- PROVIDE DATA TO VERIFY ADEQUACY OF IRT SIMULATION
- PROVIDE DATA TO VERIFY COMPUTER CODE PREDICTIONS
- STUDY EFFECTS OF ICING ON AIRCRAFT PERFORMANCE, HANDLING CHARACTERISTICS
- PROVIDE ATMOSPHERIC ICING CLOUD DATA

Figure 13. Icing Flight Research Program Objectives

The NASA aircraft icing research program, some elements of which have been briefly described in this paper, is a broad-based program. The major goal of the program is to enhance the icing technology data base over that developed by former NACA and industry research efforts and to make this technology available to the industry in a timely manner.

- FLY AN UNPROTECTED UH1H HELICOPTER BEHIND CANADIAN NRC'S OTTAWA SPRAY RIG
- DETAILED DOCUMENTATION OF ROTOR ICE ACCRETION CHARACTERISTICS
- MEASUREMENT OF ROTOR PERFORMANCE DEGRADATION DUE TO ICING
- TESTS OF 2-D AIRFOIL MODELS WITH ARTIFICIAL ICE SHAPES TO DETERMINE C_{ℓ}, C_d
- ANALYTICAL PREDICTIONS OF ROTOR PERFORMANCE IN ICING USING PERFORMANCE CODE AND EXPERIMENTAL 2-D AIRFOIL DATA
- COMPARISONS WITH FLIGHT DATA TO ASSESS METHODOLOGY

Figure 14. NASA/Army Helicopter Icing Flight Test Program

Existing Wind Observation Network

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There is an ambiguity in the title, "Existing Wind Observation Network". Before everyone rushes off for coffee, let me reassure you that I'm not going to talk about the balloon system. A better title would be, "A Real-Time Wind Observation Network". (Figure 1)

"Real Time Wind Observation Network For Fuel Efficient Flight Planning and Air Traffic Control"

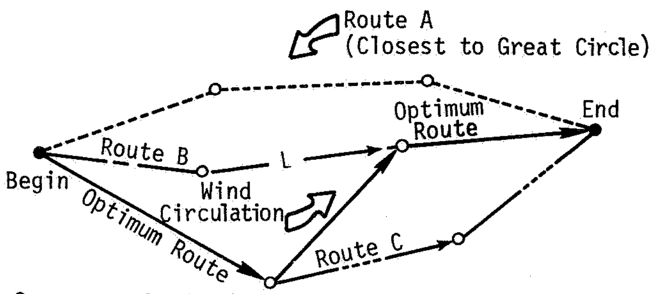
Figure 1. Proposed Experimental System

At the last workshop, our office presented a paper describing the need for better meteorological systems for fuel efficiency. We are an aviation energy organization, so that is our natural concern and perspective. Taking nothing away from safety concerns, we do believe that there is a woeful inattention in meteorology to the benefits that could accrue from fuel savings. So, we have turned our attention to this problem. The Energy Division figuratively backed into the subject of meteorology because we were developing flight planning programs that would be fuel efficient; and we soon found that you really cannot do much with high technology flight planning programs if you don't know what are the actual wind and temperature fields.

I would like to emphasize that this discussion is about a proposed system. It is for real-time wind observations and its purpose is fuel efficient flight planning and air traffic control. Let me show you an example of the kind of benefits that can accrue (Figure 2). Notice in this Figure, which was produced by the NASA/Lockheed TCV Program, that they investigated the possibilities of travelling several ways, including a great circle route, a more or less straight-line route, and following wind circulation patterns. It is interesting that the longest route actually uses the least fuel, some 14 percent less than the great circle route. This is an example of the kinds of fuel savings that are possible. I think this is an isolated example and probably not one you would expect routinely. To put this into perspective, just one percent of the air carrier fuel is 100 million gallons per year. So we think that improving the observation system has an enormous potential and probably could easily pay for itself in a year. That is, pay for itself in terms of reduced fuel bills.

