

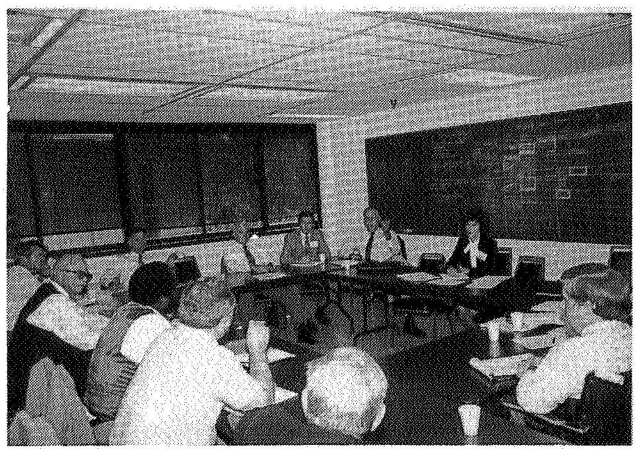
DR. WALTER FROST

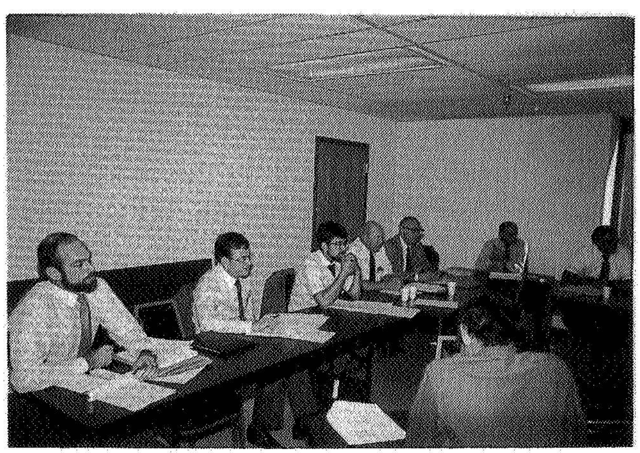
I have one last slide, and this slide says that this is the final five (Figure 38). The reason that I say this is the last five is because we are now seven. We now have the Department of Defense with us and the Office of the Federal Coordinator for Meteorology. Thank you very much for attending our program. Good night!

Figure 38. "The Last Five" before the Organization Committee became seven

SECTION VII
COMMITTEE SUMMARY REPORTS







COMMITTEE: ICING AND FROST
CHAIRMAN: DANIEL C. MIKKELSON

MEMBERS:

CHRIS BUSCH
LONI CZEKALSKI
CAPT. DAN DUMONT
MORTON GLASS
ROBERT IDE
RICHARD JECK
CHARLES MASTERS
DENNIS NEWTON
RALPH PASS
PORTER PERKINS

I would like to thank all of the members of my committee. I appreciate their efforts, and it was a very interesting workskhop. I would like to go through about five issues that summarize what we came up with. Starting with the first priority.

ISSUE: Currently there is a nearly complete lack of meaningful or adequate forecasts, or even nowcasts, or icing conditions, particularly for commuter and general aviation. This is due largely to infrequent and sparsely distributed sounding data indicative of icing conditions. To benefit the development of improved icing forecasts techniques and to provide better assessments of existing icing conditions, developmental systems, such as NEXRAD and PROFS profiler should be expanded where possible to provide data related specifically to icing conditions.

DISCUSSION: NEXRAD may not be sensitive to cloud droplet diameters in the range 5-50μm which contain the LWC responsible for aircraft icing, excluding freezing rain and droplets. In this case, NEXRAD can still be useful if it can detect the occurrence and spatial distribution of snow. Where there is snow, there is little or no LWC and, therefore, little or no engine icing, although the snow may have an effect on some engines or inlet systems. Thus, it would be valuable for icing nowcast purposes to have a snow recognition algorithm for NEXRAD data analyses.
PROFS profiler with the inclusion of a suitable, passive microwave sounder, appears to have good potential for more direct indications of icing conditions through the detection of LWC and the provision of temperature soundings. There are some inherent limitations, such as 1) the capability of only indicating the total LWC integrated over the vertical extent of the cloud(s); 2) the inability to sense cloud top or resolve multiple cloud layers; 3) the inability to seperate out the LWC that lies only above the freezing level. The basic ability to detect LWC, however, is judged to be sufficiently important to warrant development of the technique.

The MARS passive microwave radiometer/profiler technique appears promising for accomplishing the required LWC and temperature profiling referred to above in the PROFS profiler discussion.

RECOMMENDED ACTION:

1) Evaluate NEXRAD for ability to provide information on icing conditions, at least in developing algorithms for recognizing snow.
2) Develop the PROFS profiler to include measurement of LWC and temperature profiles, especially from near-ground level to about 20,000 feet.
3) Continue the MARS field trials with air truth comparisons from overflights. Fund MARS for FY-84 to keep this promising work alive.

PRIORITY: 1

ISSUE: Reporting Weather Conditions at Unmanned Airports

DISCUSSION: Remote weather observation at unmanned airports which would provide information to general aviation and commuters in order to increase aviation safety. The weather and field information needed include:

1) Runway conditions - glazed ice, snow, wetness;
2) Surface weather - winds, temperature, etc.;
3) Atmospheric conditions - cloud bases and tops, temperature, profile, and LWC;
4) Visual view of airfields and surrounding areas.

Methods to gather this information are varied, such as rotating TV cameras, AWOS to include more atmospheric conditions, pilots reporting weather conditions to FSS after landing; and determination of runway conditions with remote TV with digital signal processing and pattern recognition.

RECOMMENDED ACTION: Exploration of video systems for use in transmitting runway and surrounding conditions. Evaluate AWOS expansion capabilities. Investigate development of instrumentation for measuring runway conditions (ice and snow).

PRIORITY: 2

ISSUE: Pilots knowledge of meteorological conditions that cause aircraft icing and the nature of hazard to aircraft is deficient. Need to provide for better training of pilots so that they have criteria to judge effects of icing on aircraft performance.

DISCUSSION: Icing is a principle cause of general aviation accidents. Over the past 5 1/2 years, there have been an average of 51 accidents per year with a total of 364 fatalities.

Good weather training courses are now available from various sources, but there is little incentive for pilots to take them. There is no requirement for pilots to demonstrate weather knowledge beyond the instrument rating written test (except for those who obtain airline transport pilot ratings). Advanced weather training is not tax deductible except to professional pilots. The basic question is: what can be done to influence pilots to obtain better weather training and improve their weather knowledge, particularly of hazardous weather?

Suggest assembling new attractive training material and aids.

RECOMMENDED ACTION:

1) Make the weather portion of the instrument rating written test, and perhaps of the private pilot written test, a separate requirement for passing the entire test.
2) Create a flight instructor revalidation course devoted to weather and the teaching of weather and allow it to be accepted for flight instructor renewal or perhaps an every-other-time basis.

RESPONSIBLE AGENCIES: FAA

PRIORITY: 3

ISSUE: How to obtain better cloud liquid water content data for icing reporting, forecasting and warning.

DISCUSSION: There is a total lack of operational cloud liquid water content or other icing data to assist in forecasting and in providing reports and weather warnings. Very little accurate data is transmitted verbally in the form of pilot reports. Such data is presently available, however, from air carrier aircraft equipped with icing rate probes and ACARS data transmission capability. It could be available from many more aircraft if an inexpensive and reliable liquid water content probe were developed, and could be transmitted using the forthcoming MODE-S radar beacon system.

RECOMMENDED ACTION:

1) Develop a plan to transmit and use icing data from air carrier aircraft using existing instrumentation and ACARS system.
2) Investigate expanding airline ACARS trial program to include icing data.
3 Get plans to transmit icing data into the MODE-S radar beacon system in time for its implementation.
4) Develop an operational liquid water content probe.

RESPONSIBLE AGENCIES; FAA, NOAA, NASA, OFCM.

PRIORITY: 4

ISSUE: Continuance of the A/C icing research program

DISCUSSION: The fixed committees endorsed the present FAA, NASA, DOD Aircraft Icing Research Programs. While they did endorse the current aircraft icing research programs, they saw the need for continued and even expanded programs in basic ice physics research, analytic techniques, simulation techniques, advanced ice protection systems and atmospheric characterization. They also expressed the desire to speed up the schedules used to make information available to the user community as soon as possible. The committee, without exception, expressed the need for quantifiable measures and development of meaningful measures and development of meaningful definitions of icing intensity. There was some concern that the conservation in the standards should not be lost.

RECOMMENDED ACTION: Continue work in: analysis methods, simulation techniques; advanced ice protection systems, atmospheric characterization; develop meaningful definitions of icing intensity.

RESPONSIBLE AGENCIES: FAA, NASA, DOD.

PRIORITY: 5

COMMITTEE: FOG, VISIBILITY, CEILING AND HEAVY PRECIPITATION

CHAIRMAN: GENE MACK

MEMBERS:

AL BEDARD
JOE BOCCHIERI
BOB CROWDER
JIM LUERS
CHARLES MASTERS
JOHN PAPPAS
MONT SMITH
STEVE BROWN

First, I would like to thank the members of my committee for the conscientious efforts they put forth to come up with the conclusions and recommendations which you will find in the proceedings. As you can see, our charge is some basic terminal weather phenomena. Sometimes we expand the scope of our thinking a little bit beyond these things to encompass terminal weather in general. During the course of our delibrations, we identified approximately a dozen different topics, and I don't think we can do justice to all of those areas. I hesitate to call them issues. Perhaps, they are problem areas; but I will try to go through and summarize each of those problem areas for you. What we tried to do was prioritize the items according to whether or not we felt they could be addressed, solved or answered in near-term or in the long-term. We gave them short-term and long-term, as well as high, medium and low, priority.

ISSUE: Improved short-range terminal forecasting to enhance safety and promote more efficient (lower cost) flight operations.

DISCUSSION: Policies and programs that lead to a reduction of complete full-scale weather observations and lack of short-range computer forecasts models to solve the forecast problem are partly responsible for forecast inaccuracies. An increase in the number, frequency and quality of observational data, a reliable communication system to transmit and disseminate the data, and the development of a short-range objective forecast model are desired.

Computerized, objective forecast systems should be developed to assist the forecaster in the 1 to 6 hour projection. These sytems should have the following characteristics:

1) They should be simple enough to be run on-station on a mini-computer:

2) They should be under the control of, and interactive with, the local forecaster;

3) They should make use of recent, local surface observations as input.

Within the National Weather Service (NWS), systems satisfying these criteria are presently being developed and should continue to be supported. The techniques development laboratory of the NWS, for instance, is developing and testing the Generalized Exponential Markov (GEM) statistical model and the local AFOS-MOS Program (LAMP).

RECOMMENDED ACTION: Encourage development and implementation of systems/procedures that provide more detailed weather observations, including automated systems. Continue operational testing of GEM; make it more efficient so as to require less of the resources of AFOS computer configurations, and encourage more man-machine interaction techniques.

RESPONSIBLE AGENCIES: NWS, FAA

PRIORITY: Short-range; high priority

ISSUE: Nationwide implementation of voice response system (VRS) weather briefing information.

DISCUSSION: VRS Test Systems have been in operation since the mid-to-late 1970's. Use of the system by pilots nationwide is limited by the high cost of long-distance telephone charges. The "900" number calls are billed at the flat rate of $ .50 per call. It is recommended that the telephone number to be promoted nationally be (900) wea-ther.

RECOMMENDED ACTION: Establish a nationwide "900" telephone number, perhaps (900) weather, for VRS access. A "900" telephone number would offer a minimal fixed cost for access to VRS information and would provide revenue for the FAA to cover operational costs.

RESPONSIBLE AGENCIES: FAA

PRIORITY: Short-range; high priority

ISSUE: To enable meteorologists and aircrew to take full advantage of the potential value of meteorological data becoming available from new automated systems based on aircraft (ASDAR, ACARS).

DISCUSSION: Profile data obtained on ascent and descent would improve terminal forecasts and warnings - thunderstorms, wind shear, turbulence, and low cloud and fog. Accurate low-level wind and temperature data at frequent height and time intervals would improve short-range forecasting for low cloud and fog (thickness, time of onset, dissipation, etc.). Other parameters, such as humidity and liquid water content, would be valuable.

