TRANSPORTATION RESEARCH
E-CIRCULAR

Number E-C034 July 2001

Aviation Gridlock

Understanding the Options and Seeking Solutions

Phase III: Weather and Weather Technology

May 16, 2001
Washington, D.C.

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NUMBER E-C034, JULY 2001
ISSN 0097-8515

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Cosponsored by

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Preface

As pressure increases on the national airspace system, including airports and supporting facilities and services, it is important that all elements of the system—commercial airlines; passengers; local, state, and federal governments; business and industry—understand and work together to maintain the world's safest and most efficient aviation system. To address this need, the Federal Aviation Administration and the Transportation Research Board have launched a series of three 1-day seminars on **Aviation Gridlock: Understanding the Options and Seeking Solutions**, with sessions in February, April, and May 2001 in the Lecture Room of the National Academy of Sciences, Washington, D.C.

The seminars aim to enhance public understanding of the issues, organizations, and possible solutions to air transportation problems as the nation enters a period of increased demand, limited capacity, and inclement weather patterns traditionally associated with summer. Following are the topics and schedule for the seminars on Aviation Gridlock: Understanding the Options and Seeking Solutions:

- **Phase I: Airport Capacity and Demand Management,** February 16, 2001;
- **Phase II: Airport Capacity and Infrastructure,** April 11, 2001; and
- **Phase III: Weather and Technology**, May 16, 2001.

Phase I of the seminar series focuses on demand management by examining three areas: airport delay and congestion; administrative and market demand management options; and operational, legal, and political challenges in adopting new demand management strategies. The Phase I proceedings are available from TRB as Transportation Research Circular E-C029: Airport Capacity and Demand Management (www.TRB.org).

Phase II examines airport capacity through improvements in infrastructure. Phase II proceedings are available from TRB as Transportation Research Circular E-C032: Airport Capacity and Infrastructure (www.TRB.org).

Phase III of the series—the proceedings published in this Circular—focuses on weather as an impediment to air travel and on the technologies to ameliorate the negative effects of weather.

Each seminar features presenters from selected elements of the aviation industry and engages an audience of individuals representing the industry, the federal government, the business community, the general public, and the media.

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Introduction

JEFFREY N. SHANE
Hogan & Hartson

JANE F. GARVEY
Federal Aviation Administration

Jeffrey N. Shane: Good morning everybody and welcome to the third in a series of symposia on the most important transportation issue this country faces today—aviation congestion. Those of you who have followed this series know that the first of the symposia, which was back in February, dealt with the issue of what we call demand management: Assuming you have static infrastructure in the air transport system—the airports and runways are pretty well fixed—what are the economic and the administrative tools that we can use in order to extract more efficiency and more capacity out of that given infrastructure.

The second of our symposia was in April, this last month, and looked at the question of infrastructure: Assuming that you've done everything you can do through economic and administrative tools—how can you build more runways, how can you build more airports? We looked particularly at the issue of environmental review and environmental clearances. The conviction [was that] at all levels of government and among the public, it has taken too long to get runways built [and] too long to plan and build new airports. And while we have to be sensitive to environmental concerns and if everybody really means that, there is no way that we can get these projects done if you are riding rough-shod over any constituency. The fact is that the delays are too long; it takes too long to get these projects done.

Today, the third and final of the three symposia will be focused on the issue of weather. If you don't know what you were just listening to, that was supposed to be weather—at least that is what I am told. I suppose that was bad weather, and it is indeed bad weather that we are most concerned about in the system. Everybody says that people talk about the weather and never do anything about it. I'm hoping today that you will find out we not only talk about the weather but indeed the FAA and other organizations are trying very hard to do something about it.

I want to come back and describe the program in some more detail in just a moment and give you some of the ground rules for the day. But before I do, it is my very great privilege to introduce to you the Honorable Jane F. Garvey, Administrator for the Federal Aviation Administration.

Jane F. Garvey: Once again, Jeff, thank you very much for leading this discussion. On behalf of the FAA, welcome to all of you. As Jeff said, this is the third seminar that we have hosted at TRB and I want to thank the Transportation Research Board's Joe Breen, who has just done a wonderful job in working with us. We have really enjoyed this, and I think each one of the seminars has produced some very productive discussions, and I'm sure today will as well.

Let me also just mention to the press people who are in the room—and I know there are a number of you—most of you know Drucella Andersen, who is standing over there. But, if you don't know her and you have to ask any questions, please don't ask me, ask Drucie. So that is the deal on that.

As Jeff said, we are going to focus today on the weather. I hope we do something more than just talk about the weather. For us in aviation—and those of you who are pilots and those of you from the airlines—know this very well: Weather is fundamental to our life. There has to be a healthy respect for the weather. We need to plan for it, and certainly we need to avoid it when it is dangerous.

Here is how Robert Buck in his classic book, *Weather Flying*, says it: "You cannot count on weather because even with computers and satellites, we simply cannot outguess it 100 percent of the time." That means that there will be times when the weather will not work as forecast. That is a fact of flying life, and you must always be prepared for it.

Certainly, since Buck first wrote that book in 1970 (it is now in its fourth edition), aviation has made some wonderful strides to improve our ability to plan for weather and to operate more safely. But, we also know there is more that we could do, and that is really why we're here today.

Our focus today with the experts in the room—and I have to say I'm so pleased about the experts who have joined us on the panel [along with] the experts sitting in the audience—[has] a three-fold purpose. The first is we are going to hear about the weather and the affect it can have on airline operations, on safety, on schedules, and on predictability. The second panel will discuss the roles and responsibilities in weather decision-making. You will hear about the work that the FAA and the airlines have done to get better at planning and managing around severe weather.

Last year, we initiated our spring/summer 2000 plan. It was, as I think everyone in this room knows, a collaborative effort by industry, by labor, and by government to maximize the use of the available airspace to improve the communications and to expand the use of new technology. It was the first time that the FAA and the airlines used a common weather forecast. All of this was really designed to improve predictability for the airline operations during severe weather. We learned a lot from that plan. We did an evaluation in the fall, and I think we made the plan better. We are focused on working smarter and more efficiently and on clarifying our roles and responsibilities.

I know it is only May 16th and we haven't yet faced the worst of this year's thunderstorm season, but I think the plan is already making a difference. We are glad to see in April, for example, that the air traffic delays were down about 14 percent compared to April of last year. Now, three of our speakers this morning—Tony Henry, Al Krauter, and Jack Kies—were absolutely essential to this effort, and I'm very pleased that they could join us today.

Our final area of focus today will be on the advances in weather technology. This is important—this is critical. Technology can help. New weather technology—providing more precise, more accurate, and above all, more timely information—is a key element of the modernization effort. The objective is exactly as it should be—maintaining and improving safety. There are many initiatives in our modernization blueprint, and we are going to hear about some of those today. We also know that weather isn't the only reason for delays. There are a host of reasons that cause delays, and it has been the topic certainly of our first conversation as well. But we do know that weather is a factor, and how we manage operations around severe weather is an area where we can do better and where we simply must do better. That is why the experts are here.

Let me end where I began and that is with a comment on respecting Mother Nature.

Serious weather is and always will be a hazard to safe flight. In March at a congestion workshop, Dr. Arnold Barnett of MIT (Massachusetts Institute of Technology) pointed out that while some risk to aviation safety had decreased, risks from thunderstorms had not. He reminded us that they are ferocious forces of nature. Yet, for all that we heard last summer about it being the worst summer ever for delays and disruptions, Dr. Barnett noted one statistic rarely heard: He said flying on U.S. domestic airlines last summer posed a safety risk of zero. That is an extraordinary record, especially during the busiest and the worst weather travel season. That statistic alone, I think, speaks highly of the entire aviation community. It shows just how much we can achieve when we have got the right priorities and when we work together. We want to be efficient, of course, but most important we want to be safe, and that is what we'll talk about today.

I look forward to the discussion and thank you once again for joining us today.

Shane: Thanks so much, Jane, for that excellent introduction. We are looking forward to a superb program today. We are fortunate, as the Administrator said, to have such remarkably experienced and talented people speaking on the panels that we will present to you. I'm also mindful, however, that we have an extraordinary amount of talent in the audience as well. For that reason, our effort will be to manage the time in the presentations as carefully as possible in order to leave open as much possible time for questions, answers, comments, and discussion as we can.

I'm going to apologize to our speakers in two ways. First, I apologize for running this symposium with an iron fist. Each has been told that they should speak for no more than 10 minutes, and that is in order to facilitate the give and take that is such an important part of this. Second, I'm going to apologize because notwithstanding the fact that each of them is superbly qualified and has a very long and distinguished resume, I am not going to spend a lot of time reading those qualifications and credentials to you. For those who have the materials here, the professional biographies are included in those materials. For anybody who is looking in on C-SPAN, I would suggest logging onto the National Academy of Sciences website (www.nas.edu). There should be biographical material there.

I am Jeff Shane. I am your facilitator, your moderator this morning. I'm with the law firm of Hogan & Hartson. I have been in and out of government over many years, and I suppose that is what qualifies me for the privilege of being here today as a moderator—and that is about as much as I'll say about myself.

What I want to do is move into the first of the panels as smartly as we can. The title of the panel is "Weather and Its Role in Aviation Delays and Safety." We will follow-up with a discussion. We will have a second panel this morning: "Roles and Responsibilities in Weather Decision-Making" is the title of that panel. We will then break for lunch and have a third panel this afternoon. The third one will be a discussion of "Advances in Weather Technology." [Overall this] should be a very interesting series of panels.

Our first speaker this morning, talking to us about the anatomy of a weather delay, is Dr. Agam Sinha, the director of air transportation systems at the MITRE Corporation. He is also regional director of the Americas for International Projects at the Center for Advance Aviation System Development. Dr. Sinha provides strategic guidance on research, engineering, [and] operational aspects of all projects at MITRE, and as the regional director, he is responsible for all international projects in the Americas. He has current projects going on involving Canada, Brazil, Argentina, Mexico, and Panama. Dr. Sinha, the floor is yours.

Weather and Its Role in Aviation Delays and Safety

Anatomy of a Weather Delay

AGAM N. SINHA
MITRE Corporation

Good morning. It is a pleasure to be here. I'm going to talk about "Anatomy of Weather Delay." The two key elements are the forecasting of severe weather and the impact of severe weather on NAS (national airspace system) operations. So we need to think about it from two perspectives. One is from the meteorological perspective of what do we know about weather and what kind of weather forecasting we can do. But, that is only half of it. The other half is how are you going to use it operationally to control traffic. It is very difficult to figure out which is the worst half: Both of them are equally difficult, as you will hear also from some of the other panels.

So to get us in the right mood, the first slide is a test, compliments of Jack Kies from the [FAA] Command Center (Figure 1). On that page, from an air traffic operational perspective, what is the major problem that you see? Since we only have 10 minutes, I'm going to continue and give you the answer. If you look at the picture, clearly there is a big weather system here [through the Midwest and plains states], but there are gaps in there. As it turned out on this day, that part of it was predictable, so you could prepare for it. The one that caused the biggest problem is this little weather over here [over

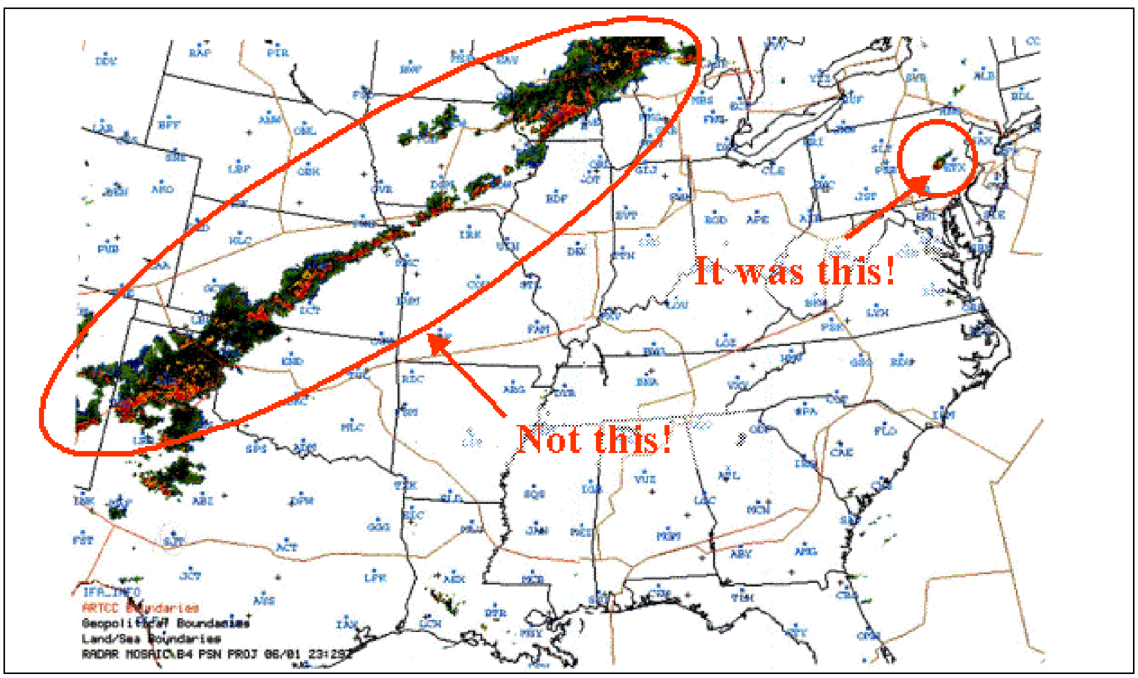


FIGURE 1 What was the major issue? (Scenario courtesy of Jack Kies, FAA Acting ATT-1.)

Pennsylvania] because its course was unpredictable, and then it affected the majority of the traffic going in and out of New York and north and south traffic near New York, which is where the heavy congestion is. So the main point of this test is that everything is not what it seems when it comes to weather. So you really have to marry the two: the weather picture and the operational picture.

What I'm going to talk to you about are two sample days—one from 2000 and one from 2001. The first case [on] April 9th of this year presents a scenario when a NAS system copes with stormy weather (Figure 2). What that title means is that there was severe weather around the country. It was predicted fairly well; nothing is predicted 100 percent, as the Administrator said earlier in her opening remarks. But since it was known, the users and the FAA collaborated to figure out a plan. When all was said and done, it was not as bad a day for the traffic. On June 14, 2000 (the second day), the weather was unpredictable, and therefore, it really did cause major disruptions in the system. I'll walk you through the two scenarios in terms of the forecast versus actual weather, what actually happened, how did the NAS respond, and again—at the end of the day—what were the performance statistics that we could look to in terms of the NAS.

[On] the first day (April 9th), afternoon and evening thunderstorms were forecast. There were ground stops and delays in the Northeast because when the thunderstorm is there, you don't have much choice. So you just have to manage it better. Storms blocked portions of the Northeast corridor, and air traffic is basically rerouted around the predictable storm. So for the weather part, this is at 5 p.m. (Figure 3). As you can see, the outline of the polygon in the yellow is the forecast. The forecast is a little bit ahead of the storm (Figure 4). It is catching up to the storm, but it missed this part of it around O'Hare (Chicago, Illinois) and St. Louis (Missouri). It didn't quite predict that. At 9 p.m.,

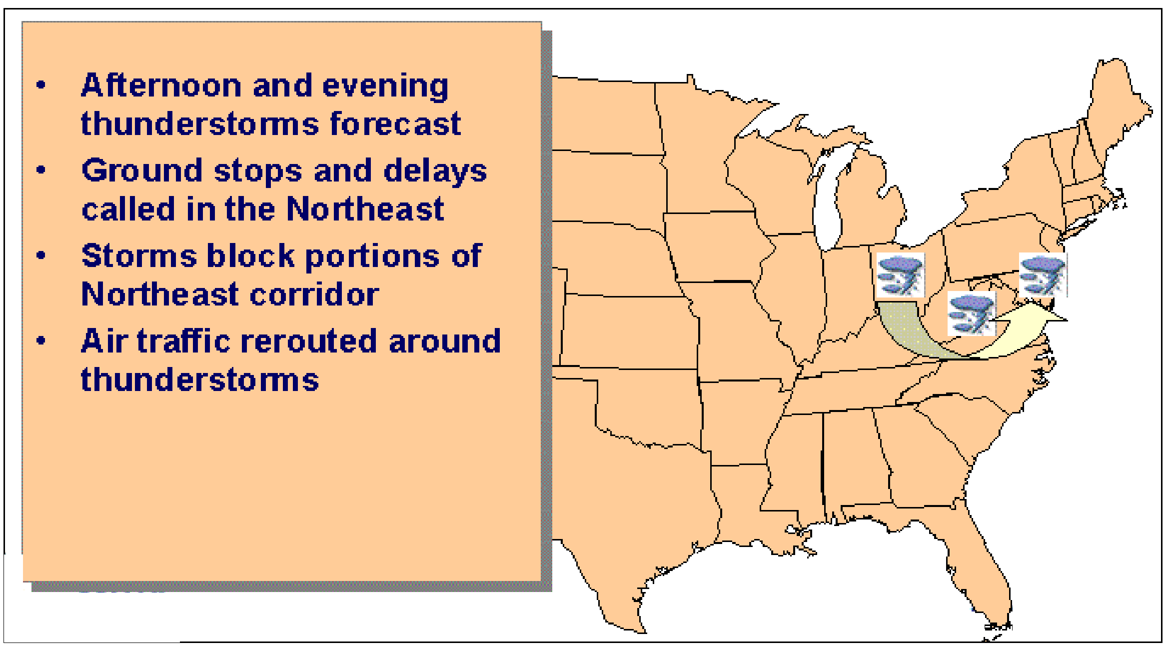


FIGURE 2 April 9, 2001—The NAS copes with stormy weather.

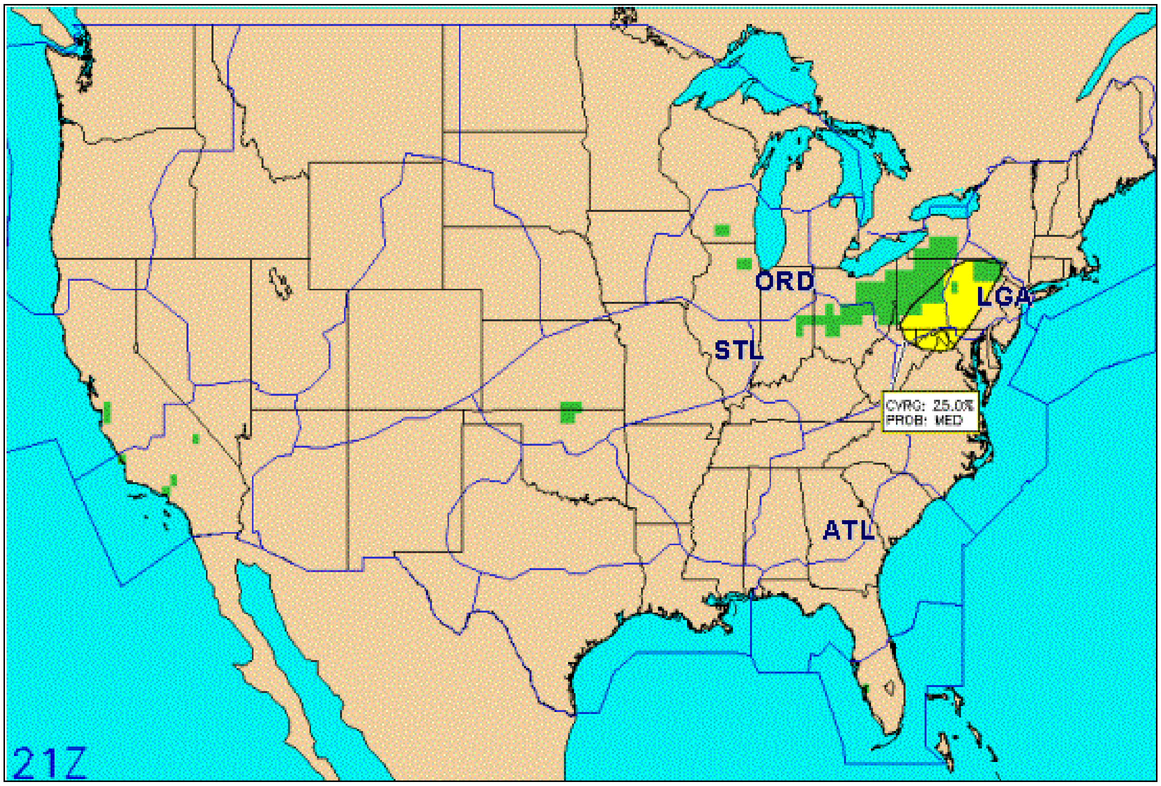


FIGURE 3 5 p.m.: Thunderstorms move east. Forecast ahead of storms.

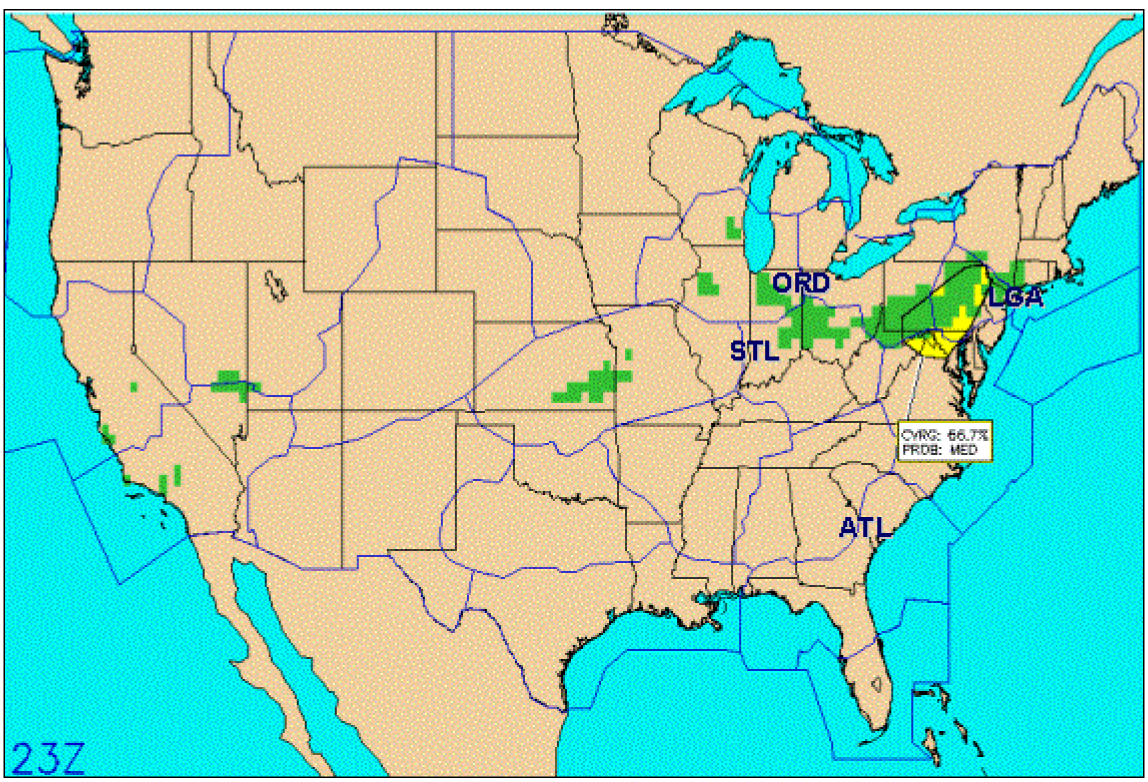


FIGURE 4 7 p.m.: Storms move into Northeast corridor.
Forecast catches up, but misses tail.

it did catch up, so the forecast and the weather matched up pretty well (Figure 5). Then, at 11 p.m., the forecast starts to move out to sea—it is just beginning to move out (Figure 6). So that is the combination of the forecast and the actual weather as it happened on that day.

What did the NAS do? I'm going to use this terminology: "stop" for ground stop and "yield" for ground delay programs (GDP) (Figure 7). I think most of you are familiar with it. I'm sure Jack Kies will talk about it in his presentation. A ground stop is basically when you have to stop the traffic because they can't take off and go wherever they want to. In a GDP, you manage the flow of traffic by imposing delays on the flow.

The important thing to note is these are not placed at airports in the various sectors arbitrarily. The FAA and the user collaboration results in these programs. So it is a well-thought through plan based on the best available information. Sometimes the information, as we saw in the weather forecasting, is not always perfect, but that is what you have to deal with.

So on this day (April 9), when we started at 5 p.m., things were fairly normal (Figure 8). Pittsburgh had a storm right over it, so therefore there was a ground stop at Pittsburgh. On the East Coast, you can see that to be able to manage the flow, there are some GDP in effect. At 7 p.m., the thunderstorm became stronger, as we saw, and so there are more ground stops in the system (Figure 9). There are about six ground stops on the eastern half. At 9 p.m., the storm started to pass over the land and [went] out to the ocean (Figure 10). So you see it was the end at about 11 p.m., and you only have four ground stops still in effect (Figure 11). That was a day when the weather forecast was good.

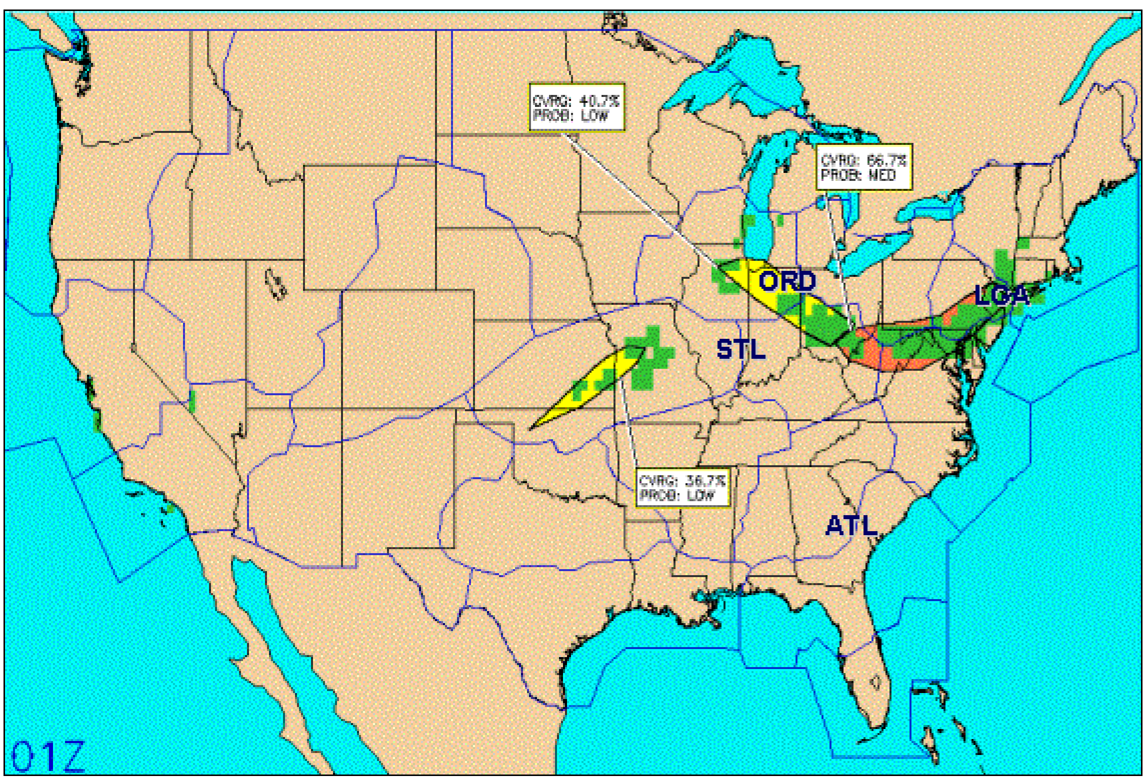


FIGURE 5 9 p.m.: Northeast corridor becoming blocked. Dense coverage over New York and Washington, D.C., airports.

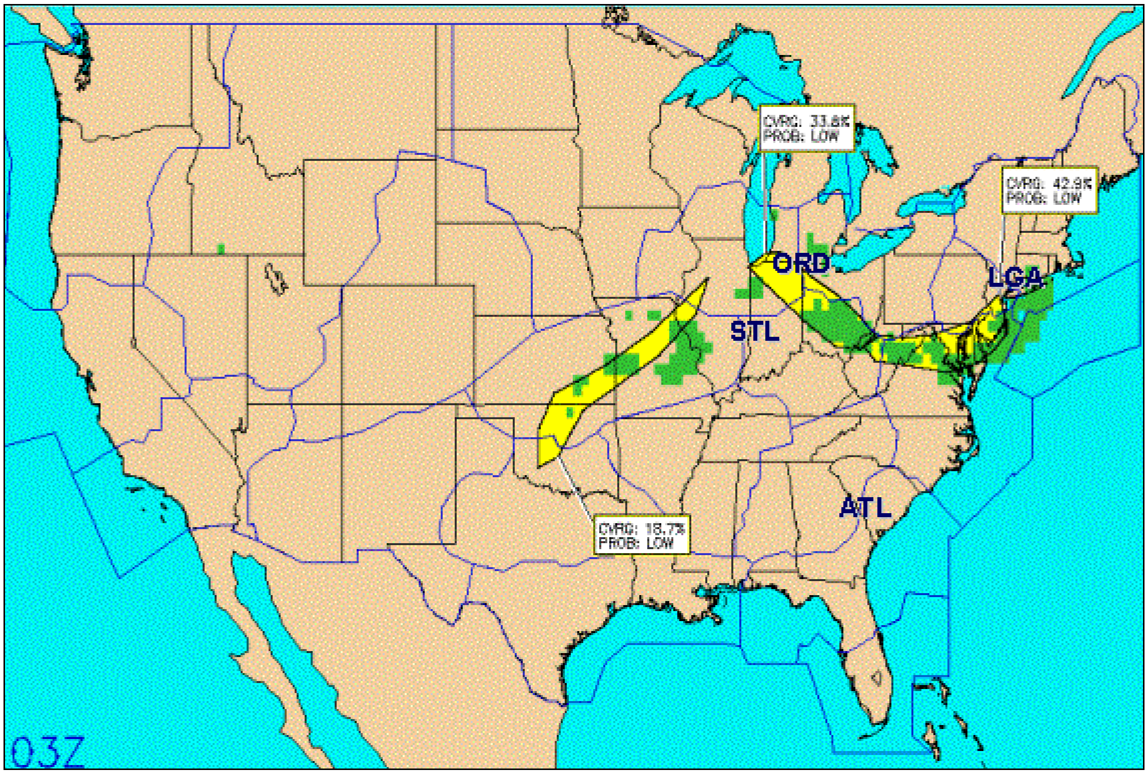


FIGURE 6 11 p.m.: Northeast corridor opens up. Storm front moves out to sea.

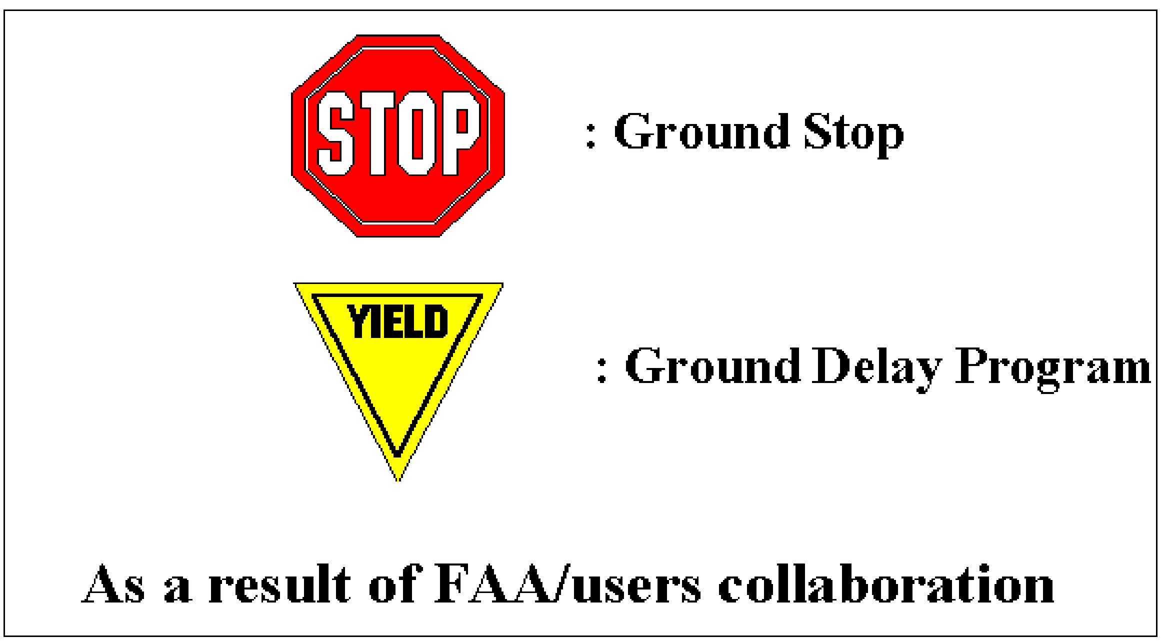


FIGURE 7 Key.

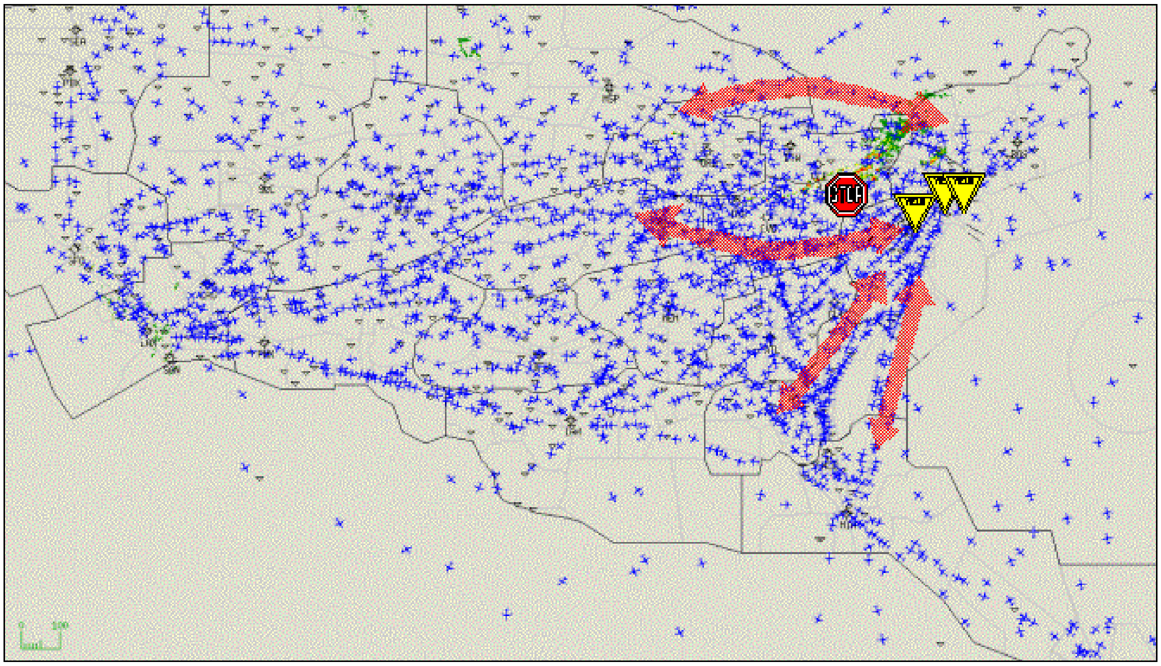


FIGURE 8 5 p.m.: Air traffic flows smoothly as storm travels east of Cleveland, Ohio.

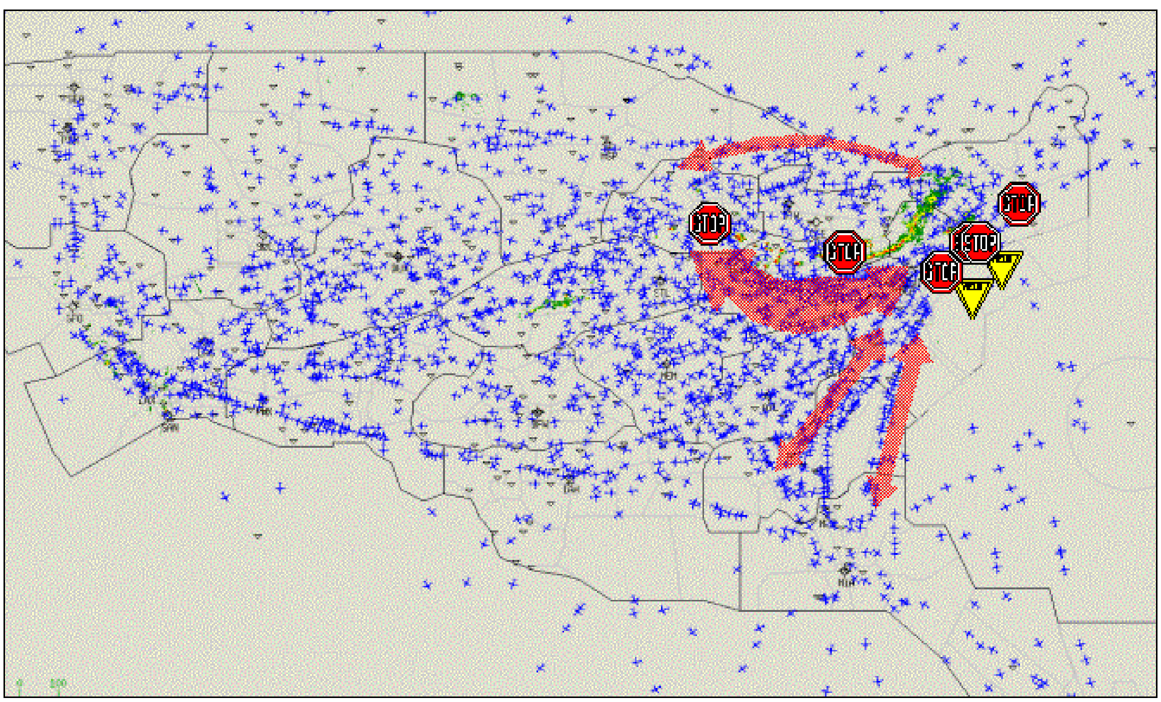


FIGURE 9 7 p.m.: Traffic rerouted south of thunderstorm.

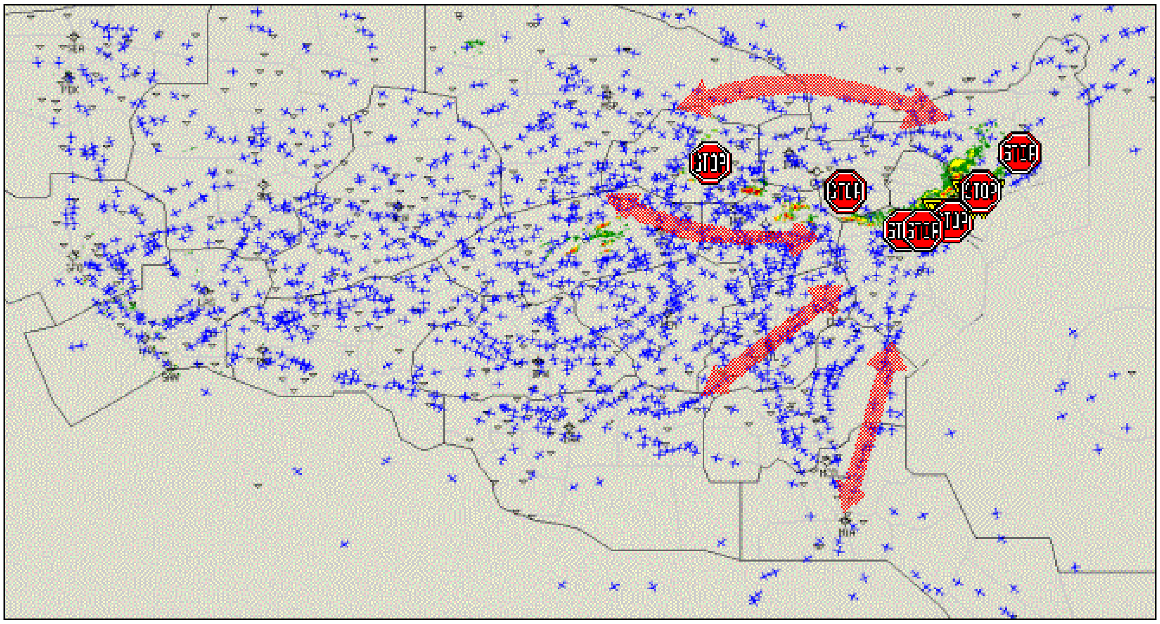


FIGURE 10 9 p.m.: Storm passes over major East Coast airports.

[On] the second day, June 14, 2000, there were two problems. There was a lot of unpredicted thunderstorms here [Southeastern states], and fog and visibility were an issue in the Northeast (Figures 12 and 13). The types of storms is another important factor. If there is a big massive storm, that is easier to predict—that is, it is easier to figure out, relatively speaking, where it is and where it is going. There are other storms that are pop-up thunderstorms—they pop up all over the place. So keep on the lookout for them because those are the ones that cause the problems. They are very tough to predict.

The other part—and again I'm sure we will be talking about it again and again—is that the science of forecasting between 0 to 2 hours is not too bad in terms of extrapolating the current information. From 6 hours on, we have good meteorological models that can do the predictions. Between 2 to 6 hours is where the meteorological forecasting is in its infancy. So the fundamental science is not there, and therefore, it is still an art. It is an art, and therefore, the results are not as well as one would like from an operational perspective. So if you had 25 percent or 30 percent of accurately forecasted weather, you are probably doing all you can from a meteorological perspective in that timeframe. Having 30 to 35 percent accuracy is very hard to deal with from an operational perspective.