The solution we see to the observation problem is the profiler instrumentation being developed at the NOAA/ERL/PROFS Program in Colorado. I need not go into the details of the program here. Some broad characteristics of the instrumentation and of the program can be seen in Figure 3. Importantly, the instrumentation can function in clear air as well as cloudy air.

Route	NMI	L 1011 LB Fuel	Excess. Fuel
A	1620	47,500	+14.4%
B	1680	46,200	+11.3%
C	1785	43,700	+ 5.3%
Optimum	1810	41,500	Minimum



Source: NASA/Lockheed TCV Program
June 81

Figure 2. Example of Route Optimization

- Profiler Provides Ground-Based Measurements of Upper Level Wind, Turbulence, Temperature and Moisture.
  - Long Wavelength VHF/UHF Doppler Radar with 3 Fixed Beam Directions, Large Fixed Antenna, 10 Minute Integration Time
  - Passive Microwave Radiometers Measure Temperature and Moisture Content
- "PROFS" Program Uses and Evaluates "State of the Art" Technology to Forecast Weather for Denver Area.
  - 4 or 5 Profilers + Surface Network + Weather Radars Connected in Real Time to Central Location.
  - One Profiler Operational, Remainder by Summer 1983.
  - PROFS Operationally Funded Until FY 88.
  - Data Link to Longmont ARTCC CWSU.

Figure 3. NOAA/ERL/PROFS Profiler

Figure 4 shows an example of the effectiveness of this new instrument system. I do not know whether or not the profiler always works this well; but these data at least indicate the type of accuracy available from the system. In this figure, the profiler data are plotted as accuracy bars of the wind velocity in meters per second versus altitude. The balloon measurements with which they are compared are shown as circles. Wind direction is shown in both sets of data as short lines relative to North. Notice that the profiler agrees with the balloon very nicely up to the higher altitudes, when and where the balloon is no longer overhead. You should expect to get quite a difference in this circumstance and you do. For temperature and vapor density, the profiler package can also do a good job. I have had people question whether this figure is a representative sample. At this time, I cannot answer the question, but expect to have much more information soon comparing the two systems. If this package is as accurate as indicated here, then it has the capability of replacing the balloon system.

If the accuracy is comparable, why replace the balloon system? Some answers to this question are given in Figure 5. The time resolution for balloons...measurements every 12 hours...is totally inadequate for the kind of benefits that we really need for flight planning; that is, for route selection and optimum speed and altitude selection. It is also inadequate for proposed advanced air traffic control techniques and for flight management while airborne. As an example, if airborne computers were tied to computers on the ground that would reveal what the wind field is before making a descent, it would be a straight-forward matter to ensure a bottom of descent with an idle throttle from the beginning of descent.

Compared to other possible observation systems, balloons really do not offer a practical chance to improve much further. The future looks very promising for satellites; however, they are many years away as wind observing systems. Of course, we have existing systems of airplanes flying, from which wind fields can be estimated. Aircraft Meterological Data Relay (AMDAR) and Aircraft/Satellite Data Relay (ASDAR), the Aeronautical Radio Incorporated Communications (ARINC) systems, are primarily used over oceans, although they could work over land. Mode-S is another airplane-type system from which ground computers could determine wind. However, in both of these cases, the distribution of wind information is not uniform in time and space. There is reason to doubt that such data could be used to calculate a reliable wind field database. The paramount advantage of the ground-based profiler system is continuous readings at all observing stations at all times.

We have envisioned a means of making this kind of real-time information available for use by everyone (Figure 6). Naturally, when people draw block diagrams, they tend to show their own interest as the largest block. The series of users at the bottom of this figure, for instance, could be depicted as large blocks in someone else's diagram. When storing this wind database in a computer, the publicly available data shown in the largest block in this diagram could reside inside of someone else's block. But the main idea is that wherever the data come from: Mode-S, AMDAR, these profilers, or in the far future, perhaps from satellites, it is important to store the observations themselves in one place. Give them a specified format of speed, direction, latitude and longitude, altitude and the temperature, if available...put these into a computer and give all users a telephone number and the format andlet them pull out the data at will. Users would not have to read the whole thing. If one were interested in only a few locations, a program could extract these few data from a time-sharing port. To me, this is an essential feature that will encourage innovative use of wind data but will in no way preclude uses of further, more processed, products such as forecasts.