Profile data could also be valuable for the crew of aircraft approaching the terminal if provided in concise form in sufficient time for crew to access impact and make operational decisions.

ASDAR/ACARS data obtained from cruise level are valuable for flight planning and for meteorological analysis and research.

International coordination of project is essential. Funding arrangements will vary country to country and are yet to be resolved.

RECOMMENDED ACTION: In view of mutual benefits, aviation and meteorological communities should cooperate to promote ASDAR/ACARS Meteorological Data Projects and to investigate technical aspects and the processing and distribution of the data.

RESPONSIBLE AGENCIES: NOAA (NWS), FAA, IATA, WMO, ICAO

PRIORITY: Short-range; high priority

ISSUE: Dissemination of RVR information (2 issues).

DISCUSSION:

1) NWS reports runway RVR for the Primary runway, but frequently RVR for the Active runway is not reported to the pilot.

2) Real-time RVR information could be effectively used by the pilot, particularly at more remote sites.

RECOMMENDED ACTION:

1) NWS modify reporting procedures to include active runway conditions.

2) Provide for RVR data up-link (to pilot).

RESPONSIBLE AGENCIES:

1) NWS, FAA

2) FAA

PRIORITY:

1) Short-range; high priority

2) Long-range; medium priority

ISSUE: The total of, and/or insufficient amounts of, weather observations at sparsely populated areas and unmanned airports make it difficult to provide accurate, current and forecast weather reports for these areas.

DISCUSSION: In order to prepare adequate weather forecasts and current weather reports, sufficient weather data must be available. Such data do not exist in those areas of sparse production or unmanned airports. A need to provide this necessary data is identified for all aspects of aviation agencies, and, in particular, general aviation, where most flights are made under VFR and the aircraft are not capable of adverse weather avoidance.

Better weather reports and forecasts would be possible with these additional data and would create a greater confidence in these reports and forecasts by the aviation community, with an expected increase in flight safety.

In some areas, it might be sufficient to know only that weather conditions are IFR or VFR; while at others, more specific information regarding ceiling and visibility might be needed. Estimated costs for these systems would be a fraction of the cost of the AWOS systems.

It is a priority to develop specification for lower capability and lower cost-automated systems than AWOS. The consensus is that where data are not presently available, any new data would certainly be beneficial. Replacement of present reporting methods is not the purpose of this recommendation.

<u>RECOMMENDED ACTION</u>: To develop and implement remotely operated weather data collection and reporting systems at various levels of sophistication and cost dictated by the kinds of data needed. The levels of reporting can range from basic weather reporting stations to more advanced systems such as used in AWOS.

<u>RESPONSIBLE AGENCIES</u>: FAA

<u>PRIORITY</u>: Short-range; high priority

<u>ISSUE</u>: Aerodynamic penalties have been measured on an unslatted 2-D airfoil when exposed to an intense water spray. Theoretical calculations and accident studies suggest that heavy rain may produce aerodynamic lift and drag penalities on a commercial aircraft with extended high-lift devices in a take-off or landing phase of operation.

<u>DISCUSSION</u>: The effect of heavy rain on aircraft aerodynamics for both general aviation and commercial aircraft is largely unknown. Possible detrimental effects due to rain may result from

A) The momentum transfer of water droplets to the aircraft;

B) The roughness of the water film that may produce 30% lift loss and severe drag increase;

C) Interference of the water film flowing off the leading edge slat with air flowing through the slat, possibly causing premature airflow separation.

A better theoretical and experimental understanding of these phenomena are essential to aviation safety. Research is needed to resolve this issue.

<u>RECOMMENDED ACTION</u>: Conduct some limited basic and applied research, both theoretical and experimental, concerning aerodynamics effects of rain on aircraft.

<u>RESPONSIBLE AGENCIES</u>: NSF, NASA

<u>PRIORITY</u>: High priority; long-range

<u>ISSUE</u>: If rain causes a significant effect on the alignment of the angle of attack sensor, this influence could prevent activation of the stick shaker when approaching stall. In addition, some wind shear monitor systems require the use of ADA measurement data which, if in error, could give the pilot bad guidance.

<u>DISCUSSION</u>: At the typical landing speed of a commercial aircraft, the angle of approaching rain is approximately 8^0 above that of the air. If the α vane aligns itself even partially in the direction of the rain, then the α vane will give indication that the aircraft is at a lower angle of attack than it actually is. Since this measurement is used to warn of stall and regulate command bars on wind shear monitor instrumentation, any significant error in measurement could result in a catastrophic event.

<u>RECOMMENDED ACTION</u>: Test angle of attack vanes for accuracy in a wind/rain tunnel of natural environment under severe rain conditions.

<u>RESPONSIBLE AGENCIES</u>: FAA, NASA

<u>PRIORITY</u>: High priority; immediate action

<u>ISSUE</u>: Flight recorder data provides a means of assessing rain effects on commercial aircraft performance.

DISCUSSION: Flight recorder data for aircraft equipped with five channel recorders are of some value in deducing aerodynamic performance penalities due to heavy rain or even more value, is for data from newer aircraft equipped with recorders documenting many more channels of information. Using these recorders, it is possible to distinguish wind shear performance degradation from heavy rain performance degradation. Several instances are known to have occurred in the past few years in which an aircraft, while executing a missed approach in a very high rain shower, was lacking in expected performance. Analysis of the FDR data could be of immeasurable value, (particularly, if it were from a newer FDR-equipped aircraft) in assessing aerodynamic effects of rain in the cited and future situations.

RECOMMENDED ACTION: NASA, FAA, ALPA and ICAO should recommend to all carriers that any take-of or landing events in heavy rain in which pilot experienced performance deficiencies to pull the FDR data and make it available to agencies interested in performing an analysis. Establish lead agency as clearing-house for data.

RESPONSIBLE AGENCIES: NASA, FAA, ICAO, ALPA.

PRIORITY: High priority; immediate action

ISSUE: In several accidents, the onboard weather radar may have been providing an inaccurate depiction of an approaching thunderstorm condition because of a water film on the radome or near field rain attenuation on the radar signal.

DISCUSSION: In the analyses of the air Wisconsin and Southern Accidents, serious questions have arisen concerning the authenticity of the radar picture in the severe rain environment. Attenuation of the radar signal may have occurred either on the radome, or in the near field, preventing the pilot from observing the severe weather cells ahead of him in sufficient time to avoid the real hazard.

RECOMMENDED ACTION: Continue study of attenuation in the radome near field due to precipitation or other causes.

RESPONSIBLE AGENCIES: NASA Langley Research Center

PRIORITY: Medium Priority; Long-range

ISSUE: A better understanding is needed of the spatial, temporal and intensity distribution of heavy rain in the natural environment.

DISCUSSION: Our present state of knowledge is limited concerning the distribution of heavy rain in convective weather systems. A basic understanding is needed concerning the dynamics of rain as an energy source for microburst activity. Experimental data may also be inadequate to establish the relationship between the structure of microbursts and location and intensity of a rain shaft.

RECOMMENDED ACTION:

- o Support basic studies concerning the dynamic interaction of rain and microbursts.
- o Support studies and field tests to establish the spatial, temporal, and intensity distribution of heavy rain in the natural environment.

RESPONSIBLE AGENCIES: NSF, NASA, NOAA, FAA, NCAR

PRIORITY: High priority; long-range

ISSUE: Information transfer: High much data to pilot? Who will make decisions if pilots doesn't have time for data interpretation?

DISCUSSION: Assuming data is available on approach for concentrated, time varying, weather hazards (e.g., Rain shafts or microbursts), could the pilot handle the additional work load of interpreting an incoming stream of data? The answer was that the work load was great and important information should be flagged, somehow; but the decision process about what action should be taken should be with the pilot.

The time scale (< 1 min.) and space scales (<4KM) involved with such systems can be so small that the data acquisition, processing, and transfer must be essentially instantaneous to be effective.

RECOMMENDED ACTION: That methods be developed for direct display of data to the pilot in a form that will provide clear hazard warnings with little impact on work load.

RESPONSIBLE AGENCIES: FAA

PRIORITY: Long-range; high priority

ISSUE: Enhanced AWOS: AWOS is better than no observations; but as currently designed, it does not supply sufficient information to supplant manned-observation stations for some operators.

DISCUSSION: Some "Part-121" operators will not operate into an airport with only an AWOS as currently configured. Replacing present human observations with an AWOS will force such operators to cease operations or arrange for supplemental observations. The missing critical observation elements are freezing rain, snow, and thunderstorms, which can preclude using an airfield. Automatic sensors for distinguishing rain, snow, ice pellets, freezing rain/drizzle and their intensity are needed, as well as thunderstorm detection and/or location.

RECOMMENDED ACTION: AWOS installation should concentrate on locations with no observations at present. Sensor development for the critical elements should proceed and be installed in AWOS systems when availalbe.

RESPONSIBLE AGENCIES: FAA, NWS, NASA

PRIORITY: Long-range, medium priority

ISSUE: Can remote sensing techniques provide for characterization of precipitation?

DISCUSSION: Can remote sensing technology provide an integrated sensing system for detecting and distinguishing hail, snow, ice, fog, rain rate, and the distribution of these parameters in the terminal areas? It may be possible to apply an incoherent radar operated in a variety of sequential modes to obtain this information. This could be done by using detection of melting band; change of polarization; attenuation from reflectors; detection of scattered returns – using different paths in the terminal area.

RECOMMENDED ACTION: Encourage development and testing of a prototype system for characterization of precipitation.

RESPONSIBLE AGENCIES: Long-range; medium priority

ISSUE: Fog dispersal

DISCUSSION: Fog dispersal is a generally desired capability, operational dispersal of super-cooled fog is accomplished routinely; but no known warm fog dispersal operations (except for Orly at Paris) are being conducted. NASA is conducting very limited experiments with a water-spray technique.

Several concepts (thermal dissipation and hygroscopic salt seeding developed and tested in the early 1970's) demonstrated that warm fog dispersal is feasible. However, both concepts have safety-related problems and both are relatively expensive to implement. It is currently believed that warm fog dispersal, using known methods, is not environmentally acceptable or cost effective.

RECOMMENDED ACTION: Research into optimizing a warm fog dispersal technique for operational applications should be encouraged.

RESPONSIBLE AGENCIES: NASA, FAA, DOD, Commercial Airlines

PRIORITY: Long-range; low priority

COMMITTEE: WINDS AND TURBULENCE

CHAIRMAN: BUD LAYNOR

MEMBERS:

WARREN CAMPBELL
FERNANDO CARACENA
JACK EHERNBERGER
JIM EVANS
BERNARD ETKIN
JOHN KELLER
JOHN McCARTHY
JOHN McKINLEY
BILL MELVIN

I would like to start out by thanking UTSI and NASA for inviting NTSB to participate in this workshop, as well as for their sponsoring of this workshop. It is refreshing to see a group of people get together to talk about implementing actions we feel have been needed for an awful long time. It is also nice to participate in that activity. I don't think the NTSB has been down here every year like Bill Melvin, Jim Luers, and Andy Yates; but we have been represented at most of them. We use the proceedings from these workshops as a textbook of what is happening in the meteorological world. We also use it to find out what is happening in the change of acronyms from year to year, as well as a telephone reference. I would also like to thank my committee and the members of the other committees with which we interacted. I thought we had some stimulating and interesting discussions. I will try, at this point, to go over what they were.

We established at the outset the objectives of the committee to have a good information exchange and to examine the present knowledge and practices to define the needs, the future goals of the aviation industry, and ultimately hope to reduce the influence of winds and turbulence as hazards to safe flight. In our committee, we confined the scope to upper-level winds and turbulence, clear air turbulence, mountain wave, terminal area wind shear, the microburst and talked a little about the vortex turbulence problem. We certainly recognized the heavy rain issue, but did not spend much time talking about it.

ISSUE: Development of a terminal doppler radar to protect major terminals, primarily from low-altitude wind shear, as well as other wind and percipitation hazards.

DISCUSSION: FAA and Lincoln Laboratory are beginning to develop an intensive program to deploy a NEXRAD derivative doppler radar for terminal protection. Initial emphasis is utilization of S-BAND radar, appropriate algorithms, and a warning product. Remaining issues are:

- Suppression of severe ground clutter;
- Adequate detection of doppler signals in weak echo situations;
- Best siting criteria to support strategy of detection for aviation needs;
- In-depth development of algorithms;
- Strong emphasis of critically successful warning product for controller and pilots (accurate and low false alarms).