So here is the picture at 5 p.m., the key being all of these things that you see in the Southeast were not forecast, so the system had to react to it (Figures 14 and 15). Some of the mainstream weather and the forecasts are now overlapping, but there are still lots and lots of pop-up storms that really come up. Again, you see [the effects] with respect to the traffic that caused disruptions in the system. At 10:30 a.m., things are flowing normally in the East (Figure 16). Some of this is hard to see, but all these orange things you see here—with little ones with the orange centers—show the severity of the pop-up storms. When they are really severe, then you really can't do much except block off the traffic

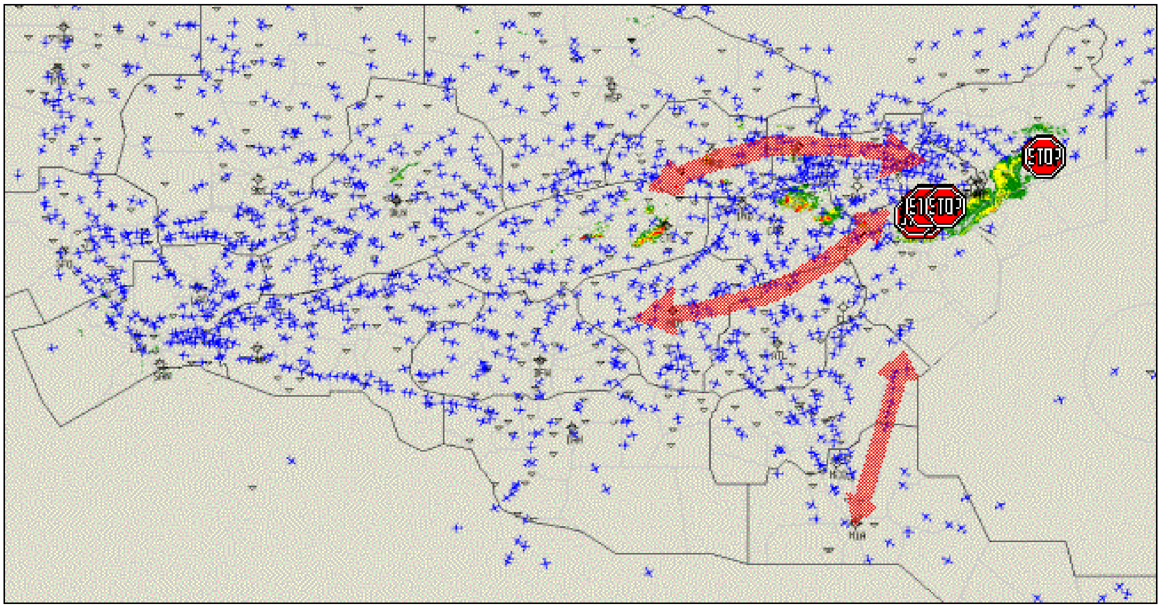


FIGURE 11 11 p.m.: Traffic resumes through Cleveland, Ohio, center as storm moves out to sea.

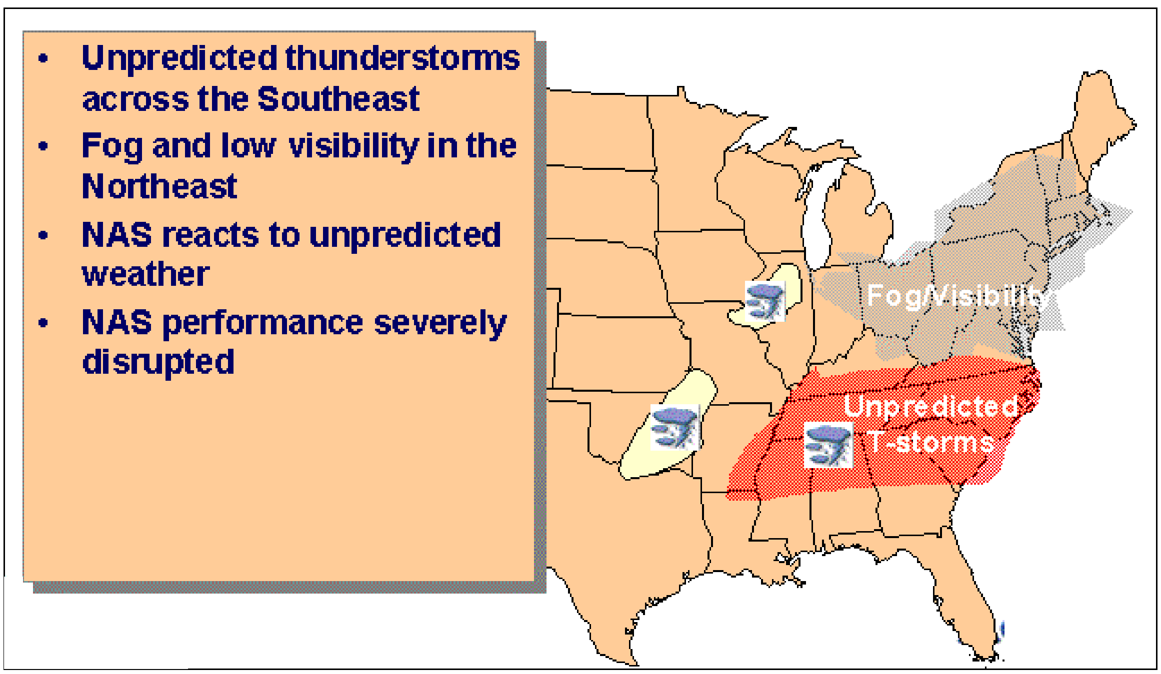


FIGURE 12 June 14, 2000—Unpredicted weather disrupts the NAS.

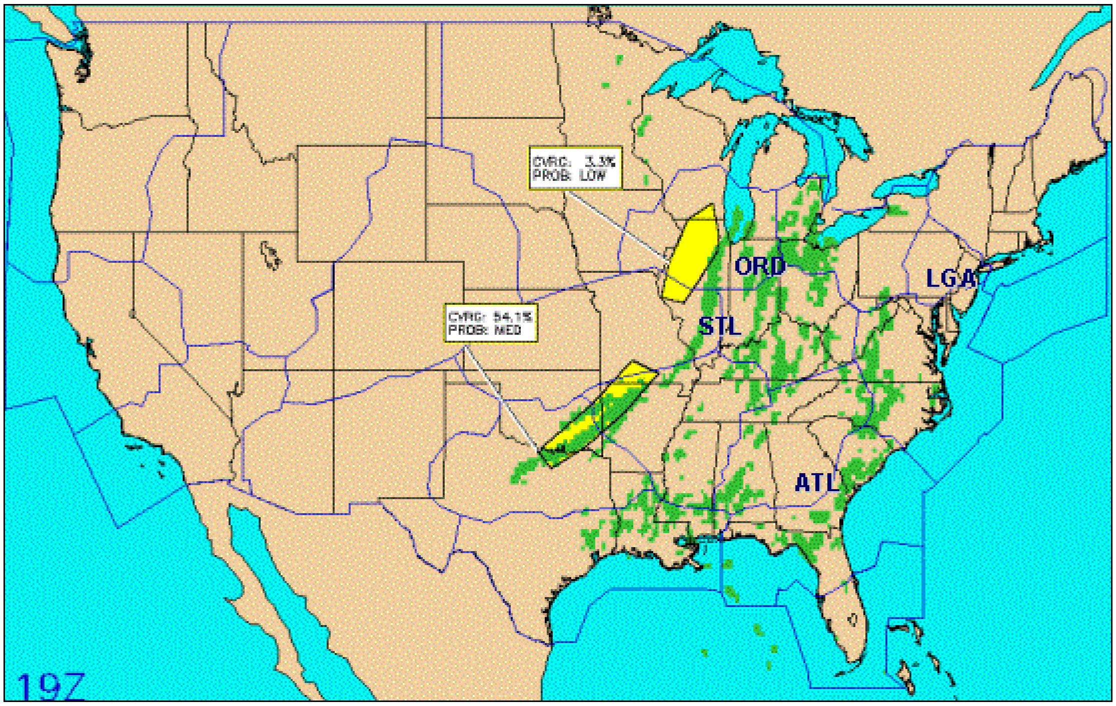


FIGURE 13 3 p.m.: Storms in the Southeast are worse than predicted.

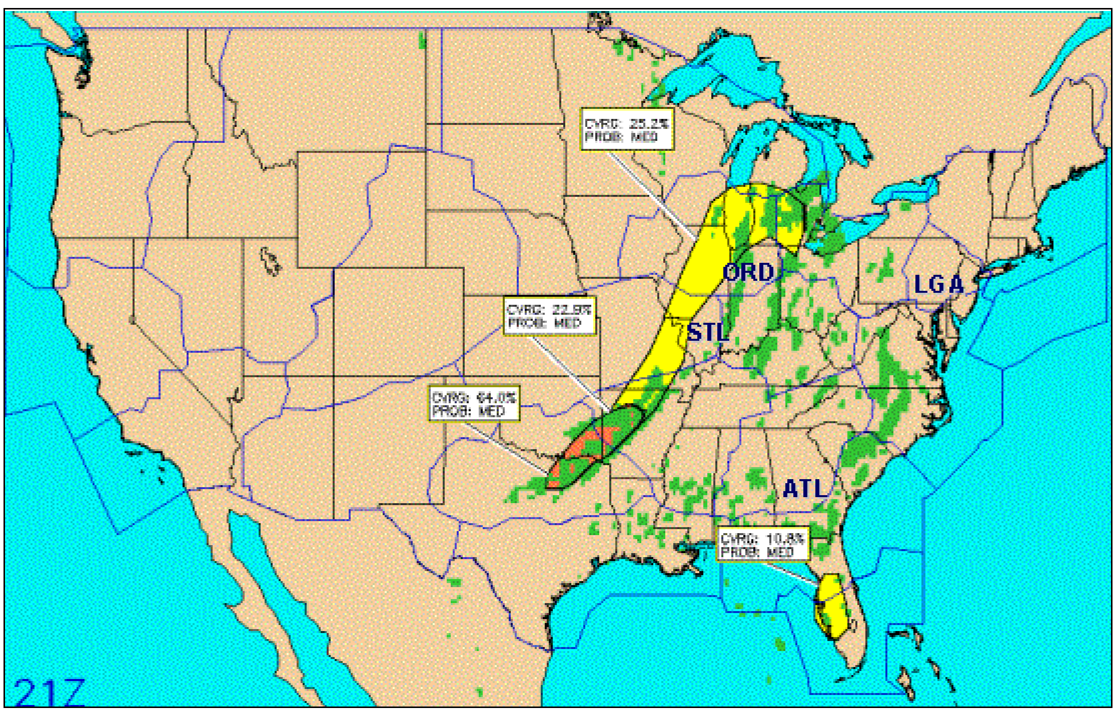


FIGURE 14 5 p.m.: Storms blanket the Southeast.

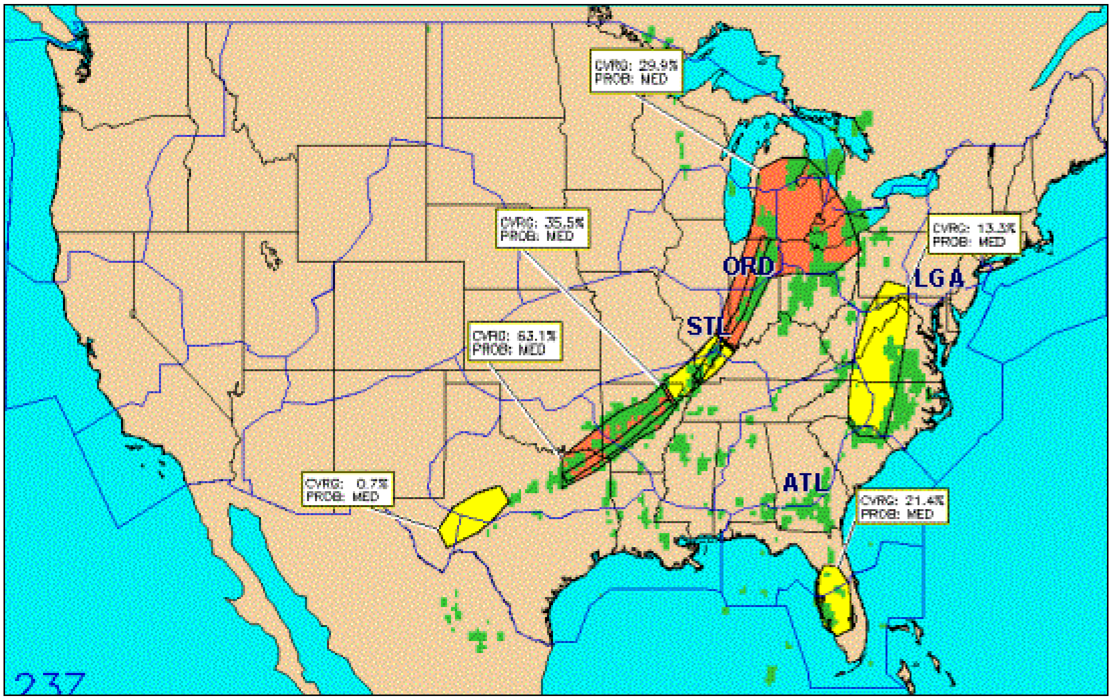


FIGURE 15 7 p.m.: Forecast catches up to weather.

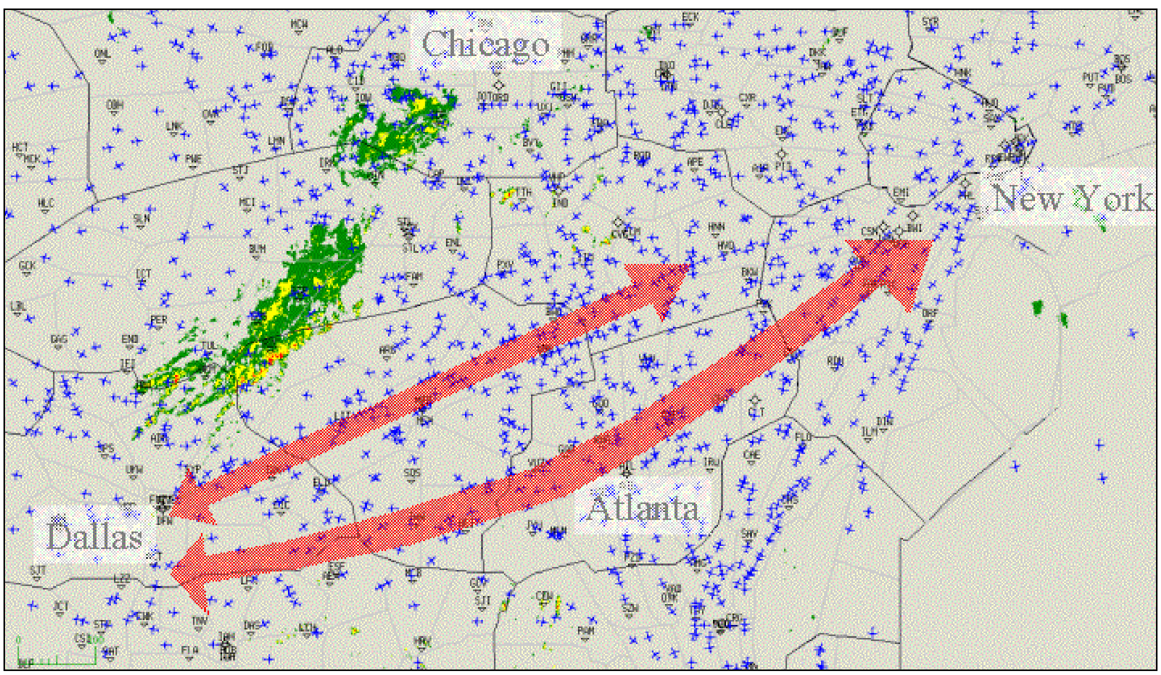


FIGURE 16 10:30 a.m.: East Coast flows normal.

because safety is paramount in the system, as it should be. So you can see here that we are already starting out with a number of ground stops and a few GDPs (Figure 17). Things don't get any better as time progresses. You do have the flexibility at this stage so you reroute this traffic to avoid that piece of the storm and some of these [can] go south and still continue onto their destination (Figure 18).

As the storm moves on, there is a gap wide enough for an aircraft to fly through safely, and that is what the system did (Figure 19). When I say the system, it is the Command Center, the FAA facilities, the airlines, general aviation—it is all the users who are working together throughout the day in this spring 2000 and spring 2001 activities that decide how to manage this kind of a phenomenon.

The bad news is that the weather system closes that gap (Figure 20). Again, it is not forecasted. Now you have a plan, you are pushing the traffic through, and all of a sudden the door shuts down. So now obviously to maintain the safety, you have to start rerouting. But rerouting does two things. First, all the traffic is not where you want it to be after the rerouting. So you have to manage all that flow to bring it around to the way you want it to go now in the rerouted form. That is one part of the problem. The other part of the problem is that it takes time, even though this part has opened up (Figure 21). If you don't have the traffic, you are not going to be able to process as many aircraft as you would have if you had perfect information. So that is kind of the dilemma of weather and operations.

Just to give you a side-by-side comparison, here is what it looks like. This [on the left] is a good day. When you look at the weather, that is why we had the quiz up front, because if you look at the weather picture from a layman's perspective, this seems to be a

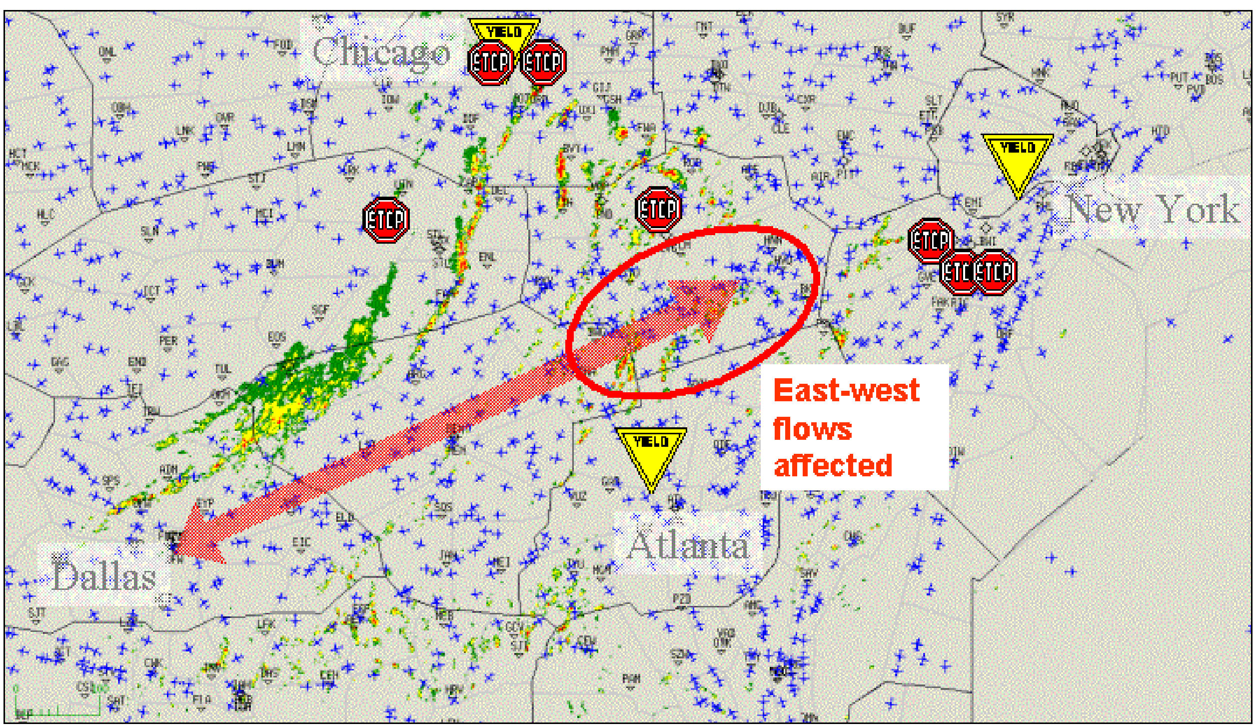


FIGURE 17 1:30 p.m.: Local weather begins to disrupt traffic.

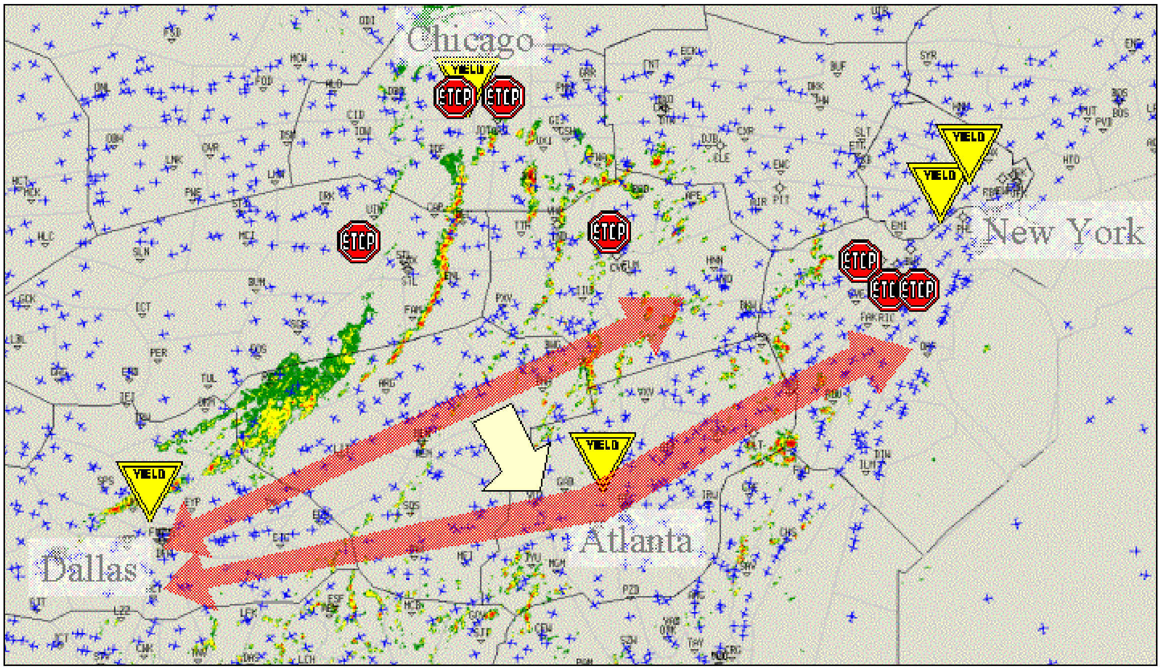


FIGURE 18 2 p.m.: Traffic rerouted to the south.

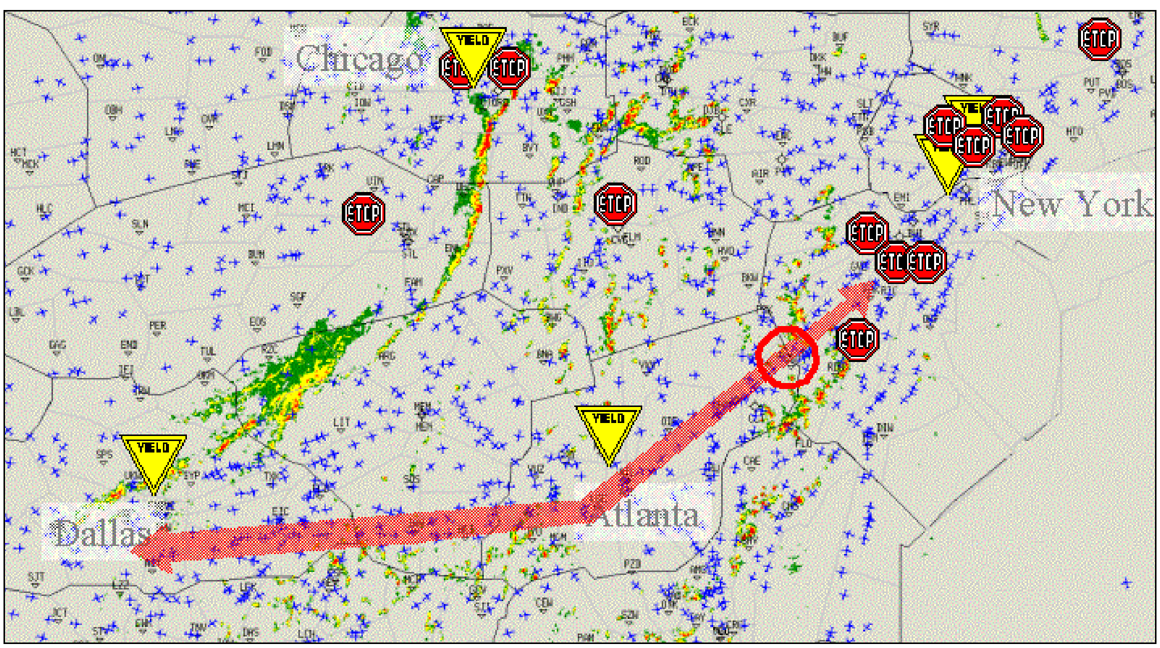


FIGURE 19 3 p.m.: Traffic flows through gap in storms.

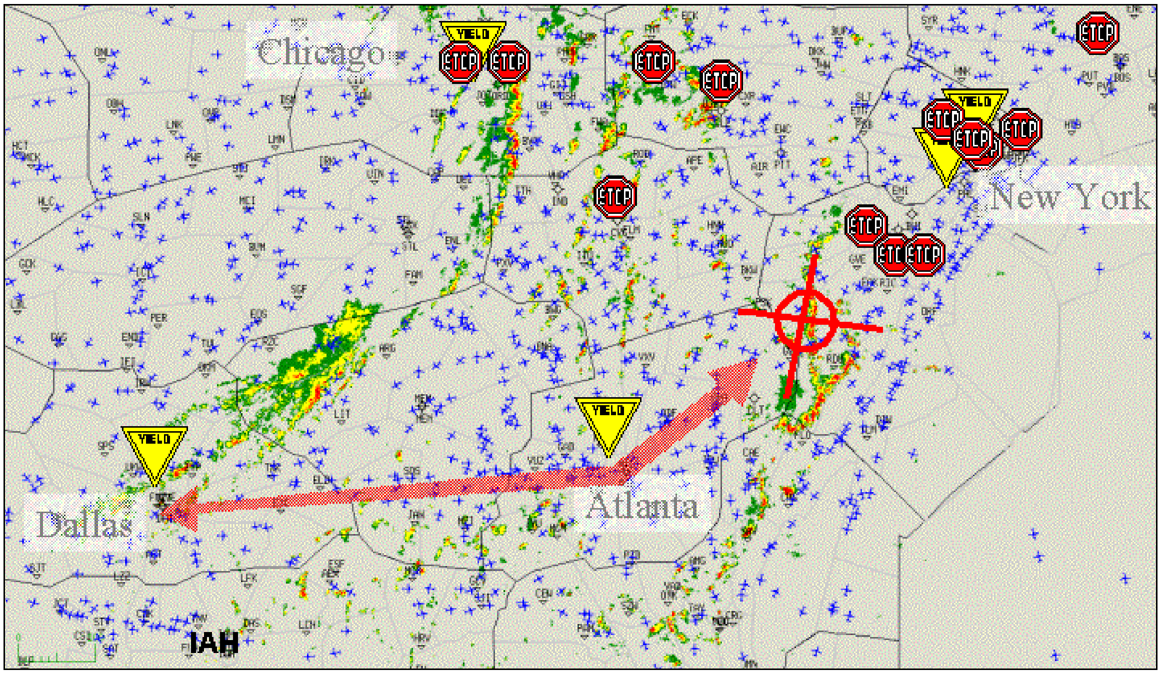


FIGURE 20 4 p.m.: Gap closes, blocking rerouted traffic.

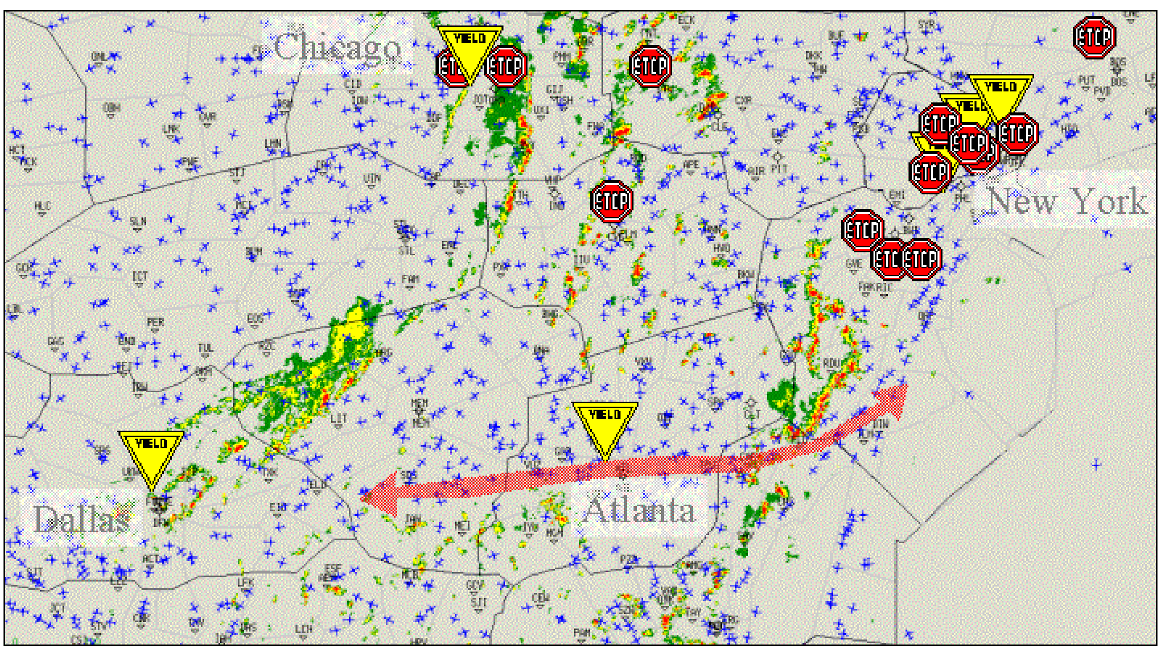


FIGURE 21 4:30 p.m.: New gap opens. Traffic volume well below normal.

worse weather day than that [on the right]. Yet, you will see more ground stops and delays on June 14 that you do on April 9. Again, let me take you back to why (Figure 22). Some of this [on April 9] was predicted, so the users and the FAA could plan around it. Some of this [on June 14] was predicted, but a lot of this was not. So when you are in a reaction mode, clearly you can't do as well as when you can pre-plan your day's activities. These two days are a good reflection of that.

To give you some statistics of what it meant, this is the number of flights delayed greater than 15 minutes (Figure 23). It shows the summer average. This is what happened on the good day—as you can see, not too much is different from the average. But on the day when it wasn't planned, it really goes up from about 1,600 or 1,700 [flights] to something like 2,350. That is one measure.

Cancellations is another measure (Figure 24). Same story. Again, cancellation on a relatively good day on April 9th of this year is not significantly different than the average. But on a day when you can't plan it, it is up in the 1,400+ range.

So whichever way you look at the system, the bottom line is severe weather really causes disruptions (Figure 25). There are no two ways about it. Nobody, from the user side, from the FAA side, from the scientists, or from the technologists, has a complete answer today. Everybody is working hard at it, but we don't have the answer today. So you will have disruptions in the system. That's a fact. You will have delays because of weather. That's a fact. It is not going to go away. What is helpful is that good forecasts do help minimize the impact, but again keep in mind that the fundamental science of 2 to 6 hours forecast of convective weather is limited. I'm sure John McCarthy and others will tell you where that part of the work is headed in terms of the meteorological sensing and forecasting.

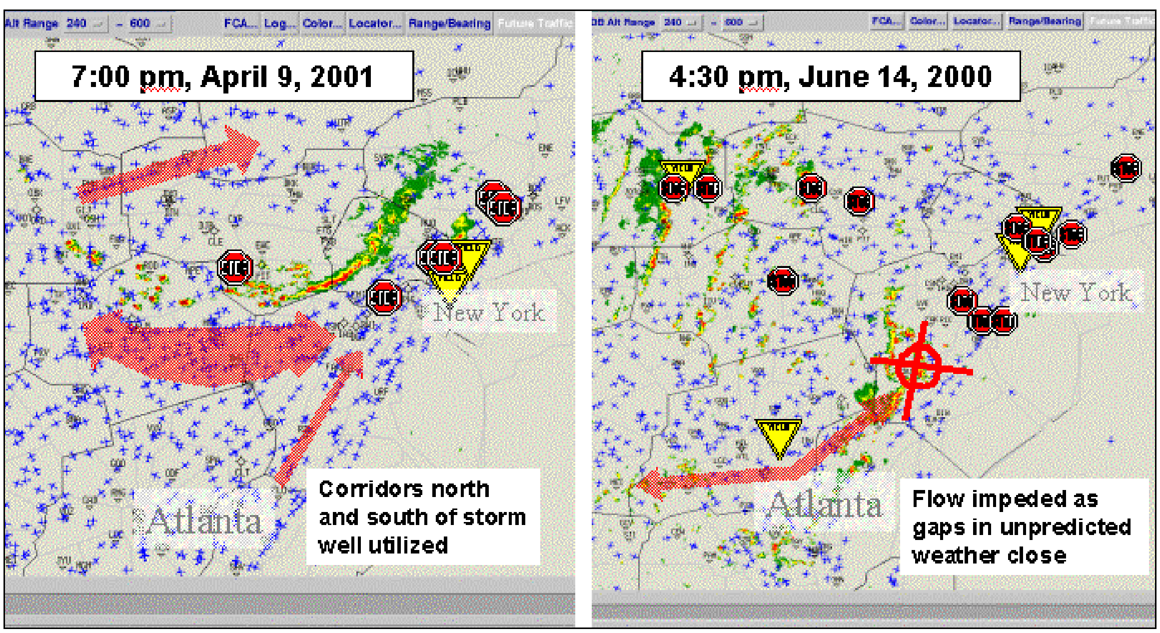


FIGURE 22 Hours of peak impact.

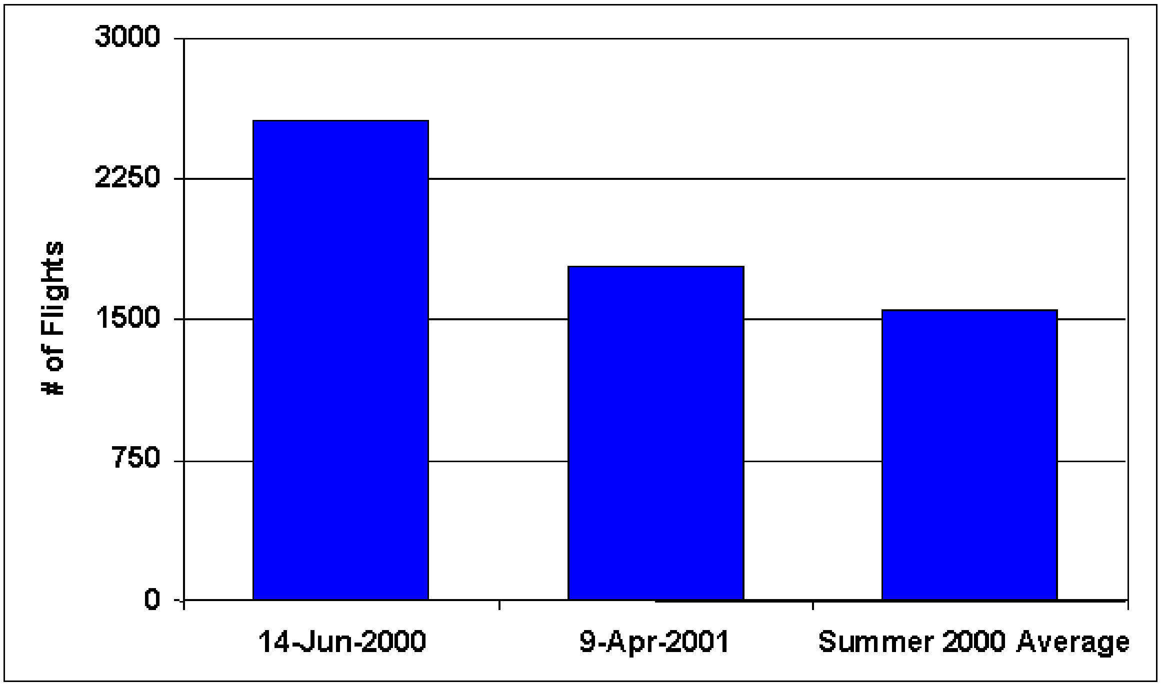


FIGURE 23 NAS performance: Number of flights delayed more than 15 minutes.

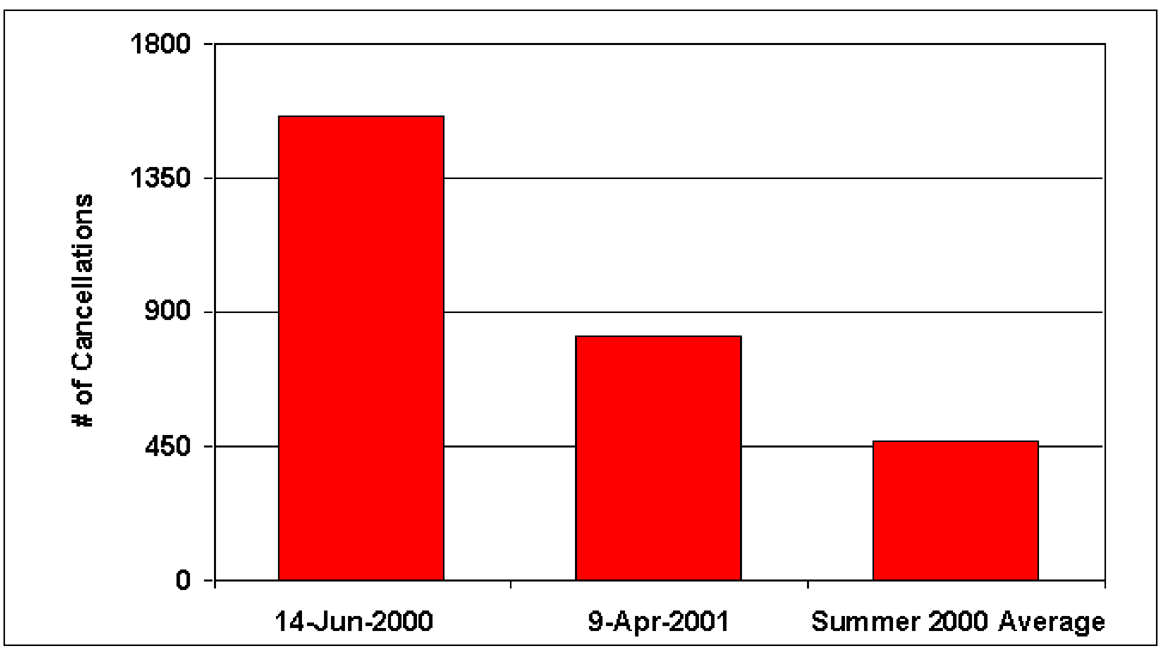


FIGURE 24 NAS performance: Cancellations.

- **Severe weather will cause disruptions**
- **Good forecasts help minimize the impact**
  — but the fundamental science of 2-6 hours forecast of convective weather is limited
- **Collaboration among users and FAA facilities is the key to managing the impact of weather.**

FIGURE 25 Summary.

Having said all that—to end on a positive note—this is the weather hand that we are dealt. So the question is what do we do with it. The bottom line of my presentation is that collaboration among the users and the FAA facilities is the absolute key. If we are not all on the same page, things will be worse. There is no difference between unforecasted weather, disruptions in the system, and players not being on the same page. They will [all] look the same. They will feel the same. So it is important for all players to figure out the solution together, and the other key part is, you're not going to do away with weather. We haven't figured that out yet. The objective is to manage the impact of the weather—to be able to do the best we can with the hand we are dealt. Thank you very much.

Click here to see Sinha's entire presentation.

Jeffrey N. Shane: Thank you very much. That is a perfect beginning to the day: Laying down the picture that we are all here to talk about—the fact of life that we call weather in the system.

Our next speaker is John O'Brien with the Air Line Pilots Association (ALPA). He is going to be talking about that weather that we just saw from the vantage point of the people in the cockpit. John has been director of the engineering and air safety department for the ALPA since 1982. In that position, he is responsible for all aspects of the ALPA air safety structure. John, welcome to the podium.

Why Is Weather a Safety Concern?

JOHN E. O'BRIEN
Air Line Pilots Association

Thank you, Jeffrey. I'm going to talk about why weather can be a safety concern, with a little bit of an introduction. As we increase the number of operations in the system, the potential of encountering some significant weather or severe weather increases. The reason for that is really severe weather is quite localized. Therefore, really severe phenomenon such as wind shear has been around since God invented it. However, the potential of actually encountering such a phenomenon only became real in most recent history. As far as aviation is concerned, I think we invented the term wind shear back in the mid-70s. As it turned out, based on the results of a FAA study, the phenomenon had been around for a long time.

I'm going to discuss today why weather is a safety concern (Figure 1). To illustrate some of the concerns, I'm going to talk very briefly about one accident and one incident. The reason I'm going to talk about the August 2, 1985, Delta L-1011 accident in Dallas, Texas, was because that has certain aspects to it that are very close and personal for me. The personal element came as a result of an interest I have had in weather for a long time (Figure 2).