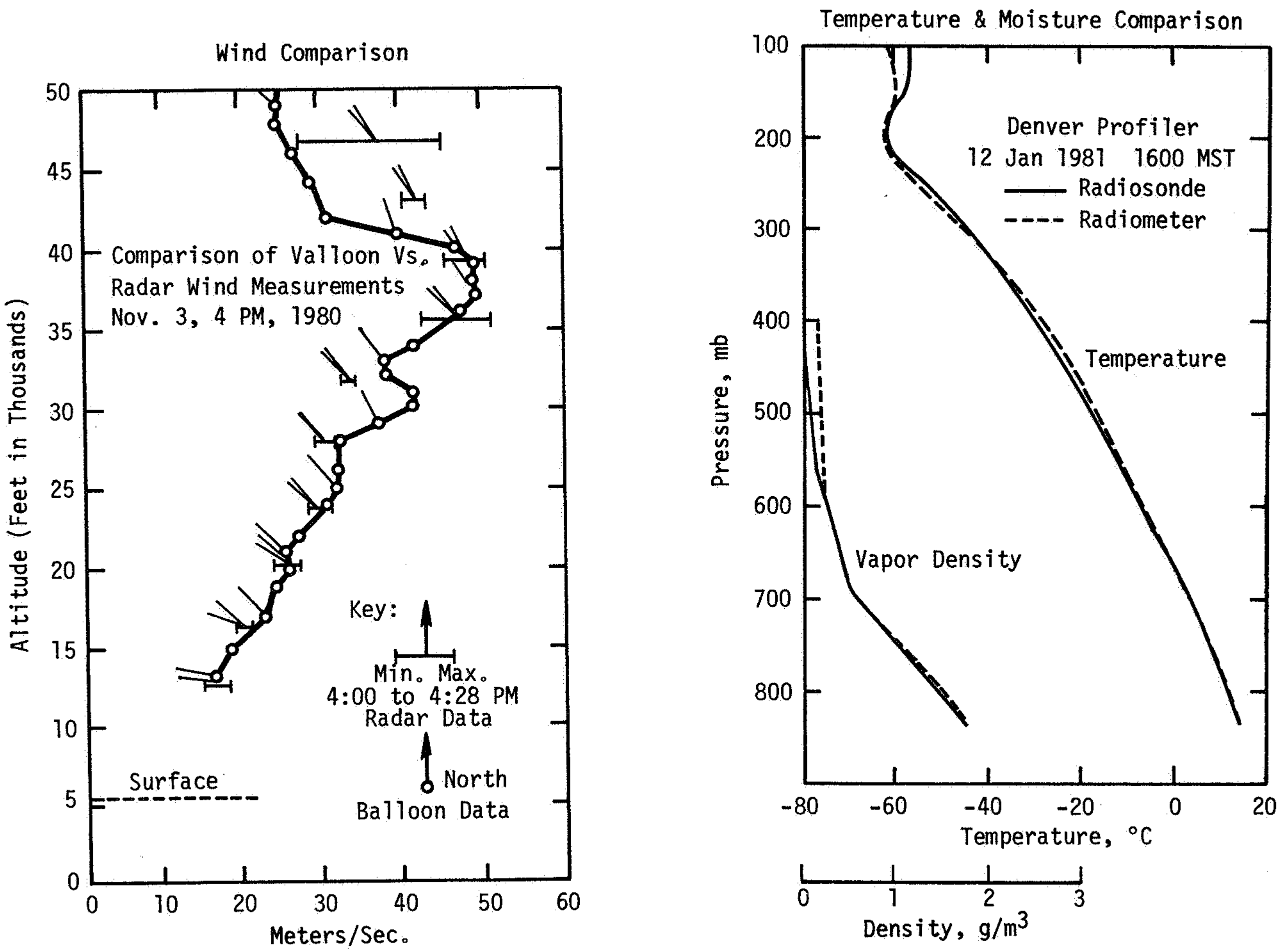


Figure 4. Profiler and Balloon Data Comparison

Why Do It?