RECOMMENDED ACTION: Support the development of terminal doppler radar as a vital singular solution, with the caution that this development must be broad, in-depth, and address remaining issues thoroughly. We caution that this development is similar to NEXRAD development, but somewhat smaller in scope; it requires mating of meteorological issues and radar hardware and software issues.

RESPONSIBLE AGENCIES: FAA

ISSUE: NEXRAD doppler radars in relationship to aviation needs.

DISCUSSION: The NEXRAD doppler radar program will place approximately 160 S-Band doppler radars as a national network, to be fully implemented by 1992. Aviation winds and turbulence hazards, including severe windstorms and tornadoes, low-altitude wind shear, as well as mean winds in the boundary layer sensed in the optically clear air, and higher in precipitation. We recognize the system to be primarily in support of en route aviation weather objectives.

RECOMMENDED ACTION: Strongly support the full deployment of NEXRAD as a full doppler system, as soon as possible, with the conviction that major advancements in aviation safety will result.

RESPONSIBLE AGENCIES: NWS, FAA, DOD.

ISSUE: Pilot training regarding the latest JAWS-related, low-altitude wind shear.

DISCUSSION: There was continued recognition of the lack of industry-wide adequate training of the nature, need for complete avoidance, and techniques for possible successful penetration of wind shear, when necessary. Most airlines appear to be addressing training well now, but the general aviation sector is significantly behind the learning curve. Finally, creative training must be continued on a long-term basis, long after the normal post-accident (Pan Am) decay of awareness.

RECOMMENDED ACTION: We recommend that creative awareness-increasing and training techniques be explored to maintain a high degree of training in the aviation community, in all pilot sectors.

RESPONSIBLE AGENCIES: FAA, NASA, NOAA, INDUSTRY, MILITARY, UNIVERSITY/TRAINING SECTOR.

ISSUE: Mountain wave activity is responsible for the majority of strong sharp unexpected CAT encounters and distortion of wind field at all altitudes. However, mountain wave know-how and awareness is relatively less than adequate at both professional and technical levels.

DISCUSSION: Due to some airlines avoiding waves relatively completely, controllers are not kept informed of wave effects on CAT, low-level updrafts and downdrafts, strong surface winds and shear.

Our capability for understanding wave activity over mountains and blocking lines of clouds has been vastly improved in the last three years. This capability applies to pressure altitude disturbances and shears, transients and turbulence above the jet as well as near the tropopause, rotor zone and boundary layer.

RECOMMENDED ACTION: Support field observations and scientific studies to exploit the present know-how.

RESPONSIBLE AGENCIES: NASA, NOAA, DOD, NSF.

PRIORITY: CRITICAL

ISSUE: Improved high altitude turbulence monitoring and forecasting.

DISCUSSION: MONITORING: Airborne sensors have been developed to give short-term indications of high altitude turbulence. However, current operational methods used by airlines involve monitoring PIREPS and performing mesoscale analyses using radiosonde soundings. This approach may become less practical in the long run due to its labor intensiveness. New data gethering systems, such as profilers and on-board data systems, may provide for adequate mesoscale resolution as a supplement/alternative.

FORECASTING: The current NWS SIG W70 is generally considered to have room for improvement. A quantitative synoptic-scale system using NMC Grid point data is being developed out of NASA Marshall Space Flight Center. Its formulation is general enough so that it could use mesoscale data, such as from the merit program, whenever it becomes available. Regardless of whether such a data bases becomes available, the successful development of a synoptic-scale, quantitative forecast technique would help airlines and airline meteorological service companies concentrate their attention on the areas of highest risk.

RECOMMENDED ACTION:

1) Research on the appropriate scale in time and space associated with the dynamics of high altitude turbulence.
2) Workshop on CAT to form a coherent and unified front in future efforts is recommended within six months.
3) More comprehensive PIREP archiving for future validation/calibration of techniques.

RESPONSIBLE AGENCIES: NASA, NOAA.

ISSUE: Transfer of Meterological Information by Data Link.

DISCUSSION: Question of standardization of data format for ease of obtaining information.

RECOMMENDED ACTION: Some industry group should undertake a study to standardize data transfer. Suggest high priority given to using standards already in use, such as ASC II Code.

RESPONSIBLE AGENCIES: FAA, Contract to ARINC, Etc.

PRIORITY: High, due to possibility of proliferation of non-standardized formats.

ISSUE: Airborne winds/ACARS and profiler observations for improved wind and turbulence forecasting and meteorological watch updating.

DISCUSSION:

A) En route winds and MERIT program concept are very much needed.
B) Profiler potential and operational configuration/use not mature enough presently to recommend operational installation in a full network.
C) Both need study on the most effective observation density and development of new numerical models to assimulate and apply their data.

RECOMMENDED ACTION: Encourage continued development and testing of prototype systems including evaluation in real applications. Wind technology improvement should be coupled with CAT forecasting.

RESPONSIBLE AGENCIES: NOAA, NASA (Research, Development and Implementation) NSF, DOD (Feasibility Evaluation and Review)

PRIORITY:

A) En route winds and merit: present priority for development and implementation.
B) Profiler: present priority for prototype experiments.

ISSUE: Transfer of digital data

DISCUSSION: DOWNLINK: What are FAA plans for weather downlink via MODE-S; specifically, the parameters indicated air speed, heading and temperature, which, combined with ground track, produce vector winds. What is the anticipated state of ACARS when MODE-S comes on line?

UPLINK: It is unclear what the "terminal weather" information system (analogous to CWP) will be for merging sources such as terminal WX radar; ASR9 WX channel; LLWSAS; PIREPS for transmission to pilots via MODE-S. Can ACARS be used as a near- or long-term digital link for these data?

RECOMMENDED ACTION: Discover the effects of unifying/merging TRACONS on tower/radar controller communications.

SUMMARIZED DISCUSSION:

1) Measurement and communication of airborne wind shear, temperature data, etc., may be improved by use of microprocessors to select the most meaningful and/or significant samples for recording and transmission.
2) It appears that the use of remote detection devices for warnings and/or "go" vs. "no-go" decisions should be considered in combination with other sources of information (e.g., forecasts, PIREPS, crew observations) as well as "stand alone" use. Such combined use should expand the value of remote detection information.
3) There appears to be an absence of directed responsibility to maintain previous special aviation weather data set...and their attending expertise, e.g., en route turbulence, wind shear, etc. (We were lucky in icing). Perhaps, we need the focus of the "joint institutes" on aviation weather.

COMMITTEE: AIRBORNE DATA

CHAIRMAN: JOE STICKLE

MEMBERS:
RICK DECKER
NICK HAAS
GEOFF MOLLOY
WEN PAINTER
PETE SUPER
DAVE WINER
RODNEY WINGROVE
JOHN YOUNG

Like the previous five speakers, I would like to begin by giving the accolades for all I have to say. That is one way to avoid blaming myself, but it is also a fact that there were lively discussions between all the groups, and especially in our own. I appreciate their support. Our committee had the subject of airborne data. The emphasis was on the use of real-time data and post-flight data. I might say that we did not constrain ourselves to staying precisely within the topic area. We had a lot of discussion about other topics; but relative to the use of airborne data, we found there was a multiplicity of usefulness for airborne data, such as winds, temperatures in the real-time sense, the need for liquid water content indicators, and other things for which you may use airborne data. As other people have pointed out, we also found that in the maze of things, there doesn't seem to be a mechanism by which we can get that information down from the airplane, through some kind of ground-based system and back up to pilots or to other users of the aircraft data. So, we decided to make a recommendation that somewhere within this grand and glorious country of ours, we ought to have a meteorological data base. That data base ought to be accessible and updated on a continuous basis. This is where the use of airborne data comes into it. We also need to establish what the role of the government is going to be to a data base system like this, either in the management or oversight of this system.

ISSUE: Meteorology data base - accessibility, updating, and role of government.

DISCUSSION:

1. Technology exits for all components of a general purpose, continually updated, meteorology data base system:
   A) Sensors (Air and Ground)
   B) Data Links
   C) Computer Data Bases
   D) Data Management Software
   F) Multiple Display Options.
2. Users would include forecasters, airline operators, general aviation and military, pilots (real-time), researchers and non-aviation.
3. Data base must be accessible.
4. Common format for input of data must be established.

RECOMMENDED ACTION: Government should take a lead role in establishing access to a meteorological data base with continous updating through data link equipped A/C.

RESPONSIBLE AGENCIES: NWS, FAA, DOD, OFCM

PRIORITY: HIGH

ISSUE: Development of liquid water content (LWC) instrument for use in operational service.

DISCUSSION:

1. LWC is needed for improved forecasting and for real-time warning of icing conditions.
2. Information would be useful to all classes of aircraft, but general aviation and commuters would benefit most.
3. LWC sensor suitable for routine operations with little cost and low maintenance is not "off the shelf" available.
4. Aircraft with current down-link capability are ACARS/ASDAR- equipped transplants which require icing information the least.

RECOMMENDED ACTION: Develop LWC instrument suitable for use in routine airline operations. Encourage or pay for ACARS-equipped aircraft to supply LWC data to NWS.

RESPONSIBLE AGENCIES: NASA, NWS, OFCM, FAA

PRIORITY: HIGH

ISSUE: The inadequate number of upper air observations severely limits the forecast accuracy of wind, temperature and other meteorological parameters. Through the use of data acquisition systems onboard commercial passenger aircraft, this deficiency can be significantly reduced.

DISCUSSION: Through the use of downlinks already in existence or soon to be implemented (ASDAR, ACARS, MODE-S), there is great potential for increasing the number of high quality aircraft observations of wind, temperature and, possibly later, liquid water content, turbulence and relative humidity. These data will be crucial to improving wind and temperature forecasts, especially with implementation of new high resolution numerical models in the next two years. The data can also be used as the basis of a high quality data base which could be accessed by the aviation community.

RECOMMENDED ACTION: Urge the airline community and corporate aircraft operators to equip appropriate aircraft with automated reporting systems (ASDAR, ACARS, MODE-S) on both domestic and international routes.

RESPONSIBLE AGENCIES: Airlines, NWS, FAA, ARINC

PRIORITY: HIGH

ISSUE: What data should be uplinked to the pilot to increase safety?

DISCUSSION: Terminal area weather conditions should be available on a more timely basis to the aircrew. Special alerts, such as the low-level wind shear alert, runway condition, visibility (landing RVR), should be available to the pilot in the cockpit on a near real-time basis.

En route winds are very important to the long-haul operators and up-to-date weather forecasts from a common data base are required. Icing conditions, augumented by PIREPS, and CAT reports should also be represented in the cockpit.

RECOMMENDED ACTION: Establish data uplink requirements sensitive to pilot needs.

RESPONSIBLE AGENCIES: NWS, FAA, NASA

PRIORITY: Requirements - ASAP, implementation with MODE-S

ISSUE: Is flight data recorder information useful for meteorological and safety considerations?

DISCUSSION: Flight data recorder information, especially following a significant meteorologically-related incident, would be useful for determination of atmospheric events preceeding and following the incident. Examples of such incidents could be wind shear occurrences, lightning strikes, icing, clear air turbulence, heavy rain, and others.

Reporting these events and documenting with data from the flight data recorder, especially the advanced digital systems, would augment the data base to assist understanding of these meteorological events.

RECOMMENDED ACTION: FAA should notify air carriers that meteorological events that affect aircraft performance be reported and flight data recorder data obtained.

RESPONSIBLE AGENCIES: NASA, FAA

PRIORITY: Establish near-term information as soon as possible.

ISSUE: Continued funding for CAT detection research.

DISCUSSION:

1. NASA has maintained a continuing effort in CAT detection since the middle 1960's.
2. During 1982, an infrared radiometer was carried aboard the B-57 during JAWS project. Results for microburst detection were encouraging.
3. Plans for 1984 included modification to permit vertical scanning and more tests of CAT detection. Funds/priority not sufficient at present level.
4. CAT continues to be a significant problem in airline operations. Improvements in detection and forecasting accuracy are needed.
5. Should NASA continue infrared evaluation; change direction; or stop and wait for new idea(s)?

RECOMMENDED ACTION: NASA, FAA, DOD and others should assess state-of-the-art and make recommendation regarding continuance or termination.