One of my favorite channels on TV is the Weather Channel. If we go back to the mid-80s, one of the more interesting local Washington, D.C., weather commentators to listen to was Bob Ryan on Channel 4. He had a weather radar system that was innovative at the time and tied into the National Weather Service (NWS) Radar from around the country. On this particular evening, August 2, I arrived home and sat down to watch the local weather at about 10 minutes to 7 p.m. Bob was talking about some very isolated cells around the Dallas area. He said that looking at those cells and looking at the local conditions, even

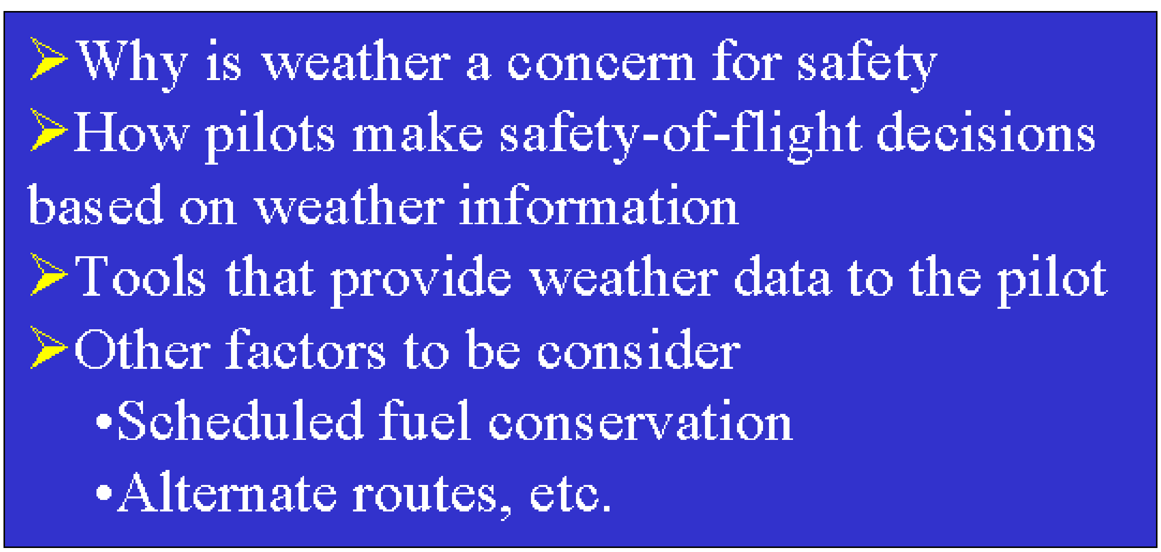


FIGURE 1 Topics to be discussed.

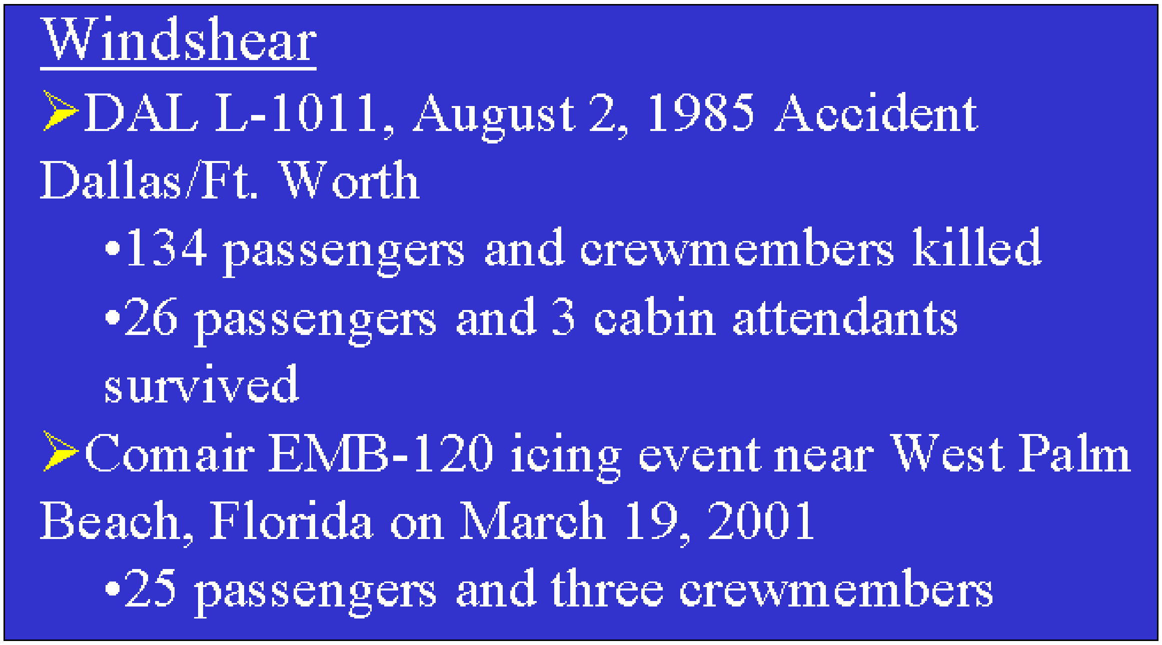


FIGURE 2 Why is weather a concern for safety?

though those cells were very isolated, he thought they were going to develop very rapidly into severe thunderstorms. Fifteen minutes later, we had the Delta accident in Dallas.

The NWS's local station that was monitoring the situation at the time was somewhat understaffed. The individual who would be monitoring this particular situation happened to be away from the station getting some food, as he was involved in an extended shift, and actually the situation at the time wasn't all that severe. There weren't any severe storms in the area, even though there was some very small cells that obviously were developing very rapidly. So there was no information provided by the NWS to the air traffic control (ATC) facilities and no information provided by the ATC facilities to the pilots operating in the area. There was, as usual at that time of the evening in Dallas, a lot of traffic coming in. There was a thunderstorm just to the north of the field that was developing rapidly. There was a daisy chain of airplanes that were flying through it at the time, and there were not really any significant reports until we had the Delta accident. It just happened to get involved in a downburst situation from that particular cell.

So the point here is that at that time, we had the technical ability to detect developing severe weather but no real ability to pass information on to people who really needed it. Since that time and even during that time, we are making significant advances in wind shear detection. We have implemented terminal Doppler radar. We have special weather observers assigned to several ATC facilities, and much better information is, indeed, passed on through LLWAS (Low-Level Wind Shear Alert Systems) and terminal Doppler weather. But occasionally we can run into a thunderstorm. The basic need here—timely, quality, quantity data information in the cockpit—still exists today.

More recently, just in March of this year, we had an icing event near West Palm Beach, Florida—kind of interesting—West Palm Beach and icing. This particular flight from Nassau in the Bahamas to Orlando, Florida, ran into some icing conditions at [high] altitude. This particular type of airplane has some interesting characteristics associated with it when it runs into icing. They suffered an upset, lost about 10,000 feet, recovered the airplane in IMC (instrument meteorological conditions), with their primary flight instrumentation inoperative. Their electronic displays had failed after doing a complete 360-degree roll, the electronics were all messed up, and the screens went blank. But they managed to recover anyway. They made an emergency landing at West Palm Beach. The airplane flew okay. After inspection on the ground, part of the skin on the elevator had delaminated, [and] there were several major components of the tail section that were significantly damaged. Twenty-five passengers [were] on board plus three crew members. Nobody was injured. The point is that there is still a need for real-time, good, quality information available to flight crews today—in this case, [about] weather information on icing conditions.

Decision-making—whether we're talking about pilots or any other profession, the following is true (Figure 3). Decisions are made on the best information available at the time. The decision is only as good as the information that is available. So if we accept the premise that we need better information on a real-time basis for flight crew decision-making today, especially concerning local severe weather phenomenon, then we still have some way to go—even though we have made significant strides over the past several years.

Going back just a moment to the Comair incident, there is a need not only to provide better weather information to make decisions, but we need better information on the icing phenomenon in order to develop the criteria that FAA can use to certify airplanes. NASA (National Aeronautics and Space Administration) and the FAA have a joint icing program. A lot of very good work is being done there. We need to do more work so we can not only provide good certification-based data for domestic airplane manufacturers and for FAA certification process but also supply to foreign manufacturers. The United States has basically delegated the regional jet production and small turboprop passenger carrier plane production to other countries around the world. Yet we are using those airplanes here. So I

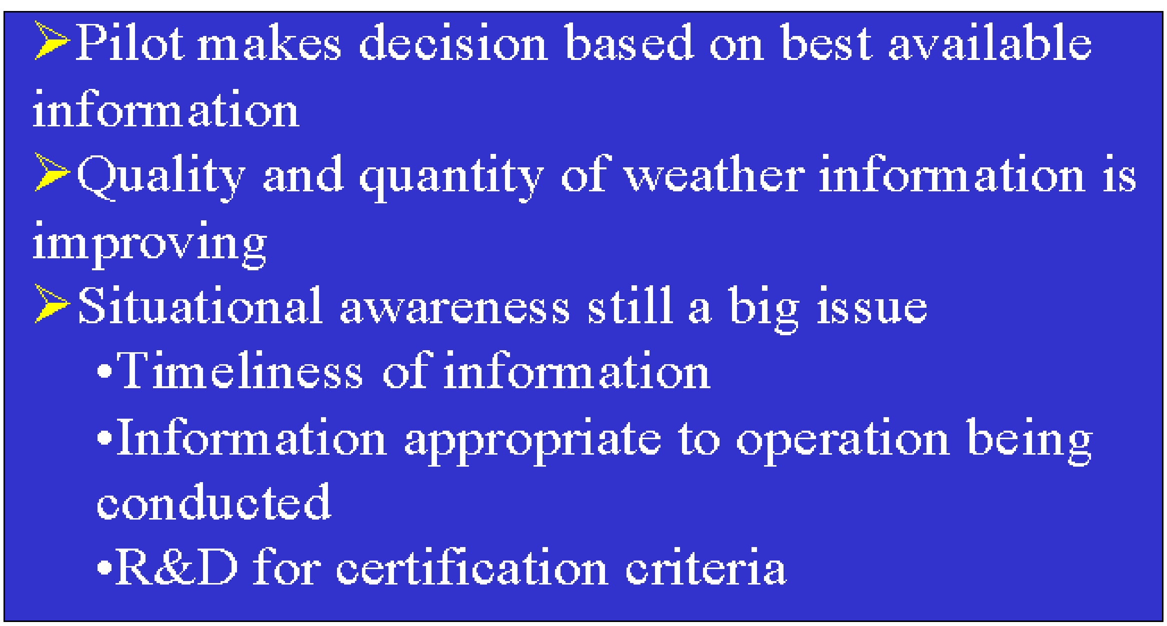


FIGURE 3 How pilots make safety-of-flight decisions based on weather information.

think we have some responsibility not only to provide good research data to domestic manufacturers but also from a public safety perspective to international manufacturers.

So what do we use for tools in normal decision-making processes (Figure 4)? We have a dispatch package obviously. Almost all major airlines operate through a dispatch system. But not all airlines have a dispatch system, and the quality and quantity of the information provided vary significantly among the airlines—everybody meets, of course, the FAA standards. Some airlines go much further than others in developing weather packages and doing a lot of work on their own.

Some years ago, Northwest developed a turbulence plot system that probably was one of the best in the world and provided very good information on severe weather phenomenon and in flight turbulence to their flight crews. That kind of capability is very costly, and so it is not normally embraced by everybody who operates in the system, but it certainly would help.

One of the best friends the pilot has is his or her airborne weather radar. It is used extensively. For those of you who have done recent traveling and have traveled on airlines who make the ATC frequencies available to you, you might plug into those and listen to them—especially this time of the year because you hear some very interesting conversations between the controllers and the pilots about deviations—what you can and can't do, and what you would like to do. Everything is compromise, especially when you get into dense traffic situations because you can't make the deviation that you would normally like to. Of course, you always have the alternative of exercising your emergency authority as captain and deviate around any weather of a severe nature. You're supposed to do that. But again, there are other factors in play here that run all the way from just making sure the passenger comfort is catered to as best as possible to the other end of the spectrum—making sure you don't run through that red area on the radar scope.

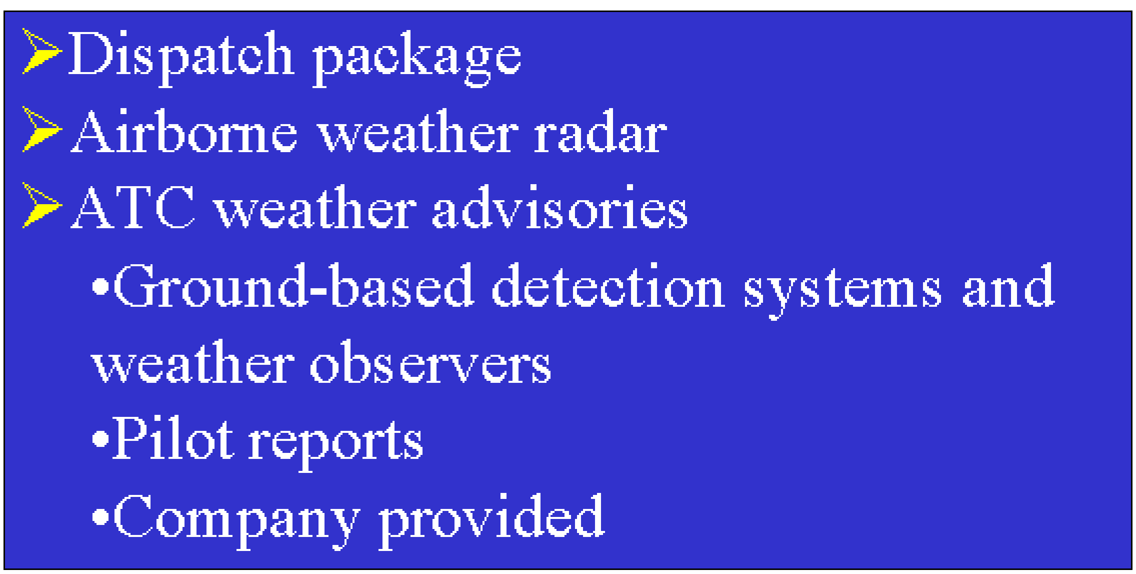


FIGURE 4 Tools that provide weather data to the pilot.

Weather information provided by the ATC system is significant. It is very important—derived from the ground-based detection systems and human weather observers, pilot reports that are passed on, and the collaborative decision that takes place between the operator and the FAA.

Other factors come into play in weather decision-making processes. The desire to make schedule [and avoid] the delays (Figure 5). Whether we like to admit it or not, there always is, in the back of everybody’s mind, a desire to make schedule, a desire to avoid delays. This is becoming more of a factor now as the media interest grows [and] the public perception that is generated by media interest becomes more focused on the increasing number of delays. There are significant pressures put on both the operator—the airline itself—and the individual components of that operation to try to do as much as possible to avoid delays. So it is a factor in the decision-making process. Also the efficiency of the operator is important if you are involved with an operator that has a significant economic situation confronting it. Obviously, you want to do everything you possibly can because your success depends upon the success of your employer. So you are obviously interested in those factors as well.

And last but not least, there is passenger comfort. As I mentioned earlier, if you listen to some of the dialog on the ATC frequencies, probably the most frequent conversation you hear is between the pilot and the controllers seeking an altitude for a smooth ride. So there is a lot of communication back and forth between various flight crews—through the controller on turbulence and what it is the best altitude. It is quite a dynamic situation.

In summary, the weather information picture is getting brighter (Figure 6). There is a lot of technology that has been employed recently. There is more coming down the road. NASA and FAA together and some people like Dr. McCarthy—who will follow me here

FIGURE 5 Other factors to be considered.

FIGURE 6 Summary.

—have contributed significantly to the safety of the aviation system by providing better technology and better weather information. There is always more to be done. The reason there is more to be done is because we have more airplanes flying all the time. Weather is still there, [and] the chance of encountering a severe phenomenon is significantly increased as we put more planes into the system to meet the growing transportation needs.

Click here to see O'Brien's slide presentation.

Jeffrey N. Shane: Thanks very much, John—a very interesting presentation. I don't know about the rest of you, but I have a bunch of questions for him when we get to the questions and answers. Next is Dr. John McCarthy, who is Manager for Scientific and Technical Program Development of the Naval Research Laboratory in Monterey, California. Prior to his joining the Naval Research Lab, Dr. McCarthy was at the National Center for Atmospheric Research in Boulder, Colorado. He has spent years working on the issues we are discussing this morning. I am very happy to welcome him to our podium. Dr. McCarthy.

PANEL 1

Frequency of Weather Delays
An Analysis

JOHN MCCARTHY
Naval Research Laboratory

Before I start, I want to acknowledge a couple of experts. One is Brant Foote, who is my successor at NCAR (National Center for Atmospheric Research), who will be speaking later. We have discovered we are going to be repeating ourselves somewhat. And also Jim Evans, who is sitting here in the room, and I want to acknowledge some incredible work that he has done. I'll be referring to it. He is at the MIT (Massachusetts Institute of Technology) Lincoln Laboratory and has done some monumental work in showing some impacts of weather delay that I think is really quite extraordinary. So with that in mind...

I'm going to talk a little bit differently than Joe asked me to do. But, since I modified my talk in the airplane—after 10 days in the Mojave Desert and my brain fried—I took that opportunity. So let me jump ahead and see if this works.

Types of delays—and I'll go quickly through this—are obviously convective storms in the spring, summer, and fall (Figure 1). [They] are clearly the biggest and most frequent and nearly continuous problem depending on the part of the country that you are in. Winter storms are, of course, major impacts of Part 121 operations, both in C&V (ceiling and visibility) and vertical wind shear. As it turns out, in a winter storm, the winds change rapidly near the ground. You can have very strong winds quite close to the ground, and they can taper off to much lower speeds. That impacts acceptance rates more than you might imagine. In work that Evans has [done], it has shown that [that] has been a significant impact in acceptance rates.

- Convective Storms in Spring, Summer, and Fall; clearly the biggest, most frequent, nearly continuous problem
- Winter storms at major northern airports impacts Part 121 operations (C&V, vertical wind shear)
- Flight in IMC conditions, or transit from VMC to IMC conditions impacts Part 91 and military operators; critical need to do better job in C&V forecasting/nowcasting

FIGURE 1 Types of delays.

Another area of delay is flight in IMC (instrument meteorological conditions) or transit from visual meteorological conditions into IMC conditions. This has a very major part on the small general aviation Part 91 and military operators—there is some work I have seen recently and I'll show you in a moment. So C&V has some interesting things that need to have happen, and some people have referred to that already this morning.

Convection, of course, is widespread, but as Agam pointed out and in Jim Evans' work, it has a huge relationship to the traffic volume such as the New York airports (Figure 2). Winter storms, of course, are in the Northern and Eastern United States, for the most part. C&V is widespread. It is a big issue in the Northeast, Mid-Atlantic, Middle and Deep South sometimes, Upper Midwest, and of course, on the West Coast.

One of the big issues is cause of delay (Figure 3). As I understand it, there are four causes of delay: equipment, ATC (air traffic control), volume, and weather. I think traditionally weather was a catch-all. When it wasn't equipment and when it wasn't ATC volume, there was a tendency to often throw delay into weather. I think only recently has

- Convection widespread, but depends on traffic volume situation (e.g., NYC)
- Winter storms north and east U.S.
- C&V issues widespread, NE, Mid-Atlantic, Middle and deep South, Upper Midwest, West Coast

FIGURE 2 Geographical impacts.

- Equipment
- ATC
- Volume
- Weather
  - Complexities of interrelationships between categories not well understood; more work needed following excellent lead of MIT Lincoln Laboratory at NYC ITWS
- Need better definitions of bins, modeling, etc.

FIGURE 3 Causes of delay.

a dissection or a careful analysis begun to look very carefully at what has [been] the cause of delay in terms of weather. I personally believe that the first definitive work has been done by MIT Lincoln Laboratory, and I'll hold up a report if you haven't seen it. It is called "Delay Causality and Reduction at New York City Airports." Frankly, I think it is the first time where this work has been done in the kind of detail that needs to be done. The complexities and the relationships need to be done much more carefully. I think the bins between these various components need to be better understood. And I think it is an area of active research that is very important for us to understand the importance of these various components. We are third in terms of weather, but I think it is a very important one. A colleague of mine thinks we can't squeeze more volume, so to speak, out of weather. I beg to disagree, and I hope to make that point today.

Boeing is a keeper of statistics. This is one of many diagrams that [shows] weather is still a factor in worldwide jet transport accidents (Figure 4). Weather is here at 7 percent. There are many different ways of looking at that. Flight crew cause is 67 percent. Weather is in there as a supporting cause. Weather as the direct cause is shown at 7 percent. I could show 50 of these diagrams and actually deleted 6 of them in order to squeeze down to my 10 minutes.

I want to spend just a couple of my 10 minutes on this diagram, which is on convective storm prediction (Figure 5). Let's see if I can build this diagram correctly and do this right. This is a diagram that looks at the accuracy of the forecast between one, which is perfect, and zero, which is no capability (and that is on the left) and out from 0 to 6 hours. We look at it from tactical to strategic and define 0 to 2 hours as tactical and 2 to 6 hours as strategic. The 2 to 6 hours is mostly defined by a product that the National Weather Service (NWS) produces at the Aviation Weather Center. [It is] called the Collaborative Convective Forecast Product (CCFP) (Figure 6), which is designed to look at the long-range products

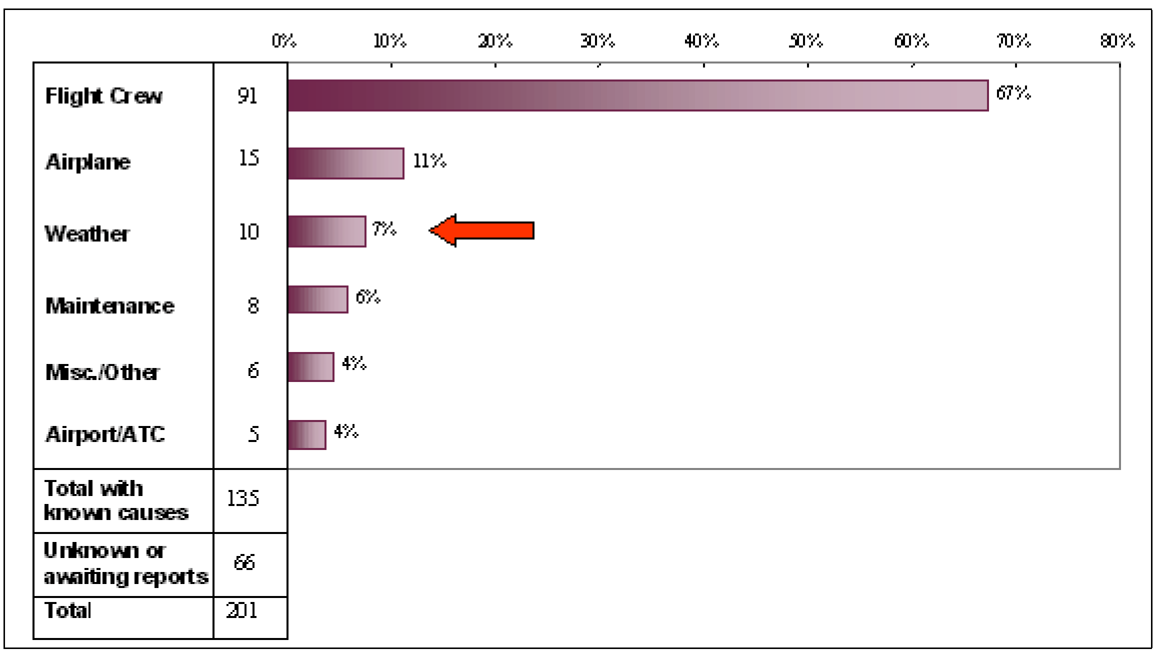


FIGURE 4 Accidents by primary cause as determined by the investigating authority. Hull loss—worldwide commercial jet fleet—1990-1999.

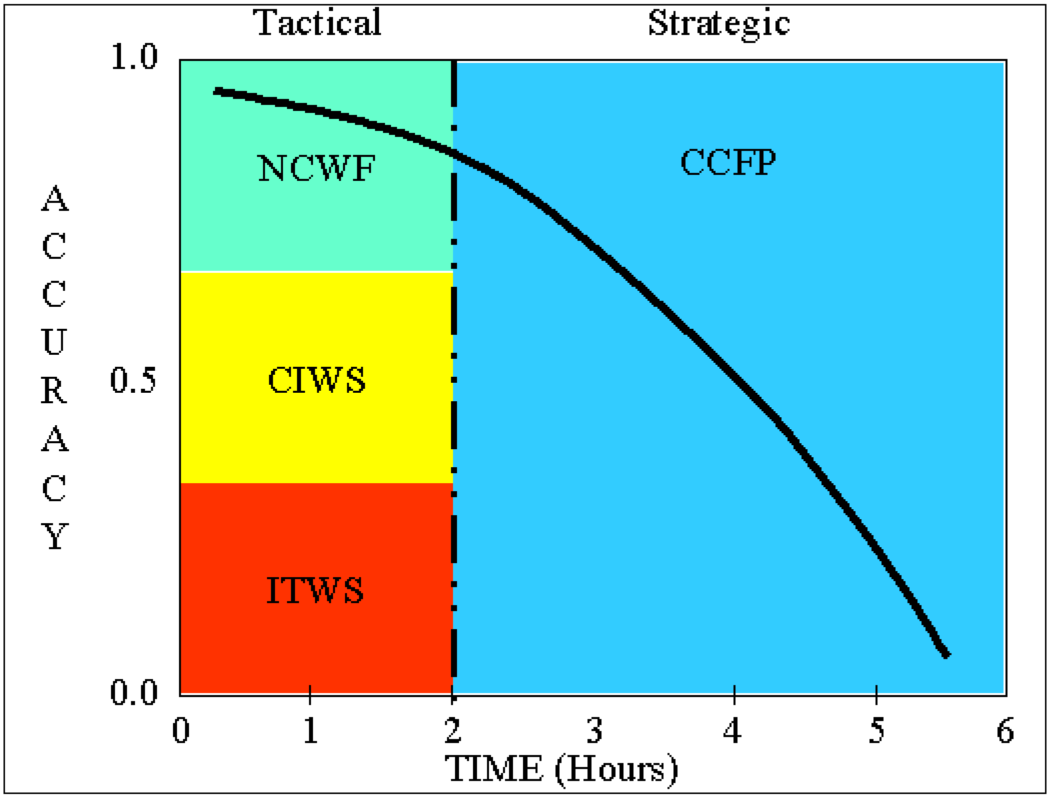


FIGURE 5 Convective storm prediction.

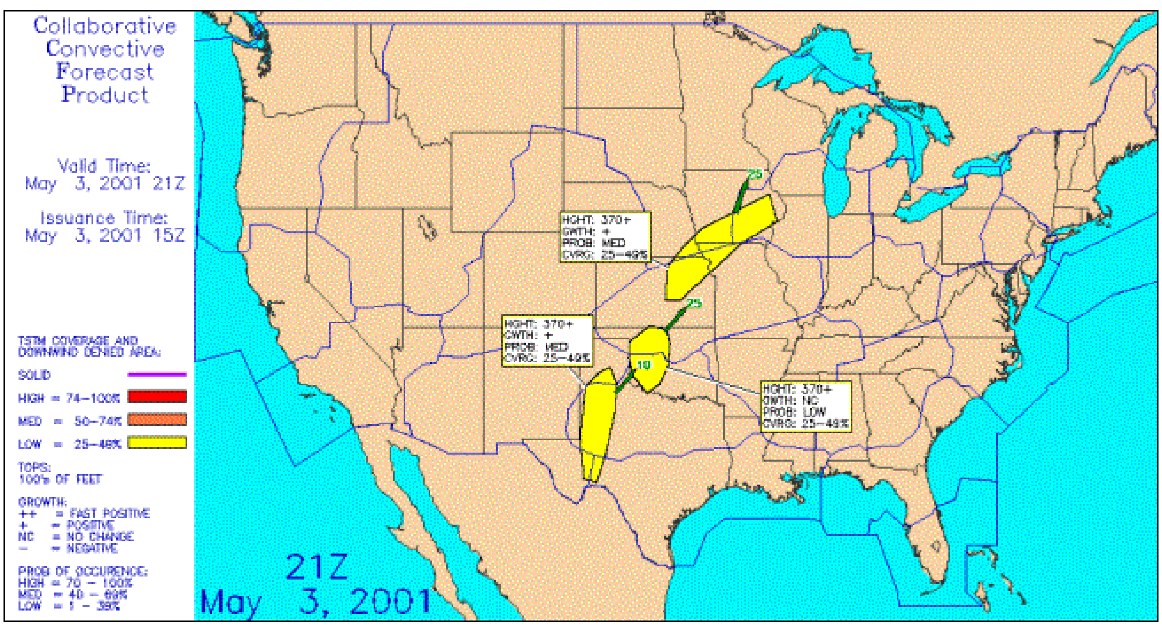


FIGURE 6 Collaborative Decision Forecast Product Aviation Weather Center.

for the collaborative decision process that Agam talked about primarily. It is designed to look at this longer-term process.

Another product is the National Convective Weather Forecast Product, which is a 0- to 2-hour forecast that has been produced by the FAA. But, it also shows as a product at the Aviation Weather Center in Kansas City (Figure 7), which is a 0- to 2-hour forecast. We'll look at it briefly. I'm going to embarrass myself and make sure I have the name—it is CIWS, Corridor Integrated Weather System, which is a program coming up shortly that I'll talk about, and maybe has already started (Figures 8, 9, and 10).

Finally, there is another 0- to 2-hour product, ITWS (Integrated Terminal Weather System) which is a follow-on in the terminal Doppler weather radar program—a more sophisticated version (Figures 11, 12, and 13).

All of the programs on the left represent the 0- to 2-hour capability and really represent scientifically what we can do today. The FAA is doing marvelous things in supporting the 0- to 2-hour tactical effort: the blue area. And as you can see by the black curve, our scientific understanding of forecasting thunderstorms falls off very rapidly in the 2- to 6-hour region simply because we do not understand scientifically our ability to forecast (Figure 5). When we talk about a forecast capability in the 25 percent or 35 percent range, we may be excited scientifically or as scientists say we may be improving it by 10 percent or 15 percent. As an operational need, it may be of no value. So by integrating radar data into models 5 or 10 years from now, we may see real value

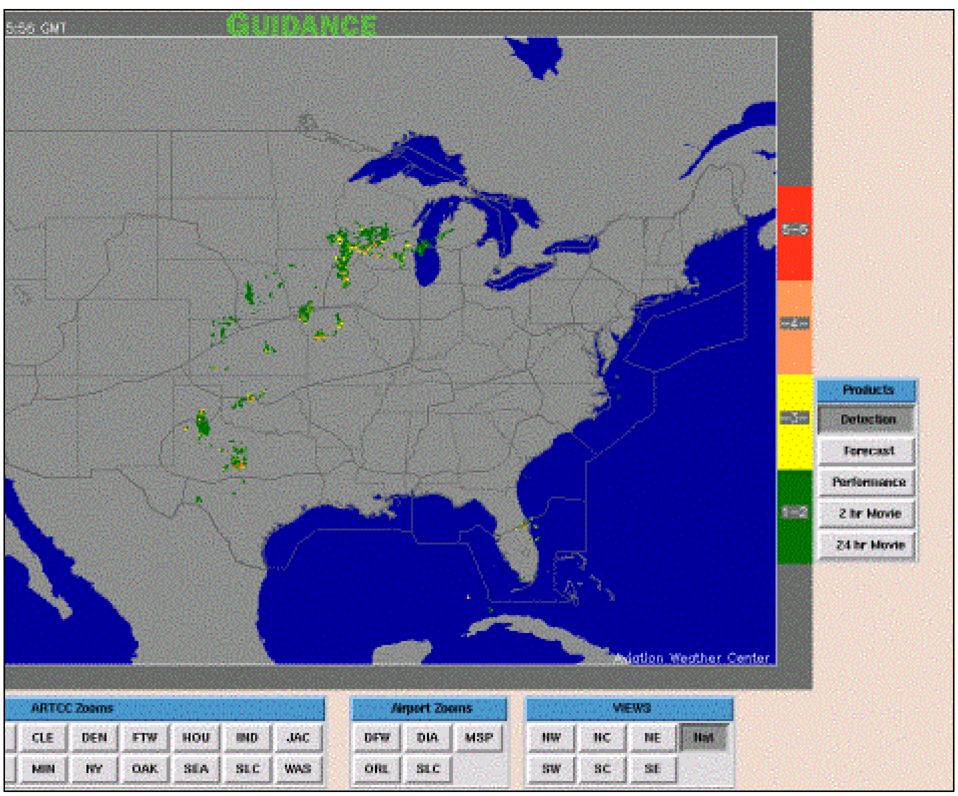


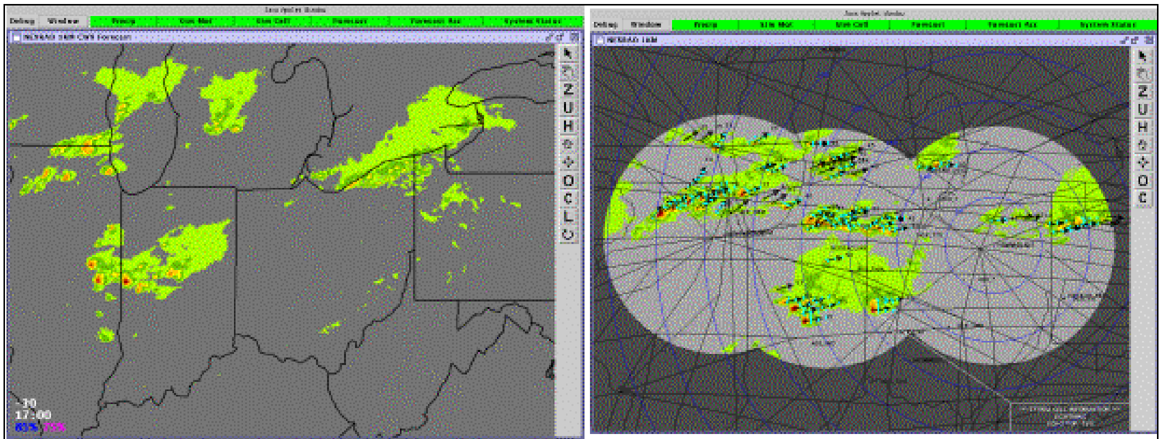
FIGURE 7 National Convective Weather Forecast Aviation Weather Center.

- Corridor Integrated Weather System is an expansion of existing ITWS technology.
- Congested en route corridors such as Cleveland ARTCC account for a large fraction of US en route delays.
- Corridor Integrated Weather System (CIWS) will use all the FAA and NWS weather sensing assets plus best available convective weather forecast technology to reduce delays.
- Real time product feed to users start in May 2001 at Command Center, en route centers, major terminals
- Critical need to insure that CIWS weather alert areas are matched with **AIR TRAFFIC MANAGEMENT ACTIONS** to take full advantage of capabilities

FIGURE 8 Corridor Integrated Weather System (CIWS).

- Delay reduction projected to be well in excess of 27,000 hours per year.
- Reduced delays at ORD, CVG, DTW and PIT would equate to a savings of $78M per year for users.
- Better decision making.
- Increased departure rates.
- Better coordination among centers, tracons, ATCSCC.
- Less unnecessary rerouting due to enroute weather.

FIGURE 9 Corridor Integrated Weather System (CIWS).



1-hr Regional Convective Weather Forecast (loop) | Precip Display with Storm Motion Vectors

- CIWS provides high resolution weather and forecasts in Cleveland Corridor
- Multi-window display allows pan/zoom and animation

FIGURE 10

What is ITWS: ITWS provides an automated capability which will:

- Integrate data from FAA/NWS sensors and systems, as well as from aircraft in flight
- Automatically provide weather information that is immediately useable without further meteorological interpretation
- Predict short-term weather changes

Purpose: Provide terminal weather prediction and hazardous weather detection to increase safety and sustain capacity in all weather conditions

FIGURE 11 ITWS.

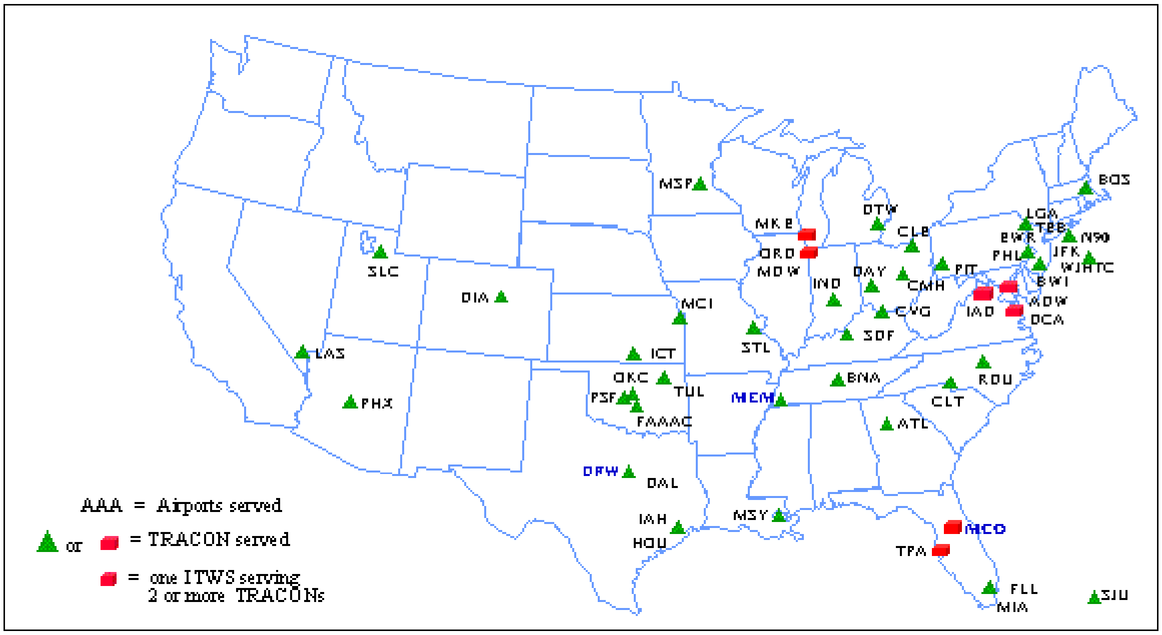


FIGURE 12 ITWS-supported airports.

Wind Shear Products	Graphic Situation Display
Microburst detection/prediction	ASR-9 anomalous propagation editing
Gust Front detection/forecast	Tornado detection/alert
Wind shift estimate	Airport lightning warning
ATIS Timers	LLWAS winds
Precipitation	Terminal Winds
Storm Products	Pilot terminal test messages
Storm Motion/extrapolated position	
Storm cell information	

FIGURE 13 ITWS capabilities.

for the operator, and this research must go on. But real value is going to be on the left-hand side. We can look at some of these. For example, the CCFP looks like this, and this is an example of a current product (Figure 6). I was hoping to go live on the Internet but could not today.

We can look at the CIWS project. This is an example of some data that shows the rapid increase in delay over the last few years, and it is quite dramatic (Figure 14). Here is an example of fuel burn for May of 1990, showing that the fuel burned between Chicago and New York in the region above seven kilometers is very high—showing that here is where the action is (Figure 15). And, it has been on the basis of this that the CIWS

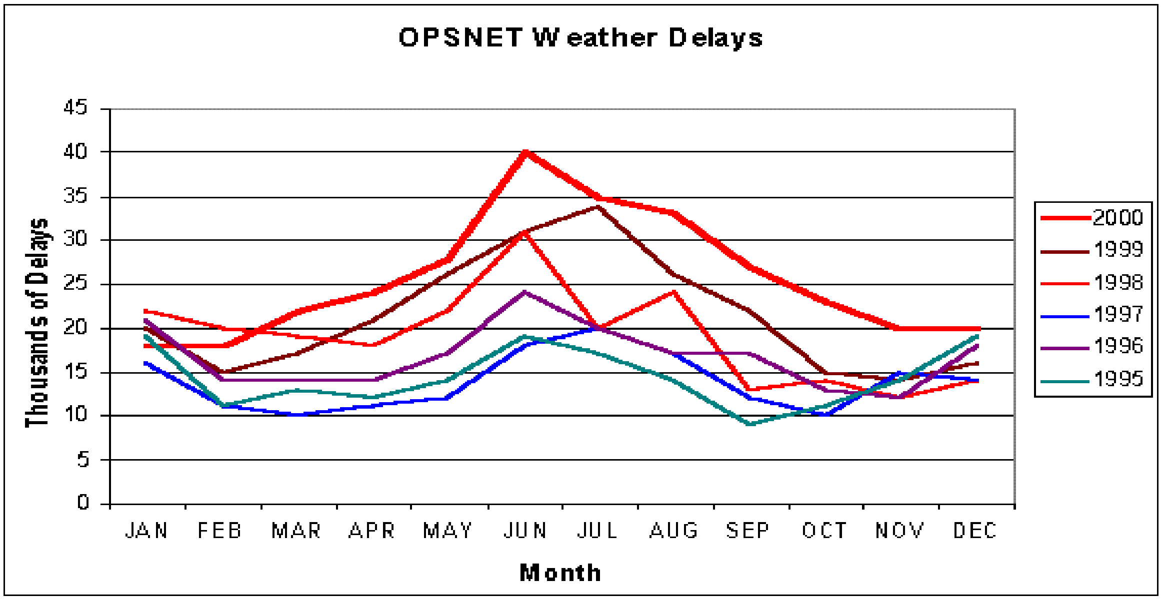


FIGURE 14 Convective weather delays.