- 12 Hour Balloon Measurements Do Not Provide Adequate Time Resolution
- Accurate Upper Wind and Temperature Data Needed for Fuel Efficient Flight Management
  - Flight Planning - Route Selection, Optimum Speed and Altitude
  - Flight Management - Computers, 4D, R-NAV Techniques
  - ATC - Metering and Spacing, IFM, AERA

What Else is Available?

- Balloons: Too Costly to Improve Time and Space Resolution
- Satellite Based Detection: Many Years Away
- AMDAR/ASDAR: Useful Over Oceans
- "Mode S": Not Uniformly Distributed Over Time and Space

Figure 5.

In order to expedite this program, we would like to set up an experimental program. A general outline of such a system is shown in Figure 7. People are not going to be convinced that this could be a workable national system until they see some evidence. So, we are seeking to augment the existing plans for the four profilers in Colorado. Apparently, you cannot have a good talk unless you show a map of the United States with circles and dots, so here is ours in Figure 8. This shows the four locations in Colorado that are planned. We think that if six more were placed in a pattern between Denver and Chicago, this woul- provide enough of an experimental basis for flight planning and air traffic control use to establish very firmly whether or not such a system is beneficial. Actually, I do not think there is any question about whether or not it would be beneficial... it would be. However, it could be proven with a lot of objective experimental data. Also, with this kind of experiment, we can establish the engineering specifications for a national system.

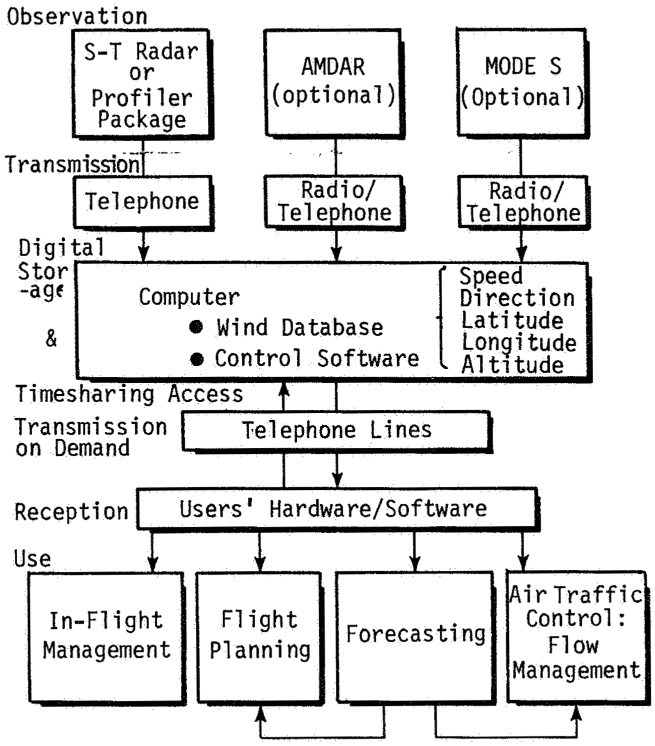


Figure 6. Proposed Wind Observation & Reporting System

- Establish Developmental Prototype System For Real Time Winds Aloft Computer Database
- Ground Based Sensors Report Wind Vectors at Cruise Altitudes
- Profiler and S-T Radar — Developmental Units to Be Installed and Operated By PROFS Program Office of NOAA ERL
- Sponsored Through Interagency Agreement — NOAA, FAA, NASA
- Wind and Temperature Measurements Transmitted to Central Database — Available on Demand to Flight Planners, Forecasters, ATC, Researchers, Etc.
- Target Date For Operational Prototype System — FY 84-85
- Airline Participation to Quantify Fuel Savings