RESPONSIBLE AGENCIES: NASA, FAA, DOD, NOAA, OFCM (NASA or OFCM LEAD)

ISSUE: What data should be downlinked from the airplane to establish a meteorological data base?

DISCUSSION: The winds and turbulence committee proposed downlinking wind information in the terminal area along with heading, airspeed and temperature if available. If the aircraft has an onboard wind shear alert system, downlink warnings and PIREPS to the ground could assist operations in the terminal area.

Winds aloft along with temperature would assist inputting meteorological information into the NASP data base. AIRREPS would be useful over water. Turbulence information en route would be very important information for broadcast to assist meteorological forecasts.

Water content and temperature would assist icing forecasts, if data could be obtained on a reliable basis.

There does not appear to be a reliable method to detect lightning in the atmosphere. PIREPS, for the near-term, seem to be the best information that can be downlinked. Automated reporting of strikes should be pursued and incidents recorded for analysis.

RECOMMENDED ACTION: Establish data format for downlink transmission, reflecting current meteorological needs. Survey available sensors on complete fleet of air carriers.

RESPONSIBLE AGENCIES: ARINC, NWS

PRIORITY: Establish requirement as soon as possible.

ISSUE: Are PIREPS useful in the meteorological system?

DISCUSSION: PIREPS, in all discussions with the respective groups, were determined to be very valuable if incorporated properly within the reporting system. This information is very time-sensitive and automated reporting would assist dissemination. Quantifying reports on turbulence (CAT) appeared to be the best method for improving forecasting of such events. Cloud information through PIREPS would also assist forecasting of fog and visibility in the vicinity of airports.

RECOMMENDED ACTION: Establish collection method within NWS for timely recording of PIREPS and dissemination to forecasting agencies.

RESPONSIBLE AGENCIES: NWS

PRIORITY: UNKNOWN

ISSUE: Use of Mode-S to transfer weather data.

DISCUSSION:
1. Mode-S provides the only data link available to a large segment/number of aircraft.
2. Uses of Mode-S are not yet defined.

RECOMMENDED ACTION: Conduct studies of beneficial ways to utilize Mode-S to improve meteorological service and weather-related aviation safety.

RESPONSIBLE AGENCIES: FAA, NASA

COMMITTEE: IMPLEMENTATION OF NEW DATA

CHAIRMAN: C. L. CHANDLER

MEMBERS:

JACK BLISS
EDWARD CARLSTEAD
JERRY HOLMBERG
PAUL KADLEC
VERNON KELLER
TED MALLORY
GLEN SHAFFER
JIM SULLIVAN

ISSUE:
A) Missing data on AWOS
B) Winds in the new ATC system

DISCUSSION: This committee feels:
A) That not enough information is available on the AWOS that would justify replacing an existing observer. Data showing the type and intensity of precipitation, such as freezing rain, freezing drizzle, snow, etc., is required. Also remarks that include thunder, cloud types, distant data (such as ridges obscured, clearing west, etc.) are necessary.
B) That improved wind forecasts should be used in the new ATC system for spacing of aircraft. Also, that minimum flying time should be utilized between various cities which exceed 400nm.

RECOMMENDED ACTION:
A) We recommend installation of AWOS at airports that do not have reporting systems. It should not be used as a replacement for existing observers, rather it should be used only as a supplemental aid.
B) That FAA (ATC) integrate winds and minimum time routes in air traffic ser-

vices. Also, train ATC controllers in advantage of minimum time routes as to separation of aircraft and savings in time and fuel. Reduce to a minimum ATC preferred routes.

RESPONSIBLE AGENCIES: FAA, NWS

PRIORITY:
A) Medium
B) High

ISSUE:
A) RVR values of active runway
B) Heavy rain

DISCUSSION: We feel strongly that:
A) RVR reports in the remarks section of the weather sequence report should show values on the active runway and not only on the primary instrumented runway.
B) Heavy rain effects on aircraft performance requires more and intensified research to obtain detailed results.

RECOMMENDED ACTION:
A) Implementation as soon as possible.
B) Continued research

RESPONSIBLE AGENCIES
A) FAA, NWS
B) NASA

PRIORITY: A & B - High

ISSUE:
A) Lightning field reporting and lightning forecasting.
B) Lightning effects on composite aircraft and micro-electronics.

DISCUSSION:
A) Consolidation of reports of lightning by various agencies into one nationwide real-time report available to interested parties.
B) This committee expressed concern on effects of lightning on composite materials in aircraft and how can damage be prevented to micro-processors or other electronic equipment on new generation aircraft.

RECOMMENDED ACTION: Further research be done on lightning effects. FAA/NWS make arrangements to consolidate and distribute lightning reports in near real-time over FAA weather data circuits.

RESPONSIBLE AGENCIES: NASA, NWS, FAA

PRIORITY: Medium

ISSUE: Icing forecast improvements

DISCUSSION: Icing intensity should be better defined for aircraft types. More pilot reports are necessary to improve forecasts. The present format appears to inhibit input at times and should be improved and made simpler. Costs incurred by commercial aviation of inputting data into the system should be addressed.

RECOMMENDED ACTION: Improved icing forecasts should become operational as soon as possible.

RESPONSIBLE AGENCIES: NWS, FAA

PRIORITY: High

ISSUE: Observation and forecasting of wind shear

DISCUSSION: There is a need for airborne wind shear instrumentation. The instrumentation must meet basic requirements. It should:

1. Be capable of providing the safest degree of handling a wind shear in case of inadvertant encounter, and proven capable of safe penetration of wind shear on an approach which will be unsuccessful without its use.
2. Provide the pilot with a continuous quantitative value of the significant hazard ahead, so that the pilot can have qualitative judgment as to whether to continue or abandon the approach.
3. Provide the safest performance after the decision to abandon the approach has been made.
4. Assure the best means of arrival over the threshold with the proper speed which the pilot's runway charts are based upon, and give him quantitative information if the speed is unacceptable.

5. Recommend continual special emphasis on wind shear-related training and education to include: A) the different types of wind shear - what to expect, what to watch for, and what to do; B) update the training information as results become available from research or other sources; C) the use of ground speed during approach; and D) the reaction of the flight director system to different types of wind shear.

RECOMMENDED ACTION: Develop standard procedures approved by airlines and FAA to utilize existing ground speed information currently available on INS-equipped aircraft to avoid wind shear during takeoff and approach. Urge development of airborne wind shear instrumentation for all aircraft.

RESPONSIBLE AGENCIES: FAA, NASA, ATA

PRIORITY: Very High

COMMITTEE: REMOTE DETECTION

CHAIRMAN: BOB SERAFIN

MEMBERS:
- DON CORNWALL
- TONY DURHAM
- BRUCE GARY
- KEN GLOVER
- GREG SALOTTOLO
- C. J. TIDWELL
- KEN WILK

To maintain some continuity, I think I would like to echo what Joe Stickle just said regarding this data base, although I would not like to restrict that data base to be just national, but international, in scope. It seems to me that we have the communications capability. Everyone has a desktop computer these days, and the technology is here. We ought to think about a global data base. With all meteorological data being available to virtually all users, not just the aviation industry, but the public and private sector as well, I am happy that Joe brought that up. It is a shame we were not able to interact with them during this meeting, but we certainly echo that recommendation.

ISSUE: To what extent can radar (NEXRAD) assist in icing forecasts?

DISCUSSION: Super-cooled cloud measurements with radar are difficult. Drops 50 microns in diameter are much smaller than radar wavelengths. NEXRAD is very sensitive. Doppler radar can, through velocity AZMUTH display (VAD) techniques, estimate moisture flux into clouds and precipitation out. NEXRAD office now has no algorithms for icing, but icing forecasting is a NEXRAD objective.

The freezing level in stratiform precipitation can be easily measured with radar.

RECOMMENDED ACTION: Look at existing data sets - cyclonic extratropical storms project (cycles), cooperative convective precipitation experiment (CCOPE), etc. Determine reflectivity and liquid water content relationships. Determine NEXRAD capabilities. Do research now on developing techniques for icing prediction. Consider shorter wavelength radar, if necessary. Develop algorithms for NEXRAD, if possible.

RESPONSIBLE AGENCIES: FAA

PRIORITY: 1 - FOR ICING.

ISSUE: The potential for passive remote sensing.

DISCUSSION: Microwave atmospheric remote sensor (MARS) is a dual wavelength radiometer for measurement of cloud base temperatures, cloud base height and vertical distribution of liquid water. The system is useful for measurements of integrated liquid water and is not sensitive to ice. Its problem is that it provides little information on vertical structure and, therefore, icing conditions as a function of altitude cannot be predicted.

RECOMMENDED ACTION: Continue research on this technique. Include this statement in any aircraft, radar or sounding experiments aimed at comparative system evaluations.

RESPONSIBLE AGENCIES: NOAA, FAA, NASA

PRIORITY: 2

ISSUE: Terminal doppler radar design

DISCUSSION: The major unanswered questions relate to ground clutter, siting, and automation because microbursts are small, short-lived, low altitude, and sometimes weakly scattering. Optimum wavelength is an unanswered question. We considered wavelengths from coherent LIDAR through 10cm radar. This is a System Problem, not just a sensor problem.

RECOMMENDED ACTION: FAA assess fully the capabilities of competing technologies and examination of JAWS data analysis. Proceed with all due dispatch to develop and deploy an effective system.

RESPONSIBLE AGENCIES: FAA

PRIORITY: 1

ISSUE: What are the roles of airborne doppler techniques?

DISCUSSION: Microwave doppler potential has not been fully exploited, but microwave doppler is not going to detect clear air turbulence (CAT).

Continuous wave doppler LIDAR can give short-range advance notice of shear and turbulence. (4 second warning - pseudo quantitative). Pulsed doppler LIDAR will work for CAT and low-altitude wind shear, but it may not be practical for aircraft use.

Combined scanning IR Radiometer and CO_2 LIDAR can be used to estimate Richardson number.

Pulsed microwave doppler may do low-altitude wind shear but ground clutter is a serious problem.

C-band is probably the best wavelength for storm avoidance.

X- or K-bands are better for low-altitude wind shear.

RECOMMENDED ACTION: This is a very important development not ready for operations. Use the NOAA P-3 radar for further testing and evaluation. Build a multi-wavelength, forward-looking radar with state-of-the-art processor and test using ground-based systems.

RESPONSIBLE AGENCIES: NASA, FAA, AIRLINES, NOAA, NSF

PRIORITY: 2

ISSUE: Effectiveness of profilers; wind; temperature and humidity.

DISCUSSION: Mixed opinions exist on this subject. Winds are measured well. Temperatures and humidity have poor vertical resolution. General agreement exists that hybrid system using profilers, satellite and possibly some conventional RAOBS with ACARS and other aircraft-equipped sensors is likely to prove fruitful. Upper-level wind variability (time and space) is of smaller scale than now predicted or available in existing data. Winds over water are very important (WINDSAT).

RECOMMENDED ACTION: Conduct numerical studies to determine improvements on forecasting that will result from profiler deployment. Try to quantify. How good is better? What does it cost? What does it save?

RESPONSIBLE AGENCIES: NOAA, in general. FAA should examine deployment and cost effectiveness for winds and CAT detection along well-traveled routes.

PRIORITY: 1

ISSUE: Measurement of intense localized and transient rain in terminal areas.

DISCUSSION: Combined terminal doppler and 20 GH_Z absorption measurements should be able to measure heavy rains and locate them. Importance of heavy rain or influence on aircraft performance is not clear or well established. If update rates of one per minute or higher are necessary, conventional radar will not be fully satisfactory.

A 20 GH_Z absorption system at airports with automatic weather observation systems (AWOS) may be useful.

RECOMMENDED ACTION: In designing terminal doppler radar, do not ignore heavy rain observations.

RESPONSIBLE AGENCIES: FAA

PRIORITY: 2

ISSUE: Protecting aircraft from lightning strikes.

DISCUSSION: Lightning strike incidents do not always occur where natural lightning has maximum frequency. Some cases are documented well outside of convective precipitation and in stratiform clouds.

Aircraft seem to trigger the lightning. Good E-field observations with penetrating aircraft and radar observations have not been made.

RECOMMENDED ACTION: Design a research program that measures frequency of hits as a function of relative location to convective cells and correlate with ground strikes, and radar reflectivity contours.