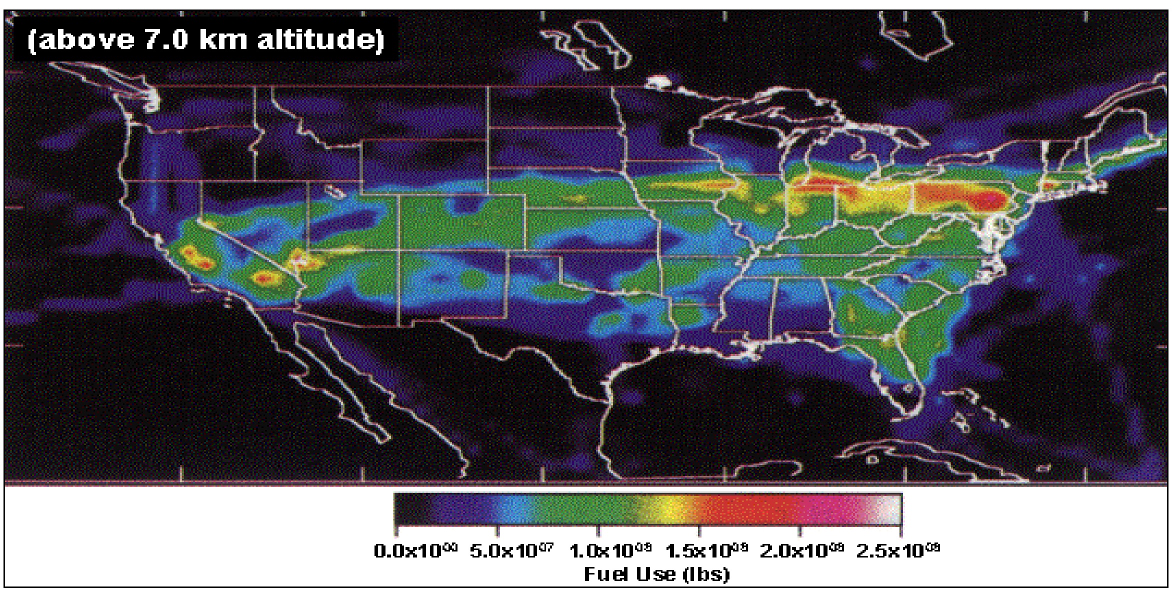


FIGURE 15 CIWS—Commercial and military fuel burned (lbs/day) for May 1990.

program has been put together of bringing radar from both NEXRAD (next generation radar) and FAA centers to bear in this area to look at what is called the corridor program to expand ITWS technology and bring all of these capabilities into facilities in this region (Figure 16). The critical need will be to bring these weather capabilities to bear on air traffic management decisions given these very high-resolution capabilities during this program. Delay reduction projects like this will bring, we hope, reduced delays at O'Hare, Chicago, Illinois; Cleveland, Ohio; Detroit, Michigan; and Pittsburgh, Pennsylvania. [This] ultimately makes better decisions for inbounds and outbounds out of New York, and also impact the system's command center, which will also be playing a significant role in the program (Figure 17).

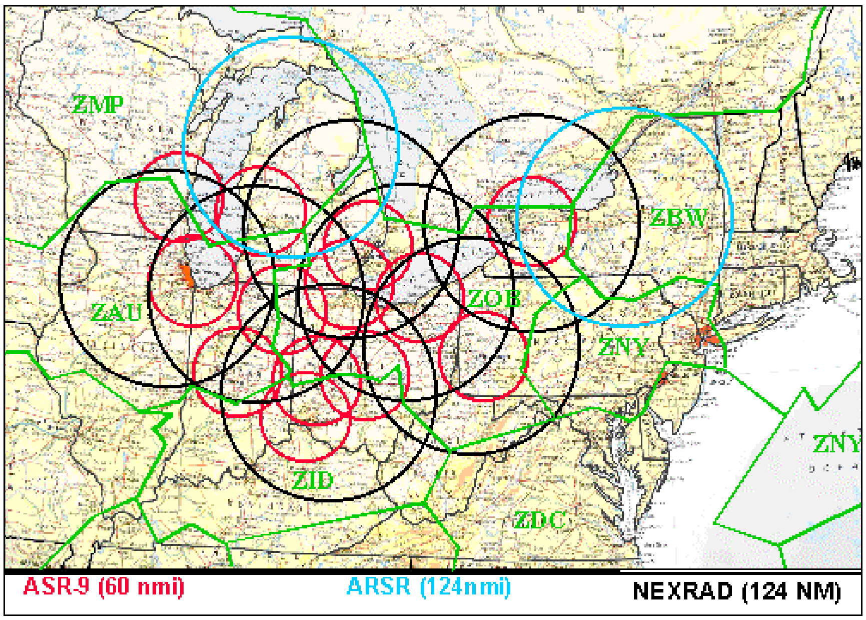


FIGURE 16 Coverage of sensors for CIWS.

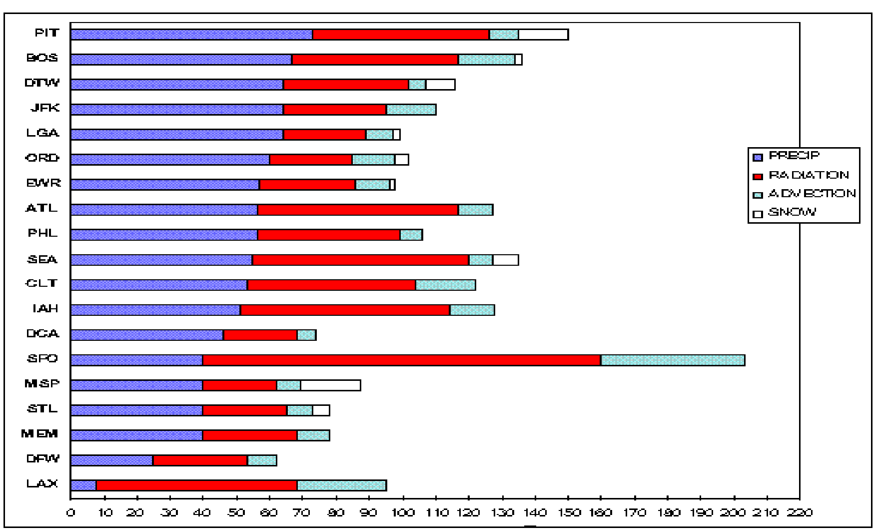


FIGURE 17 Impact of C&V at delay airports.

Let me go back to ITWS. I think many of you are aware of it. It is simply an expansion of the existing terminal Doppler weather radar program that MIT Lincoln Laboratory and NCAR were involved in, and this is to provide a much improved system at a variety of airports shown here (Figure 12). Again, I'm not going to spend time on it—but a greater array of products to deal with wind shear products, precipitation, and a variety of other things, including terminal winds to allow better spacing and metering, which I think are very important in terms of predictions. There have been four locations in which prototype systems have occurred—Orlando, Florida, Memphis, Tennessee, Dallas, Texas, and New York, so far (Figure 18).

Let me talk briefly about a very new program that is just coming off the blocks and is just finishing up that has been funded by the Navy, by NASA (National Aeronautics and Space Administration), and by the FAA involving MIT Lincoln Laboratory, the Naval Research Laboratory, and NCAR—I won't go through all the folks—looking at the impact of ceiling and visibility delays (Figure 19). It was cantilevered off the big delays

- Currently 4 prototypes operational
- Situation Displays located in following facilities-
  - Orlando: MCO, TPA, ZJX
  - Memphis: MEM, ZME
  - Dallas/Ft. Worth: DFW, DAL, ZFW
  - New York: N90, JFK, LGA, EWR, TEB, ZNY, ZBW, ZDC, ATCSCC

FIGURE 18 ITWS prototypes.

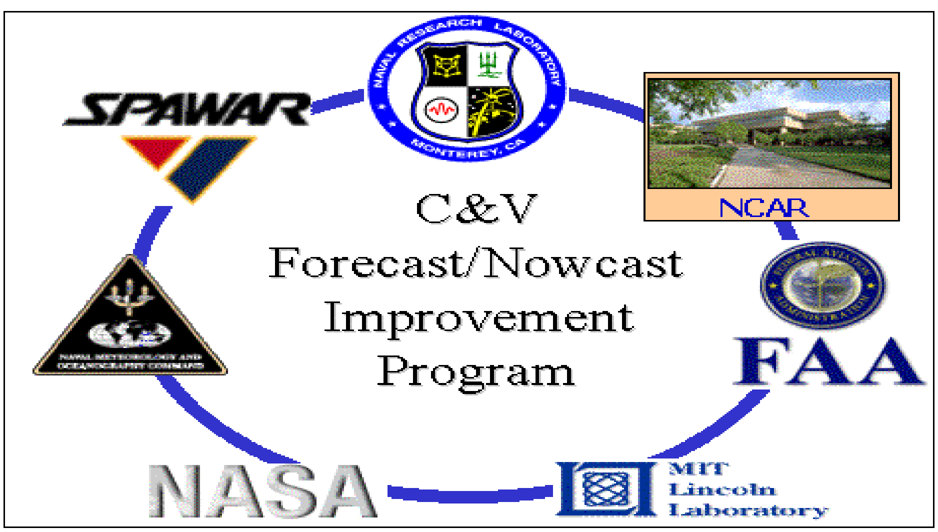


FIGURE 19

of San Francisco, California, and also stimulated by a very interesting piece of work. We have a Navy guy who just did a master's degree at the post-graduate school who looked at 9 years of data for Class A Navy accidents and found out that nearly 70 percent of Class A Navy accidents were visibility related as factors in these accidents, not causal based upon the way that the Navy Safety Center defines accidents. I expected the principal related factors to be more thunderstorm-related instead of visibility. So a very large percentage of accidents were related to a loss of visual reference, flight from visual into instrument conditions, and things like that. It surprised me. So this is just a piece of his work (Figure 20). It is a study that takes modeling satellite data and surface METARs (meteorological aerodome reports) data, puts it into a fuzzy logic system, and comes up with a system that contours VFR (visual flight rules), marginal VFR, IFR (instrument flight rules), and low IFR conditions into a contour of the United States, or for that matter, anywhere in the world. It looks at it every 15 minutes out to 4 hours. If I could go live on the Internet, I would show it to you anywhere in the United States right now, but I can't unfortunately. So we are working very hard on that. It is currently being tested in Southern California at NWS/FAA facilities in a very early operational test and evaluation.

So let me jump to some parting thoughts (Figures 21 and 22). There have been some many exciting things happening in the FAA—more exciting things than I have seen in my career, I have to tell you that. It is really very much of a thrill. Weather is a major cause of delay, but too little is known about the complexity of those delays. It has been, I think, a blow-off to a certain degree, and we haven't understood it. We've been saying: Look, in the tactical area there is a lot of information—sort of like pouring alcohol into a glass of alcohol and cotton—a common physics experiment—there is room for more alcohol (surprising to students). If you keep pouring alcohol/traffic into the system, there

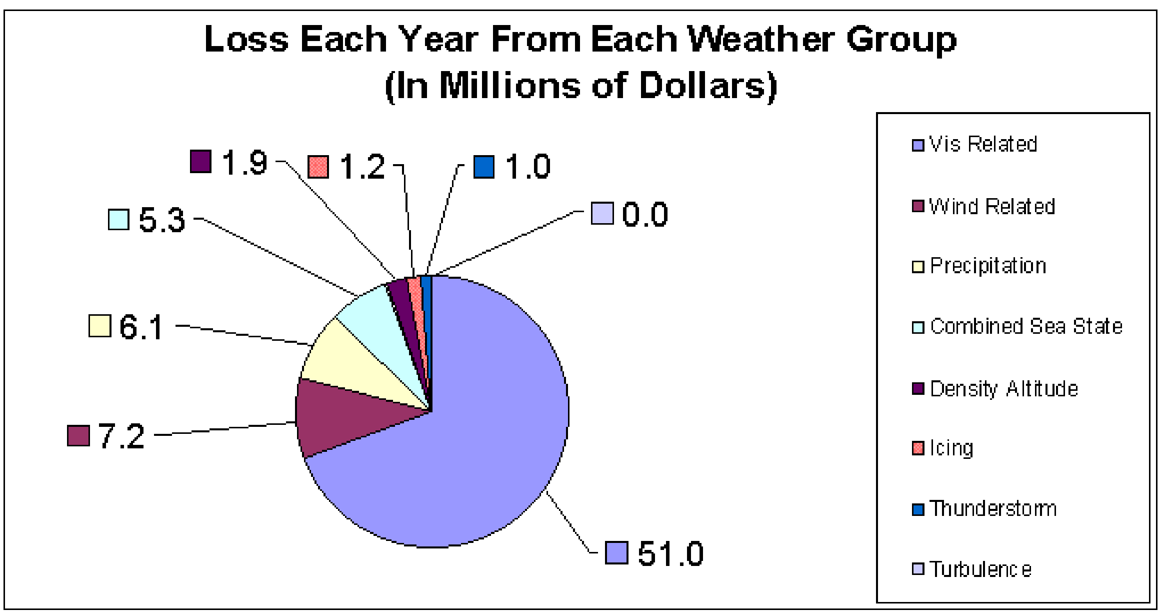


FIGURE 20 Class A mishap dollar loss due to weather per year ($74 million).

- Many valuable weather developments at the FAA
- Weather is a major cause of delay, but too little is known about the complexity of weather impacts
- More research on complex models on weather impacts is needed to understand weather more thoroughly how weather fits into ATC/ATM delays
- I am of the opinion that the impact is both larger than previously believed, and reducible, due mostly to studying the results of Jim Evans of MIT LL

FIGURE 21 Parting thoughts.

- Weather remains quite distributed throughout the agency, and while excellent work is occurring, better “big picture” coordination of weather within the agency would be beneficial regarding delay and safety
- There continues to be a need for a senior executive level atmospheric scientist with operational experience who has the respect of the weather community who can help FAA senior management get a broad, integrated handle on weather, and integrate it back to ATC/ATM

FIGURE 22 Parting thoughts continued.

is more information that you can put in there. And it requires complex models to understand how the molecules work, how we can build that model. I would say that the work that Evans and his people has just begun to scratch the surface to understand that. We need to understand that more completely. So more research needs to be done in how all that fits together.

I'm of the opinion that the impact is both larger than previously believed and reducible. I'm repeating myself. Weather remains quite distributive throughout the FAA. While excellent work is occurring, the aviation weather research program, the work that is supported at ITWS, the work supporting the WARP (weather and radar processor) program, the coordination with the agency in terms of air traffic—I think it is beginning to become better coordinated for sure. I think it can be even further coordinated. I am of the belief, and I can sing this song and I have sung this song before, that there needs to be a senior executive-type person that looks at weather in a senior way—that helps look at how it all fits together. How does the jigsaw puzzle work? Research in weather delay, weather systems, and air traffic's use of weather—how does that work? I think that needs to happen. I thank you very much.

Click here to see McCarthy's slide presentation.

Question-and-Answer Session

Jeffrey N. Shane: Thank you, John. It is 11 a.m. and that gives us about a half hour according to our program to throw out some questions and comments at our three speakers this morning. I have a number myself, but I suppose I shouldn't dominate this proceeding. Let me see if I see any hands out there. I do indeed. Thank you very much for using the microphone. Please introduce yourself.

Richard Marchi: Dick Marchi with the Airports Council here in Washington. Much of today is going to be talking about tactical issues regarding weather, but we have a strategic issue that I would like to get on the table and maybe get some reaction and then, of course, to something John McCarthy said. By categorizing a lot of the airport-related delays as weather, I think we do ourselves a disservice in trying to figure out how to deal with them. For instance, at San Francisco, you had a chart up that shows the ceiling as a big factor there, that probably 20 to 25 percent of the time cuts them down to a single runway. In one sense, that is a weather-related delay, but in another sense it is really not. There are things we can do to lower the ceiling restriction for visual approaches at that airport using technologies. They can build a new runway, which they obviously are attempting to do. I guess my observation is that by not parsing the weather out in more detail, we don't get information that allows us to make the strategic decisions as to what is the best approach to dealing with the delay situation at many of our airports. I would invite some comment on that.

Shane: Let me just ask you to amplify on the question a little bit. You say by not parsing out weather, are you talking about information that is not being given to operators?

Marchi: Right. By just saying that X percent of our delays are due to weather and not looking more at the greater level of detail as to just what kind of weather is causing specific delays. I'm saying this is particularly true at airports. I think we lose information that can help us make decisions as to how to deal with that weather.

John McCarthy: Are you asking that question of me? I certainly cannot argue with the point that you are making. The point is that in any given situation or variety of situations, it is a complex matter. Living near San Francisco, I am very much aware of all manner of things that are being looked at to try to maintain capacity when it is otherwise lost. It certainly is a complex one. When stratus burns off at San Francisco is but one of those things. So it is a complex matter. So we have to avoid compartmentalizing the solution. The solution is indeed an integrated one. Is that your point?

Marchi: I guess maybe it is more just an observation or a request that FAA might want to put some effort into parsing this weather out in a more detailed way that lets us have a better sense of what the solutions are—rather than just lumping everything in as one category of weather.

McCarthy: I agree.

Shane: I would put that question, if I may, in a somewhat different way and make it a little bit more general. I came away from the three presentations this morning both very encouraged but then a little discouraged—encouraged by the amount of sophistication and the science today. I think if you could take nothing else away from the three presentations you've just seen, you will know there is a tremendous amount of work going on, and it is going on at a very sophisticated level. We know a tremendous amount about weather in the system, and yet we had the worst summer in the history of aviation last year, and we are hoping we don't have another one this summer.

Having developed a level of sophistication to that extent, is it fair to conclude from these presentations that we've picked all the low-hanging fruit—that the additional information that all of our presenters have said that we need is not going to be available to us in real-time? That it is going to take some exponential increase in the level of sophistication that the science displays today in order to really produce improvements through the study and the technology that we apply to this weather situation? Agam Sinha, [do] you have a view of that?

Agam N. Sinha: I have a view, but I'm not sure I have the answer. To add to the first comment on the slicing of the weather differently by cause—I think that is definitely true. I agree with that. We need to look at weather not as a single entity but by types of weather. But the other part, I think, that is also important to think about is that solutions to any of these problems are going to be local. So there is no magic technology, weather or otherwise, that we are going to deploy throughout the system and solve all of the delay problems.

If we stick with the San Francisco example for a minute, clearly, the morning fog is one of the biggest problems resulting in the capacity being cut in half. Now, you can increase the capacity through technology by adding a runway that is spaced far enough apart [from the other] that you can run parallel runways even in the IMC (instrument meteorological conditions) weather—under the instrument weather conditions like Chicago (Illinois) does and Atlanta (Georgia) does. But again, there are no magic bullets that are going to solve the problem across the system. So when we think about the solutions, we can look at the causes of weather. We also need to think locally, and we also need to think about who are all the stakeholders. It is the FAA. It is the airport authority. It is the National Weather Service if it's a weather problem. It is the meteorological community. It is the scientific community. It is the technologies. It is the users. It is all of them. So I would recommend that when we start looking at the solutions, that we almost stop talking about global solutions and go to the specific locations and specific problems.

Jim Evans: My name is Jim Evans, and I'm at MIT (Massachusetts Institute of Technology) Lincoln Laboratory. We have been looking at this question for about a decade. It is not just how much of the delay was avoidable. Some of the significant amounts of delay are absolutely unavoidable—runways were closed, there may have been a snow storm, and by golly everything is shut down and you can't even get to the airport. However, we have never gotten good statistics on what fraction of the delay that occurred was actually avoidable. In principle, there was no reason if we had better information and you gave it to FAA users, it could have been avoided. I'm going to tell you that right now we have technology that is going into the field. It is not there—and won't get there fully for several years—that would have made a significant difference. I believe based on what we have seen in New York, we could probably get rid of 25 percent of the delay at a place like New York. I believe a very significant fraction of the delay at San Francisco in the summer is avoidable delay with better forecasts. I've lived there, too. I can tell you it hinges very delicately on what time of day it burns off and when the traffic flows. There is a lot that can be done, but we have no quantified statistics. I think Administrator Garvey has made a good point. As the FAA goes to a performance-based system—and it hopefully has a funding stream that reflects that—when you go and look in detail at this, you will find there is a lot of delay that is avoidable. As Agam says, you have to look at it on a per airport basis—it is not a generic answer. It is a substantial investment. It is the kind of investment that American industry has made that has dramatically improved its competitiveness internationally, as we have seen this tremendous increase in our national economy in the last decade, and it can apply to the aviation system.

Shane: Are you saying that the capability to improve predictability is there today?

Evans: There are systems we have demonstrated at four airports, for example, that aren't at many of the airports yet. The production system is going to be deploying them shortly. But the point is I'm saying there is technology that is off-the-shelf today that you could put in at airports that is not there yet. It is exactly as John said: It is tactical systems that we know can better reduce delays, but we don't have it at the airports yet. But yes, it is in the pipeline. The train is chugging.

Shane: Any comment from our panel?

John O'Brien: There is no question, getting back to Dick's basic premise, that if we break up the weather data into types by location and unique circumstances, that we can define tools for facilities at particular airports—whether they be procedural, hardware, or software—that will eliminate a significant amount of delays. The key is, though, better information. I can't think of one technique, whether it is closely spaced parallel operations at San Francisco or St. Louis or Philadelphia or wherever we want to go that wouldn't benefit from better weather information. We are working on these things. Not only is improved weather information needed but other information as well to make good decisions on which tools to implement. So it is a hand-in-glove operation. You have to take a systems approach. It would be better to have a more thorough understanding of exactly what part of the delay contribution is directly associated with a particular weather phenomenon. So then if we are indeed looking at some kind of a closely spaced parallel operation at San Francisco, exactly what component of the delay is going to be reduced with the morning fog situation or whatever it might be?

There is good data available now on potential delay reduction based on the contributions of weather, the contribution of various techniques, and the contribution that a particular operating procedure might have at a unique location. But beyond that, there are, in my opinion, additional questions. Let's just look at the San Francisco situation for a moment. Wake vortex is not a weather phenomenon, but it is associated with the environment, and we do need better means of detecting and tracking wake vortices if we are going to get benefits from closely spaced parallel operations.

Shane: Wake vortex. Just making sure that everybody is keeping up with the terminology.

O'Brien: Solving the problem of delays by allowing additional operations at the closely spaced runways at San Francisco under low-visibility conditions will make a significant contribution to reducing delays at that airport. However, we are never going to get there without the means of detecting and tracking wake vortices. The key is between 300 and 1,500 feet on approach. We need a better means of tracking the vortices. Some of the technologies that are being worked on today have the capability of doing that. What contribution will this make to the total delay situation at San Francisco? I don't know if anyone has a truly accurate picture or idea on that. But it would be significant.

Shane: Agam?

Sinha: Just a general comment, and this has been made many times, but I don't think it can be said enough times. When we look at technology and we look at the success that we have obtained from the technological perspective, what we should always keep in mind is that for it to be effective, we need to talk about technology, we need to talk about procedures, and we need to talk about people. By that, I mean the roles and responsibilities of the different players the air traffic management (ATM) system has, including the users, the controllers, the traffic management people, the dispatchers, the pilots, and so on. Though technology is a big part of it and we should embrace all the advancements, let's not forget that all those things have to come together before we have success.

Shane: I just wanted to ask a quick question about the allocation decision-making responsibility, but forgive me because it is a lay question, if I may. I'm going to put it to John O'Brien. Everybody is aware of the Department of Transportation's (DOT) on-time performance statistics. It is one measure of the quality of an airline's operations. Tell us, please, that an airline is not penalized by this [DOT] statistics by not taking off in a storm.

O'Brien: Depending on your perspective, the airline is or it isn't. Yet, the basic premise that you're operating from here is that the flight crew has a responsibility to make a decision based upon the information that is available to it. I want to go back to some comments that have been made recently—and some that have been attributed to Secretary Mineta—that we need to allow operations more flexibility today. Some of the ATC (air traffic control) procedures we are putting place in response to weather are inhibiting the flow of traffic. I'm sure they didn't mean from the terminal area perspective. They probably meant en route, and I'm sure they were referring to some of the procedures described in the presentations we saw earlier this morning. Agam made a great presentation there about how accurate forecasts can be and how accurate they are not in some situations. So the question, I think, that Secretary Mineta and others were posing is a question on how do we balance the operational flexibility that we could gain by letting people use information that may be available to them in a tactical sense, as opposed to the conservatism that is put in place in a strategic sense by avoiding severe weather?

Now delays—back to your main point. I think if my understanding of the DOT requirements are correct, the weather delays—the ones that we are talking about here... that are caused by a FAA decision to implement flow restrictions based on the weather's effect on the ability of the ATC system to handle normal demands—don't influence the on-time arrival of a particular airline. So strict interpretation of the guidelines that DOT has put in place would allow me to say that, no, weather delays are not influencing airlines' ability to portray an accurate picture of what is going on from this reporting system. However, you could argue very effectively that we're not sure what a weather delay really is. Are all the delays that are reported as weather really weather delays?

Shane: But there are two things, and forgive me for just following this up, but I think it is important for those of us who are not up to our necks in the science and division of labor to understand this as clearly as possible. If the Secretary of Transportation is suggesting that there needs to be greater flexibility accorded to the captain in terms of his ability to fly the airplane, that suggests that there is a lot of decision-making responsibility in the cockpit. I wasn't sure that is what the Secretary meant. I thought also there might very well have been too many ground holds put on. It was a suggestion that the FAA, if you will, is being a little bit too conservative in responding to weather problems in the system. As a frequent passenger, I thought to myself: Too conservative? How conservative is too conservative to me? That is what I'm trying to sort out. Just as a piece of important baseline data, if you will. Who decides that an airplane is not going to take off? Who decides that a flight has to be cancelled?

O'Brien: Many people actually decide that. The captain has the ultimate responsibility to make the decision to move the airplane. The decision is based upon information that is available to him or her—through many sources including looking out the window and listening to reports of departing flights or approaching flights. This is an example of very real-time and near-term decision-making. However, the FAA, in conjunction with the airlines, based on a consulting process, also has the ability to make decisions that stops the flow of traffic as well. It may be a weather situation en route that is causing a ground hold. Back to Secretary Mineta's statement—I jumped to the conclusion that, yes, he was indeed talking about ground holds and he was talking about delays and rerouting in flight as well. But all of those situations result from information that is either projected or forecast and on occasion based on pop-up thunderstorms. So rather than suggesting that the flight crew second guess FAA flow control, we need better weather information available quicker, so improved decision making can take place in flow control and in the cockpit, as suggested in the presentations made by John and Agam.

Before I give up the microphone here, the question of a tactical decision-making on part of the flight crew and exercising that dynamic ability, which I think the Secretary was referring to, is indeed a very sensitive issue from our perspective. It goes back to the issue that I talked about during the presentation. For those of you who have a specific interest, there is an opportunity to listen to pilot-controller communications en route. I think United uses Channel 9 or something like that in their entertainment system at the flight crew's discretion. If you listen to a situation en route [with] no severe weather [but] just maneuvering around cells, the amount of conversation and discussion involved in a simple change in altitude or heading gets very complicated at times. And not in the very bad weather situations, [but] just on what I call a relatively normal situation. So if we were to try to exercise a little bit more flexibility, especially in the area of significant weather, I'm not sure that our communications capabilities today are adequate to the task or gain the kind of flexibility that was suggested. Referring back to the discussion that we were having earlier about what kind of technologies are available to help in the communication process, [there are], for example, communications between a pilot and a controller during dynamic weather conditions. In this situation, we need better information as well as direct communications between a pilot and a controller. Capabilities like CPDLC, NEXCOM, and ADSB will help. But as someone said earlier, we really do need a systems approach to gain the benefits.

Shane: Thank you, John. Do you have a question or comment?

Ron Haggerty: My name is Ron Haggerty. I'm from United Airlines air traffic operations. Rather than a question, I have a concern. Dr. McCarthy, I was extremely impressed with your presentation—and please don't take offense—but I have seen yours so many times that it's great. The concern I have is that I was especially impressed with the corridor integrated weather system (CIWS). The concern rests with—I would hope that, Ms. Garvey, as we are going down the path of developing these products and making the science give us an operational product—it was mentioned several times how the science and the operational end are far apart, and I'm a consumer of that operational end of products—that we fashion them collaboratively with the people who are going to use them. There have been some products developed that were given to the industry and the air traffic folks to use, and it was a solution based on what people thought that should have been. I see the CIWS as a great product. I hope we collaboratively develop that and make it work for the controllers, the dispatchers. There are several venues that we have that enable us to do that rather well. That is my concern.

McCarthy: There are other people who I know want to answer this question, but I'm going to since, luckily, it was addressed to me. I'll take the first shot at it. I'm very concerned about the same thing—that is, if CIWS is used to route traffic through Canada, for example, we're lost. If CIWS is used to squeeze more capacity out of the corridor, we gain. The only way we are going to do that is an intimate relationship between the weather information that we gain from CIWS and the way that air traffic uses information. So the way in which CIWS works is an intimate relationship with the air traffic process. This is what I believe you're saying...

Haggerty: Yes, if we can shape it together to meet our needs, that is, the essential element I'm hoping will occur with this.

McCarthy: Right, and there are a couple folks in the room that are intimately involved in CIWS and perhaps they could respond. I know Jim is here. Dan Strawbridge, the FAA CIWS program manager was at least here. Maybe he can respond to that comment because technologically there is a lot going on. It is important, though, that it link through to the operational system. Without an intimate users group in CIWS, involving scientists, ATC, ATM (air traffic management), and the airline users, we cannot extract the full use of the concept.

Evans: John, one of our great successes has been wind shear avoidance. There was a Terminal Doppler Weather Radar/Low-Level Wind Shear Alert System (TDWR/LLWAS) users group that from the start was not just FAA. It had flight standards. It had the development community. It had the airlines. It had the pilots from the outset. It has been a wonderful success. We have not, cross our fingers, had a wind shear accident at a TDWR/LLWAS-equipped airport since those systems went in. We were crashing planes about every other year before that point. I think this was one of the great successes. We do not have a similar users group yet for the Corridor Integrated Weather System (CIWS), and I guess I'm a development lead for the program. We need to have the airlines sit with us in the development of the system as we did in TDWR/LLWAS, which was a wonderful success. We have worked with the airlines on the Integrated Terminal Weather System (ITWS), but they were not end-users, and hence they weren't intimately involved.

Haggerty: I certainly feel better, thank you.

Shane: Agam Sinha, you had a slide up there that showed different rates of delay, and you had a bar that you characterized as a good day and it listed 450 delays. Dr. Sinha, why do you think 450 delays is a good day?

Sinha: To put it in perspective, when meteorologists get excited about weather, the transportation system says it is a bad day. The question is how well can the system respond to it to keep the disruptions to a minimum? One of the comments on the last slide was that everybody needs to work together to figure out how we are going to manage the impact. To me, the good part of it was the impact of all that weather was managed as well as it could be. So it certainly was not a good day for the system as a whole in terms of experiencing delays, but again, given the cards that you are dealt, all the players did a good job of minimizing the impact.

Shane: Would anybody like to hazard an estimate of what the prospects are for improving our predictive technologies sufficiently to make a palpable difference in the delay picture in the next 5 years? John McCarthy, you must have an opinion?

McCarthy: Yes, I think with some caveats, and the caveats are identified. I think it is a research topic; it is a baseline question. We understand the baseline more effectively. I think hidden out in that baseline are numbers like 10 percent recoverable delays.

Shane: We had a comment here that suggested we have technology in place for airports around the country that would produce a 25 percent improvement right off the bat.

McCarthy: You get out into the outlying airports and the numbers go down because the number of aircraft go down. So I'm not sure what the number is. I'm contrasting that with people who say there is nothing available in terms of weather improvements in delay. I think the number is at least 10 percent. It's probably higher, perhaps 25 percent, to be verified with more delay research along the line of Evan's work.

Shane: Remember, my question is specifically focused on predictive science. I'm not interested in squeezing more benefit out of the present technology. I want to know how do you get to that next stage? Does it take a super computer?

McCarthy: I think in the next 5 years—you said 5 years?

Shane: Just to give you a benchmark.

McCarthy: I think in the next 5 years we are going to learn to use the tactical products pretty well. That is three products on the left. If we don't, we screwed up royally in my opinion, and that is because we didn't connect what we know to the operating system. So that to me is no excuse if we don't do that. The scientific problem is on the right-hand side of the diagram, which is in the prediction in the 2 to 6 hours. I think in the next 5 years we will begin to learn how to deal with the interface between the extrapolation problem which is the 0- to 2-hour problem and the model problem which is 6 hours and out. So for example, we'll begin to understand how to assimilate NEXRAD data into data simulation schemes and do very high resolution modeling around metroplexs, for example, in New York, San Francisco, and other areas where we want to see very high resolution information. I think we will make a lot of progress in the next 5 or so years to improve our ability to see and make predictions in the 2- to 6-hour timeframe. I think that is where the scientific breakthroughs will be. Instead of being a 25 percent or a p-value of 0.25, we will start seeing P-values in the area of 0.75 or 0.85. That is where we begin to get excited about the case that Agam had where there was a squall line in the central part of the United States and a little reaction in the New York area. We will begin to see that, whereas we didn't in his really crummy case. That is where I think the action is going to be.

Shane: We are just at about 11:30 a.m., but John, why don't you have the final comment, and we will move on to the next panel.

O'Brien: I just wanted to comment, and this only addresses delays as a byproduct, that I see a significant increase in safety coming from an ability to predict more accurately the icing phenomenon. This really affects the low-altitude operation of your regional aircraft and not just turboprops, by the way. There are some very exciting capabilities, about to be realized, which improve our ability to more accurately predict the extent and the severity of the icing phenomenon. It is a significant safety improvement and does have some spin-offs into avoiding delays as well.

Shane: I know there are some questions that didn't get asked and comments that didn't get made, but you will be able to do it in the next session because all these panels are pretty closely related. Let's give a warm round of applause to our panelists this morning. Thank you so much.

PANEL 2

Roles and Responsibilities in Weather Decision Making

Introduction

JEFFREY N. SHANE
Hogan & Hartson

Dr. McCarthy was talking about linking what we know to what we do, and that will be broadly stated in our next panel: Roles and Responsibilities in Weather Decision-Making. If we could have our three panelists come up to the table please.

[comment not recorded]...really the allocation and decision-making responsibility from several perspectives—from the perspective of an air traffic controller and from the perspective of a dispatcher and from the perspective of the FAA and its command centers. We are not taking a break ladies and gentlemen. Those of you in the back, we would like to resume the proceedings so that we will not lose any time. Thank you very much.

ur first speaker this morning is going to be Mr. Tony Henry. Mr. Henry has almost 20 years experience as a certified professional air traffic controller, and he represents the National Air Traffic Controllers Association regarding a whole host of issues involving traffic flow management. Tony, thanks very much for joining us this morning.

PANEL 2

The Controller’s Perspective

TONY HENRY
National Air Traffic Controllers Association

Good morning. The slides I have were just something for you to ponder on (Figures 1 and 2). It wasn’t anything of any real importance. You will have to bear with me. This is not my area of expertise—an air traffic controller with a sideline in union negotiations, so I will plod along here.

I was asked to touch on a couple subjects. The first was very easy. It was to speak to getting pilot weather feedback through the system. From a controller’s perspective, that is very limited. We receive reports. We write those down. We get them to the first line, and they go off. They come back through the system either through weather advisories or whatever where we again announce it out on the radios to whomever we happen to be advising—that is a pretty simple issue.

The next two are a little bit different and are more difficult. I’m going to lump them together. It’s handling traffic in bad weather and the unique safety concerns controllers face with volume and complexity. Traffic volume and complexity is just slightly less than

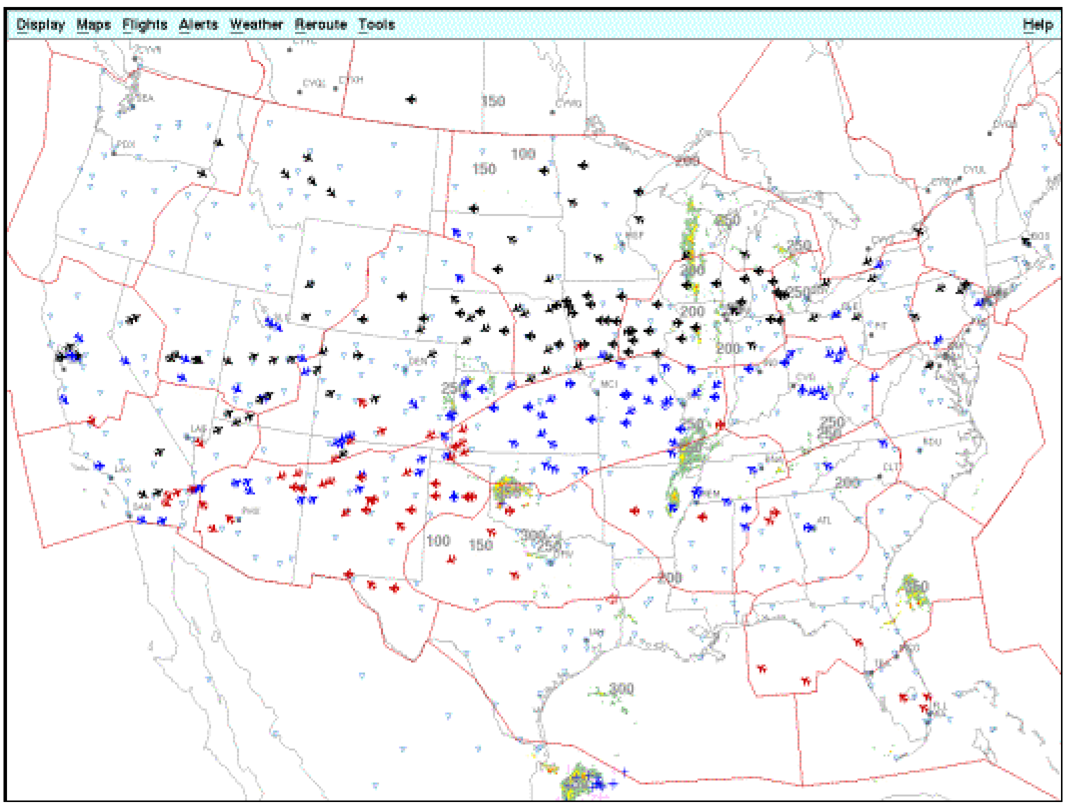


FIGURE 1

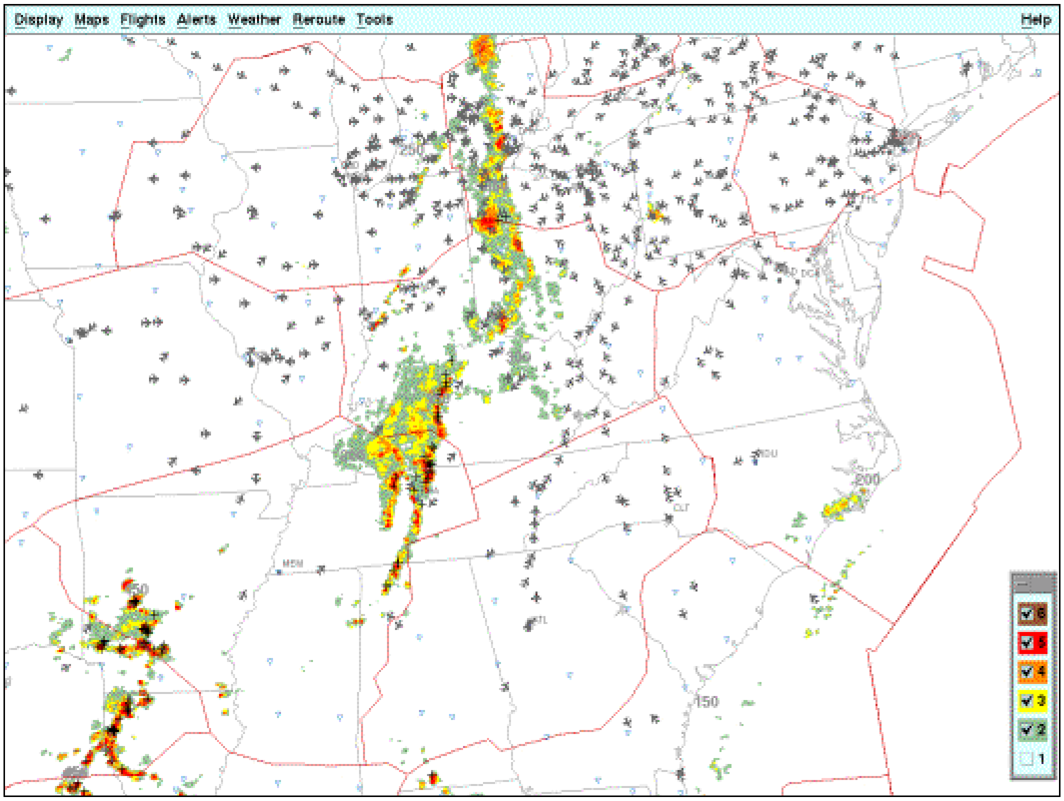


FIGURE 2

dealing with traffic in bad weather. As weather increases, it becomes much more difficult, and communications are key. Radar controllers are working sectors day in and day out to fill up a routine or a normalcy of traffic patterns. They know their airspace. They know the flows of traffic. They know the occasional odd flights to cut across. It is very...the term I first came up with was “comfort zone,” but I was told that was politically incorrect. So you can be in a comfort zone and be working many planes—dozens of planes—25–30 planes. It just depends on the situation and still feel quite comfortable and in control. The best analogy I could come up with was driving your car either on the interstate or to and from work. There are times on the road where traffic is a little bit heavy. It is moving. It is a normal day. The weather is pretty good. You’re just rolling along, and you’re in control. You’re not worrying about anything. You know when you’re going to get to work. There is not a lot of worries to worry about. As opposed to driving your car in bad weather—snow and ice around here is a prime example. If the weather gets worse, the roads get slippery. The traffic starts sliding and slowing down, and it congests. It gets a lot more complicated, and there is a lot more worries as far as you as a driver to think about. The same applies to the radar controllers as weather develops in their airspace. It becomes much more restrictive. Airplanes are deviating. You are wondering how much they will deviate? Will they deviate into this sector? Will they deviate into this facility? If they do, with approved point outs, the traffic that normally goes down through certain routes no longer goes those routes. Are those routes coordinated? How long will it take to get those routes? That is kind of the crux of the information.