Figure 7. Proposed Experimental Wind Observation Network

The functional specifications for profiler instruments are still in the early developmental stages. There are trade-offs that could be made in antenna size, and power, and frequency and so on; but if we're going to develop this particularly as an aviation system, we need to put some real-time observation instruments in place and work with them. These objectives are listed in Figure 9. Our office has recently entered into a contract with the PROFS office, in the form of an interagency agreement. We have asked PROFS to make a preliminary investigation of the specifications for aviation purposes. Also, we have asked that they document their estimates of the cost of the system and the benefits in fuel savings.

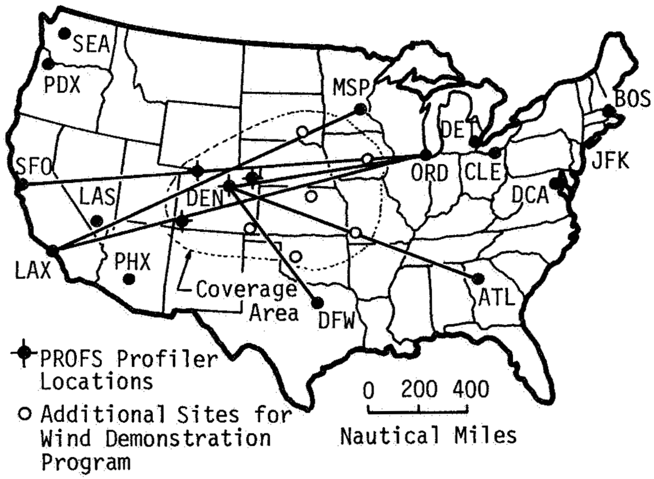


Figure 8. Possible Sensor Locations - Experimental Program

- Determine Utility of Using Real Time Wind Data For Flight Planning, Flow Management, And ATC Operations
- Obtain an Operational Data Base to Determine Fuel Saving Benefits of Real Time Wind Data System
- Establish Functional Specifications For Sensors — i.e., Frequency, Antenna, Power, Spacing, Etc.
- Establish Functional Specifications For Central Data Base

Figure 9. Experimental Objectives

Let's return to the subject of benefits. For flight planning, it is very important to know both the temperature and the wind field. Figure 10 illustrates the importance of knowing the wind field. One wants to get the best use of the tailwind or minimize the headwind. As a flight proceeds from place to place, it might pay in fuel saved to shift altitudes. Only with computers can you assimilate and use real-time wind data for optimum in-flight planning. Computer programs for this purpose are being developed. Our office is progressing on a model that we hope will tell exactly where to fly as well as what altitude and speed to fly to get the most out of the fuel. This technology is of limited value unless the computer is provided actual wind data. We really do not know what the upper winds are right now. Instead, we have forecasts, and these are of uncertain and varying quality.

Turning to air traffic control, there are also benefits (Figure 11). For integrated flow management, real-time winds would help to establish better routing. Air Traffic Control might wish to advise how to go around severe weather; but again, if they are to advise from a fuel-savings standpoint, their computers will need to know what the winds are quite accurately. If ATC is to advise how to plan for the next few hours, they need better short-term wind projections than seem to be currently available. It seems obvious that if real-time wind information were available, short-term projections could be made more accurately. The en route automation program has a number of valuable uses for real-time wind as seen in Figure 11.