RESPONSIBLE AGENCIES: NASA

PRIORITY: 1

ISSUE: The role of NEXRAD in the aviation system for wind shear, turbulence, and short-range forecasting.

DISCUSSION: NEXRAD will be effective in the summertime boundary layer and in precipitation and ice clouds. Effectiveness in super-cooled or warm clouds needs further study. There are now 61 algorithms planned, but they do not address all of the potential applications or objectives of NEXRAD. The user community knows little about its interface with NEXRAD or the products. do not be alarmed! It is premature to begin training now. NEXRAD is aware of this and plans to hold symposiums and training programs as the program proceeds.

RECOMMENDED ACTION: Examine the full potential of NEXRAD for all aviation needs. Proceed with NEXRAD - full speed ahead!! NEXRAD is the most important new system for aviation safety. It will represent a quantum step upward in capability over existing NWS radars.

RESPONSIBLE AGENCIES: FAA, NWS, AIR FORCE

PRIORITY: 1 - #1 over all others.

COMMITTEE: UNMANNED AIRFIELDS

CHAIRMAN: JOANN PAINTER

MEMBERS:
LEO BOYD
BILL DAY
BOB FRITTS
DAVE VERCELLI
FRANK WENCEL

My committee looked at problems and concerns that we have at unmanned airports, and these are areas in remote sites or airports that are unmanned after hours. There are certain periods when the air traffic control only has certain hours of operataion. They may operate from 6:00 a.m. or 8:00 a.m. until 8:00 p.m. or 10:00 p.m. We do have IFR traffic going into these areas. We are concerned with general aviation, business and corporate aircraft and airlines for making flights into these areas. One major concern that we all agreed with was communication. We are concerned with getting information to the pilots of weather conditions in these remote areas. Briefly, we found that we had a lot to talk about in these various committee interactions. We thought, at first, perhaps since we were talking about remote areas, knowing that the money is usually spent in areas of high concentration where you have more traffic, we still want to let people know that we do have problems in these areas. We were gratified to see that many of the committees did take our suggestions and made recommendations concerning some of these areas of concern.

I do want to express our appreciation to Walt Frost and Dennis Camp for the efforts that they have put forth in providing this workshop. It is an excellent opportunity for all of us to get together and interface to express our concerns and to work together to try to meet some of the requirements that we all have. I especially want to thank my committee. They were a great bunch of people, very well qualified, and without them, I could not have done it. Thank you.

ISSUE: Ongoing need for current weather reporting at unmanned airports with approved instrument approaches.

DISCUSSION:

1. EFAS with associated communications problems.
2. AWOS - Planned future distribution.
3. VRS - voiced response service.
4. Standardization - consistent quality.
5. IFR flight without local weather reports and criteria required by FAR Part 91.
6. Economic impact of general aviation on local industrial development.

RECOMMENDED ACTION: Expand present AWOS plan to include all unmanned airports with instrumented approaches. Consider an alternative federally funded reporting device that could optionally be offered for purchase by users. Supplement with 800 code national voice response service. If unfeasible, substitute 900 code telephone service with revenue passed on to FAA.

RESPONSIBLE AGENCIES: FAA, NWS

ISSUE: Notification to pilots of hazaradous ground and/or flight operations resulting from atmospheric electricity and lightning events occuring at/in vicinity of unmanned airfields.

DISCUSSION:

1. Research being done on composite aircraft components.
2. Lightning detection via AWOS.
3. BLM/DOD lightning reporting systems.
4. R & D in ground operations during lightning conditions.

RECOMMENDED ACTION:

1. Incorporate lightning detection error into AWOS package.
2. Include valuable AWOS-generated remarks (e.g., lightning NW)

RESPONSIBLE AGENCIES: FAA

ISSUE: Detection of icing conditions at unmanned airfields

DISCUSSION:

1. Braking action problems under various icing conditions.
2. Awareness of icing problem of:
   - Observation
   - Communicating
   - Reporting

   At unmanned airfields.
3. Inconsistencies in terminologies of defining and describing icing conditions.
4. Use of NWS co-op reporting system as an added resource in identifying icing conditions.
5. Need to enhance pilot education regarding icing conditions and the hazards of ice (both on ground and in-flight).
6. Need for improved short-term icing forecasts.

RECOMMENDED ACTION:

1. Enhance distribution of icing research data through continuing education programs for operational pilots.
2. Develop more precise forecasting methods with special emphasis on in-flight icing conditions in remote areas and surface/low altitude icing conditions at terminals.

RESPONSIBLE AGENCIES: FAA, NWS, NASA

ISSUE: Providing winds and turbulence data for unmanned airfields.

DISCUSSION:

1. EFOS System
2. Hazardous low-level winds
3. Wind socks and UNICON advisors
4. Visual aids such as black and white checkerboards system tested in past.
5. Local conditions conductive to generating wind hazards for unmanned operations.

RECOMMENDED ACTION:

1. Establish lighted wind socks at all public-use airports.
2. Develop and standardize visual aids for weather information at unmanned airfields, e.g., tetrahedrones, socks, etc.
3. Educate the general aviation pilots in wind and turbulence hazards beyond the current emphasis on wake vortices.

RESPONSIBLE AGENCIES: FAA, NWS

ISSUE: Improve the standards of pilot and controller meteorological knowledge.

DISCUSSION:

1. Difficulties in implementing state-of-the-art technology attributed to weakness in pilot/controller knowledge.
2. PIREP problems were discussed as addressed by the FAA/NWS through the national airspace plan.
3. En route weather advisory service (EWAS); its strengths and weaknesses as a vehicle for PIREPS, forecast, en route, severe weather, etc.
4. The FAA ATC controller's responsibilities and priorities as regarding the distribution of weather information.
5. Current FAA pilot examination
6. Need for controller awareness of pilot weather data requirements.

RECOMMENDED ACTION:

1. Require the applicant to pass a specific section of meteorology as part of the private, commercial and instrument examination.
2. Ongoing meteorological instruction for controllers with special emphasis on local phenomena as applied to air operations at unmanned airfields.

RESPONSIBLE AGENCIES: FAA, NWS

COMMITTEE: ENGINEERING ANALYSES

CHAIRMAN: RICHARD L. SCHOENMAN

MEMBERS:

ROLAND BOWLES
HO-PEN CHANG
KIM ELMORE
TOM GENZ
JOHN HOUBOLT
K. H. HUANG
JOHN KLEHR
JOHN PRODAN
BEN TOLLISON
BOB SKONEZNY

It appears that the crowd is thinning out a bit, but there are a few of you hearty souls still here. I would like to thank Dr. Frost for inviting me to come down and participate in this session. I think, maybe, I have been a listener more than a Chairman because I found that you folk speak a different language than I do. We have our own set of terminology and acronyms, and it took me almost a day to figure out what all the different wording was that you were actually using. I will say, again, that I feel this was a very interesting and educational exercise for me. I thought maybe I was alone, but Bernie Etkin and I were sitting here together discussing this same subject, and he told me that he was really lost about the first day when all of that terminology was being used.

I would like to spend just a minute and tell you a little bit about the make-up of our committee, because I think it is important with regard to the subject matter we were asked to cover. In our particular group of 10 people, we had three pilots. We had a commercial airline pilot from Northwest, an FAA pilot, a commercial test pilot, a gentleman from the simulator manufacturing area, a simulation expert from NASA, and myself, from the aircraft manufacturer's community. I am primarily involved in the flight controls area and not really very knowledgeable about weather situations, except from my own private experience as a pilot. We had a couple of fellows from private research: one from the university research area; we even had a student from UTSI. What we found ourselves doing really relates more to the evaluation or identification of problems we say as a group. As you can probably recognize, most of the people on this committee were probably the users of information in one form or another, rather than the generators of that information. We found ourselves trying to address the problems of engineering analysis, but, generally, slipping on towards the identification of problems that we saw as a part of the user community. A user of information in our area, of course, is regarding our interest in 3-D and 4-D navigation, which is going to be a part of the National Airspace Program as it develops; and the weather information, particularly, the prediction of winds aloft, are very important with regard to operating of these big transports in a fuel-efficient manner.

<u>ISSUE</u>: Better temporal and spacially resolved weather information is required for forecasts, observations and information updates consistent with broad-based support of the operational aspects of NASP. Timely and reliable weather data acquisition and dissemination to all elements of the system is the key.

<u>DISCUSSION</u>: A number of issues/requirements were identified during a diverse and lively discussion. Chief among these are:

A) More accurate and timely forecast and update of winds aloft.
B) Improved utilization of PIREPS/AREPS as regards icing.
C) Enhanced cockpit access to weather information:
   –Wind shear alert and warning;
   –Winds, turbulence and icing parameters;
   –Weather contour maps (CDWI);
   –Mode-S environment.
D) Expand availability and use of aircraft-derived data, e.g., ACARS, etc.
E) Exploit opportunities afforded through remote sensing;
   –Ice forecast;
   Is liquid water content needed?

There was a general agreement that more accurate and reliable forecast implies better sensing. Increased number and utilization of rotor-craft for missions of varying complexity are expected to pose special requirements on NASP.

<u>RECOMMENDED ACTION</u>: Continue analysis, refinement and implementation of the NASP, including broad aviation community input to establish utility of particular weather products, services and parameters based on need, cost and technical achievability.

<u>RESPONSIBLE AGENCIES</u>: FAA, NWS and other government agencies are required.

<u>PRIORITY</u>: 1

<u>ISSUE</u>: Continuation of JAWS and other wind shear-related data analysis is necessary. Transfer of current information to the aviation community, both military and commercial.

<u>DISCUSSION</u>: Generally recognized that there is still a need to gather data to characterize low-altitude wind shear, especially the microburst phenomenon. In addition, a careful analysis of existing data is required consisting of simulation modeling by industry and NASA. These models are necessary for flight crew training purposes and to establish standards for developing systems which require FAA certification.

<u>RECOMMENDED ACTION</u>: Fund NASA to analyze existing JAWS data and develop appropriate simulator models for use in real-time simulations. Distribute data in-hand to industry for purposes of incorporation into flight crew training simulators.

RESPONSIBLE AGENCIES: NASA, FA

PRIORITY: 2

ISSUE: What are the effects of heavy rain on the flying qualities of the aircraft in addition to wind shear? What are the effects on engine thrust in heavy rain? Are angle of attack sensor accuracies affected by heavy precipitation?

DISCUSSION: There is work yet to be done in understanding the effects that heavy precipitation has upon the flying ability of aircraft in heavy rain. It may have been a factor, along with wind shear, in Pan Am- New Orleans 727 crash. Leading edge high lift devices may be adversely affected by heavy rain as well as the effect of increasing drag. The question of how engine thrust is affected by rain was raised. Another problem may be that angle of attack vanes are affected by heavy rain. This would mean that the pilots would not know how close to stall the airplane actually is. This, combined with the possible adverse effect on leading edge high lift devices, could mean real trouble for penetration of heavy rain areas.

RECOMMENDED ACTION: More study is needed on the overall effect of heavy rain on airplane performance. Since the angle of attach indicator is necessary for stall warning devices, and stalls close to the ground are extremely dangerous, a wind tunnel study should be done, and could be done well enough since angle of attack vanes can easily be placed in wind tunnels. Since two crashed, Allegeny-Philadelphia and the Jordanian flight, look like they may have followed stalls, the effect on angle of attack accuracy should be studied first. It seems, also, to be the most feasible.

RESPONSIBLE AGENCIESA: NSF, NASA,ALPA, NCAR.

PRIORITY: 3

ISSUE: Icing (ground and flight) continues to be a problem in aviation. A review and validation of icing conditions is needed as the industry progresses into areas of new technology.

DISCUSSION: The use of new materials and construction techniques may impact how we deal with the icing problem. In-flight icing as well as ground snow and ice accumulations continue to present hazards to aviation. Current technology, such as high capacity bleed air systems, may not be available or even work on the next generation of aircraft and some method other than visual inspection may be needed to determine if ice/snow is accumulating on the ground.

Some concerns are that icing certification efforts by both the large and small aircraft manufacturers are limited by their ability to perform any theoretical analysis. Another concern is that we not abandon a conservative philosophy on aircraft icing in the pursuit of more efficient operations. Finally, the transfer of new technology from the research efforts of NASA and others must be encouraged to aid in the development of more efficient aircraft.