The worse the situation, as far as in terms of weather, the less information seems to get passed down. That is the key—the lack of communication and coordination as things get busier is vital. That is what we have been working to develop through S2K—trying to get out to the field and increase the communication. My primary goal with S2K was to get the information from the pilot level to the controller level and back again—up and down, through two ways—so that everybody has a piece of a plan that they can understand how they fit into. [They say] well, you are ground delayed for a half-hour, but it is due to this. Everybody has a little explanation as to why they are doing things. I believe it is going to make the system improve.

Is it the magic answer? No. But it is the opportunity for us to make real-time improvements this year and work toward next year. That's about it. Thanks.

Click here to see Henry's slide presentation.

Shane: Our next speaker is Allan Krauter, senior instructor for flight dispatch at Northwest Airlines, with 23 years of experience in airline operations as an aircraft dispatcher.

PANEL 2

The Dispatcher's Perspective

ALLAN KRAUTER
Northwest Airlines

Good morning and thank you for the opportunity to speak today. I'm going to talk to the dispatcher's role as it relates to weather decision-making, and I'm going to give you an overview of what an aircraft dispatcher is and how it interfaces with the FAA and the strategic planning team. I'll start with our basic foundation, as stated in the Federal Aviation Regulations: The aircraft dispatcher and pilot in command are jointly responsible for the planning around and avoiding known or forecasted weather phenomenon that may affect the safety of the flight (Figure 1). To that end, I'll talk about our operational responsibility and how we achieve that goal. Then I'll talk about the interface with the FAA Command Center throughout our strategic planning process or SPT (strategic planning team) (Figure 2).

Our operational responsibility is shared by pilots, air traffic controllers, and dispatchers (Figure 3). We call this the air safety PAD (pilots, air traffic control, dispatchers). Just like a three-legged stool, which will always sit firmly on the surface on which it is placed, if you remove one of the legs, you remove some of that structural integrity. The same thing holds true in the air safety PAD: All three of us have to be on the same page.

All three of us have to be in the communications loop or we run the risk of potentially eroding the safety of that flight (Figure 4). Our operational responsibility—the primary responsibility is to assure safe flight operations. We believe we do it with efficient operational procedures and enhanced communication techniques. There are a

FIGURE 1 Basic foundation.

FIGURE 2 Overview.

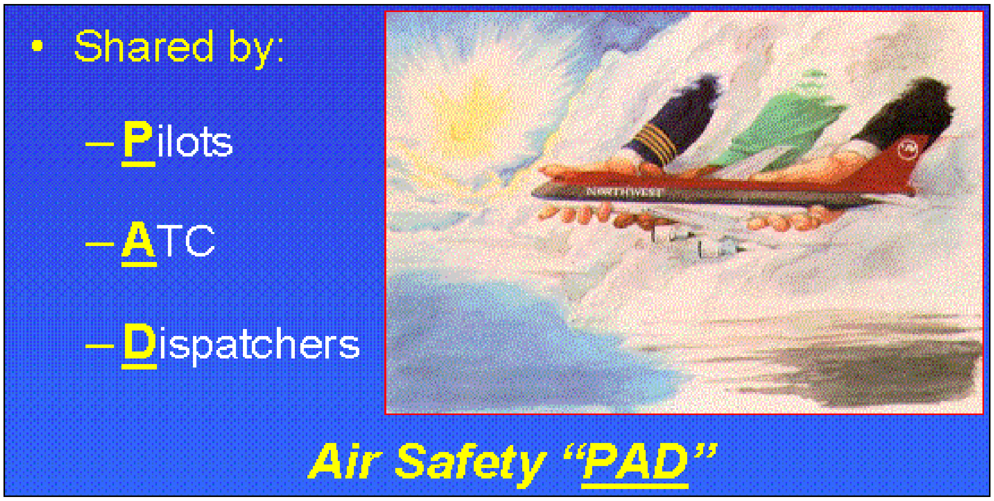


FIGURE 3 Operational responsibility.

FIGURE 4 Operational responsibility.

tremendous amount of built-in redundancies throughout the entire system and constant information exchange throughout all phases of flight.

Air carriers maintain safe operational control by pilot and dispatcher joint responsibility, as outlined in the regulations: FAR 121.533 deals with our domestic operations, and FAR 121.535 relates to our international flight operations (Figure 5). Both of them state that the dispatcher is responsible for the preflight planning phase. The dispatcher and pilot will agree on that particular flight release. Once they have agreed, we can now operate that particular flight. However, our greatest responsibility to that flight crew is our in-flight responsibilities because we believe pilots do not make bad decisions. Pilots will make a perceived bad decision based on bad information, old information, or no information. It is our responsibility to get the most current and accurate information available to that pilot in command, so he or she can make the best decision for the flight.

Preflight planning phase—we will take a look at adverse weather avoidance, match a flight routing to avoid that weather, and then pair the fuel to that particular flight routing (Figure 6). We make decisions and have an impact. Should we delay or cancel a flight in the interest of safety? We will also consider aircraft performance as well as aircraft selection. Marketing departments generally assign aircraft based on seating capacity. We may ask for another aircraft for operational needs—whether it be another aircraft that has greater fuel capacity or additional payload uplift capability.

Continuing on, we will look at destination specifications and the need for an alternate airport (Figure 7). We will assign an alternative airport as an air carrier operation only if needed. We do have guidance in the regulations for that.

Any inoperative aircraft items—we will consider those as part of the preflight planning phase. Some inoperative items such as coffee makers have no adverse impact, but if we do have an inoperative item on that aircraft that would restrict us from operating in known or forecast icing conditions, we have to establish a route of flight that would avoid those known or forecast icing conditions. We will pair it with the government regulations to assure that it is not only safe but also legal. Further regulations will also

FIGURE 5 Operational responsibility.

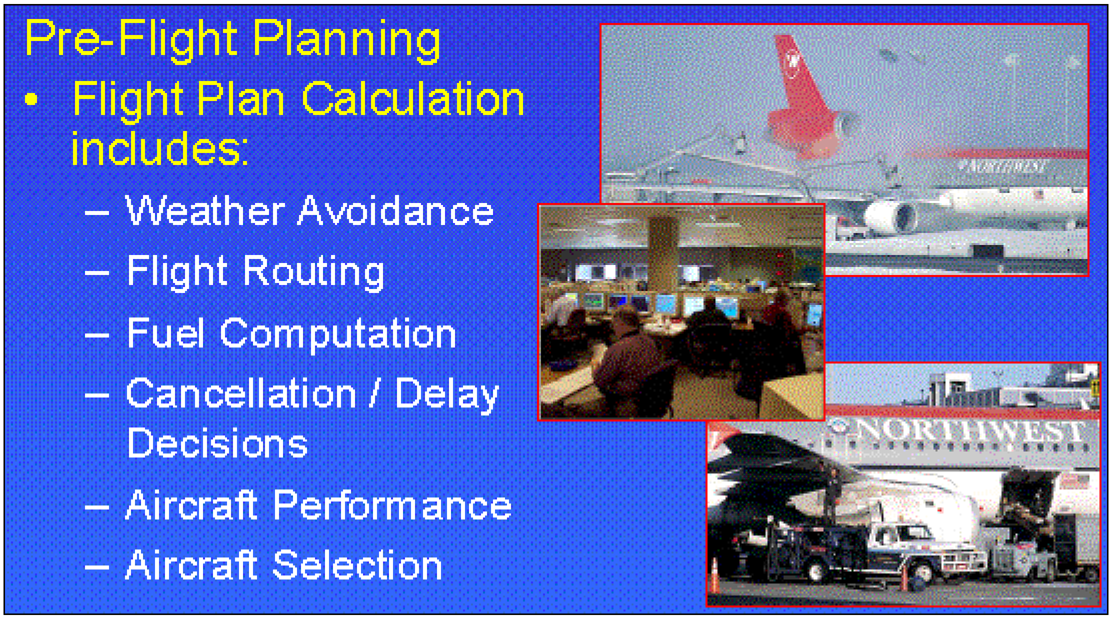


FIGURE 6 Operational responsibility.

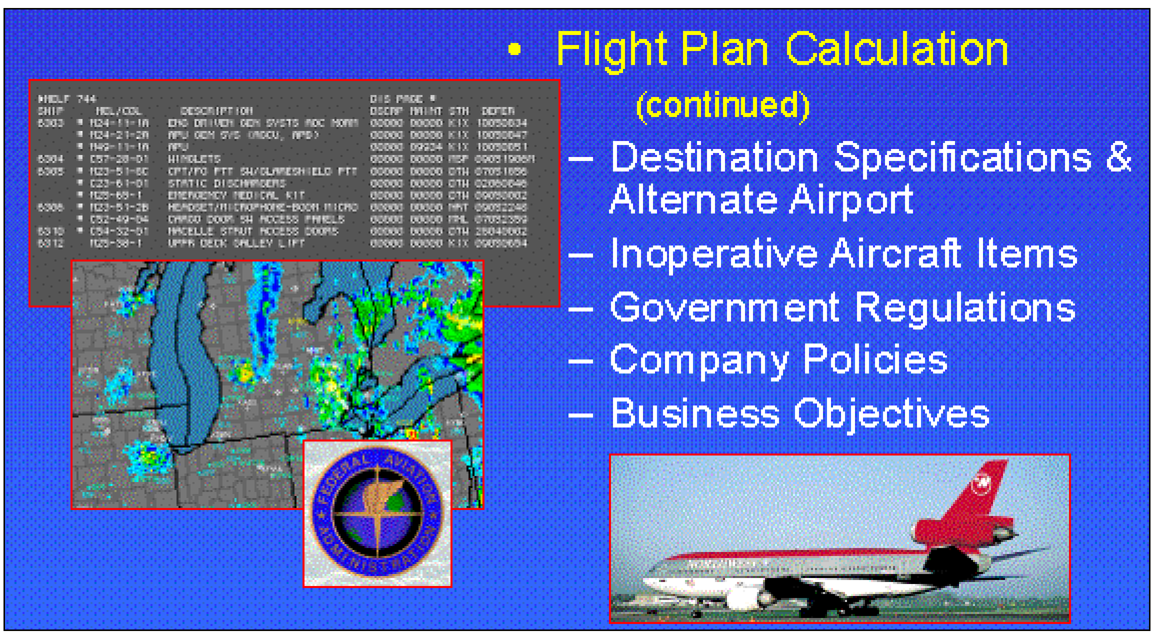


FIGURE 7 Operational responsibility.

match that to our company policies, as outlined in our flight operations manual, to assure that we are company-compliant as well.

Then, we have to work somewhat of a delicate balancing act between safety, legality, and economics. Safety and legality are first, but we also have to consider economics because as air carriers, we are in the business of making money and we have to try to do this as inexpensively as possible. With fuel prices being what they are, we definitely have to watch closely.

Our in-flight responsibilities—dispatchers should be 200, 300, or 400 miles in front of an airplane telling the pilot in command what that pilot needs to know before he or she knows they need to know it (Figure 8). We need to provide predictability in the cockpit, and the way we do it is to monitor the progress of the flight. The number one work maker for us in recent years has been weather updates and flight planning reanalysis. The preflight planning phase is generally done 90 minutes to 2 hours prior to departure. As conditions change, we must amend our plan to reflect the changing conditions.

Mechanical irregularities—there are representatives within the airline operations centers to deal with any mechanical irregularities, and the pilot and command and aircraft dispatcher have to agree on how they are going to operate that flight if there is a mechanical irregularity.

Medical emergencies—if there is not a doctor or nurse onboard and we have a sick passenger, most airlines do have some semblance of a contract with a hospital or an agency that does provide that service where you can initiate phone patches or radio patches to assist a sick passenger.

Aircraft emergencies—a whole host of information that the dispatcher has at their fingertips at the desk through automation that they can assist this flight crew, so they can focus in on their primary responsibility of getting the aircraft safely on the ground.

We stay 200, 300, or 400 miles in front of the airplane, as I stated. This will monitor the flight's progress, and at the very tail end of this presentation, I will show you one of the greatest tools we have for assisting us in doing that. And we will provide information updates and re-dispatch, as necessary.

To this point, it seems like it is pretty much just the air carrier doing just their little piece. How does it all fit within the constraints of the national airspace system? The strategic planning team (SPT), as a result of the Spring 2000 initiative—the FAA and the airlines established a process to develop collaborative solutions, which govern air traffic operations during severe weather and/or heavy traffic events to maximize airspace and

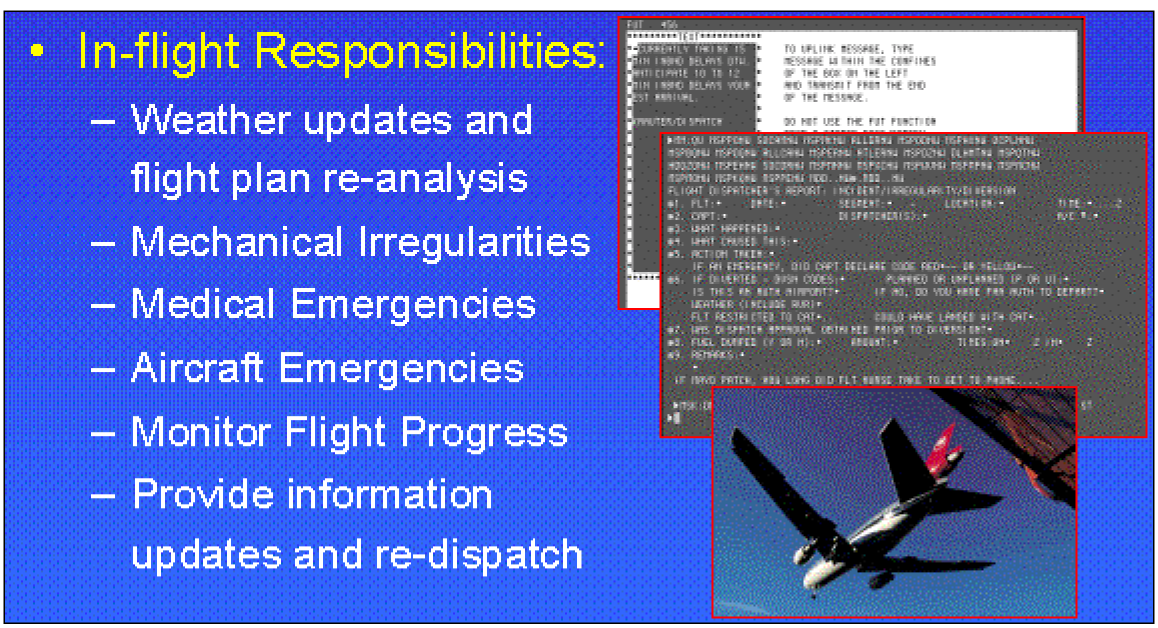


FIGURE 8 Operational responsibility.

minimize delays within the national airspace system (NAS), allow users to operate with their own capabilities and economic objectives, and exchange information to build collaborative solutions to constraint problems (Figure 9). We are working hand-in-hand with the FAA as air carriers. The airlines, the FAA and NATCA (National Air Traffic Controllers Association) are all working to try to come up with solutions for constraints in the NAS. But the first way we do it is through the strategic planning teams.

The airlines' mandate was to implement a formal process to enhance collaboration within the airline and between the FAA and the airline and other users and to develop a team of specialists who collaborate with the air traffic control (ATC) system command center (Figure 10). That team of specialists is our strategic planning team. Their mission is to make strategic decisions that meet the operating goals of the airline.

Objectives of the airlines' SPT—for as difficult as it is, we try to look 2 to 6 hours into the future to come up with some semblance of a plan (Figure 11). We're looking at known or forecast and events and try to come up with a plan that would allow us to safely and reliably achieve our operating goals; coordinate with the air traffic control system command center and let them know what we are doing or what we recommend; and then provide analysis to critique and improve current procedures. If it worked yesterday, let's try it again today if the situation is the same. If it didn't work yesterday, then let's try something different today.

Here are some examples of how the strategic planning team does work (Figure 12). These are actual examples that happened last year. On the right is the preferred route. You can see the routed flight from Orlando, Florida, to Minneapolis, Minnesota, is going through a line of weather. This is the desired, more economical route. However, there is a low-pressure system in northeastern Wisconsin with a cold front extending. As that cold front went over Lake Michigan, it cooled the atmosphere, and in cooling, the weather dissipated. It looks okay now, but we anticipate this afternoon—when that flight was going to depart—

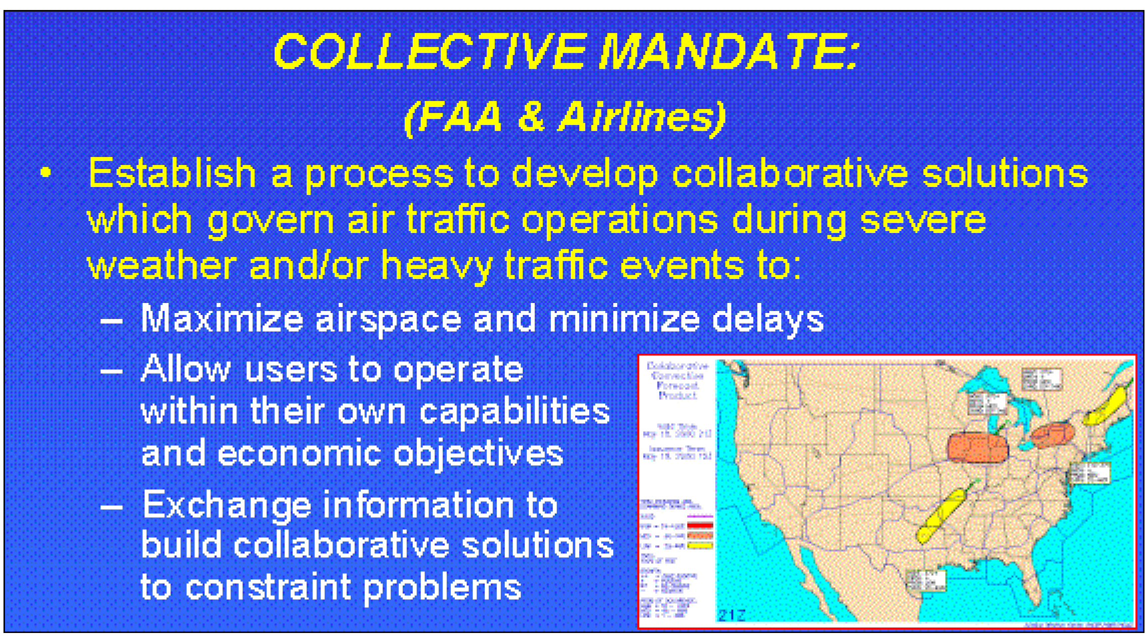


FIGURE 9 SPT.

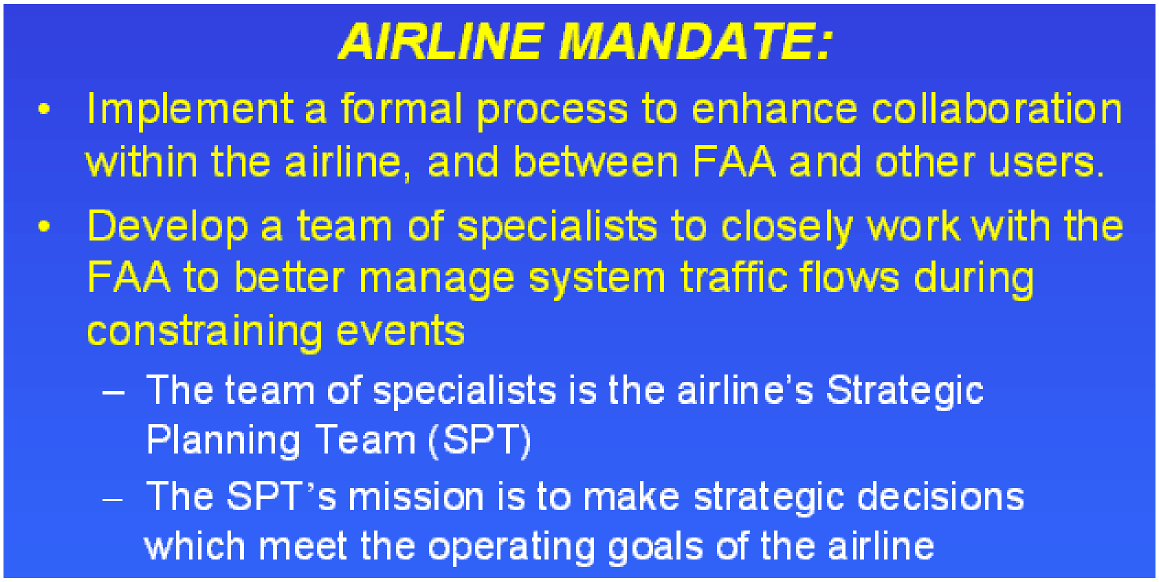


FIGURE 10 SPT.

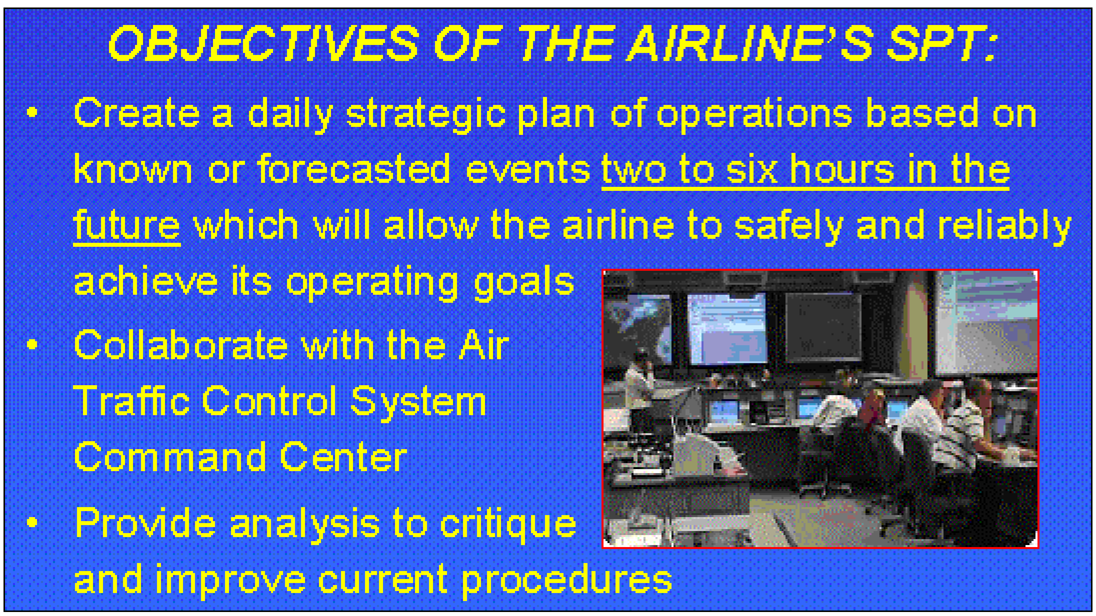


FIGURE 11 SPT.

that pumping some heat into the atmosphere and going over dry land that that line will become a solid line of thunderstorms. We can't go over it or through it—we're going to have to go around it. So the dispatcher recommended this SPT route here. They recommended it to their strategic planning team. It was coordinated through the ATC system command center. They said that looks like a good route for adverse weather avoidance, and that became the plan. The airlines that were scheduled on that SPT collaborative route that day departed on time. Those flights that did not were delayed until such time as they could refile on the SPT routing. The bottom line in the strategic planning process is that the system works.

From a tactical standpoint, again, this is another actual scenario where the white line depicts the airline dispatcher's choice of routing in attempting to avoid this line of thunderstorms that went roaring through the Twin Cities, Minneapolis and St. Paul, last summer (Figure 13). We were pretty proud of the fact that that was a good plan. From a dispatcher's perspective, it looked very well until the Minneapolis center traffic management unit called and said you have created for us a flow-constrained area. We need you to move some of your traffic up and around for a "birdie" arrival into Minneapolis because we have too many aircraft coming in over the one arrival fix. ["Birdie" arrival is a standard terminal arrival route into Minneapolis–St. Paul.] The airlines said these aircraft can't handle it, but these aircraft can. You can move these selected aircraft. The selected aircraft, which had the fuel on board to be moved, were moved, and in this particular instance, there were no diversions as a result of that

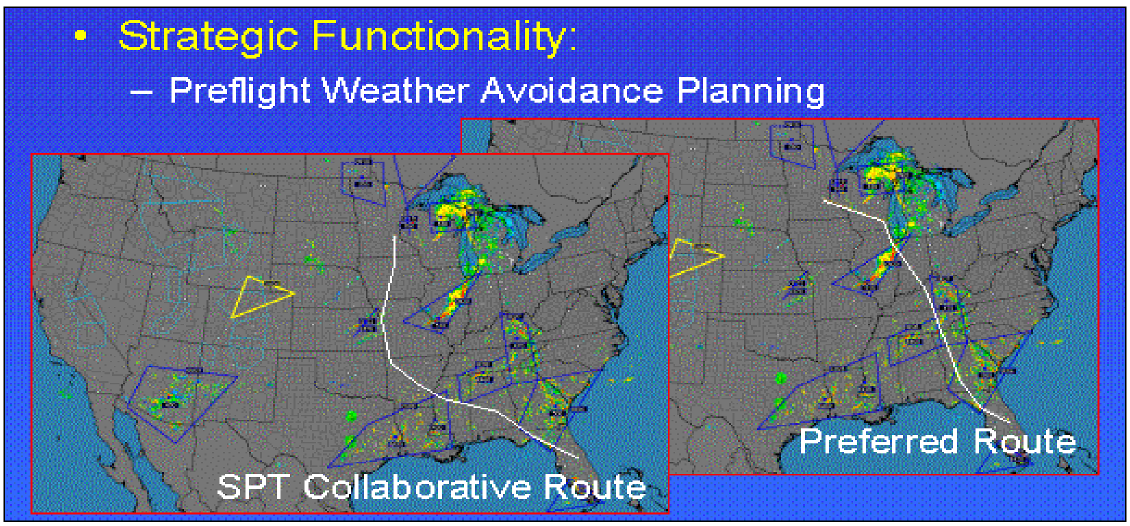


FIGURE 12 SPT.

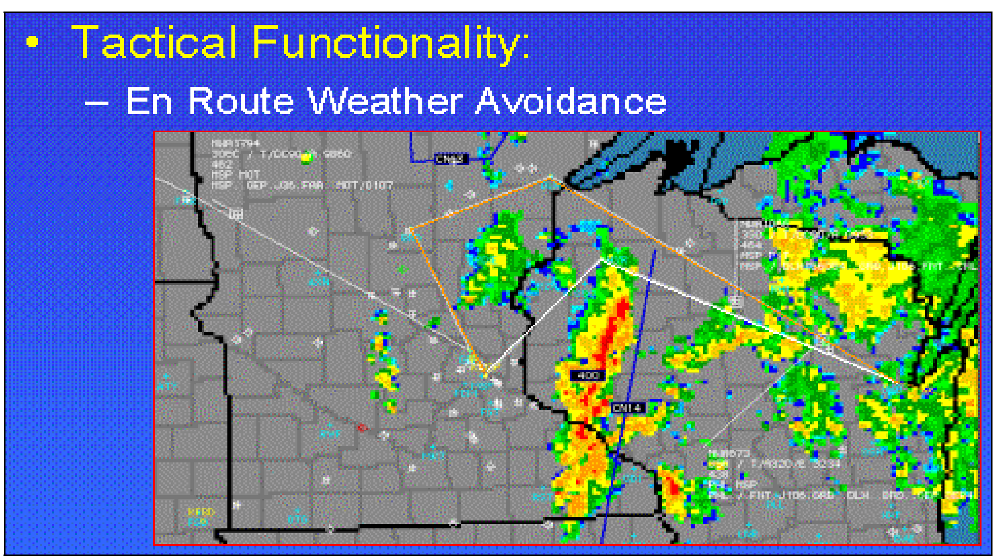


FIGURE 13 SPT.

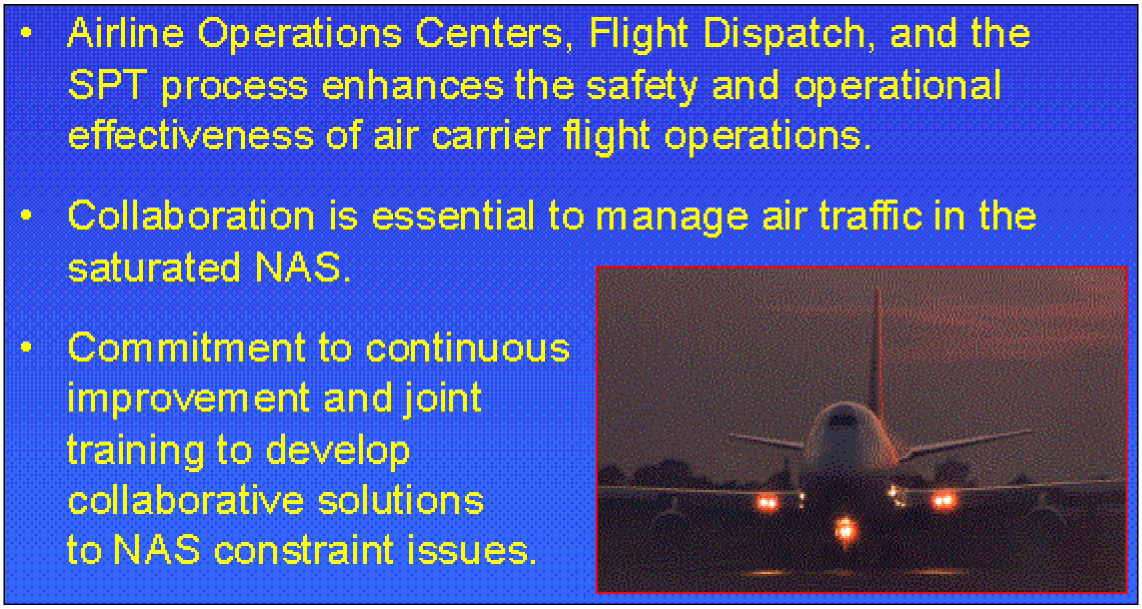


FIGURE 14 Conclusion.

particular line of thunderstorms. As recently as 2 years ago, we may have had six diversions without this lack of collaboration and cooperation. So once again, the system is working.

In conclusion, I most sincerely believe that airline operations centers, flight dispatch, and the SPT process truly does enhance an air carrier's effectiveness and safety (Figure 14). Collaboration is essential to manage air traffic in the saturated national airspace system. And there is a commitment to continuous improvement and joint training that will help us develop collaborative solutions to NAS constraint issues. Thank you very much. I'm Al Krauter.

Click here to see Krauter's slide presentation.

Jeffrey Shane: Thanks, Allan. That was excellent. Finally, the third speaker in this segment of our program is Jack Kies, the Acting Program Director for Air Traffic Tactical Operations at the FAA. Mr. Kies has more than 30 years of operational air traffic control and management experience. Mr. Kies, welcome.

FAA Command Center

JACK KIES
Federal Aviation Administration

Thank you, Jeff, and thank you for the opportunity to speak this morning. I agree with everything Al said. Thank you. Al certainly hit it on the head, and he has been a very important element in all the things we have done since the spring 2000 initiative. I would like to point out that he is a cadre member and has been instrumental in training activities that we have taken nationwide—embracing not just the air traffic perspective but bringing on the dispatch perspective in interfacing with our air traffic control (ATC) workforce. I believe this has paid significant dividends, not just in terms of the training effort, but I think in terms of the performance we are witnessing, even as recently as last night.

The national airspace system (NAS) is clearly most susceptible to thunderstorm activity between April and October, and these thunderstorms can and do disrupt the normal and organized movement of air traffic and do significantly increase the workload at impacted facilities—both in FAA facilities and in the AOCs (airline operation centers). Tony and Al can witness that.

To meet this challenge, we have established the strategic planning and severe weather management teams. Al alluded to them earlier. When the potential for severe weather exists and it will cause a disruption to the normal traffic movement, these severe weather management specialists implement procedures designed to optimize the use of available airspace. Strategic planning is an integral part of severe weather management and the responsibility of everyone involved.

Facilities get called upon and accept traffic that would not normally be routed through their area. In the interest of a balanced flow and to minimize delays, we expect air traffic facilities to accept this ultimate flow of air traffic. All facilities are expected to participate and cooperate when called upon. A properly developed, coordinated, and implemented plan will result in the maximum utilization of available airspace. I point out available because what we are talking about here is airspace that we cannot penetrate in many instances, and that translates into a volume problem for those competing for that available airspace.

We have embraced the strategy of collaborating with our customers. We don’t just talk the talk—we do indeed walk the walk. Bad weather drove us there, and now we do every day—all day every day—a true use of a strategic plan of operations. We do it to reduce the impact of severe weather on FAA facilities and system users and improve operational methodology—it was required. Collaborative planning among FAA facilities and NAS operators, incorporating common situational based technology [and] operational strategies—it clearly is the best way we know currently on how to deal with these weather scenarios. The need for an improved scientific activity in terms of technology is clearly on our agenda.

The strategic planning team was created and is largely composed of FAA and airline strategic planners and dispatchers, the military, international facilities, and even general aviation elements can and do participate in the process. I point out international because we do have a tendency to call on Canada from time to time, depending on the movement of the severe weather we are trying to avoid. Together, we collaborate on the formulation of a strategic plan of operation. This plan is updated, amended, and evaluated on a recurrent basis through a dedicated telephone conference phone bridge from the Command Center. The conference occurs every 2 hours—with a look ahead 2, 4, and 6 hours.

The collaborative convective forecast product (or CCFP, as you heard mentioned earlier) is the consolidated input of air traffic control center weather specialists, aviation weather center personnel, and airline meteorologists. The CCFP is the primary product used in the strategic plan development, and it is the very foundation of all the activities upon which we build our strategies. What is most unique about this is that it a singular forecast. It is one forecast that we have all signed up to use as that foundation. In years past, we had any number of forecasts, and weather guessing can be a very tiresome activity when you have varied opinions.

Balancing demand with capacity during adverse weather is the dance we do. We must identify actual or anticipated constraints and determine capacity of not just the impacted airspace but the other airspace affected. That is the ripple effect I spoke of moments ago. We have to have an accurate demand picture in order to equitably distribute that remaining capacity. We explore several options all the time.

- Expanded miles of trail—and by that we simply mean increasing the mileage between airplanes.
- Reroutes—augmenting the normal file route of flight. That has to take into consideration fuel and aircraft characteristics and capabilities.
- Ground delay programs—we hold airplanes on the ground based on slots available at the specific airports that are capacity constrained or even airspace [constrained]. Then, the dreaded ground stop, which is probably our most strident initiative, where we stop all the airplanes until we can assimilate under the new circumstances.

The severe weather team is established to discern reroutes around areas of constrained weather, and they use precoordinated and validated routes—SWAPs we call them, severe weather avoidance program routes. They are done in preference to dynamic rerouting—maintaining an orderly flow, as has been said earlier, is more efficient than a fits and starts activity.

To that end, we have collaboratively developed coded departure routes and an actual play book. Coded departures routes is a pre-ordained alternatives to the standard fare base on activities at airports and weather phenomenon that are not normally anticipated. The national play book is not unlike a football play book where we have routes predetermined through our in-route traffic control centers, and we share that with anybody who has a need to know.

I'm compelled to point out that even with our best plans and our best collaborative efforts, Mother Nature can and does completely shut down elements of our system. Pilots will not fly into severe weather, and nobody would want them to. When this occurs, our goals shift a bit, and that shift is toward system recovery and prioritizing flights that may have been diverted and those that have been on the ground the longest. The key to this, given our current scientific handicap where forecasting is concerned, is timely and accurate communication—not just to a cadre of air traffic experts, pilots, and dispatchers but to the flying public.

We have developed and continue to improve upon our use of the Internet. Sharing information regarding system performance is also one of our most important charges. These viewgraphs are a couple examples of the many elements resident on our web page and available to the general public (Figure 1). The operational information system is one advisory national play book. You can access just about any piece of information of any importance in the NAS system.

This is just a snapshot of the operational information system. That is the page address (Figure 2). From here you can see, in this instance, there was a ground delay program in Boston on May 4. These were the time periods, the facilities in the United States and in Canada, the reasons for the delay, the computer-generated maximum delay time, average delay time, AAR (the arrival rate—we were running into the airport), and a program rate manifests that number. Ground stop is another element, and in this case, St. Louis was being impacted by thunderstorms. Any airport inside Kansas City and the first-tier centers were being stopped for this period of time. Delay information is put on this board as well. It is real-time and updated every 5 minutes. Any de-icing activity, miscellaneous—just about anything you want to know about the national airspace system is resident on that page and is accessible as the web is to you.

So I would encourage you to investigate this web page and find out what we have to offer. If information is powerful, we have one powerful technology at our beck and call. Thank you.

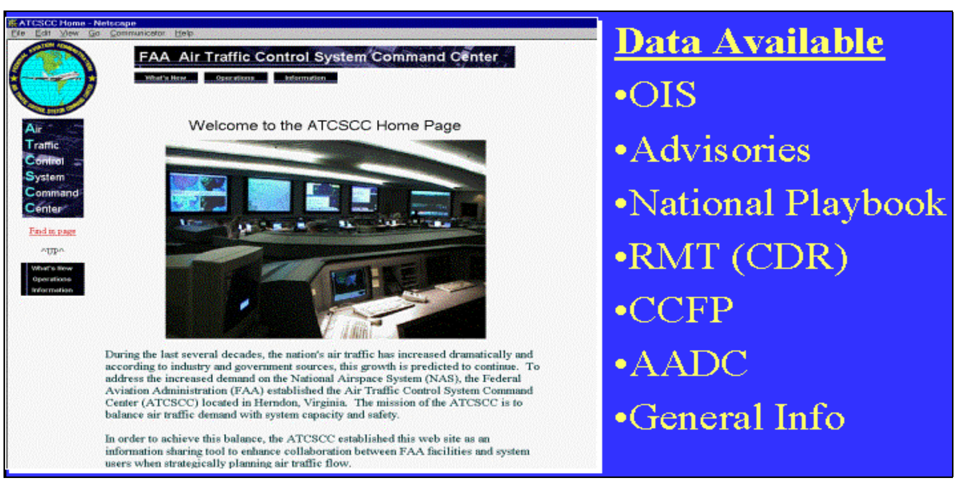


FIGURE 1 ATCSCC website.

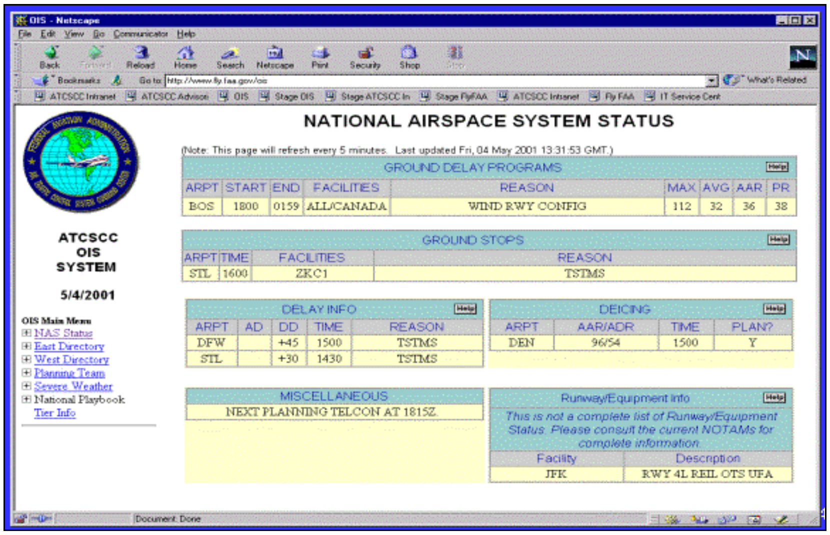


FIGURE 2 www.fly.faa.gov.

Click here to see Kies' slide presentation.

Question-and-Answer Session

Jeffrey N. Shane: Thank you, Jack. Once again, we have come in right on time. We are going to spend the next half-hour discussing what you have just heard, and I wouldn't restrict anybody if they still had comments and questions that go back to the first panel.

I'm going to throw out the first question, if I may, just to get the ball rolling. I'm going to throw it to Jack. First of all, I want to confirm something you said. Anybody who hasn't checked out the FAA's website just needs to do so. If you are interested in any aspect of aviation in this country, it is one of the most breathtaking Internet websites that the government has available to the public. Even lawyers can find everything they need here, so it is a really spectacular performance and a credit to the FAA for figuring out that the Internet was an enormous resource.

We talked earlier, Jack, about the Secretary of Transportation's suggestion that there are too many ground stops in the system, and maybe we need to be a little bit more flexible—at least I am interpreting that. The reason that I focus so much attention on what Secretary Mineta said, in case anybody hasn't figured it out, is that Secretary Mineta comes to the job of Secretary of Transportation more qualified, I think, than just about anybody else who has ever been appointed to the job. They all got qualified, but he was qualified on day one. So when he said something like that, based on his vast experience—and I know he spends a lot of time examining the system up close and personal—one takes it seriously. How do you interpret that? Do you believe there is more flexibility there, and that there is too much, if you like, conservatism in the way the system is being run today? I don't mean to put you on the spot—I'm only asking you to criticize your boss, but I'm sure you can handle it.

