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.

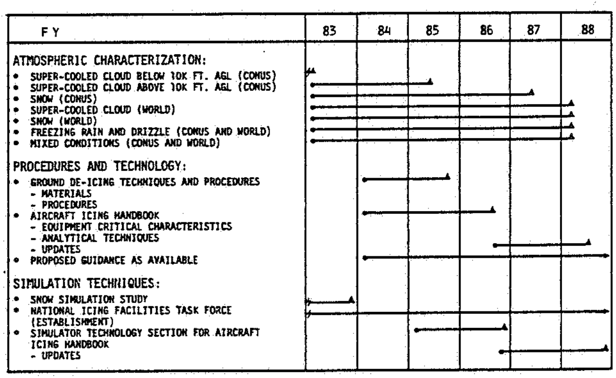

Figure 13. Aircraft Icing Program Planning Schedule

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.

- 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

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 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.

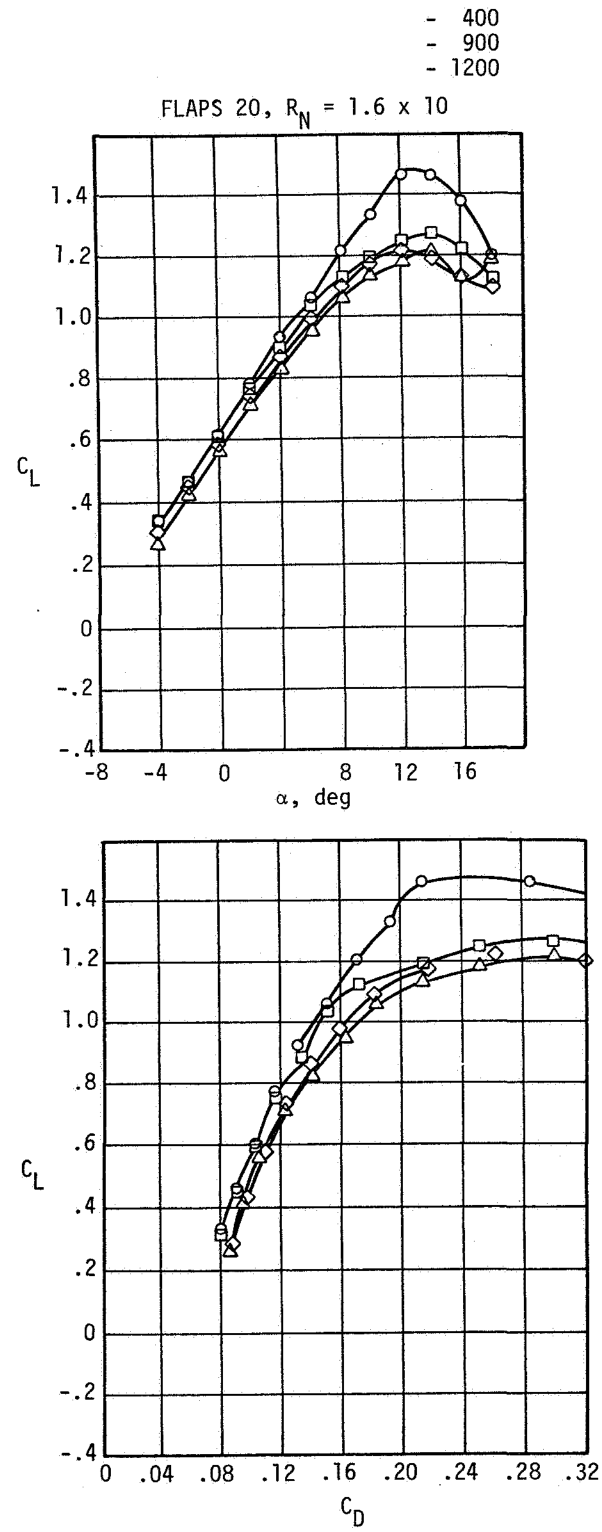

Figure 3. Effects of heavy rain on C_L and C_D

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.

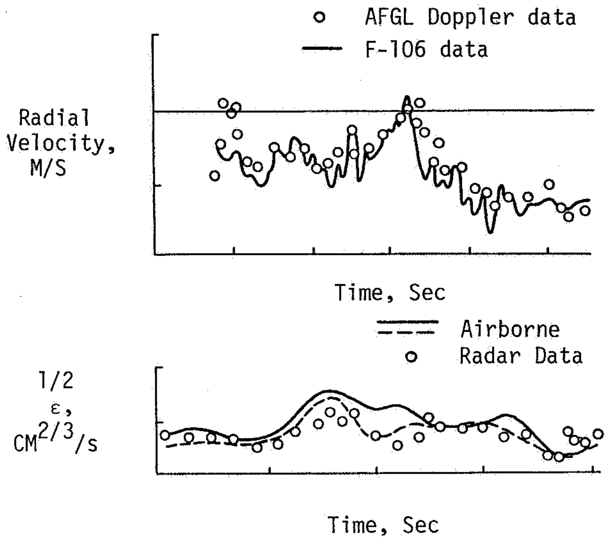

Figure 4. Example of F-106B wind measurements and ground Doppler comparisons

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.