RECOMMENDED ACTION: The current efforts of FAA and NASA in the research and development areas must continue with coordination to eliminate duplication, fully funded to assure completion, and completed as rapidly as possible. The planning effort by the Office of the Federal Coordinator of Meteorology (OFCM) should be completed to give an overall view of the total government effort in the icing area.

RESPONSIBLE AGENCIES: FAA, NASA: Defined R & D needs OFCM: Government Plan NSF

PRIORITY: 4

ISSUE: Helicopter operations in some segments of aviation are vital. Inevitably, operations in icing conditions limit the utility of the helicopter. Therefore, a process for helicopter icing certification is needed.

DISCUSSION: Special applications of helicopter operations dictate the use of helicopters in all types of weather, which include icing. The military's need to operate anywhere/anytime, as well as emergency missions out to offshore oil platforms, are just two examples of these applications.

A variety of applications, such as boots and electrothermal methods, are being examined. Remote sensing applications also need to be examined.

RECOMMENDED ACTION: Complete the necessary work and establish the criteria for helicopter icing certification.

RESPONSIBLE AGENCIES: NASA, FAA, Industry: Research and Development FAA: Rulemaking to codify the process.

PRIORITY: 5

ISSUE: From a flight operations and training point of view, how far away from a thunderstorm must an aircraft be to be free of the threat of lightning strikes?

DISCUSSION: Lightning strikes are more common than previously believed; and it was stated that there is evidence that the aircraft, itself, may trigger the discharge. Many cases of lightning occurrence in stratiform clouds were discussed. Most occurred near the freezing level or in stratiform clouds between thunderstorms. Operational criteria for thunderstorm avoidance were discussed. 5 miles upwind side, 1 mile on the downwind side, stay out of the overhang, etc. It was stated that a pilot will not be able to avoid all lightning by just avoiding thunderstorms. In very turbulent regions, however, the charged particles are not able to separate, and little lightning occurs.

RESPONSIBLE ACTION: Flight operations review the criteria for thunderstorm avoidance; training for lightning strikes be included in flight simulators to provide the strong blinding, disorienting, and startling effect.

RESPONSIBLE AGENCIES: ATA, ALPA.

PRIORITY: 6

ISSUE: Frequency of weather observation should be increased with low-cost instrumentation with the objective of improved short-term forecasting.

DISCUSSION: More reliable weather forecasts could result in reduced requirements for weather-related reserve fuel. There is still, however, an interest in cost-effective fog dispersal.

With some limitations, AWOS seems to be a way to obtain more frequent and reliable data for improved forecasting. To retain accuracy, ceiling height is held to 5000 feet with ± 10% error. For forecasting purposes, ceiling heights to 10,000 - 20,000 feet are needed.

Some concerns relative to AWOS are down time and maintenance, i.e., when should the glass be cleaned and how? A more basic concern is the absence of observers' remarks as to verbal description of conditions around the observation site and the nature of the trends. These would be noted at a manned station. This could be helped, in part, with video transmission; however, TV may be more expensive than retaining a manned station.

RECOMMENDED ACTION: Continue to observe the AWOS and other automated systems that are being used on a trial basis to ascertain its cost-effectiveness; but, more importantly, to see if more reliable weather information is, in fact, obtained.

RESPONSIBLE AGENCIES: FAA (Neal Blake)

PRIORITY: 7

ISSUE: Need exists for continued research at NASA Langley research center, using the F-106B aircraft with special instrumentation, to determine the characteristics of the lightning hazard, especially in the low-altitude regime.

DISCUSSION: Although a large number of strikes have been measured, most have been at high altitudes (above 20,000 feet) and are, therefore, of the cloud-to-cloud type, which are probably triggered by the aircraft, itself. Tests are necessary at lower altitudes to measure cloud-to-ground discharges. While 2×10^{11} amps/sec current rates are used as an industry criteria. Rates of this magnitude have already been measured on the F-106 leading to the conclusion that the criteria may not be high enough. Ground analysis of the data gathered needs to be generalized from the F-106 to today's aircraft design and construction, i.e., consideration of composite materials strength degradation, micro-electronics susceptability to lightning-induced pulses through shielded and/or unshielded wire, and effect upon fiber optics performance.

RECOMMENDED ACTION: The NASA research should be continued relative to both a conclusion of the flight-phase and the ground-phase analyses. Early and strong consideration should be given to the use of the F-106 as a flying laboratory with respect to experiments in both composite materials and micro-electronics carried in, or as a part of, external stores.

RESPONSIBLE AGENCIES: NASA, DOD (USAF)

PRIORITY: 8

ISSUE: With the advent of new meteorological and environmental information about lightning and the extended use of composites and micro-electronics, the existing certification proccedures and criteria need reviewing for adequacy and applicability.

DISCUSSION: As a direct result of the F-106 storm hazards program, more information is known about lightning and its effect upon aircraft–at least, the F-106 technology. However, new material (e.g., composites) and new systems (e.g., all-electric aircraft and fly-by-wire) appear to be in the future for aircraft design and construction. The impact of these new approaches must be integrated with the certification process to validate these proceedings or to determine new ones. The present approach to meeting the certification requirements appears to be the over-design technique–which is costly in weight, material, time and money.

RECOMMENDED ACTION:

1) Continue the present FAA review of the currently-used practices.
2) Accelerate the use of the F-106 as a flying laboratory for lightning effect on the performance of composite and fly-by-wire systems.

PRIORITY: 9

ISSUE: Detection of lightning from the ground and at flight altitudes is required to establish avoidance procedures.

DISCUSSION: A brief discussion of the various types of lightning detection systems revealed that the ground-based systems performed well but the airborne system had difficulty in determining the true range to the lightning activity. At unmanned airport stations, it was felt that a lightning detection system be included in the automatic weather observing stations (AWOS). Satellite-based detection systems are now being tested and validated.

RECOMMENDED ACTION: A more range-reliable airborne lightning detection system should be developed for thunderstorm avoidance at altitude.

RESPONSIBLE AGENCIES: NASA, FAA, NOAA

PRIORITY: 10

ISSUE: Lightning, as an operational hazard, does not generally exist apart from other hazards such as heavy rain, hail, turbulence, strong vertical and/or horizontal currents, etc. Yet, it is often studied as if it were.

DISCUSSION: Many researchers have concentrated on the study of atmospheric electricity and/or lightning to the exclusion of other meteorological hazards. For a convective system, many of these phenomena are present and there is quite probably an interaction among them. A wealth of data exists on aircraft penetrations of hurricanes and thunderstorms that should provide an initial source of information to be used in the analysis of the convective system hazards.

RECOMMENDED ACTION: Accelerate the programs underway in the meteorological research community to correlate the severe weather phenomena which have been observed and studies in the past research program, e.g., TRIP (thunderstorm research international program); SESAME (Severe Environmental Storm and Mesoscale Experiment); Rough Rider, NHRE (National Hail Reserach Experiment), F-106 storm hazards, etc.

RESPONSIBLE AGENCIES: NSF, NSSL, NOAA, NCAR

PRIORITY: 11

COMMITTEE: METEOROLOGICAL SUPPORT WITHIN THE NASP

CHAIRMAN: JAMES DZIUK

MEMBERS:
ED FERGUSON
SEPP FROESCHL
KELLY KLEIN
COLIN NOBLE
GENE WILKINS
ANDY YATES

Representing the Meteorological Support Within the NASP Committee, I would first like to thank all the committee members for their support in interactions which we have had, as well as the rest of the staff here and wonderful people from NASA that sponsored this with us.

ISSUE: There is a need for more PIREPs and AIREPs to provide information on: icing conditions, turbulence; winds aloft; temperature; low-level wind shear.

DISCUSSION: The need for airborne detection and reporting of the phenomena listed above is acute. Significant improvements to forecasts and aircraft safety cannot be made until the density and reliability of the data base is increased.

The problems associated with obtaining PIREPs and AIREPs appear to be focused in communication shortcomings. Since many of the PIREPs on more hazardous conditions come from pilots flying under instrument flight rules, tower and en route controllers, rather than FSS specialists dedicated to PIREPs are the receivers of these reports. Controllers have limited access to the established PIREP distribution network. They generally must relay the report orally to someone else in order for it to get into the system. The significace of the report is not always readily apparent to a busy controller. Many times, the pilot provides significant weather information as part of a request for a change in route or altitude. This is not usually considered as a PIREP by the controller. He may keep it locally for his own use, relaying it to others who fly through his area. Most of the data contained in PIREPs and AIREPs is very perishable and must reach the meteorologist in a timely fashion if he is to make use of it. The PIREP problem is compounded by the Pilot's apparent reaction to the ATC system's inability to handle PIREPs according to some previous standards. They have, in many cases, stopped reporting. Also, some airlines have kept their weather reports to themselves in the conus. The AIREP distribution problem in many parts of the world also has a significant impact on the wind and temperature data base. Greater automation on the distribution and processing of AIREP data would be of considerable benefit.

RECOMMENDED ACTION: There is a need to improve the handling of PIREPs in the NAS. There is also an urgent need to get automation of AIREPs through the implementation and expansion of the AMDAR/ACARS systems to automatically sense and communicate weather data from aircraft into the weather data base bypassing two of the current PIREP bottlenecks, pilot and controllers.

RESPONSIBLE AGENCIES: NOAA

ISSUE: There is a need for more accurate turbulence forecasts. There is also a need to forecast mountain waves.

DISCUSSION: Turbulence and mountain waves are essentially mesoscale phenomena and increasing the accuracy of turbulence forecasts and forecasting mountain wave requires:

> Denser, reliable observing network. This means that airborne sensors with automated reporting, manually relayed PIREPS, ground based sensors, such as the vertical profiler, space based sensors (existing and proposed) and existing observations must be integrated into a mesoscale network of data; and techniques must be developed or refined to assimulate and use the information.

RECOMMENDED ACTION: Those programs and research leading to an improved mesoscale upper air observation network must be continued to prove concepts confirm effectiveness, and result in implementation.

RESPONSIBLE AGENCIES: NOAA

ISSUE: There is a need for more accurate forecasts of winds aloft.

DISCUSSION: Improved accuracy of winds aloft forecasting can significantly improve the efficiency of operations within the national airspace system. Optimal flight path selection and improved flow management are directly dependent upon the accuracy of the forecast wind information available. The accuracy of winds aloft forecasts is dependent upon the accuracy, amount and spatial distribution of wind measurements and the capabilities of the forecast model.

RECOMMENDED ACTION: The most immediate improvement in the winds aloft data base can be achieved through increasing the number of PIREPS and AIREPS in the data base. This can be done today through the AARS systems. Every effort should be made to convince operators of INS equipped aircraft to participate in this effort to improve the global winds aloft data base. Improvements to the models being used to process this data must continue.

RESPONSIBLE AGENCIES: NOAA, NWS, FAA, NASA and other world meteorological authorities.

PRIORITY: 1

ISSUE: There is a need for more accurate short-term forecasts.

DISCUSSION: If the increased airborne reports issue is resolved, an improved data base on which to base in-flight advisories and short-term forecasts will exist. In this event, existing detailed advisories from center weather service units (CWSU) will be improved. Automated surface observations, frequently updated, will also provide an improved data base for 0 - 12-hour en route and area forecasts.

RECOMMENDED ACTION: The requirement for any additional "Short-Term" forecasts should be explored and defined. Existing "Short-Term" forecasts and advisories should take advantage of improvements in the airborne and automated surface observation systems.

RESPONSIBLE AGENCIES: FAA, NWS

ISSUE: There is a need for more and better weather sensors to observe surface conditions and upper-air phenomena.

DISCUSSION: More accurate and frequent measurements of weather phenomena are required to support the desired changes in forecast accuracies, forecasts of phenomena not presently forecasted, and the operational safety and efficiency of the national airspace system.

The planned increase in surface observations through the implementation of automated sensing systems will significantly increase the amount and quality of surface observations data. The NEXRAD and terminal NEXRAD program will greatly increase the upper-air information data base. However, the areas still not adequately measured are the winds aloft, temperatures and liquid water content. There is more than one method to achieve some of these measurements. Development and implementation of sensors must be accompanied by continuing trade-off analyses to determine proper balance of forecasts model capability, ground-based sensors and aircraft-based sensors.