Jack Kies: I think the system, like any other system, is susceptible to a pendulum swing of too conservative one day and then reacting to that conservatism by being a bit too aggressive the next. Our customer base is very diverse—not just in terms of the air carriers, but the air traffic controllers who anticipate traffic management will, in effect, manage the traffic. And, if we overload or underload a sector by virtue of a miss in terms of our forecasting technologies or anything else, we haven't served all those we serve as well as we could. So our goal is to try to find that middle ground and ensure that we maximize the airspace using all the technology and the current collaborative techniques that we are learning how best to use. I think we are getting there. I think we have significant proofs this season to be sure.

Shane: Allan Krauter, you gave an interesting example that you characterize as an SPT route where there has been collaboration. You saw the weather. You anticipated it, and a new flight plan was filed. And, in fact, you were able to go around without any substantial delay in the system. But you also mentioned there were flights that didn't take advantage of that information that therefore got held up. Is that a fair interpretation of what you were saying? So the question that flows from is how do you close that gap? How do you make sure there isn't anybody left out there—not taking advantage of the information that the smart guys took advantage of?

Al Krauter: It is interesting to note or important to note that happened last year, and it was the first year of the spring/summer 2000 initiative. We have expanded and worked on that for spring/summer 2001. It is my belief that the airlines who didn't embrace the process of collaborative decision-making last year realized that if you don't want to play the game by the rules that are out there, you probably won't get to play. There was enough of that going on last year to where it heightened some awareness. I sincerely believe that [with] the training program that the FAA, NATCA, and the industry put together—where we delivered to the facilities, we delivered to the airlines, and we delivered to the command centers—everyone now fully understands what the SPT process is. I believe in the months ahead you will see more of that coming on board—recognizing that the strategic plan of operations is there for a reason. It is to facilitate flow in the national airspace system, and we have to all be on the same page. The industry, as well as the FAA, have to be on the same page if we are going to truly facilitate that flow of traffic. So what you saw in that example last year is a true scenario. I don't believe you will see that with as great a frequency this year as you did last year because people are beginning to embrace the concept.

Shane: Comments?

David Stempler: David Stempler from the Air Travelers Association. I represent passengers. Jack, I have a question for you having to do with preflight and how it fits in with all this weather thing. But I think I can't move past this point about the Secretary's comments about this. I think we need to put this in perspective. What we are really suffering from in this country is really having to do with an aviation infrastructure problem. All of these issues about trying to squeeze more airplanes into systems and trying to deal with problems at LaGuardia really come down to that. Until we start working on that problem in terms of improving our air traffic control system, getting more runways, taxiways, terminals, and gates, we are going to come up with things like pushing people to fly in weather that is not quite right or trying to limit flights at certain airports and trying to limit all kinds of things. So that is really where we need to be in this. That is where our focus needs to be.

Jack, the question of free flight—how does it fit in with all this weather stuff? We talked about all these reroutes where we are now running airplanes over designated routes and things, but if we are starting to have free flight, which we think is going to be a great salvation for the system, and you get all these airplanes flying direct routes off airways, how do you deal with a weather situation and rerouting those particular airplanes?

Kies: I think the best way is the way Al described. We are taking a look at the technology that is readily available today and developing plans around that weather. We do have the national route program activity that is one of the early steps toward free flight in place today. When we understand and appreciate the factors impacting on routes of flight, it just doesn't make sense to [have a] flight plan into that kind of weather, not to mention that is contrary to FARs [Federal Aviation Regulations] and common sense. So free flight occurs around those obstacles that are in our way, and we coordinate that long before the airplanes get in the air.

Jim Crites: Jim Crites with DFW (Dallas–Fort Worth) International Airport. I really appreciated Al's presentation as well as Tony's and Jack's. I wanted to piggyback on something that was raised in the prior session that I think you folks are the key people that might be able to answer the question. That is, we have some new emerging technologies out there. It was noted by Dick Marchi that if we had a better understanding of the weather at specific airports as to what systems might be able to help address the problems, such as San Francisco—if the ceiling is a problem and there are technologies out there that can address a lower ceiling and fly to that lower ceiling as opposed to thunderstorms or fog or something of that nature. That would be nice to know on the part of the airport authority and the FAA so that they could potentially address that situation. It would seem to me that with the program you have put into place, you are seeing real-time every day cause and effect of weather. And you're starting to see, I would assume, at some of those airports that have systems such as ITWS and the like, probably opportunities whereby a system like an ITWS or CIWS—if it was fielded—might help to alleviate some of the concerns or provide you better information to help you deal with those situations on a day-in and day-out basis. So my question to you would be is there a process that you are working with as a second step to this SPT program to advise, if you will, decision-makers or program managers for programs like ITWS, like AVOSS (aircraft vortex spacing system), and the like—of some of the near-term opportunities or the significant improvements that could be realized through expedited fielding of some of these systems at a few of the airports?

Kies: In a word, the answer is yes. We do interface. ITWS, for example, shows in fairly definitive terms the decaying activity around a thunderstorm, for example. In days past, if we used simple radar returns, we would wait until we saw it from that perspective until we would introduce airplanes. That frequently manifested a matter of space that was left fallow. So now if we can predict with some certainty the decay of a thunderstorm, we can introduce airplanes in a timely enough fashion that we are there when the storm is dissipated, and safety is not abridged, and volumes of traffic are maintained correctly.

Krauter: Jim, as far as what are we doing to actively get this information, you have to realize I am just a dispatcher. I come to work, and somebody has found this stuff for us, and we have a tremendous amount of information and technology available to us. I don't know the process by which it happens. I know there are people who are actively pursuing it from an air carriers' perspective. I believe from an industry perspective, [that] there are people actively pursuing it. I don't know the process, but it is there. We are, as Jack stated, using it to its fullest potential, or at least as well as we can knowing the limitations of the current tool today. It has helped in a number of instances with facilitating the operation.

Ron Haggerty: I think one of the significant values of these seminars is the scientific community and the operational community come together, along with the media, to understand issues. We spoke earlier in the presentation, plus our three folks up here, about the value of strategic planning versus tactical planning and why we have to separate them.

Two years ago, as a consumer of this data from United Airlines air traffic ops, I camped on Jack Kies' doorstep with a lot of complaints about delays. We were, in fact, doing things that we weren't on the same page with. This comment really is important to state in that we need to acknowledge as a system the leadership that Jack Kies is specifically giving to this tactical operation of every day air traffic management (ATM). The issues that we are dealing with now every day have never been done before. It is significant to note that, in fact, tactical decisions are being made collaboratively, resulting in successful air traffic operations for the system. So I particularly want to express my appreciation from United Airlines to Jack for his leadership role and for Al and Tony in participating in everything, so that we can, in fact, have these types of discussions and find out where we are at. Thank you.

Shane: It is one of the misfortunes of anybody who is in the business that when it all works, nobody gets any credit for anything. It is only, of course, when it doesn't work that suddenly you become the focus of everybody's attention. And I mean everybody's attention because when there are delays in the summertime, it becomes front-page news. There is something wrong with the system. People simply cannot understand why the United States of America is incapable of mapping a system that can fly through bad weather. It is important that we have seminars like this to be able to convey what the real difficulty is, what the state of the technology is, and how we stand right now in attempting to address that problem in a way that is going to finally bring some satisfaction to people—even in times of duress. But I appreciate the comment, and I'm sure the FAA does as well. I'm sure Jack does.

Jim McKenna: I'm Jim McKenna with the Aviation Safety Alliance. I'm trying to tie everything from the previous panel with what you folks are saying together. So forgive me if I'm a little dense. It seems like a central element of everybody's comments concerns the communication cycle—the time between when you recognize the strategic picture is changing and when you can actually implement the tactical changes to take advantage or respond to that change. You folks seem to be saying that the cycle has gotten much better this year over last year. My question is—and John O'Brien alluded to it in terms of pilots trying to deviate around an activity and just the time consumed in affecting that process—how much shorter does that communication cycle need to become? As a practical matter, how much shorter can it become and what steps need to be taken on the part of the air traffic system—the controllers, pilots, dispatchers—to achieve that shortening of the cycle so you get a faster reaction time to the changing conditions?

Krauter: One of the premises in the S2K+1 training that we did was we wanted to focus in on the strategic planning. We believed that if we did proper strategic planning, some of the tactical issues would not evolve. So we will still have tactical issues, but our focus was if we plan properly—and it was a good plan, and we out-guessed the weather, if you will—we may not have as many tactical issues. We still will have them, and when we do, the whole premise of being 200, 300, and 400 miles in front of an airplane from a dispatcher's perspective is how we deal with those tactical issues. We will do our best as an aircraft dispatcher to work with the pilot in command in coming up with an alternative route. The pilot in command, in completing that air safety PAD (pilots, air traffic controllers, and dispatchers), will coordinate with ATC (air traffic control) and say this is the best routing for us based on conditions further on our route of flight. Air traffic then provides the separation. There may be instances where we have to go one step beyond that and say we had all of our airplanes' flights planned this particular way, but things have changed and we need to get the SPT (strategic planning team) group involved because it is not just a single flight, but it is going to be a series of flights. The communication aspect of the cycle is good for right now. I'm very pleased with how things have happened so far this year, and I hope it continues to get better—especially as the adverse weather starts to impact us. But I believe we have made great strides in attempting to recognize some of the issues and deal with them strategically so that we will have fewer tactical issues.

There are also instances that dispatchers will do what they can to keep a flight crew out of any adverse weather. There is also on-board weather radar, and we tell the flight crews that there is no substitute for your on-board weather radar. If you are involved in a weather scenario, use your radar. We will provide guidance from the ground, but you are there, and you are seeing it in your radar—use it.

I do believe in the air safety PAD, and I think the communications cycle that exists today, and especially the free flight planning phase and the collaboration that exists between the airlines and the FAA is going to make things a whole lot better in the short term and in the long term as well.

Kies: If I may piggyback on that—it is often a question of timing. As is often said, timing is everything. When you have to consider a flight that is leaving the West Coast and is going to impact the weather 3 or 3.5 hours from now, there is a certain amount of anticipation that has to be born in terms of developing that plan. If you don't consider the other airplanes that are going to be coming off the ground in between the West Coast and that weather, as you go west to east for example, you have a volume problem. At any given time, our system has upward of 7,000+ IFR (instrument flight rules) operators in it. That is a significant number of airplanes. The equity is key in terms of how we deal with that when routes are significantly impacted, and you're trying to squeeze 7,000 airplanes through a 500-mile hole, where before you had 1,000-mile hole. So all of that has to be considered when you consider how quickly we communicate. Choreographing this dance is a dicey issue, but it is one that we are getting better at.

Tony Henry: I would just like to add a few things to that. I use the term "a work-in-progress." We finally got the industry, the bargaining unit, the FAA, and the airline industry turned around in the direction of the communication and finding ways to work together. It is not done yet. So I believe there is some room for some significant improvements in how we do business as this becomes the routine of how we do business instead of the exception. We are already showing a lot of benefit in just the way we deal with each other on a daily basis. It is a lot more cooperative in trying to work the situation instead of trying to protect your individual facility or airline.

Jack Fearnsides: Jack Fearnsides. I'm a consultant today for PriceWaterhouse, and I have a question for Jack and for Al and probably a follow-up on one of your questions Mr. Moderator and a follow-up on Jim's question. That is, Al's presentation in particular indicated that the focus of attention was 2 to 6 hours, yet that is the time that the weather forecasting is pretty bad. It looks like technology is helping to solve the 0- to 2-hour problem, which may not be the problem we've got. So the question I have is how much of the delay do you anticipate is caused by or could be helped by knowing the 0- to 2-hour delay, and how much is still going to be left? It seems clear to me that we are pretty far away from doing a much better job in predicting 2 to 6 hours.

Kies: As is often the case, Jack, you cut right to the quick of the matter. Clearly, the science keeps us behind the power curve, so we're doing our best guess in terms of the numbers of airplanes we believe we can handle, given the paucity of forecasting technology. So that is a delicate balance and that frequently manifests into those who say we are overly conservative in some instances or too aggressive in others. So it is frequently an historical sense. We do an awful lot of interfacing for local expertise people who have lived through this experience in the local areas—both weather people and air traffic controllers. That is an incredible important element as we factor in this process. But all the stakeholders have an opportunity to weigh in, and that is the most important piece of this process. We built consensus. We rarely go down that road any other way.

Krauter: From the airlines' perspective, one of the things that makes it a challenge to dispatch is that we generally are putting together our preflight plan 90 minutes to 2 hours prior to departure, and that is the window when you have the most accurate weather forecasting capability. It has been like that for years. We have to provide that lead time to the station personnel and the pilot in command so that the station can load the aircraft through the approved schedules, and they don't exceed any performance limits, they know what the plan is, and the pilot has time to review the plan and understand what the plan is. That is where the tactical piece comes in, and that is why I stated that I believe our in-flight responsibilities to the flight crew is our greatest responsibility because conditions will change. We are going to give it our best guess, and I would like to think that 99.9 percent of the time it is going to be an educated guess. Other times, it is just going to be a feel. But we are going to come up with a preflight plan based on what we anticipate will happen. As conditions change, we will amend our plan to react to those conditions. Whether we have to go through the strategic planning process in order to make those changes, or whether we can do it on a flight-by-flight basis, is primarily dependent upon what kind of constraints we have in the national airspace system, and we will go through the SPT and command center to find out where they exist.

Drucella Andersen: Drucie Andersen with the FAA. Jack Kies mentioned our center website: www.fly.faa.gov. A week ago we announced that you can get this airport status information directly sent to your pager, cell phone, or PDA (personal digital assistant). Within days of announcing that, 2,500 passengers from around the country had already signed up. So if you would like that information to all of you here and all of you listening through C-SPAN and Weather Channel audience, we encourage you to get that information.

Shane: It is www.fly.faa.gov.

Andersen: You can pick an airport, or you can pick as many as you want, and that status information will be send directly to your cell phone, pager, or PDA.

Shane: That's great. What if that information contradicts what the airline is telling you while you are waiting there in the airport?

Andersen: You definitely should check with your airline about that information.

Shane: I don't want to distract our attention from the immediate issue, which is how to get better performance out of the system, but the perception question is an important one. You guys are again up to your necks in this issue every day in your working lives. You are aware that any time there is a hold on any airplane in the system in any way, all passengers are immediately informed by the captain that the FAA, with a big sigh, has held up the flight. What are you doing about that, and what can be done about that?

Krauter: I can speak of one airline, based out of Minneapolis, that has given its flight crews explicit instructions not to blame traffic flow constraint delays—to blame ATC for traffic flow-constraint delays. That is an education part on the process from the airline. We need to educate our flight crews as to what is the cause for the delay. Yes, there is a delay and for years it has been an ATC delay, but what has caused that delay? It is an air traffic delay; it is not an ATC delay. It is an air traffic delay.

Ninety-nine percent of the time it is going to be weather related. That weather-related delay is going to create a flow-constrained area. There are times when there are navigational aids that restrict some of our flow. But the delays in the NAS more often than not are weather-related delays, and it becomes increasingly difficult for passengers to believe an airline if you have a line of thunderstorms that goes from say Buffalo, New York, down toward Oklahoma City (Oklahoma), and they are going from Atlanta (Georgia) and Boston (Massachusetts), and they say they are on a weather delay. The reason they are on a weather delay, even though there is no weather between Atlanta and Boston, is because that line of thunderstorms from Buffalo down toward Oklahoma City is creating flow-constrained areas, and we have a bottleneck in the Northeast. That is the reason for the delay. It is not an ATC delay. It is truly a weather-related delay. That is the information that we need to get out to the public. We need to attempt to educate the public more so on why some of these delays are happening, and if there is a growth opportunity for us as airlines, that would definitely be it.

Shane: So the information being provided to passengers has become the most important issue in Congress right now. There are 13 different bills pending right now on passenger rights, and a lot of them have to do with the kind of information passengers are getting. It is an amazing comment on perceptions of the aviation system that we have in the country.

Kies: If I may follow-up on that, Jeff. It is equally important to point out that we have an open-book approach to what it is we do day-in and day-out. We are very proud of the men and women who serve the system as well as they do every single day. Proof of that, for example, is with Monte Belger; we took a chance and asked the Air Transport Association to populate our workforce at the command center. It is the only facility in the country where we have anything quite like that. That was a risk we took—affording an outside entity, so to speak, to take a look inside. If there was dirty laundry, they would certainly find it. It has proven to be a very beneficial experiment in that we now have an additional resource at our beck and call. We have learned a little more than we might have otherwise, and the fact of the matter remains—we're the best system in the world, and that is a source of pride for us, and not something we want to hide. So we will share our information as readily and as quickly as possible.

Shane: I think Al puts his finger on a big part of the problem, which is the information may be shared with the companies—the operators themselves. Whether that information finds its way through their systems—even to their own cockpit crews and ultimately to passengers—is still a pretty open question.

Kies: That is why the web page is so important. A passenger sitting at Picken Airport can actually get on that web page and read the strategic plan right now that we are operating under.

Shane: Not when you're sitting on the airplane.

Kies: Well, not after they close the doors. I think you have to turn electronics off.

Shane: That's a bit of a digression. Let's get back to the subject at hand.

Glenn Morse: My name is Glenn Morse, and I'm with Continental Airlines. Al gave a marvelous description of the pervasive impacts of weather, and he hit the nail right on the head. I'm from the New York area, and we are constantly suffering from the impacts of weather that may be 300 or 400 miles away from us, which shows the complexity of the system. With that in mind, I would like to go back to a question that you asked earlier and perhaps seek a clarification on the answer. It had to do with whether there was an "exemption" for weather in the DOT (Department of Transportation) on-time reporting statistics? I believe the answer that we heard from Mr. O'Brien was that somehow weather was exempted. I can't see where he is. Was that the impression that you got in his answer?

Shane: I think he said the definition—my impression was the definitions aren't precise enough to be able to answer the question with any great precision. But in general, yes, if it is a genuine weather delay, an airline is not going to be dinged by the FAA in terms of its on-time performance.

Morse: Okay. I'm not an expert in the DOT performance statistics, but in fact, during the course of the discussion, with the wonders of modern technology, I paged my boss down in Houston (Texas). In fact, we do not receive any special treatment with regard to the DOT on-time reporting statistics for weather. As Al indicated, although I don't think it is quite 99 percent, I think FAA statistics clearly show over time, weather delays and their reporting system range from 60 to 70 percent on a constant basis. In fact, that is the burden that the carriers are facing on a continuing basis—dealing with the impacts of weather and the havoc that they wreak on our system, particularly when you get into a severe weather circumstance that a lot of people, starting with Agam, have described here this morning. So I just wanted to clarify that and make sure there wasn't any misunderstanding—that the major burden that we are dealing with, and we, too, have instructed our pilots not to advise our passengers that the ATC system is causing our delay to the extent that we can.

Shane: We're just at the end of the session and have time for one more comment.

Jon Hilkevitch: Jon Hilkevitch with *Chicago Tribune*. Since scheduling is based on a blue sky day, what is being done operationally when the weather becomes lousy so you mitigate the fact that you're not landing planes at 1 a.m., 2 a.m., or 3 a.m., waking up people who live by airports, and then for passengers the next day—so it doesn't take you a day and a half to recover to get crews and planes where they need to be?

Krauter: A lot of times when you do have some type of a constraint that reduces the arrival rate at an airport, what the airlines will do is look at consolidating loads. We will spread it out over time so that instead of the last flight arriving at midnight—if it doesn't have a curfew—the last flight might arrive at 2 a.m. If you can only have so many aircraft per hour, it may have to go longer. We will also work through selective canceling where we will try to consolidate loads and move passengers that way. Selective canceling of flights and consolidating loads where possible will reduce the number of aircraft into that airport and that may help with some of that congestion as well. Last summer we had some very high record loads as an industry, and the consolidation issue wasn't as readily available. We continue to have reasonable loads—the economy I hear is going south, but yet we are still carrying a few people. When I flew up here, it was a full airplane and that is a wonderful thing. But when there is an adverse weather situation, that is one of the first things we will look at—the consolidation of loads.

Shane: Thank you. That brings us to the end of our second panel. The presentations were wonderful, and the comments and questions were wonderful. Let's give us a warm expression of thanks to the panelists. We are now going to break 1 hour for lunch. Joe Breen of the National Academy of Sciences will now give you an administrative announcement about how to get fed.

PANEL 3

Advances in Weather Technology

Introduction

JEFFREY N. SHANE
Hogan & Hartson

Thanks very much everybody for coming back. We have had two panels today so far. We have had one on weather and its role in aviation delays linking the whole issue of weather technology to aviation delays and congestion in our system. Second, we looked at where the rubber meets the road. The division of labor and responsibilities for decision-making in weather-related situations in air traffic.

This afternoon we are going to look at advances in weather technology. I think we will find perhaps some of the answers to some of the questions we were asking in the first panels during this panel. First up is Brigadier General John J. Kelly, Jr., Air Force Retired. He was appointed as Assistant Administrator for Weather Services and the Director of the National Weather Service for the National Oceanic and Atmospheric Administration in February 1998. He came to that position after more than 30 years of experience in all facets of the weather field. General Kelly, the podium is all yours.

PANEL 3

National Weather Service

JOHN J. KELLY, JR.
National Weather Service

Thank you, Jeff. My task today is to cover three points and to do it in 10 minutes, so I will tend to move pretty quickly. What I would like to talk about first is the role of the National Weather Service (NWS) in the nation's national airspace system. The interface between the government and the private sector—and in that I'm talking in terms of those private sector companies that produce weather products—and I'm going to look at the future and talk about some issues that will impact the directions we go in the future.

Right off the bat, weather is important to the NWS (Figure 1). If you actually go back and look at the history of the NWS, it has been around under a variety of names since the last century. Through the first 50 or so years of its existence, the two primary it things it did was (1) support agriculture activities in the United States and (2) then in the last century get more involved into aviation. As a matter of fact, it moved from the Department of Agriculture to the Department of Transportation to the Department of Commerce because of being involved in aviation. Over time, through a variety of legislative actions, our role in the agricultural business has decreased significantly, but our role in the aviation business is still pretty strong.

We have a number of activities and a number of people that support aviation

FIGURE 1 Role of the NWS in aviation forecasting.

operations in this country, and it is always difficult to slice and dice a budget because almost everything we do has multiple uses. So we have gone through our budget and tried to sort out—if you could parse that piece of it which is almost exclusively on aviation-related services and what it would be—our estimate is somewhere around $60 million a year, through the production of weather products and weather information produced by the FAA and used by the airlines and by the general purpose aviation community.

We have 121 forecast offices spread around this country, and each and every one of those produces forecasts and warnings for the airports within their area of responsibility. We have two national centers—one in Kansas City, the Aviation Weather Center—that produces forecasts of aviation hazards that are given to in-route traffic control centers and given to the airlines. And we call it national, but it's really state, but in Alaska aviation is big, and we have an Alaskan Aviation Weather Unit dedicated to producing products for aviation in Alaska. And we operate one of the world's fastest and the nation's fastest numerical weather prediction computers to produce simulations of how the atmosphere will unfold. That information is given to the airlines and given to the FAA.

If you look at numbers of products in a given year, we probably produce 900,000 forecasts for the nation's airports—about 260 specific textual products every day for the aviation industry. For the general purpose aviation community, we produce something called transcripted weather en route broadcasts (TWEB is the affectionate name), which is given to the flight service stations to help them brief the pilots who need to do the planning and get the clearance to operate.

In addition, while this can be a somewhat controversial subject in some audiences, the automative surface observing system, which in fact is the main observing system that observes the weather that occurs at the airports—there is about 900 of them, and 600 are run by the FAA, and 300 are owned by us. We maintain all of them. The product improvement work that is done is done jointly by the FAA and us, but we had the lead for product improvement. So we have a fair amount of involvement in aviation forecasting business.

There is in this country a growing private weather sector—that is, those companies that produce weather forecasts and sell them. Growing in the last 10 years, the revenue of those companies has grown from approximately $100 million to about $500 million, and there is an increasing number of them. One of the things we in the government have to do is try to better understand what is the role of the government providing services, and what is the role of the private sector, and how do you balance those two? Now, it is clear that we in the government have to ensure that we get the best possible forecast and warning information out there for customers who are subject to weather-related hazards. At the same time, when you go beyond that—our system of government—the private sector is supposed to be developing tailored, user-specific products for industries in this country. So how do you balance things?

It is pretty clear that we believe the taxpayer has a right to expect essentially [to pay] for only the marginal cost of connection, access to all the data and products that the NWS produces because the products are, by and large, produced with taxpayers' dollars. So they should have access today. And they have an expectation that we should produce products and provide services to keep them out of harm's way when they are in an aircraft.

The private sector, on the other hand, their job in life is to develop, market, distribute, tailor products to help the national economy (Figure 2). Now, there are distinct roles between the two of us, and frankly there has been tension in that area. The tension goes like

FIGURE 2 Differing responsibilities between the public and private sectors in providing aviation weather services.

this: "We in the government say you have been slow to make products, so we are going to continue to develop and produce products." The private sector says, "We don't produce products because we can't count on you not producing them. We invest internal research and development dollars, produce a product, and low and behold you market it, and you make the government product available for free—so there is no incentive for us to do that."

Steve Brown and I last week sat down and said we need to try to work a way through this—how we can figure out what is the right balance. So one of the things we are going to do is we are going to ask the private sector to help develop for us their view of what ought to be the series of guidelines that are used to determine whether the government ought to or the private sector ought to produce a product. What are the characteristics that the private sector would look for a product to have market utility? The second thing we are going to do is we're going to ask the National Academy to do a study to answer the following question: In the digital age, what really is the role of the government in the providing of weather services to this nation? Hopefully that will move us off the current area of tension.

A quick look to the future. Before I do that, I'm sitting at my job running the Weather Service; I not only provide services to the FAA, to the airlines, to the aviation community, but I fly in international airspace systems. So this morning when you were talking about delays, I'm a veteran of delays. So you get to do some musing about what we in the weather business might be able to do to help alleviate the delays. A couple of questions come to mind. Question number one—and Brant is going to talk about it, and John McCarthy talked about it a bit this morning—is do we really have an issue where given the state-of-the-art in forecasting the weather, do we have a mismatch between the state of the science and the operators' needs? Two, are we effectively communicating all the information we have about what is going to go on in the atmosphere in a way that is meaningful to you? Three, given the information we give you, are the operators using it in the most efficient and effective way? I don't know the answers to those questions, but those answers to that question will frame some of the progress we will make. And the last one, are we today producing products whose utility was great 40 years ago, but whose utility is not as great today? And the resources that are devoted to producing those products are getting in the way of diverting those resources to produce products that would be more useful and more meaningful.

One thing I have learned in the job of Director of the NWS is the hardest thing is not to introduce a new product. The hardest thing is to cease doing a product that we have done for a long period of time.

Now, with those questions as a backdrop, let me talk about where I see us going in the next few years (Figure 3). First of all, it has been talked about this morning—the collaborative convective weather forecasts, which is produced by the Aviation Weather Center at Kansas City. We're going to move next month into doing that 24-hours a day. We and the FAA have reached an agreement that we are operationally going to start producing a national convective weather forecast—that is, a 1-hour forecast of significant thunderstorm activity and update that forecast about every 5 minutes. Later this year, people are going to reach agreement that we will be able to start operationally issuing a new deicing product and following that should be a new turbulence forecast product.

We are also working with the FAA to operationalize the aviation digital data service, which frankly has become an operational tool for many, many users. And while we may not classify it as operational, the users view it as an operational system.

Then a little further downstream, we are moving to the capability for all the products where we have put in a digital format and then from that, one can create a three- or four-dimensional grid of fields to represent that information.

Now, I've talked a lot about the Weather Service. If there is a message that I would like to give about the aviation weather system in this country, it is first of all best in the

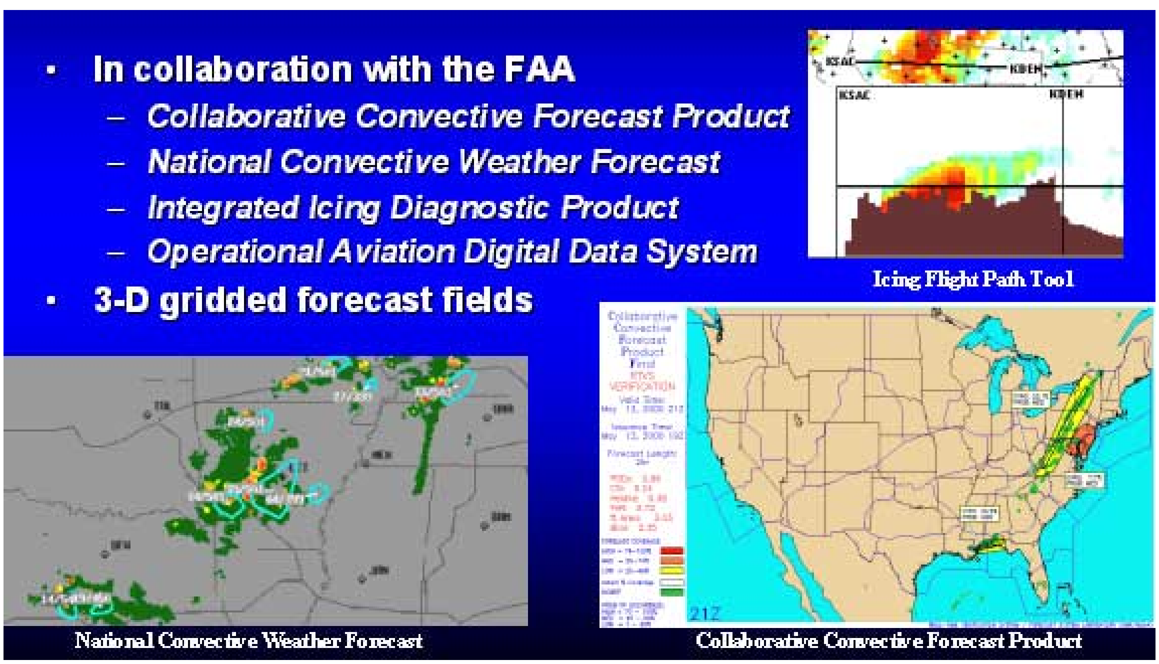


FIGURE 3 Weather service advances in providing real-time aviation weather.

world. Second of all, it is the best in the world because there is just not one entity responsible for it. There is the NWS. There is the FAA. There is the private sector. And there is the research community. Those four have to work together as a partner to make this thing succeed. I say again, I believe on the weather support side, we have the best weather support system in the world. That doesn't mean it doesn't have room for improvement, but we have the best weather support system in the world—primarily because of the involvement of those four entities. Now, I'll turn it over to Brant who can talk about where we are going in the future from a science point of view.

Click here to see Kelly's slide presentation.

Jeffrey N. Shane: Brant, you've already been introduced, but I'll just fill in the blanks a little bit. Dr. G. Brant Foote is the Director of the Research Applications Program at NCAR—the National Center for Atmospheric Research—where he deals with directed research and technology transfer and an entrance course on applications to aviation. Dr. Foote has been in this business quite a while, and he has over 100 papers published on the subject, and I think we are going to be very interested in what you have to tell us about weather technology today.

PANEL 3

Current Technologies

G. BRANT FOOTE
National Center for Atmospheric Research

Good afternoon. The assigned topic to me was advances in weather technology. That topic is getting easier and easier because each one of my predecessors has chewed away at some of the materials I'm going to show you—and perhaps some of my job is to show it all in one place and maybe a little more depth in a couple of places.

I was going to point out the people who are participating—FAA, Lincoln Labs, NASA (National Aeronautics and Space Administration), NCAR (National Center for Atmospheric Research), a couple of different parts of the NOAA, National Weather Service (NWS) and the Environmental Research Lab, and the Naval Research Lab over here—who are all participants in this coordinated program on aviation weather improvements.

We have the worst weather in the world—the United States does. Everybody knows it. Jack said we have the best weather forecasts and the best weather facilities, and I agree completely. Those two make a nice match. We also have something called a fundamental research program in the United States, and everything we are doing here has built on the long-standing program supported by places like the National Science Foundation and others that have got us up to a certain plateau.

But the material I want to talk about today is material that has been accelerated by a focused research program of the FAA's with all participants that you just saw. The things I'm going to talk about today wouldn't have happened if the FAA hadn't stepped up and taken ownership of weather as something that was important for their administration, for their problems. In the last 2 years, NASA has something called the aviation safety program that my colleagues talked about (Figure 1).

I'm going to roll through something like six or eight topics. The one we have been talking about primarily up to now, thunderstorm forecasting—I'm going to have to do it very quickly in 10 minutes. I put out in front a list of copies of my talk for those who would like to see a little more detail that I won't be able to get into. The state of the science in thunderstorm forecasting—we have a pretty accurate, very useful, 1-hour

- Built on the foundation of the nation's long-standing investment in atmospheric research (NSF, NOAA, NASA)
- Greatly accelerated in the past decade by the FAA's funding of highly focussed R&D
- In the last few years NASA has been a significant partner in the focused effort

FIGURE 1 Research results in aviation weather.

forecast (Figure 2). It's an extrapolation forecast—thunderstorms are here, they were there, and they are headed over here. That captures a big part of the problem. It doesn't capture all of the problem. We're working using these techniques of extrapolation on 2-hour forecasting, and we think those are feasible in just a couple of years. Accurate forecasts beyond 2 hours are very important, as you heard today. What is our skill in that? Not very good. These are automated products up here. This is a human-based product, as we heard someone talk about this morning. It is based on the art of forecasting and interpreting data and trying to figure out the best way possible in a collaborative sense what is going to happen and make some decisions based on that. You heard a lot by name of the Terminal Convective Weather Forecasts dealing with airports. That is the national thunderstorms forecast based on a web site hosted by the Aviation Weather Center. We have some other things that we talked about. I don't have to dwell on them because they've been talked about to some extent—collaborative convective forecasts. Here we have something called the Autonowcast System that actually will predict the formation of a thunderstorm from the clear sky. There are no storms there now, but in 1 hour, there will be a storm sitting over Pittsburgh (Pennsylvania), for example. The system is based on measurements that are made possible by this wonderful network of radars that we have, a consequence of the NWS modernization in the past decade, where we measure convergence in the clear air with the radar. You could see it with your eyes if you could see with microwave vision. You can't. You see in what we call the visible spectrum. But if you could, you would see these regions, and you would be able to forecast the weather—at least as far as thunderstorms are concerned.

Terminal Convective Weather Forecasts products—we talked about, as John McCarthy mentioned, a study that was done by Lincoln Labs, about delays associated with this and the costs of those delays and the savings that could be incurred by implementing systems to deal with those (Figure 3). In the Integrated Terminal Weather

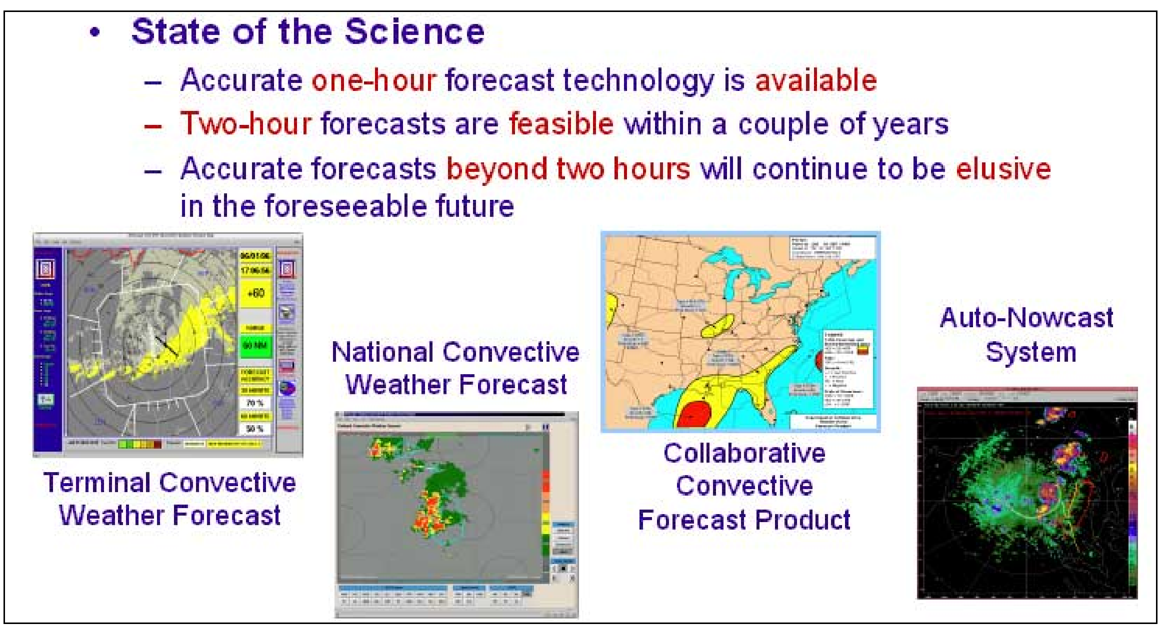


FIGURE 2 Thunderstorm forecasting.

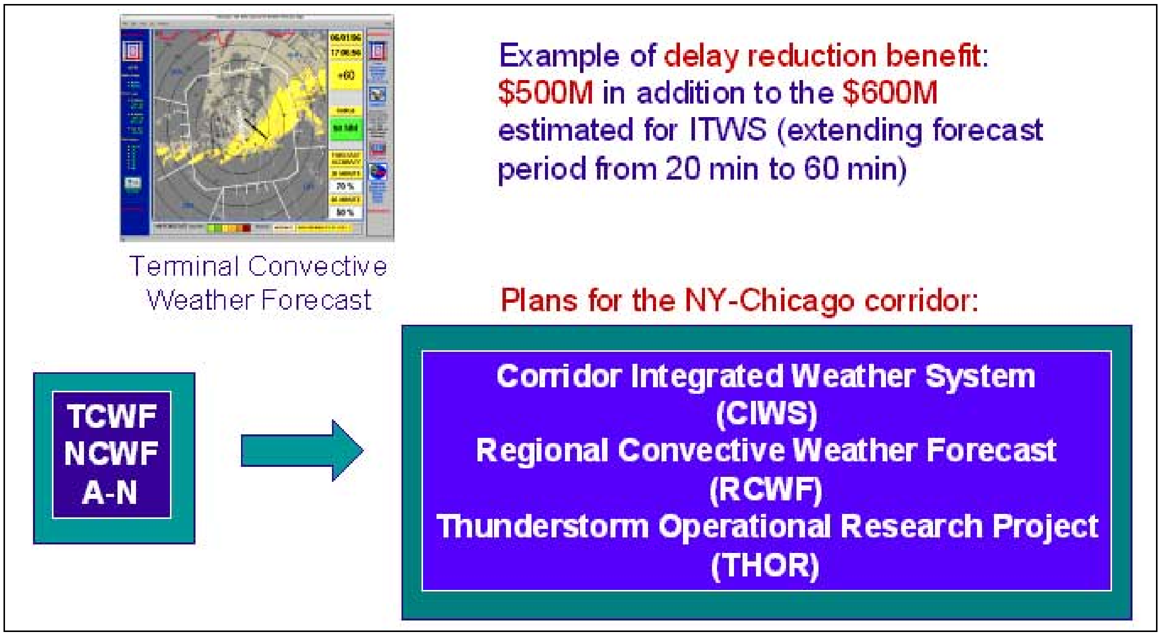


FIGURE 3 Thunderstorm forecasting.

System (ITWS), it was estimated $600 million in delay reduction savings could be realized by using the 20-minute forecast that is built into that. By extending that out to 60 minutes with this system, [there is] another $500 million in delay reductions. It is substantial—in a 1-hour timeframe—not the 2- to 6-hour timeframe. We are talking about something we can do now and something that could be implemented and something that is on the pathways to implementation now, but it is not implemented yet.

What is on the horizon? We heard about the plans for the New York/Chicago corridor and systems that are going to be tested—FAA systems, NWS projects. I'm going to return to this toward the end of my talk, but let me go on to a few other items.

Turbulence is a big topic for the airlines—a few hundred million dollars worth of injury-related costs every year, passenger unrest, rerouting airplanes, looking for good altitudes (Figure 4). There has been a lot of work going on in turbulence, using a variety of techniques—clear air turbulence, turbulence around airports, look-ahead systems using improved techniques involving radar. This data is from the NASA 757, and maybe you're [Mike Lewis of NASA] going talk about this a little bit later.

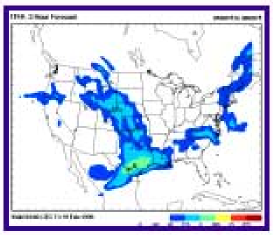
You have heard about icing as well this morning (Figure 5). Thunderstorms are a big problem if you're worried about the weather in the summertime and delays, but if you are talking about the regional airline that just had an accident or had an upset, there are many other factors such as icing that become headline items. We have now a very useful 3-D diagnosis of where the icing is occurring now. If we have thunderstorms, we have a network of radar and remote sensing instruments that will paint you a picture of where they are. We don't have a remote sensing techniques for turbulence, and we don't have any remote sensing techniques for icing. We have to do it some other way. We have to be a little more clever. We have a data fusion technique using a wide variety of input that goes into this. I won't have time to talk to you about the details, but in addition, you can imagine vertical cross-sections over here that show the vertical limit of icing. If you fly above here or below there, for example, you're not in the icing—you are at a safer

State of the Science

- Useful forecast technology for upper-level clear-air turbulence is available
- Automatic aircraft measurement and downlink of turbulence encountered is transitioning to the airlines
- Improved on-board radar sensing of turbulence in the vicinity of thunderstorms will soon be available
- Terrain-induced turbulence detection near problem airports has been shown to be feasible
- Considerable additional research remains in forecasting thunderstorm turbulence and low-level clear-air turbulence

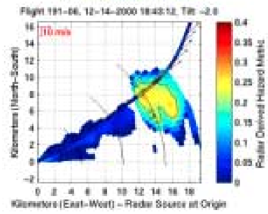
R and D Technology

Integrated Turbulence Forecast Algorithm



Automated aircraft reporting of encountered events

On-board radar



Hong Kong Windshear/ Turbulence System

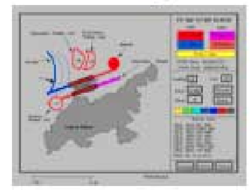


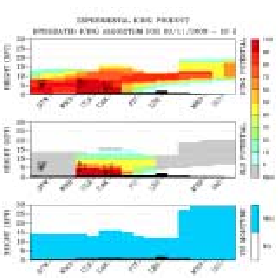
FIGURE 4 Turbulence.