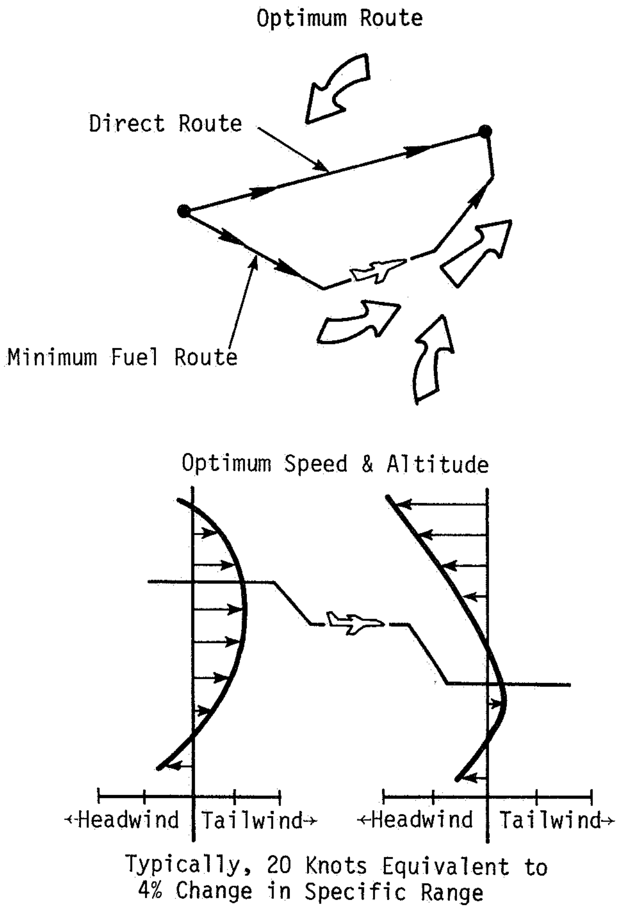


Figure 10. Flight Planning Benefits

- **Flow Management (IFM)**
  - Optimal Routing
  - Severe Weather Avoidance
  - Predict Sector Utilization & Congestion Areas
  - Develop Flow Management Strategies
- **Enroute Automation (AERA)**
  - Improved Enroute Fix Accuracy
  - Conflict Resolution
  - Optimum Utilization of Random Routes
  - Delay Management
  - Descent Planning

Figure 11. Real-Time Upper Wind Data - ATC Benefits

Conflict resolution and estimates of arrival time over fixes can be improved for fuel efficiency purposes if ATC could sharpen the bell-shaped distribution curve of uncertainty. The tie-in to fuel conservation and system efficiency comes about from generally decreasing the uncertainty of exactly when an airplane will be at the next navigation point.

We conclude that the availability of widespread continuous real-time upper wind and temperature data will dramatically improve aviation efficiency, simultaneously helping both the users and managers of the airways. The NOAA/ERL/PROFS profiler instrument package appears to offer a near-term solution to the problem. Further development into a cost effective aviation system seems likely, but interagency and public support are needed to hasten introduction of an operational system.

Questions from the Floor

QUESTION: Andy Yates, United Airlines

A couple of comments: one, the fuel savings are generally accomplished over the long-range trips and not generally on shorter segments, by flight planning and using some of these winds. As an example, going from San Francisco to New York, you could achieve quite a bit of fuel savings over that range. But, going from Chicago to New York would not be that substantial. The other factor is that while we do have flight plans to give us the most economical or lowest fuel-useage route, we can't fly it because the preferential routings which have been established by ATC in order to cope with the present traffic problems.

RESPONSE: David Winer

I've heard your last comment many times. Air traffic control is frequently being made out as the bug-a-boo in this problem. Regarding the first part of your comment about your flight planning program...there are really lots of ways to improve all the airline flight planning programs. Nobody really has the ultimate answer yet, although, I think United has one of the better ones. As far as ATC goes, I don't have the answer. If you would like to let ATC have a bigger hand in helping plan flights in the future, I think that could be done; but you're going to have to want that. Right now, we're in a current situation that is quite abnormal. I don't think we are in a position even to talk about doing the most fuel efficient things right now. We are struggling to stay afloat. But in the future with advanced systems, if the ATC can have a measure of control of the flight planning, at least a strength of recommendations greater than they have now, I think they can probably help you out of that problem.