RECOMMENDED ACTION: Development and implementation of the NEXRAD, terminal NEXRAD and automated surface sensors should continue as a high-priority program. Development of suitable ground, air and space-based upper-wind temperatures and liquid water content sensors should be given priority. Trade-off analyses should be carried out in parallel.

RESPONSIBLE AGENCIES: NASA, NOAA

ISSUE: There is a need for more accurate aircraft icing forecasts.

DISUCSSION: Aircraft icing is a high-percentage fatal safety hazard. More accurate icing forecasts are required to minimize this hazard.

More information on the physical properties of clouds is needed before a significant improvement in icing forecasts can be realized. The FAA's current icing characterization and certification programs could also affect the content and utility of icing forecasts by requiring that liquid water content be specified.

RECOMMENDED ACTION: Cloud physics studies should be emphasized and work should proceed on developing methods for measuring the liquid water content of clouds. These data must then be communicated in a timely fashion for use as input to icing forecasts and modeling efforts.

RESPONSIBLE AGENCIES: NOAA, FAA, NASA

ISSUE: The need for current weather information by operators, users, and supporting meteorologists, coupled with the expected increases in available data will require an improved communications capability.

DISCUSSION: Aviation weather observations, both surface and airborne, will increase by many orders of magnitude in the near future. Examples of these voluminous observations are manifested in the approximately 1,000 automatic weather observation systems, NEXRAD doppler radar network and low-level wind shear advisory systems and the many other automated sensor systems in the development stages. These data cannot be manually sampled as in the past with the paper teletype. Most will be unseen in a computer data base until requested or automatically retrieved when certain weather parameter limits are exceeded. This explosion of meteorological information will require user friendly software, powerful processors, and a communications sytems that will be reponsive.

RECOMMENDED ACTION: A system must be developed so that the users of meteorological information have available to them the most current pertinent information. These users include pilots, controllers and meteorologists all associated with the national airspace system. The system must be able to exchange alpha-numeric and graphic data in a timely fashion and be available on request to pilots. All meteorological information within the national airspace system should be shared and distributed by all.

RESPONSIBLE AGENCIES: FAA, NWS

COMMITTEE: ATMOSPHERIC ELECTRICITY AND LIGHTNING

CHAIRMAN: ROBERT FEDDES

MEMBERS:

RICHARD CALE
NORMAN CRABILL
MAJ. ROBERT KOROSE
JEAN T. LEE

What we did in the Atmospheric Electricity and Lightning Committee, was to meet with all five committees and came up with five action items. It is quite interesting to note that without consulting the 1979 report, we had exactly the same items. That is rather interesting, and based on that report, and the activity that has been taken since that report, we prioritized our items accordingly. Throughout many of the committees with which we met, support to research seemed to be the main theme.

ISSUE: Cloud-to-ground lightning location are routinely collected by and for several agencies across the country. They are not, however, routinely consolidated and made available to all prospective users.

DISCUSSION: Many users, both in aviation and other concerns, could benefit from timely and standardized consolidated data presentations. The NWS western region has begun consolidating and presenting BLM lightning information on the AFOS system. Results appear promising and accurate. This could possibly be adapted as a model for a nationwide communication and dissemination system.

RECOMMENDATION ACTION: Continue to develop and evaluate the NWS western region's collection and display of this information on AFOS. Develop a standardized collection and timely dissemination system nationwide.

RESPONSIBLE AGENCIES: NWS

PRIORITY: LOW

ISSUE: Detection of lightning-strike potential on composite aircraft may be desirable.

DISCUSSION: The effects of lightning on composite aircraft is generally understood and basic lightning hardening schemes have been developed. However, fleet-wide experience of aircraft with such structures in lightning-strike events is needed to fully assess their adequacy. Pending such assessment, such aircraft should strive to avoid lightning strikes through detection and avoidance.

RECOMMENDED ACTION: Develop suitable in-flight probability-of-strike instrument for use in reducing the number of direct strikes to such aircraft.

RESPONSIBLE AGENCIES: FAA, NASA, DOD

PRIORITY HIGH

ISSUE: Lightning at unmanned airfields and the effect on ground operations and traffic is a problem.

DISCUSSION: The need for lightning detection on unmanned airfields would be an aid to general aviation. Some type of instrumentation to determine lightning activity would be helpful and a method to distribute the information would be needed. The equipment should be able to provide both direction and distance of strike information. Cost of the program would have to be modest.

RECOMMENDED ACTION: Investigate the feasibility of incorporating lightning detection equipment into proposed automated weather observing stations (AWOS) to include a communication of the information in real-time to the user.

RESPONSIBLE AGENCIES: FAA

PRIORITY: LOW

ISSUE: Interface aspects of atmospheric electricity/lightning and remote detection systems.

DISCUSSION:

1) Statistical analysis indicate that aircraft structures damage costs due to lightning strikes are substantial, and in the case of helicopters, may even be life-threatening.
2) Research on the incidence of lightning indicates it cannot be attributed to any single type of circumstance or atmospheric process.
3) Coordinated systems such as satellite and ground-based sensors can provide extensive synoptic coverage of electrical threat areas on a real-time basis.

RECOMMENDED ACTION: Correlate the meteorological record of damage occurrences with the available archives of lightning data to develop prediction models which may be useful for avoidance or, at least, for minimizing operational hazards associated with atmospheric electricity. Separate fixed wing and helicopter.

RESPONSIBLE AGENCIES: FAA, NASA, DOD.

PRIORITY: MEDIUM

ISSUE: To understand the lightning mechanism: characterization of lightning at all levels and determine its effect on composite aircraft of the future.

DISCUSION: Some information is being determined by the continuing research into the characterization of lightning. The research should be focused on determining and understanding the cause of lightning. The current programs underway appear to be addressing the major issues.

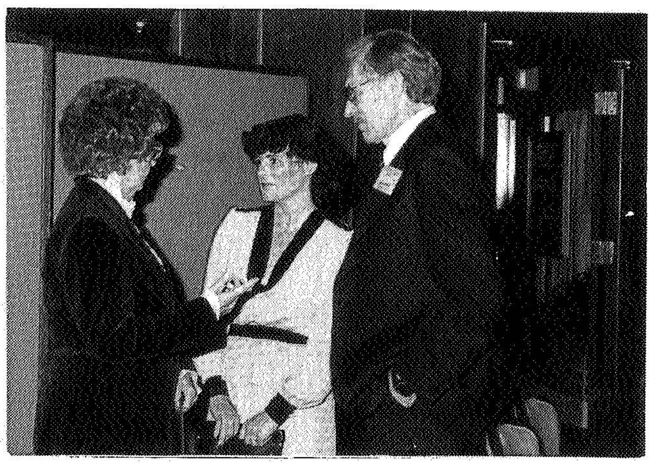
Collection of data must be increased from the various available sources and applicaltion of this data to determine effects on composite materials and digital systems continued.

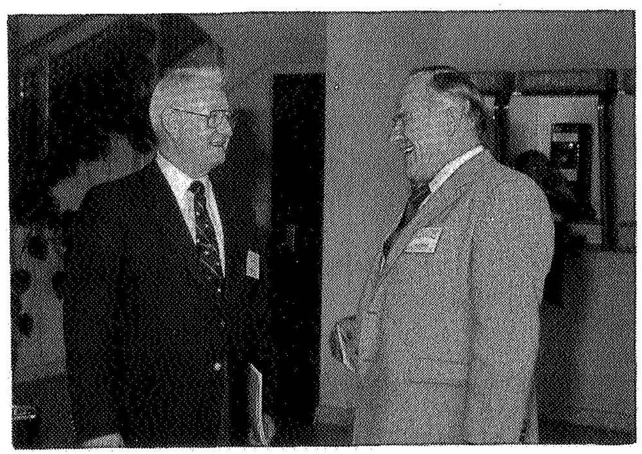
RECOMMENDED ACTION: Continued emphasis should be placed on understanding the impact of lightning on composites and digital systems with simulation models developed to generalize lightning effects on new generation aircraft.

RESPONSIBLE AGENCIES: NASA, DOD, FAA.

PRIORITY: HIGH

SECTION VIII CONCLUDING REMARKS





CONCLUDING REMARKS

DR. FROST
At this time in the program, I would like to thank all of you for being here, and to call upon the various members of our Organization Committee to see if they have any concluding remarks. I am going to start with Dan Bellay.

DAN BELLAY
I would like to say that before coming here, I was skeptical as to whether there would be meaningful dialogue between all of us. I come from the Navy, and we are austere when it comes to travel funds; therefore, this concern was in the back of my head. However, having been here, I truly acknowledge that this is a productive way for people in industry, research, operations, and government to get together and exchange ideas. Even a more fundamental note is just the exchanging of information with people for further dialogue to continue throughout the years. I have been pleasantly surprised and hope that, perhaps, next year I can also attend. Thank you.

DR. FROST
I would like to ask Charlie Sprinkle from NWS if he would make a few concluding remarks.

CHARLIE SPRINKLE
Thank you, Walt. A lot of us have been here since Sunday and we are flat-out tired. I don't think you work many places as hard as you do here, where you go 12, 14, or 16 hours a day. But, like Walt says, if you are not working, what would you do? So, very quickly, I would like to thank all of you who have attended, for your attention and hard work during these sessions. I think it was very productive. I would also like to thank all of the people behind the scenes, especially the gals who did the viewgraphs very hurriedly this morning, and for all of Walt's and Dennis's efforts. They are the ones who do almost all of the work. The Organization Committe members who are away from here have very limited input into this; but we do try to help. A special thanks to Linda Hershman, who outdoes herself each and every year in helping us all ease into here and ease out. Thank you, Walt.

DICK TOBIASON
Obviously, we want to thank Walt, Linda, the Dean, and everyone who works very hard here at UTSI to put this on. I think Walt does more of the agenda definition than anyone else. We also want to thank Marshall Space Flight Center in the form of Dennis Camp and his bosses for continuing to support this idea. It is a fairly unique thing that a Space Flight Center would support a thing like this in aeronautics in NASA. The Organization Committee as Charlie has said, does not do an awful lot of work. We send them money, pat them on the back, set up definitions as to when we are going to meet and a few other things like that; otherwise, the rest is done by Walt and Dennis. I have to thank Linda for her smiling attitude and getting things done. I did make a comment to Tom Genz and Bill Day to pass on to Dan Sowa our best regards for his recovery in his health. We would like to get Dan here next year before he retires. I think the workshop always is productive. We are going to put together a little fact sheet that explains the definition of some of the acronyms. Each agency should write up something outlining what will be done in the areas of interest in each of these groups. Then to reflect on those fact sheets what we heard out of this workshop. They would help us in being more productive here. Many of these programs have come a long way, and we want to be aware of the updates on these things.

Many factors are not represented here this year that should be. We hope to get more attendance from general aviation committees, such as computers, the small aircraft manufacturers, GAMA, AOPA, etc. We need to keep this in mind to get these people here. The National Science Foundtion should be represented here. We also need to do a better job of looking at the meteorological data to see what we are doing wrong within our aviation systems from a meteorology point of view. We should have a task on this next year. We need to take a better look at the use of Safety Board data; i.e., the aviation safety reporting system. There are about 25,000 reports and a good chunk of those are weather related, and the incidents are forecasters of potential accidents. We should have some sort of paper written before the fact to describe the weather problems we are now seeing either as incidents or accidents. We could do that on an international level if we were real clever, to echo one of Bob Serafin's ideas. I would like to recognize our three friends from Australia, who have our Americas Cup. Some of us are going to come down and talk to you next March, because you have indicated an interest in putting on some sort of workshop like this, and we would be delighted to come down and help you. Dennis and Walt are also perfect attendees, along with Bill Melvin, Jim Luers and Andy Yates. We have enjoyed this, and feel it has been very productive, once again.

DR. FROST
Before Dennis comes up here, I would like to ask Manny if he has any comments to make?

EMANUEL BALLENZWEIG
The Office of the Federal Coordinator for Meteorology is very glad to have had the opportunity to help sponsor this meeting as well as participate. The interaction between the various groups was great. As was mentioned, I think some of the best interaction occurred in smaller groups that were not established by Walter and company, in setting things up. I do not think that the interaction is over yet because we did not get a chance to discuss the comments, issues, and recommendations that were presented today. I would like you all to go home and review this, and if you have any comments, please send them to Dr. Frost or Dennis Camp. I am sure that it will be helpful and help shapen the proceedings. Thank you all.