State of the Science

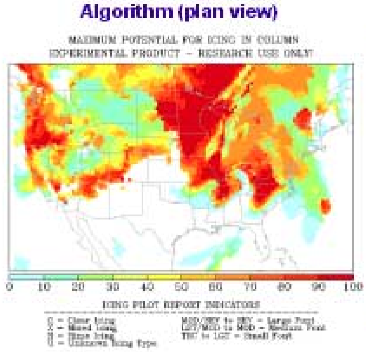
- A useful 3-D diagnosis of current icing areas is available now
- A 3-D 6-hour icing forecast product will soon be available
- Remote sensing of icing from the ground, satellite, and aircraft is still in its infancy

R and D Technology

Integrated Icing Diagnosis Algorithm (cross-section)



Integrated Icing Forecast Algorithm (plan view)



Radar Remote Sensing of Icing (cross-section)

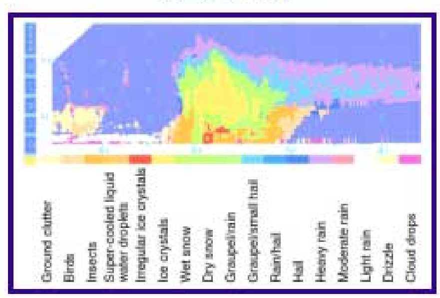


FIGURE 5 Icing aloft.

altitude. These things are available on an experimental website now—the one that Jack Kelly referred to.

Snowfall on the ground and de-icing—the same kind of problems: Snow on the wing, it contaminates the wing, you lose lift, you increase the drag (Figure 6). Aircraft have crashed because of this. There are other operational factors. Snow impacts the arrivals and departures at the airports. If we knew when the snow was falling and when it was going to stop falling, you could take advantage of that in very important economical ways to improve the use of the airport and increase capacity.

Ceiling and visibility were also referred to (Figure 7). The concern is not just with problems like the parallel runway situation at San Francisco. General aviation, for example—the fatality statistics with regard to weather are dominated by pilots flying in poor visibility conditions when they shouldn't be there. Improvements in this area have to be made if you want to make an improvement on total fatalities in aviation. There is some very significant work that has just been started on that topic.

Oceanic weather—obviously thunderstorms occur over the ocean as well (Figure 8). If you fly from Los Angeles (California) to New Zealand or Australia, you might go through a thunderstorm over the intertropical convergence zone down here. We don't have radar or we don't have surface anemometers. We don't have the same kind of things we are used to here. We do have satellites, so let's learn how to use satellites. There is a combined program going on now in oceanic weather.

We have to get the data out to the people who need it. If we have new products or a new weather capability, they don't do any good unless somebody can get a hold of them and make use of them. The Internet is the most wonderful invention that we have ever seen in the history of these kinds of things (Figure 9). At this URL down here, you will hook on to a web page at the Aviation Weather Center sponsored by the FAA. It has a

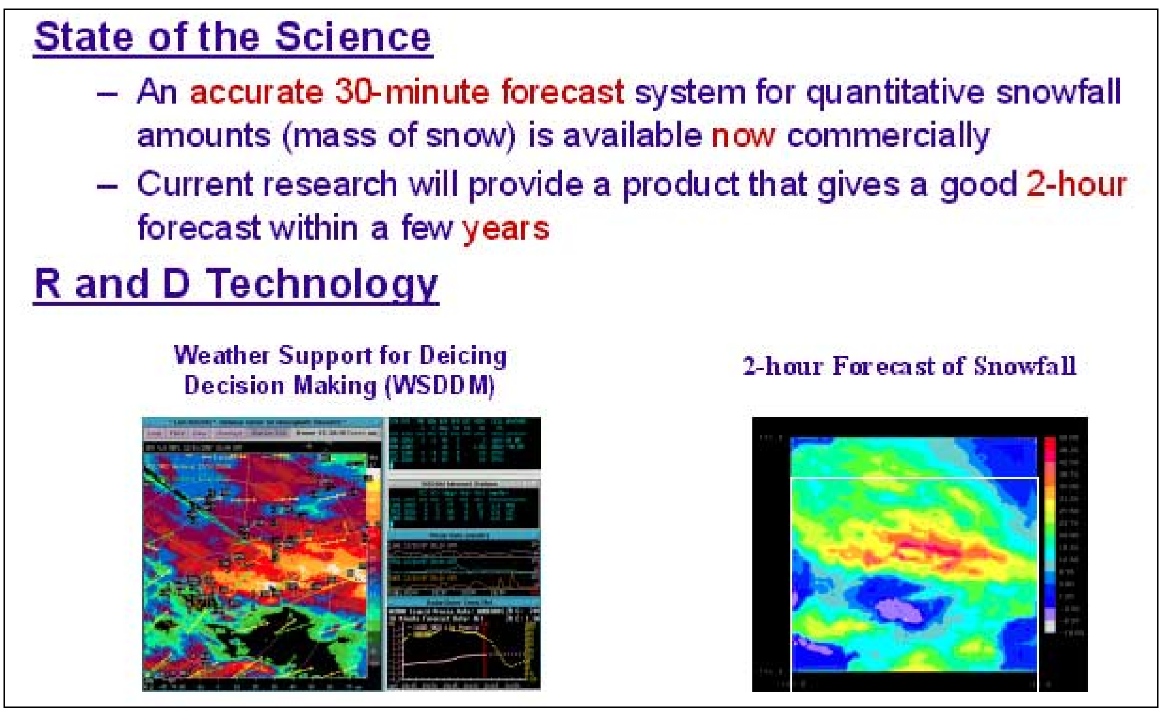


FIGURE 6 Snowfall and ground deicing.

State of the Science

- A system to provide accurate forecasts of morning low cloud burnoff at San Francisco is ready for application
- A national-scale diagnosis and forecast product is being tested and will be ready for initial operational use within a few years
- Highly accurate forecasts for specific airports is a difficult research problem with many years of work needed

R and D Technology

San Francisco Stratus Problem

National-Scale System

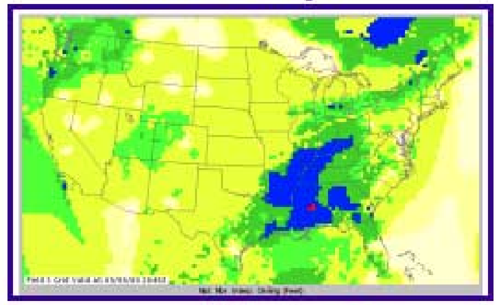


FIGURE 7 Ceiling and visibility.

State of the Science

- A satellite-based thunderstorm detection product is currently being tested and will soon be available for deployment
- Within a few years, a one-hour thunderstorm forecast product will be available
- Other oceanic products such as thunderstorm turbulence, clear-air turbulence, and icing are several years away

R and D Technology

Oceanic Convective Nowcasting System

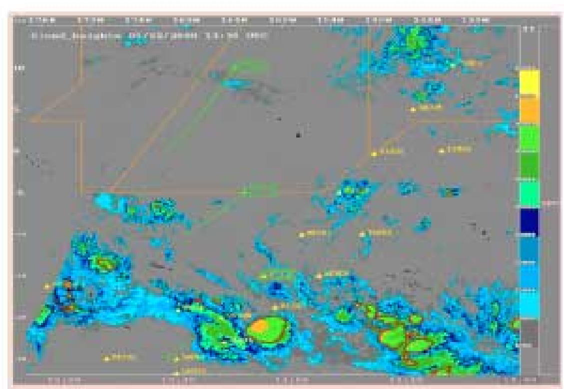


FIGURE 8 Oceanic weather.

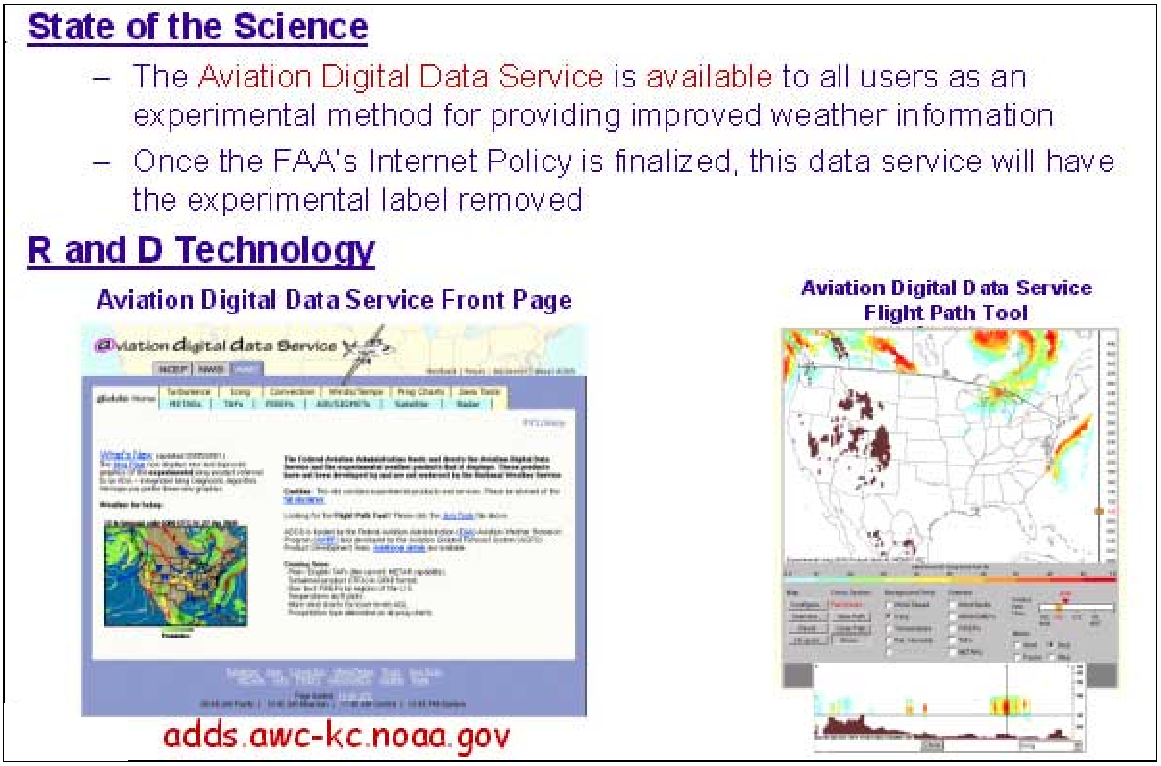


FIGURE 9 Internet dissemination of improved weather information.

whole range of experimental products, which are in the process of becoming official—operational projects, as you heard mentioned, including a flight path tool that you can click and point on the route of flight and bring up the vertical cross-section showing a weather phenomenon, its height range, and so on.

It is not just advance planning based on pre-flight weather information that is important but also weather information in the cockpit to the pilot in command. If I'm flying from Miami to Seattle, I need to know what exists now—not what was forecast to exist 2 hours ago when I did my flight planning. If I am going to fly around the squall lines, should I go around the north end or the south end? I have flown a lot in the cockpit with commercial pilots, and every one of those has a horror story about, "Yes, I got up to a storm, and I didn't know it was going to be there and went around it the long way, and I could have saved 40 minutes if I made another decision." Tactical planning—by having things like a national weather radar mosaic in the cockpit—that would be of tremendous value. These sorts of things are in the pipeline as part of NASA's joint program with industry to put these things in the next generation of avionics (Figure 10).

So I was asked to talk about priorities for funding (Figure 11). A lot depends on what the purpose of the weather product is and the specific benefit that you're looking for. Obviously, if we are talking about summer thunderstorms, we know we need to emphasize 1- or 2-hour thunderstorm forecasting—it is what we have available now. It is not everything that we want, but we've got a lot of progress made here.

What should we be doing in the research area (Figure 12)? Well, we should be using these terminal forecasts and these national forecasting and extending them out to 2 hours. We should be demonstrating better capabilities. We have a generation of forecast

State of the Science

- NASA Advanced Weather Information (AWIN) program has accelerated the development of commercial cockpit systems employing new display and product technology
- FAA's Flight Information Services Data Link Program is working with vendors to put in place a capability for General Aviation to receive basic weather information in the cockpit
- New graphic products for thunderstorms, turbulence, icing, ceiling, visibility, and oceanic weather will eventually be inserted into these cockpit systems

R and D Technology

Honeywell AWIN Display

ARNAV General Aviation Display

FIGURE 10 Cockpit dissemination of improved weather information.

- These depend on the
  - Purpose of the weather product
  - The specific benefit sought

FIGURE 11 Priorities for funding?

Funding Area	Purpose/Benefit
1-2 hour thunderstorm forecasting	Safely reduce summer delays

Specific Priorities

Research	Implementation
• Extend TCWF and NCWF to two hours (CIWS and RCWF)	• Implement TCWF at all ITWS sites
• Demonstrate forecasts of storm initiation, growth, and decay in THOR program	• Implement NCWF at AWC to feed FAA's WARP and ADDS
• Continue to encourage funding for the difficult 2-6 hr forecast problem from basic research sources (e.g., NSF)	• Make TCWF and NCWF available to FAA facilities and airlines through CDM-net and ETMS

FIGURE 12 Priorities for funding: an example.

products that is now better than what we ever had, and let's start moving on with it.

The very difficult problem is this 2- to 6-hour forecast arena that we have heard a lot about, and that is very important in the flight planning process. It is very difficult from the scientific point of view to make progress on that problem. Why is that? Two reasons. I'll just mention them briefly, and then I've got to sit down. Number one, there are rivers of moisture in the atmosphere that slide between all our networks. Thunderstorms like to form on them. They are maybe only 50-miles wide, and we have a 200-mile network of observations. We don't know where those are because we don't have the remote sensing tool for measuring water vapor. So there is an uncertainty associated with that which feeds into an uncertainty in thunderstorm prediction. Number two, when the first thunderstorm forms, there is some predictability. But the first storm will spawn a second generation of storms, and they will spawn a third. It is like hitting a pool ball—you know where the cue ball goes, and you know the first ball it hits, but after it bounces off the wall and hits two or three other balls, you start losing predictability very quickly. That is what we are facing many times in the 4- to 6-hour thunderstorm problem. It is going to be a tough problem, and we need to hack it with fundamental research capabilities like those sponsored by the National Science Foundation in the universities.

So just to finish up—there is a lot of benefit in reducing summer delays, but there is a whole host of other things that are important that we have gone through. I don't have time to talk about these, but we have to transfer these R&D (research and development) results to operations if we are going to make any difference in realizing any benefits (Figure 13). There is a considerable body of improved capability. Product delivery is available now on the Internet. The cockpit weather information is coming (Figure 14).

Where is the challenge (Figure 15)? Expedite the integration of all of these things into the system. The FAA and National Weather Service has a responsibility for officially

Funding Area	Purpose/Benefit
• One to two-hour Thunderstorm Forecasting	Safely reduce summer delays
• Turbulence Forecasting	Reduce airline injuries
• Icing Aloft Forecasting	Improve safety of regional airlines
• Snowfall and Ground Deicing Weather	Improve Winter airport capacity
• Ceiling and Visibility Forecasting	Reduce fatal accidents; better utilize airport capacity
• Oceanic Weather Information	Safely improve utilization of oceanic routes
• Aviation Digital Data Service	Improve safety through better preflight information
• Advanced Weather Information (AWIN) and Flight Information Services Data Link (FISDL)	Improve safety through better in-flight information
• Transfer of R and D to Operations	To realize all preceding benefits

FIGUE 13 Priorities for funding.

State of the Effort

- There is a considerable body of improved capability available as a result of research sponsored by FAA and NASA
- The internet and commercial vendors of cockpit equipment provide the technology base to make new product delivery possible

FIGURE 14 Moving research and development to operations.

The Challenge:

Expedite the integration of these capabilities into the system (FAA and NWS responsibilities)

- Agency acceptance
  - Official "blessing" on new products
- New procedures for using products
  - ATM
  - Flight Standards
- Produce products reliably in an operational setting
- Use of products by end-users
  - How to integrate information into decision process

FIGURE 15 Moving research and development to operations.

accepting that we are going to use these products and get them into the system. There is a lot of work associated with getting them into the system. It is not an easy process. It is not a cake walk. It will involve new procedures, new ideas, and new ways of doing business. The automated products that we are developing—they are not the normal way of doing things. We are used to having a forecaster in the loop. Internet delivery. How do we interact with the private sector with regard to the specialized products? Product reliability has to be there before we are going to get ahead of the curve as far as liability—we can't be putting out products that aren't proven.

And then, once we do all this, we have to figure out how to get the end user, particularly the pilots, into the loop. If the pilot doesn't think it is a more accurate product, are they going to use it? I don't think so. We have a lot of education to do and a lot of training to do on a whole generation of new projects. It is a big effort. We need to get on with it, and we need to expedite that integration.

Click here to see Foote's slide presentation.

Jeffrey N. Shane: Brant, my heart goes out to you. You tried to cram so much information into your allotted 10 minutes that I thought we should have given you 15. You will have a chance to amplify on that, but thanks so much for everything that you managed to squeeze in. I think we probably will want copies of that presentation because you went through it so necessarily quickly.

The third and last speaker this afternoon is Mr. Michael S. Lewis, Director the NASA Aviation Safety Program, who has worked with NASA since 1983. Mr. Lewis is the guy at NASA who is basically in charge of aviation safety, and he is going to tell us everything that is going on at NASA in terms of the kinds of advanced technology that we are looking and waiting for. Mike.

PANEL 3

National Aeronautics and Space Administration

MICHAEL S. LEWIS
National Aeronautics and Space Administration

Good afternoon. I'm batting last here. I'm not going to say everything that is going on at NASA in terms of aviation safety because there is clearly not enough time. I'm going to pick out a few topics. Some of them have been gone over before. Some of them have not. I have some views from my perspective.

As I look at aviation system capacity, I see six key hurdles to overcome (Figure 1). First, as John O'Brien talked about a little bit this morning, is reducing wake vortex separations and trying to close up especially in IMC (instrument meteorological conditions)-type conditions as we operate today [and] to close up on required separations and do that very safely, in fact safer than we do even now. Second [is] something we talked about as well this morning—increased efficiencies in the terminal area with weather and the environment—both on approach and landing as well as take-off departure and so forth. [This is] closing up both prior to weather coming in and then, as we talked about earlier today, following weather efficiently once hazardous weather moves out of the area. Third is en route airspace management and the density of traffic in the current en route system. Fourth is eliminating visibility and surveillance limitations, and I'll talk more about that. Fifth is clearly more pavement on the ground. Sixth is the noise problem that comes along with airports and increased density in operations. I view it from almost a tactical standpoint—attacking these kinds of six fundamentals are getting at the nut of the aviation system capacity challenge.

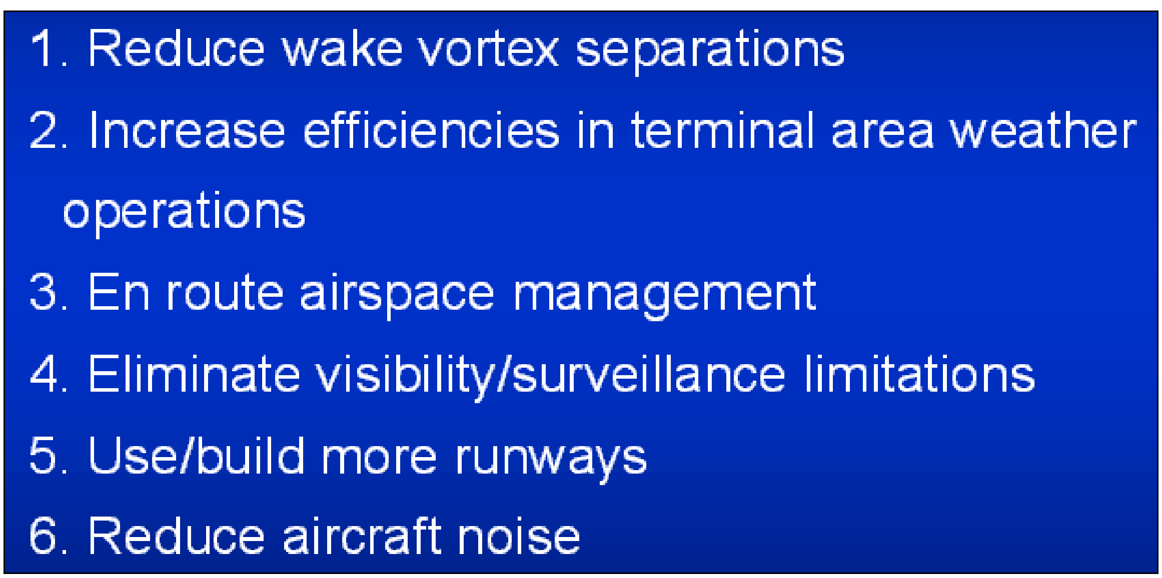


FIGURE 1 The six key hurdles for increased system capacity.

Curiously, to the topic of this conference, three or three and a half of those are weather–atmospheric types of considerations. It is not just improved automation on the ATC (air traffic control) side. Weather and atmospheric conditions are a significant part of the capacity challenge that we have. So let me talk about just three of these subjects, and I'll try and go quickly.

Wake vortex spacing—you all know what wake vortices are (Figure 2). There is a picture in the upper left here showing a vortex coming off the wing tips, and obviously for small aircraft following large aircraft, the separation needs to be required in case the smaller airplane runs into the strong vortex coming off the wing tips of the lead airplane. However, the atmosphere is not the same everyday. Vortices don't stay in the same position every day. Depending on the atmospheric conditions and the winds, vortices can either linger or move out of the way very quickly. So the opportunity is to take advantage of short-term forecasts and wake vortex modeling and confirming sensors on the ground to confirm in effect that the vortex is where you think it is. [Then,] use that information [and] reliability to predict that information with the half-hour or so of lead time that the ATC system would need to take advantage of that. One can then begin to close up on the spacing that the current system requires and take advantage of those kinds of days. There are significant numbers of those type of conditions where the vortex is moving very safely out of the way. A demonstration of this type of technology—on both a ground-based system and the forecasting and modeling—was conducted last year at DFW (Dallas–Fort Worth) Airport. Jim Crites is in the audience, and he can tell you more about it than I can. But it showed along the order of 10 percent or so efficiency just from

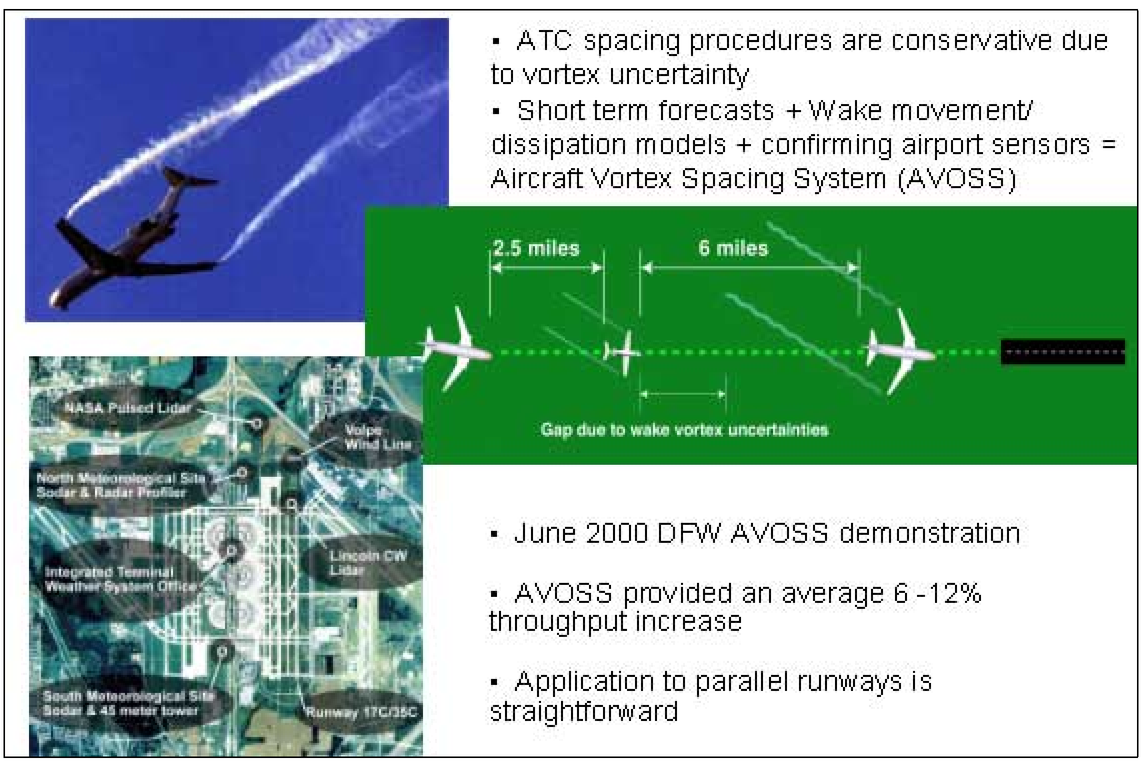


FIGURE 2 Wake vortex spacing.

this particular application in the early stages of it for a single runway. Applications to multiple runways—sometimes we close down a parallel runway because of wake vortex types of considerations—the augmentation there would be 100 percent.

The second subject area—the headline [“Report: Pilots get worse weather data than public” in *USA Today*] is true. Pilots in the air today, for the most part, maybe get the information below (Figure 3) in the cockpit. The opportunity is to turn that into graphical weather information and improve decision-making in the cockpit by taking advantage of all this information we have talked about during the course of the morning and early afternoon. Since the *USA Today* article was written a year or two ago, significant amounts of activity and progress toward getting graphical weather information displays and technology in avionics and the communications data link infrastructure to support that have happened. NASA is involved in some of it. The industry is involved in much of it. We see the kinds of display systems that are coming online. [For example,] United Airlines has in-service evaluation of this electronic flight bag—a portable device hooked up in the cockpit with tactical weather displays as well as the potential for other applications. [These are] NASA pieces of technology. Boeing and FedEx and others with a similar type of system are getting graphical weather displays. This type of information is low-cost for the general aviation application. Our simulation and flight test applications and testing show that getting graphical weather information for both these 1-hour types of forecasts, as well as a real-time type of weather display, allows pilots to not only avoid hazardous weather by increased margins, but they save time when they do it. [This is] because, as we talked about, you are not flying right up to the front of a thunderstorm cell and trying to decide which way to turn—left or right: You are making a decision in a more strategic way and saving time and increasing safety.

Second, NASA efforts underway in trying to contribute some of the model data or data required to improve weather forecasts. Two things to point out here. One is a new sensor that we are getting ready to install on the GA (general aviation)-types of airplanes because they fly at the lower altitudes that are significant for weather formation on the data that is required (Figure 4). The system is called TAMDAR—I forget what it stands for—humidity, temperature, pressure, winds, and other types of information link together to increase the density of the information feeding into these forecast models—so we can move away from relying only on balloons launched every 12 hours at various sites around the country. They are trying to close up on this gap of the information and data

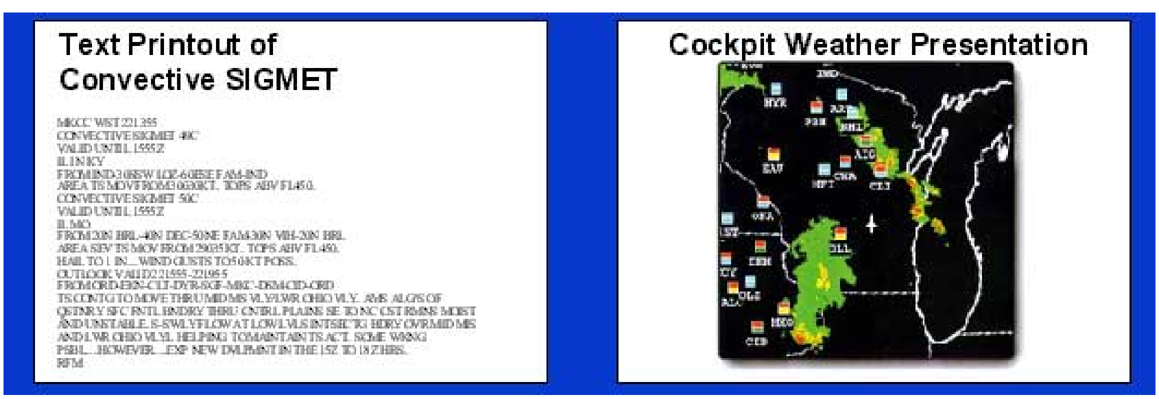


FIGURE 3

FIGURE 4 Graphical weather technologies for GA and commercial aircraft.

that is available to initiate the model. And coming soon—but not nearly as soon as this type of approach—[are] space-based applications. Looking down—and you can’t quite see the pictures here, but the potential for new types of interferometric sensing from space will allow, instead of some balloons launched every 12 hours or so at various airports and other locations around the country, the equivalent of thousands upon thousands of these “pseudo-balloon” launches detected from space, checking the atmosphere from space every 15 minutes (Figure 5). So the density of the initiating data and information for forecast weather models, over the coming 5 to 10 years, is going to be increased significantly, and the accuracy of these both near-term and longer-term models should go along with that (Figure 6).

The last topic I will talk about is visibility. It is incredible over the last eight decades worth of flying what the aviation system has developed and grown up with and worked around to try to deal with low-visibility situations (Figure 7). In fact, there are lots of costs and lots of systems underway in the infrastructure of the aviation system that deal with low visibility. [The examples are] ILS (instrument landing system) both on the ground and the air and autoland systems, [along with] extensive training, extensive airfield approach lighting, and the real estate needed for the lights, special operational procedures, and so on. We build control towers 200 feet into the air so controllers can see the airport and airport environment. Visibility is a fundamental challenge to the way the system operates. But yet, there are still consequences to low visibility situations. John McCarthy talked about the Navy study showing three-quarters of Navy Class A accidents are related to low-visibility types of issues and causes. [Examples are] control flight into terrain and obstacle collisions, and loss-of-control accidents in the general aviation world

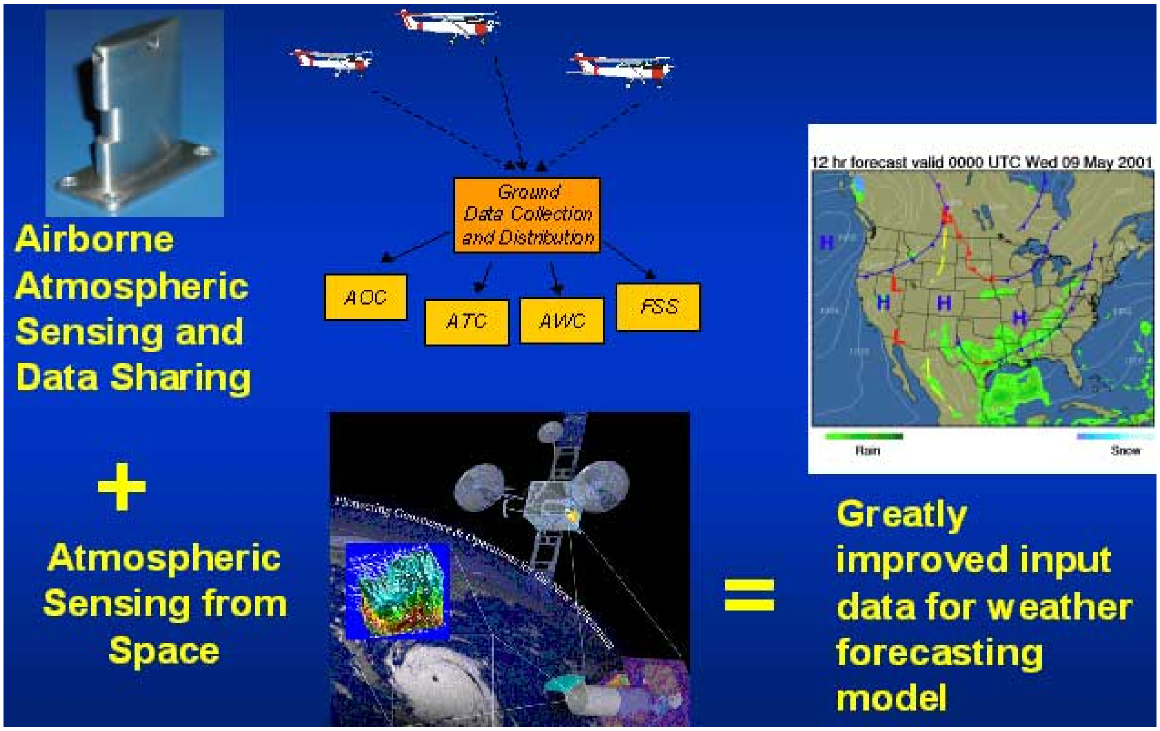


FIGURE 5 Improving weather forecasts.

- Higher resolution/more frequent atmospheric measurements
- More reliable terminal area short term forecasts
- Airborne graphical weather displays and shared airborne/ground decision making for increased safety <u>and</u> approach/departure flow efficiencies

FIGURE 6 Weather R&D objectives.

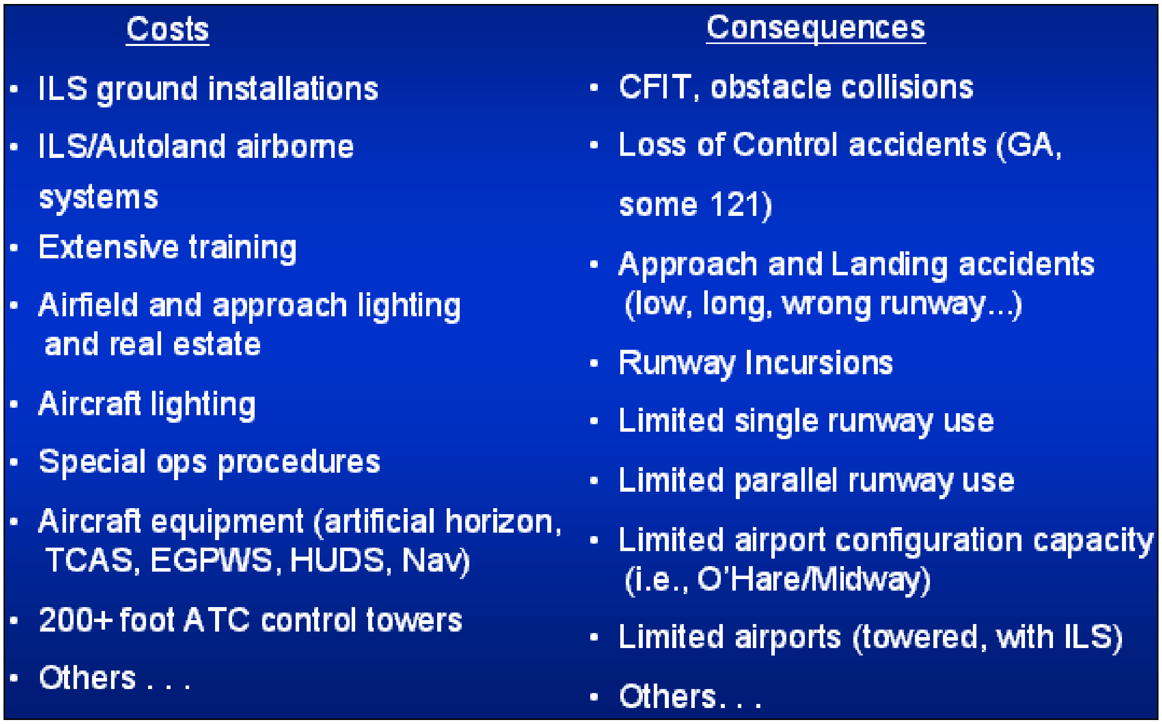


FIGURE 7 What the need for visibility makes us do.

when low-flying pilots fly into low-visibility situations. [These pilots] sometimes don't keep the wings as level as they should and a significant proportion of GA accidents are these types of loss of control situations. [Also,] approach and landing accidents [may happen, along with] runway incursions on the ground as well. These are safety sorts of issues and operational issues. We limit how much we use a particular runway. We limit how much we use parallel runways. We limit how much we use given airports when visibility conditions...Chicago's O'Hare starts to shut down when the ceiling drops below 5,000 feet because of interactions with Midway Airport. Think about it over the next few months if you are flying on the system—how many times you hear about the relationship of visibility to the way the system operates.

The FAA benchmarking study that just came out showing optimal landing and arrival rates at a given airport versus reduced rates: I would hazard that a primary contribution to these reduced rates is the visibility restrictions that limit the use of a particular runway (Figure 8). To some degree, it is adverse winds at those airports, but there are still 10-20-30-40 percent type reductions in the capacity of the system due to visibility.

Four fundamentals can attack this (Figure 9): GPS (Global Positioning System) and accurate positioning of where your aircraft is precision traffic information coming from systems like ADSB or multilateration on the ground, a digital terrain and airport obstacle data base, and then the processing and display to bring it all together.

Coming up is a picture of the Asheville, North Carolina, airport over the mountainous terrain in North Carolina (Figure 10). This is the type of picture that no matter what the visibility—night time, fog, heavy rain, moonless night, etc.—the pilot can see by bringing together GPS, an accurate high-resolution map of the airport, and just

Airport		Optimum	Reduced
ATL	Atlanta Hartsfield International	185–200	167-174
BOS	Boston Logan International	118–126	78–88
BWI	Baltimore-Washington International	111–120	72–75
CLT	Charlotte/Douglas International	130–140	108–116
CVG	Cincinnati-Northern Kentucky	123–125	121–125
DCA	Washington Reagan National	76–80	62–66
DEN	Denver International	204–218	160–196
DFW	Dallas-Fort Worth International	261-270	183-185
DTW	Detroit Metro Wayne County	143–146	136–138
EWR	Newark International	92–108	74–78
HNL	Honolulu International	120–126	60–60
IAD	Washington Dulles International	120–121	105–117
IAH	Houston Bush Intercontinental	120–123	112–113
JFK	New York Kennedy International	88–98	71–71
LAS	Las Vegas McCarran International	84–85	52–57
LAX	Los Angeles International	148–150	127–128
LGA	New York LaGuardia	80–81	62–64
MCO	Orlando International	144–145	104–112
MEM	Memphis International	150–152	112–120
MIA	Miami International	124–134	95–108
MSP	Minneapolis-St. Paul International	115–120	112–112
ORD	Chicago O'Hare International	200–202	157–160
PHL	Philadelphia International	100–110	91–96
PHX	Phoenix Sky Harbor International	101–110	60–65
PIT	Greater Pittsburgh International	140–160	110–131
SAN	San Diego Lindbergh Field	43–57	38–49
SEA	Seattle-Tacoma International	90–91	78–81
SFO	San Francisco International	95-99	67–72
SLC	Salt Lake City International	130–132	95–105
STL	Lambert St. Louis International	104–112	64–65
TPA	Tampa International	110–119	80–87

FIGURE 8 Benchmark capacities.

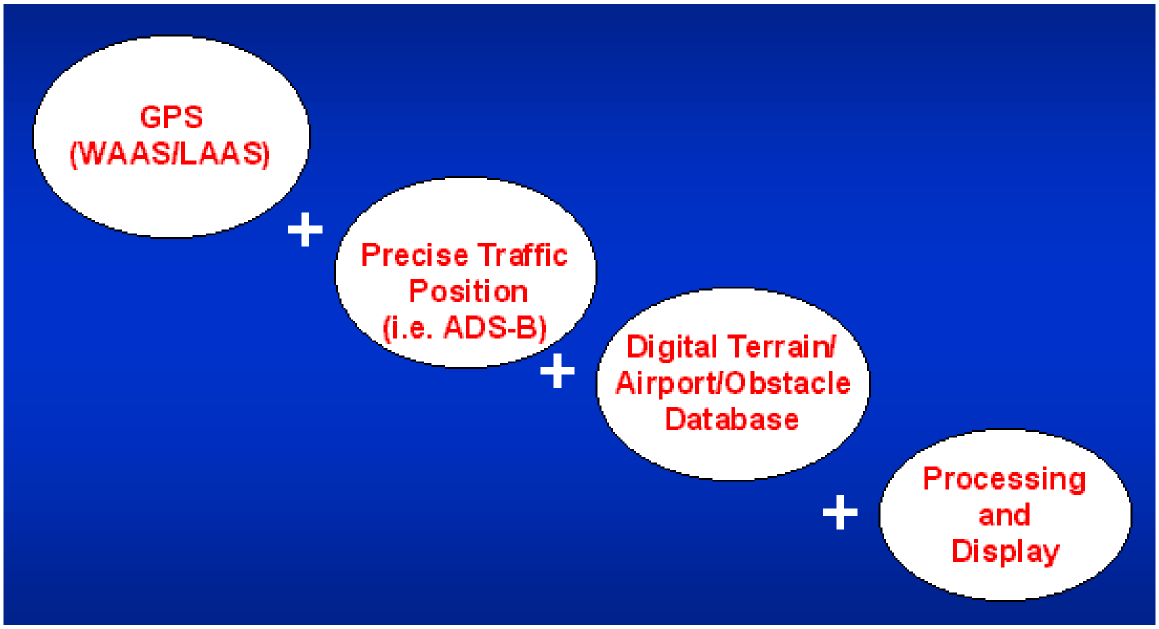


FIGURE 9 The four fundamentals.