DR. FROST
Dennis, would you like to make a few comments at this point?

DENNIS CAMP
I would like to comment on something Dick just mentioned, and something we do intend to do this time. We want to get out a summary of at least the Committee Chairmen's Reports to each of you within a very short period of time. It will be in a draft form to let you see what was discussed. Some of the Chairmen made comments that they did not present all of the recommendations, so I am sure that you will be interested in seeing the others. The full proceedings we hope to have out quicker this year, and that is the reason we tried to go with a format on the Committee Chairmen's Reports. This is something we want to have in as good and concise manner as we can. The comment that I generally make at the close of the workshop and will make at this time is: If you have some bad remarks you would like to make about the workshop, make them to me or Dr. Frost; if you have good remarks, spread them around to everyone you can. Thank you, because without you this workshop would have been a failure.

DR. FROST
In terms of where we go from here, we will take the various forms which the Committee Chairmen have filled out, and along with these recorded sessions, which will be transcribed, we will begin to put the proceedings together. We certainly hope to have the proceedings out much sooner this year than we did last year. I would like to ask Linda if she has any comments to make to the group in terms of helping you to get the proceedings ready? I found that Linda is such a tremendous public speaker, I am going to let her do it all in the future.

LINDA HERSHMAN
Once again, I must tell you what a pleasure it is to work with such a courteous and helpful group during this workshop. I don't know exactly what Dr. Frost has actually covered, but anyone who has had anything at all to say at this workshop, I would like a written copy of it. If you have prepared any reports, I also need copies of those, as well as copies of viewgraphs used in your presentations or any other material of importance, such as slides, photographs, etc. I will have your group photographs mailed out to you as soon as they are reproduced. You have been a terrific group, as usual. These are three very exciting days in my year, and I thank you for them.

DR. FROST
Well, that brings us to a close. I was pleased with the new approach of using forms for the Chairmen to fill out. If you have any comments on how we might improve those, we would be glad to hear them. We do need the small aircraft manufacturers here as well as helicopter people and corporate airlines. Although we have some representation in that area, we would like more. It is not because we didn't try. We made many contacts, but have not been too successful in getting them here. I think we will get very good support now from the Coast Guard through Mont Smith, who told me he was impressed with the workshop and would be sure we had better representation from the guys that fly in that terrible weather off the coast, in Alaska, and in places like that.

Well, it is getting late and I don't want to spend any more of your time. I do want to thank all of you for coming to the workshop. A lot of people have been favorably impressed with the workshop and have made very kind comments to us; but you must bear in mind that it is your expertise we uti-

-lize in making this successful. What you are really enjoying when you come here is the opportunity to talk to some of the people who are leaders in their respective fields. Although most fields represented are similar, each perspective is different, and this workshop gives us an opportunity to discuss these differences and the needs of each. If you didn't come, we couldn't accomplish this, so thanks a lot!

APPENDICES

APPENDIX A
LIST OF ACRONYMS

ACAR	ARINC Communications Addressing and Reporting System
ADI	Attitude Display Indicator
ADAP	Airport Development Aid Program
ADP	Advanced Development Program
AEDC	Arnold Engineering Development Center
AEH	Atmospheric Electricity Hazards
AEHP	Atmospheric Electricity Hazards Protection
AFFDL	Air Force Flight Dynamics Laboratory
AFGL	Air Force Geophysical Laboratory
AFOS	Automation of Field Operations and Services
AFTN	Aeronautical Fixed Telecommunications Network
AFWAL	Air Force Wright Patterson Aeronautical Laboratories
AGL	Above Ground Level
AIM	Airmen's Information Manual
AIRMET	Airman's Meteorological Information
ALPA	Air Line Pilots Association
ALWOS	Automatic Low-cost Weather Observing System
AMDAR	Aircraft Meteorological Data Relay
ANGB	Air National Guard Base
AOPA	Aircraft Owners and Pilots Association
APU	Auxiliary Power Unit
ARF	Aviation Route Forecast
ARINC	Aeronautical Radio Incorporated Communications System
ARSR	Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ASD	Aeronautical Systems Division
ASDAR	Aircraft/Satellite Data Relay
ASI	Airspeed Indicator
ASR	Airport Surveillance Radar
ATA	Air Transport Association
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
AVRADCOM	Army Aviation Research and Development Command
AWOS	Automated Weather Observation System
AWP	Aviation Weather Processor
AZRAN	Azmuth and Range
BA	British Airways
BFG	B. F. Goodrich
BLM	Bureau of Land Management
BSM	Back-Scatter Meter
CAT	Clear Air Turbulence
CCOPE	Cooperative Convective Precipitation Experiment
CDC	Control Data Corporation
CDI	Course Direction Indicator

CFCF	Central Flow Control Facility
CG ATIS	Computer Generated Automatic Terminal Information Service
CGI	Computer Generated Imagery
CHI	Cloud Height Indicator
CNRC	Canadian National Research Council
CONUS	Continental United States
COSPAR	Committee on Space Research
CRREL	Cold Regions Research and Engineering Laboratory
CRT	Cathode Ray Tube
CSIS	Centralized Storm Information System
CSU	Colorado State University
CW	Continuous Wave
CWA	Center Weather Advisory
CWP	Center Weather Processor
CWSU	Center Weather Service Unit
DABS	Discrete Address Beacon System
DABS DL	Discrete Address Beacon System Data Link
DBV	Diagonal Breaking Vehicle
DC	Direct Current
DFC	Distinguished Flying Cross
DMSP	Defense Meteorological Satellite Program
DNA	Defense Nuclear Agency
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DR	Dead Reckoning
DSD	Drop Size Distribution
DUAT	Direct User Access Terminal
EDF	Exploratory Development Facility
EFAS	En Route Flight Advisory Service
EFWAS	En Route Flight Weather Advisory Service
EPA	Environmental Protection Agency
ERL	Environmental Resesarch Laboratory
ETABS	Electronic Tabulator Display System
EWEDS	En Route Weather Display System
FA	Area Forecast
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FBO	Fixed Base Operation
FL	Flight Level
FSDPS	Flight Service Data Processing Systems
FSF	Flight Safety Foundation
FSM	Forward-Scatter Meter
FSS	Flight Service Station
FT	Terminal Forecast
GAMA	General Aviation Manufacturers Association
GASP	Global Air Sampling Program
GE	General Electric
GEM	Generalized Exponential Markov

GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmenal Satellite
GPS	Global Positioning System
GWD	Global Weather Dynamics
HIFT	Helicopter Icing Flight Test
HISS	Helicopter Icing Spray System
HIWAS	Hazardous In-flight Weather Advisory Service
HUD	Heads-Up Display
IAF	Initial Approach Fix
IAS	Indicated Air Speed
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICS	Intercommunication System
IFR	Instrument Flight Rules
ILS	Instrument Landing system
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
IRT	Icing Research Wind Tunnel
IVRS	Interim Voice Response System
JAWOS	Joint Aviation Weather Observation System
JAWS	Joint Airport Weather Studies
JDOP	Joint Doppler Operational Project
JFK	John F. Kennedy Airport
JPL	Jet Propulsion Laboratory
JSPO	Joint Systems Program Office
LaRC	Langley Research Center
LATAS	Laser True Airspeed System
L/D	Lift-to-Drag
LDV	Laser-Doppler Velocimeter
LFM	Limited Fine Mesh
LLP	Lightning Location and Protection, Inc.
LLWS	Low-Level Wind Shear
LLWSAS	Low-Level Wind Shear Alert System
LORAN	Long-Range Naviagtion
LPATS	Lightning Position and Tracking System
LSA	Leased Service A
LWC	Liquid Water Content
MARS	Microwave Atmospheric Remote Sensor
MCIDAS	Man-Computer Interactive Data System
MDA	Minimum Decision Altitude
MERIT	Minimum Energy Routes using Interactive Techniques
MLW	Maximum Landing Weight
MSFC	Marshall Space Flight Center
MSL	Mean Sea Level
MTOW	Maximum Take-Off Weight
MVD	Median Volume Diameter
NACA	National Advisory Committee on Aeronautics

NADIN	National Airspace Data Interchange Network
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NASNET	National Airspace System Network
NASP	National Airspace System Plan
NAVAIDS	Navigational Aids
NB	Nanobars
NBAA	National Business Aircraft Association
NCAR	National Center for Atmospheric Research
NEXRAD	Next Generation Weather Radar
NHC	National Hurricane Center
NHRE	National Hail Research Experiment
NM	Nautical Miles
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NOTAM	Notice To Airmen
NPRM	Notice of Proposed Rule-Making
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSSFC	National Severe Storms Forecast Center
NSSL	National Severe Storms Laboratory
NTSB	National Transportation Safety Board
NWS	National Weather Service
OAT	Outside Air Temperature
OFCM	Office of the Federal Coordinator for Meteorology
OWRM	Office of Weather Research and Modification
PATWAS	Pilot Automatic Telephone Weather Answering Service
PDP	Program Development Plan
PIREP	Pilot Report
PIRM	Pressure Ice Rate Meter
PMS	Particle Measuring Systems
PROFS	Prototype Regional Observation and Forecast System
PSBT	Pilot Self-Briefing Terminal
PVD	Plan View Display
RAA	Regional Airline Association
RAE	Royal Aircraft Establishment
RCO	Remote Controlled Observations
R&D	Research and Development
RE&D	Research, Engineering, and Development
RMS	Root-Mean-Square
R&T	Research and Technology
RRWDS	Radar Remote Weather Display System
RSRE	Royal Signals and Radar Establishment
RVR	Runway Visual Range

SAR	Synthetic Aperture Radar
SD	Storm Detection
SERI	Solar Energy Research Institute
SESAME	Severe Environmental Storm and Mesoscale Experiment
SIGMET	Significant Meteorological Advisory
SST	Supersonic Transport
STOL	Short Takeoff and Landing
SVR	Slant Visual Range
SWAP	Severe Weather Avoidance Plan
TAS	True Air Speed
TASC	The Analytical Sciences Corporation
TCV	Terminal Configured Vehicle
TIDS	Terminal Information Display System
TOMS	Total Ozone Mapping Spectrometer
TRACON	Terminal Radar Approach Control Facility
TRIP	Thunderstorm Research International Program
TSC	Transportation Systems Center
TWEB	Transcribed Weather Broadcast
UDRI	University of Dayton Research Institute
UHF	Ultra-High Frequency
UK	United Kingdom
USAF	United States Air Force
USCG	United States Coast Guard
UTSI	University of Tennessee Space Institute
UWS	United Weather Service
VAS	VISSR Atmospheric Sounder
VFR	Visual Flight Rules
VHF	Very High Frequency
VISSR	Visible and Infrared Spin Scan Radiometer
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional Radio Range
VRS	Voice Response System
VS/ERI	Vertical Speed/Energy Rate Indicator
VSI	Vertical Speed Indicator
VS/ERI	Vertical Speed/Energy Rate Indicator
WAVE	Wind, Altimeter, and Voice Equipment
WBRR	Weather Bureau Remote Radar
WFC	Wallops Flight Center
WMO	World Meteorological Organization
WPAFB	Wright Patterson Air Force Base
WPL	Wave Propagation Laboratory
WSFO	Weather Service Forecast Office
WSI	Weather Service International
WSO	Weather Service Office
WSR	Weather Surveillance Radar

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16. ABSTRACT

The proceedings of a workshop on meteorological and environmental inputs to aviation systems held at The University of Tennessee Space Institute, Tullahoma, Tennessee, October 26-28, 1983, are reported. The workshop, jointly sponsored by NASA, NOAA, FAA, DOD, and OFCM, brought together many disciplines of the aviation communities in round table discussions. The major objectives of the workshop are to satisfy such needs of the sponsoring agencies as the expansion of our understanding and knowledge of the interaction of the atmosphere with aviation systems, the better definition and implementation of services to operators, and the collection and interpretation of data for establishing operational criteria relating the total meteorological inputs from the atmospheric sciences to the needs of aviation communities. The unique aspects of the workshop were the diversity of the participants and the achievement of communication across the interface of the boundaries between pilots, meteorologists, training personnel, accident investigators, traffic controllers, flight operation personnel from military, civil, general aviation, and commercial interests alike. Representatives were in attendance from government, airlines, private agencies, aircraft manufacturers, Department of Defense, industries, research institutes, and universities.

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