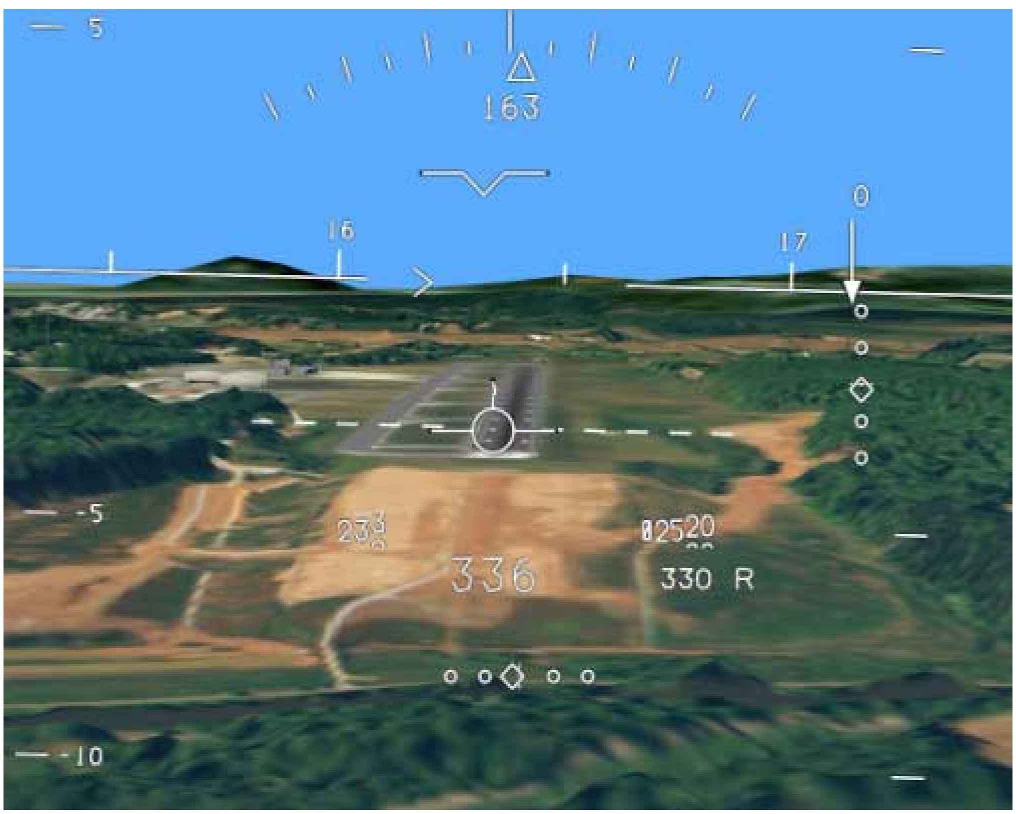


FIGURE 10 Day VMS—all the time (Asheville, North Carolina).

drawing the display in front of the pilot—either head down, head up. In the future, it will be right on the guy's eyeglasses. The opportunity is to remove visibility of an aviation issue.

We talked about ceiling and visibility forecasting and trying to improve upon that. You can bypass that. That is good stuff, and that is important, but the opportunity is to just never have visibility restrictions both from a safety standpoint and from an operational standpoint [that] impact aviation. That is, Asheville, North Carolina. These are pictures from databases we developed and flight tested over the last couple of years. There is Dallas–Fort Worth Airport (Figure 11). Coming up, we are heading to Eagle Vale, Colorado, which is a significantly terrain-impacted airport, where we will be operating at our NASA 757 this August (Figure 12).

The challenges to make this work and to apply this type of technology are not really technology developments. A new invention is not required. It is the systems integration and implementation challenge to bring this kind of technology—certifying and making it work in the aviation system. We can. The timing only matters as to how aggressive we go about doing this. We can remove visibility as an aviation system problem—which is a huge step forward.

As well, the same fundamental technologies attack the runway incursion issue (Figure 13). [With] GPS, ADSB, or precision traffic information, an accurate airport map—drawing a map of where you are and where the other traffic is and a warning system that goes with that—and from all of our simulations and from all of our flight testing, we can not just cut runway incursions by 10 percent, by 15 percent, and nibble at it. We can remove the errors that lead to runway incursions. So the opportunities to benefit from these technologies are big (Figure 14).

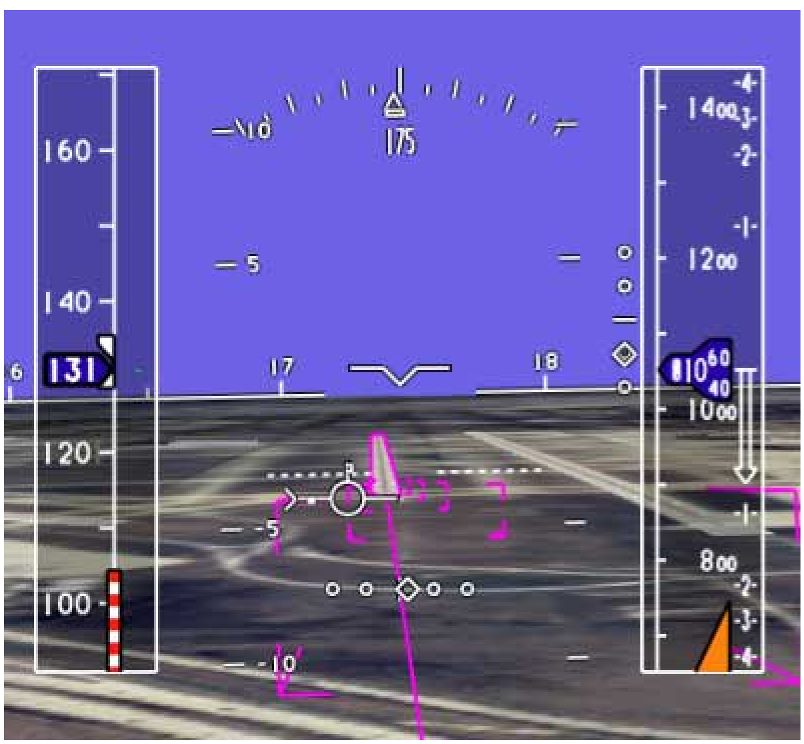


FIGURE 11 Day VMC—all the time (Dallas–Fort Worth).

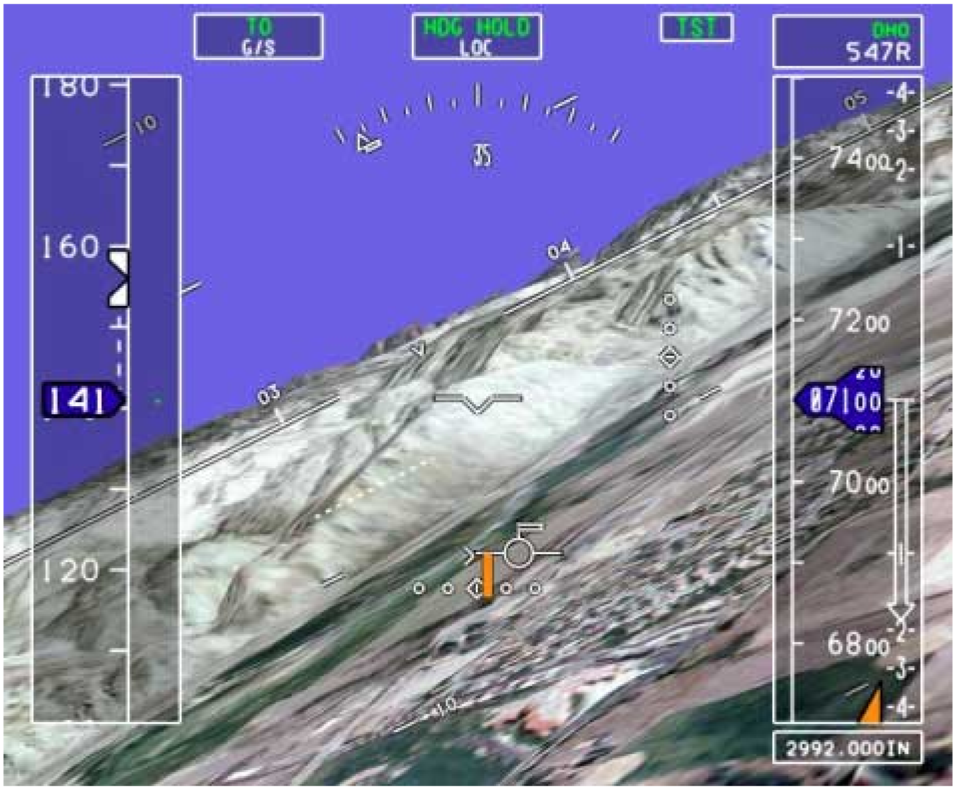


FIGURE 12 Day VMC—all the time (Eagle–Vail, Colorado).

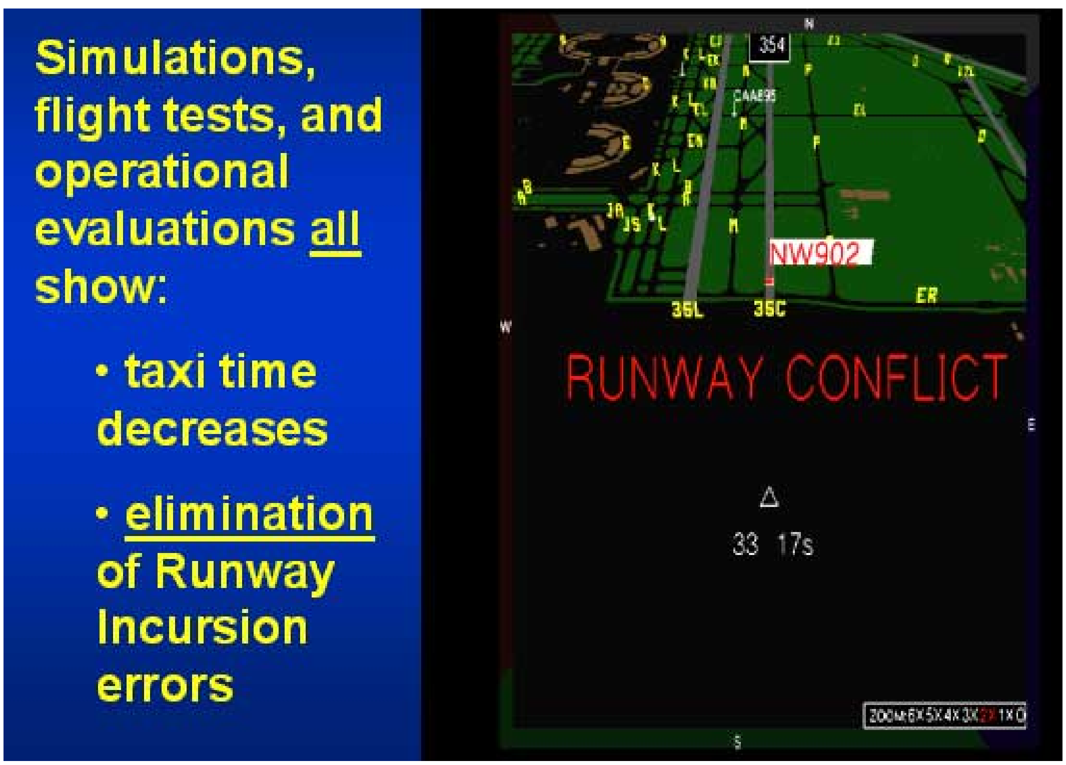


FIGURE 13 Taxi map displays.

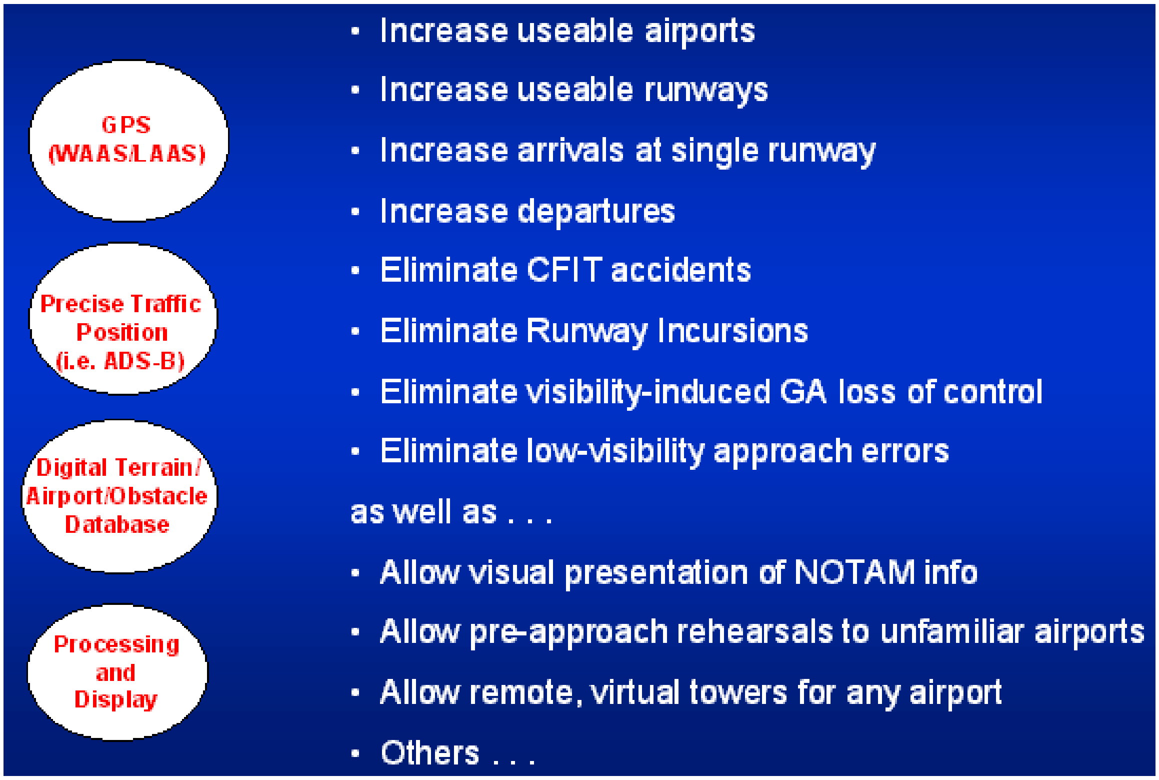


FIGURE 14 What these four fundamentals can yield.

FIGURE 15 NASA R&D initiatives in partnership with the FAA.

So four fundamentals are there on the visibility side. I'm talking about increasing usable airports, increasing usable runways, eliminating whole categories of accidents (95 percent of control-flight into terrain accidents happen in the night-time or the IMC-visibility type of conditions). These are fundamentally visibility problems. I am harping on this a little bit, but the application is here, and the potential for this is huge—both from a safety standpoint and from an operational capacity standpoint.

So I talked about those six key hurdles (Figure 1). There are lots of particular NASA R&D efforts underway in partnership with the FAA (Figure 15): the Aviation Safety Program, which I run; the Aviation System Capacity Program (the ATC automation tools under development); [and] the Small Aircraft Transportation System program (SATS) is trying to bump up many of these technologies for the GA-type of airplane.

Finally, there's a significant program underway for the aircraft noise problem, which I didn't talk about. It is basically trying to take the objectionable noise of a particular airplane and keep it within the airport's boundaries—the design of the engines and the design of the airplane to keep the objectionable noise within the airport boundaries so noise doesn't become a limitation to the growth of aviation and capacity of the system.

This is a whirlwind tour of a handful of things on the horizon. Hopefully, what I can impart here is basically everything I have talked about is not Buck Rogers 10 to 15 years out. From a technology standpoint, it is doable basically now and in the very near term. We can apply this as aggressively as we in the aviation system put our hearts into it.

Thanks very much.

Click here to see Lewis' slide presentation.

Question-and-Answer Session

Jeffrey N. Shane: Thank you very much, Mike. That was like your two colleagues of the panel—a breathtaking presentation. I know it will stimulate a lot of conversation during the remaining time that we have. I have a number of questions, but let me not monopolize the question-and-answer process. Let me see if there are some hands out there.

Jim Evans: I would like to get a little explanation on this visibility and runway airport capacity. The fundamental problem isn't visibility—it is collision risk on a closely spaced parallel. Just because I have a synthetic vision view of the runways doesn't mean I don't have to worry about the plane next to me. I live in San Francisco, and boy, that is the problem. It isn't that we can't land on those runways. We can land on the runways. But we can't land when there is a plane wing-tip to wing-tip that we can't see. How will you solve that problem?

Mike Lewis: It is a visibility challenge because in clear weather you can see out of airplanes. So it is a visibility issue. The solution, which I would propose, is not just drawing a picture in front of yourself of the runway and the airport. One of the four components there was ADSB, which is precision traffic information. We need to bring in the high precision surveillance of knowing where other traffic is, combine that together, and operate in a visual environment so you avoid the mistakes and errors that sometimes lead to control flight into terrain, getting off path, etc. A combination of knowing where the other traffic is in a precise way and the visual environment in operating your own aircraft is attacking this fundamentally as a visibility problem. When the system works BMC, San Francisco is up at 100 percent when it is a clear day. So you see where the other traffic is. The separation decisions and so forth are more in your own cockpit. You fly your own aircraft in a visual environment much safer than you do in other types of environments as far as control flight into terrain and other accidents are concerned. So the challenge is to combine those two things together and with a visibility type of approach extract those same capacities.

David Stempler: David Stempler from Air Travelers Association. Jack, what percentage of the activities for the National Weather Service are focused on transportation activities?

Jack Kelly: As I tried to say in my talk, it is awfully difficult to categorize them. Let's talk about a snow forecast that we put out for the Washington metropolitan area. It covers the interstates. So you could argue that forecast has an impact on the interstate corridor around Washington. At the same time, the general American public uses it. So it is almost impossible to do.

When we look at aviation, we try to cull out and we come up with about $60 million of activities that are purely directed toward aviation. But again, the automated surface-observing system, which we put in with the FAA, which takes observations at the airports (so it is used to make operational decisions at the airport), that is also input data into the numerical weather prediction models that we use, and it is also input data into the data that our forecasters use to make forecasts for the local area. So is that transportation related? What other relation is it? How you compartment is a tricky thing to do. Clearly, the terminal forecast that we produce is aviation related. So for aviation, say about $60 million...

Stempler: Out of a total of what?

Kelly: About $700 million.

Stempler: One of the questions I had was whether we would be better served to have the National Weather Service as part of the Department of Transportation. You said historically it had been in Agriculture then moved over. When you go out to the Herndon center, you see all the FAA folks there. Then there is a separate section over there for National Weather Service and the FAA folks go over there and they're talking. I was wondering if it would be better coordination from the weather components if it was part of the same agency?

Kelly: I would be surprised that you find the National Weather Service component out at Herndon because I don't think there are National Weather Service people out there. You talk on the telephone to National Weather Service. But I will tell you this: if you go into the 21 en route traffic control services, you will find National Weather Service people in there. I don't know whether you would be better served or not better served. I know one thing, in Washington you can get involved in what I will call sand-box issues; we will get into major jurisdictional arguments about should it be in the Department of Transportation or should it be in the Department of Commerce? I think what would be better is if we could sort out is there, in fact, a requirement for full-time weather people in Jack's facility. If the answer was in the affirmative, then how can one make that happen rather than trying to debate should the National Weather Service be in the Department of Transportation or should it be in the Department of Commerce? I will tell you this, the Secretary of Transportation I worked for when he was the Secretary of Commerce, Secretary Mineta. So I'm not sure that is the most productive use of our time. I think it would be better if we sort out what is needed and then how one might get the resources to do that.

Now, having said all that, I think the relationship and the cooperation between the National Weather Service and the FAA is as good as it has ever been. There is a lot of close collaboration now. Both of us also face another thing, and it is budget time—and I'm not doing a plea for more budget—but I am telling you [that] there is more on their plate and there is more on my plate than we have resources to use. So we have to constantly do some priority kinds of juggling. That would happen if the National Weather Service was in the Department of Transportation or not.

Shane: Thanks. Jack, you started off your presentation with some rhetorical questions. One which I thought was pretty provocative was is there a mismatch between the National Weather Service information that they are providing and the needs of the users? I'm not sure I heard an answer to that question. Is that because you are not qualified to answer it or because the answer has to come from someone else?

Kelly: I think the answer has to come from somebody else. But I think you heard this morning that the 2- to 6-hour thunderstorm forecast is very important to the efficient operation of the national airspace system. I also think you heard from the scientists—and there is at least two to my right and some in the back—who will tell you that a 6-hour accurate thunderstorm forecast is years away. So if you have an operational concept that is counting on an accurate 6-hour forecast and the state of science is such that you're not going to get an accurate forecast for quite a while, is there a mismatch between what we are giving you and the way you're operating? I just pick on that as one example.

We have troubles doing accurate location-wise forecast of turbulence. I am saying that we are better at it, but it is not an easy thing to do. These new products that are coming out are going to have more skill than the old products, but there is still room for improvement on all of those products.

Mike presented an interesting comment in his talk, which was ceilings and visibility forecasts are important, but, oh, by the way, there may be technology out there that allows you to leap frog over the need for those good forecasts and allow you to operate whether the ceiling is or is not low. I don't know. They are questions that as a weather guy I can't answer. I don't know the operational method you use. I can tell you what we can do, and I can sit back and take a look and say: I know what our capability is, and I know you want us to be better. But I know where the science is and where it is going, and we are far better today than we were 40 years ago or 10 years ago or 5 years ago. But you have to look at your operational system and ask is it maybe asking for more than the science can deliver? I don't know.

G. Brant Foote: I think there is an area of new capability that is really providing some wonderful things, and there is an area of requirement. And there is no doubt a broad overlap between those, but it is not complete. There is a mismatch at the moment. We are not ready to work on that problem in a very focused way. It is a fundamental research problem; it is going to take some more time. The agency, very properly, is going to try to move ahead and doing the best it can with the problems as it has it now.

One of the things we might do better on is defining ways to utilize, to optimum benefit, those new capabilities that we have—get them implemented more quickly and start reaping the benefit in delay reductions, saving dollars, etc., by using techniques that have been developed and been tested. We have seen examples of those this morning. They are on the books, but they are not moving all that quickly. We clearly have more problems to solve in figuring out how to use those to optimum benefit.

Shane: I want to come back to this issue of implementation, and I'll pick of questions in a moment. But before I leave this subject, Mike Lewis talked about visibility. One has the impression that there are different kinds of weather problems. There are problems that are primarily impacting aviation because they cut down visibility and they produce delays in the system and real challenges to safety. The solutions that Mike was talking about—the virtual displays and so forth—are obvious solutions to those visibility problems. Is there a category of weather problems that go beyond visibility? You can't fly through some kinds of weather, whether you tend to see your way or not.

Lewis: In the air, there are three fundamentals that are hazards you don't ever want to fly through, and that is severe turbulence, hail, or icing types of conditions, if you're not well-equipped. Everything else basically airplanes can handle in the air. Volcanic ash may be a fourth one that is not very common. Airplanes have no problem with heavy rain, by and large. In the airport environment, landing or take-off, there is crosswind considerations, runway contamination, wind shear, and wake vortices. There is a finite handful of things that are hazardous to airplanes that we all want to do a good job of actually detecting and staying away from. Everything else, from a safety perspective, is not a big issue. So putting smaller and smaller and more accurate boxes around those hazards—turbulence, icing, and hail—and turbulence and hail go hand-in-hand because weather radars are good detectives of that. Clear air turbulence and some icing as a detection problem is much tougher.

Jim Crites: More of a comment if I could because I had the luxury of being in all three of these sessions. It was kind of interesting that we started out in our first session talking largely about the economics of flight supply and demand relationships, and we understand that the cost of delay is quite high—not only the direct operating cost but the impact on the economy in lost opportunities of providing goods and services and that.

We had a very interesting transition in our second meeting to talk about traditional methods to improve capacity and safety. The traditional norm for airports, since they take the lead of that role in going after those capacity and safety enhancements, is to do the cost-benefit analysis largely done on the standpoint of direct operating costs. We also extended that out to the national impact a new runway might have, and that is part of the EASE (expediated aviation system enhancements) legislation whereby we have identified a number of runways that will not only have a local impact but also a national impact.

What is really appealing to what I've heard today is that, as an example on ITWS (integrated terminal weather system), to hear that ITWS, when we complete the research and extend out its forecasting capability to 60 minutes, it will be a $500 million, on top of an already $600 million, add $1.2 billion of benefit for a system that takes on a per installation side between $200,000 or an upper bound of $500,000 to implement. That is a huge return on investment—far exceeding any runway I've ever heard of on an annual basis. We have [the] luxury of having a prototype ITWS system at DFW Airport for over 6 years now. The first year alone, in a prototype status, it saved our major carriers $15 million a year, and that is just grown every year.

I have also had the luxury of hearing Michael's brief in detail because they did some work at DFW Airport and Atlanta and others. What is really intriguing is that we are using off-the-shelf technology and integrating it to provide for the first time true situational awareness—relevant information to a pilot and a controller—and grouping it to be able to make good, accurate decisions of what is going on out there in the community. The interesting thing that I think is a little bit lacking, though, in our discussion of these new technologies is that Jack said the "B" word—the "budget" word.

One of the things that is very intriguing about ITWS, as well as these others systems that are out there, is that they have had to fight very tough battles for very scarce dollars, yet they have huge economic and safety benefits. We have not added that into the equation in terms of trying to appropriate the right level of funding. I'm very careful here not to say that they take it away from any of the other extremely valuable programs that are being pursued by FAA and NASA. But ITWS is a weather system, and we live by it down at DFW International Airport, and I know that they do so elsewhere. I've seen the benefits that the TAPS (terminal area productivity system) program that NASA and FAA have worked on together has been able to provide.

The challenge I think for all of us, though, is to take the paradigm that we use for traditional capacity and safety enhancements, return on investment, [and] cost-benefit analysis and apply that to these systems. They are going to blow you off the scales, which I think if we do that in an organized way, local, rational way, is going to make a very good argument for providing the right appropriations levels to field these systems. If at least not that, provide other entities, such as airports, the ability to procure these systems that are desperately needed out there—which can be fielded in a much shorter timeframe.

As we discussed in our last session, the average runway takes 12 years to see it from start to completion. I don't believe it would take 12 years to fund ITWS everywhere or where it needs to be placed, or fund and field most of the terminal area productivity systems. It wouldn't take 12 years to go ahead and put those in places where the strategic planning team is out there identifying real-world opportunities in a much shorter timeframe with much greater benefit in the end. So I applaud your work. I hope we now extend our paradigm for everything else in terms of cost-benefit analysis applied to you all and see your systems fielded in a much shorter timeframe. Thank you.

Shane: [comment not recorded] It's strange credulity to think that with as much technology that is available on the shelf today, including the things that are being done at NASA and elsewhere and things we have heard about just this morning, the amount of attention being paid to just the delay problem—never mind the safety problem—that we aren't quickly addressing the issue through the application of dollars and cents. I just don't understand it frankly, and I hope that at least one important result of the fact that the FAA and the Transportation Research Board have put these symposia together is that official Washington wakes up to the fact that there is a big solution just staring you in the face. It is not going to happen overnight. It will still take a little time. But the fact is we are not inventing new technology in many cases. There is a tremendous amount of improvement out there ready and available for the asking. So thank you for that.

John McCarthy: John McCarthy with Naval Research Lab. It is hard to follow those comments, but I do want to re-emphasize further what Brant said. You've brought us together a very interesting mix of people here—people from all sides of the system here in terms of weather. There is some great news here. Let me emphasize the great news. There are some systems that are here now that are able to produce what some of us believe are tremendous reductions in delay. If we all continue to do the homework right, those numbers are huge. Those numbers can have a tremendous impact on the system and as also a great user of the system, the frustration that people feel about using the system and those delays.

We also hear the word collaboration in terms of how "systems are being used," and that is great too. Some of the systems that are being used in collaboration: the science is not there yet. We have scientists here, including myself, who are saying, "Gee, we're trying to collaborate on systems that we are not ready to use, but we are collaborating and that is great too." The point I want to make, and I think the point that Brant was making earlier, is let's spend some time learning how to collaborate more effectively on the systems we have now. [These systems include] ITWIS, CIWS, the national convective forecast system that is becoming available through the Aviation Weather Center, [and] the short-term 0- to 2-hour products that are really coming online. [And we can develop] user groups that can make air traffic control and management operation centers and the scientific folks work together so that we can extract the most that we can now and at the same time work on the 2- to 6-hour problem, which, as Brant effectively described, is a long-term problem. So I just want to emphasize the importance of that. Let's use the bird in the hand process because we can do a lot with it.

Jack Kies: Perhaps before you close it off, I could ask one question. It is a great segue that John gave me as to where collaboration is concerned. The CCFP, which is in effect a collaborate convective forecast product, showed us some leading-edge technology. Frankly, as I said earlier today, it is the very foundation for much of our planning. Unfortunately, there is very little collaboration where it comes to interpreting that data. The FAA users of that technology, along with the dispatchers, were frequently pointing fingers at one another about creating no-fly zones based on probabilities that the controller workforce is not familiar with. So I think our challenge this year and in the future would be to interpret that data in a fashion consistent with what the forecaster intended. We lack that interface currently, and I think that is an Achilles heel on the current methodology.

Kelly: Actually, I agree with you. One of the questions I threw out was are we effectively communicating all of the information we know and the answer to that question is, in the case you just talked about, "no" because the numbers mean something to the forecaster, but they don't mean anything to one of the users who are the dispatchers or some of the controllers. We need to collaboratively work together to make sure that the information gets out in a form that is useful to the destined end-user and not just be useful to the meteorologist.

Foote: Maybe I could jump in a little bit. I hope I didn't discourage you that your problem is too hard for the scientific community and there is no help for you right now. That is not the case. There is a lot of work going on there. That is one of the major impetuses of something called the U.S. Weather Research Program, which is to make those kind of forecasts. There are a lot of people working on it. But one of the areas that we might think about doing more is just the area you've been talking about—about uncertainty and how you quantify uncertainty and how you use uncertainty. That is to say, if you forecast a 50 percent chance of thunderstorms in this region, you close out the airspace for 4 hours and for 6 hours, and [when] thunderstorms don't develop—[then] you have thrown away airspace. If you can't find a way to recover from that—if you don't have a contingency plan that says in those cases with 50 percent probability, we will do something different so that if it doesn't materialize—we still have that capacity. I think there is probably a lot of room we can do in helping advance how accurate those probabilities are. What is the chance of error in making those forecasts, and how do we deal operationally with that issue of uncertainty?

Evans: The challenge here is partly a meteorological challenge. It is also in part an air traffic problem. The issue really is if I even showed you where some weather was, what was the capacity now that the weather has impacted some routes? One of our problems is that we don't know yet really how to relate the distribution of the weather to the achievable capacity. People are looking at this. You get into controller workload and so on. What air traffic would love to get is just an estimate of the capacity—30 percent capacity or 40 percent capacity—we don't know how to do that quite yet. That is one of the important research agendas that needs to go forward: How to take the forecast and make it come out in numbers that traffic flow management understands. They understand two things: They understand capacity and percent capacity. They deal with that all the time in airports. They understand possibly the routes, but that is one of the big challenges—to get something that is a capacity estimate and not some weather probability estimate because what you have to run against is capacities.

Shane: Anybody else?

Chris Fotos: Thank you, Jeff. My name is Chris Fotos, and I'm editor of a newsletter called *Airports* here in D.C. Michael, day VMC (visual meteorological conditions) display that you were showing in your presentation—I wasn't quite clear if those were just conceptual illustrations or whether you've stuck that in an airplane and flown it around?

Lewis: The latter. It is real.

Fotos: Bureaucratic obstacles aside, how long would it take to implement that kind of technology systemwide—order-of-magnitude guess?

Lewis: Our goal is to try and get initial applications, which is not systemwide, but it is just initial certifiable—and there is a big range on certifiable because it depends on what you're trying to use it for. If it is just a safety advisory system, perhaps it is one thing. If it is a fly-in to achieve lower minimums on your approaches, it is another hurdle. But the program goal is to have those kinds of technologies, in which the initial phases of it are in operation in the order of 2 to 4 years. I say that as opposed to 10 years. So it is on that horizon which, from a NASA perspective, is relatively near-term.

Will it solve this summer's problem? No, it is not there. But I guess my point is that there are plenty of technical issues—certification issues for sure—not a new invention required to get that kind of safety information in front of the pilot. There are lots of industry folks pushing in this direction already. We are working on a partnership with some of them. So there is motivation in various pockets of the community to do this and try to do it fairly quickly.

Fotos: Now, is it just one of many NASA programs of that ilk? Does it have a champion of some prominence?

Lewis: I am kind of a champion...

Fotos: The reason I ask the question is it speaks to what we were just talking about which is unfortunately we have a history at places including FAA where probably literally a couple billion dollars have been spent on other technology initiatives that really haven't produced a whole lot. Some of them have, and some of them haven't. It is very frustrating to people to see all this great technology lying around, and we say why can't we just use it? But I think everybody in this room knows that the first time a major funding request comes up for something like that, a lot of people in Congress are going to be thinking, oh boy, here we go again—goodbye $2 billion. So deciding how to fund which particular program, as everybody knows here, is not a trivial exercise. That is one of the reasons we are still stuck with some of the delays that we do have.

Lewis: It is a very hard problem, this implementation thing. I have a bit of a luxury in the R&D (research and development) world, or at least traditionally folks have thought that implementation is somebody else's job. In the program that I'm running, we think it is a lot of our job as well—to develop the technologies in such a way that implementation is helped. But the operational implementation is not a trivial thing. It is just not a matter of telling somebody to go do it. There are plenty of hard, hard issues that have to be covered. But from my strong perspective, the end result will be worth it in this case.

Shane: I would put Chris' question in a slightly different way. I would say we all know, of course, that implementation is very complicated, and it is a big industry out there and will take a lot of time to get this stuff going—even when it is ready for prime time—to get it deployed to the point where it is actually part of the system. Has anybody provided the mandate? Has anybody said we are going to have the man on the moon by 1969 in terms of putting this kind of technology in cockpits throughout the fleet?

Lewis: I don't want to focus too much on the one particular technology. From a national goal perspective, yes, we feel like we do have a mandate. We have a national goal of cutting the accident rate 80 percent by 2007, and this is a goal not just endorsed but being taken under wraps and run with by the FAA, by the industry, and from a NASA R&D contribution perspective. So we feel like we have a national mandate to do not just the 10 percent kinds of things but the fundamental things that need to be done to achieve such a goal. The question gets tougher when you talk about particular projects or implementations of one versus another and near term versus relatively longer term. But there is strong communications and collaboration in both the commercial aviation side and the general aviation side to try and review those—prioritize them. This particular technology of synthetic vision is, in fact, on the agenda for the commercial aviation safety team as well as the general aviation joint steering committee, which is the GA side of trying to contribute to that goal. So I'm optimistic, but it is still—again talking about this particular project—this is something that is different, and it is new. The aviation system is pretty conservative and, rightly so, has a little bit of a challenge in doing something that is a little more different than some other things.

Shane: In response to somebody's question, you mentioned ADSB—have I got those initials correctly?

Lewis: Yes.

Shane: This is somewhat of a less exotic but still very exciting technology for bringing a lot more information into a cockpit than is available today and to put it there in a graphic format. Basically, [it is] airplanes telling each other electronically where they are so they appear visually on a screen. It can be the same display and provides a lot of other information as well.

Now, that actually has been deployed. I saw that briefing just yesterday morning put on by UPS (United Parcel Service), which has this technology in a number of its airplanes. It is apparently working. What is it that prevents the FAA tomorrow from saying by the end of 2005, every airplane in the fleet is going to have ADSB or some variant thereof, if it turns out that a little more research is necessary?

Lewis: That is, for sure, a good question to ask of the FAA. I am not them.

Shane: People are just much too polite. That's why they don't get beneath the heart of the matter. I wanted to put a question to Brant, who I think somebody just picked you up on this—I think it was John McCarthy. I think the phrase you used was to look at predictability to improve the quality of our predictive abilities beyond the 2-hour level—that it is going to be elusive for the foreseeable future, which is why you say appropriate a lot more money for it. Suppose we do appropriate a lot more money for it, will the foreseeable future hold some promise of success on that front, or do you really thing it is more...

Foote: I was talking particularly about the thunderstorm problem when I said 2 hours—not necessarily icing or winds that are still going to hit Chicago or a lot of these kinds of things, which we have a lot better handle on with the American forecast models and other things that start getting very accurate at 6, 12, 18, and 24 hours. The problem with numerical models is that when we started numerical models, current weather, like clouds, rain, and hail and so on, are not in the model. They have to generate those internally, and it takes a while to do that, so they don't really get accurate with that until they are 6- or 8-hours old. Extrapolation systems work very well for an hour or so, and with expert systems, you can start going toward 2, 3, or 4 hours. But there is a gap, and that was referred to earlier. In the middle of there, none of the systems are working too well. The 2- to 6-hour gap is a historic one that we are trying to fill.

When I was talking about the thunderstorm problem, I was saying let's not throw FAA money at that problem or a mission agency and a directed solution to that problem because it is still in the fundamental mode. Let's use NASA Science Foundation and the universities and people that are currently working very hard on that problem, and let them crank on that for another few years before we start thinking about focused attention to peak solutions that are coming out of that aviation problem or service transportation or marine or some other kind of economic sector that is impacted on us by weather. Does that sound...

Shane: Yes, makes better sense. More comments? More questions?

Evans: If we go back historically at airports, ceiling and visibility and related IMC capacity have been reviewed as the major constraint, and when we look at the FAA tables, that is what is reflected. The problem and the challenge with ADSB is that it is a single thread. FAA has redundance, and when you talk about ADSB, you are using the NAV (navigation) system as part of your surveillance system. You are then vulnerable to an error. If one of those planes is a wing tip away has a bad navigation system, you don't know it in ADSB. That has been the fundamental problem. It is the same problem that has happened with GPS as a blind-landing system. How do I monitor this system unequivocally to ensure it is not being jammed because, for example, ADSB uses GPS very heavily. But we have now the problem of GPS vulnerability. I tell you, in San

Francisco you run wing tip to wing tip virtually—it is very close. We don't have an independent surveillance system. ADSB is the NAV system also on those planes. It is not an independent monitor. That is the challenge. So when we say it is all going to go away, it is not going to go away for closely spaced operations unless we solve the surveillance problem. It can't be the same system as the navigation system.

Shane: We were talking there about some percentage failure rate—a failure rate of a technology that presumably can be measured along with the failure rate of the present system, correct? Isn't it possible that without creating perfection in the system—having some level of failure—you're still producing a palpable improvement over the failures that we have in the present system? I'm just asking that as a question. I don't know.

Evans: When I started my career in air traffic control, I worked on the microwave landing system. The criteria you work against in landing, when there is turbulent conditions, is that the system—the landing navigation shouldn't contribute an accident in more than one intended set of landings. I have a suspicion that if we are going to start talking about landing closely spaced planes in IMC conditions, if you get stuck with the one part intended to settle the situation, I'm going to tell you it is a tough criteria for you to meet.

Jim Baumgarner: Jim Baumgarner, *Aviation Daily*. I believe that ADSB was developed by UPS in the cargo carriers as an anticollision device en route—not for on the ground—to take the place of TCAS (traffic alert and collision avoidance system). The FAA has never let TCAS be used, to my knowledge, as a safety device. It is a warning system. I think ADSB was developed to take the place of TCAS by the freight carriers.

Shane: It's one of its obvious benefits. It is a more sophisticated TCAS, if you will.

Maybe we have come to the natural end of this very interesting day, and indeed we have come to the natural end of a wonderful, three-part series of symposia that has been sponsored by the Transportation Research Board, together with the FAA. I think most of you probably noticed that the Administrator and the Deputy Administrator, Jane Garvey and Monte Belger, were here for most of today, as indeed they were here for most of the other two symposia. These have not been just more meetings, I think it is fair to say. In fact, I could try to summarize what took place on all three days, but there is one important common thread, I think, and that is that in all 3 days—whether we are talking about demand management or some approach to the congestion problem or trying to address the infrastructure problem by pouring more concrete, speeding up the process of reviewing proposed projects and so forth, or addressing the congestion problem the way we have been discussing today through weather technology and other kinds of air navigation technology—the difference between these discussions and everything that has preceded, in my experience, is that there is a conviction in this country that we have now hit the wall, and there is no more time to dither. So we are going to see some real proposals in the demand management categories. Administrative proposals will be made, and I have no doubt that we are going to start seeing some economic proposals for how airports charge airplanes and airlines for the privilege of landing an aircraft. I have no doubt that there is going to be a serious effort to telescope the runway proposal planning and approval process. I think that there will be a mandate far stronger than the one we have right now to start implementing real technologies in real time—particularly those that have already proven themselves to a point where they have an acceptable level of success.

That is very exciting and I just want to take off my hat to the FAA and the TRB—and particularly the TRB, which assembled the people who spoke at all three of these symposia. You really couldn't have had a better cast of speakers in terms of rare ability to put these issues on the table in a way that was comprehensible but gave us a real sense of what is possible in the real-time—and to give us some hope that we aren't going to just see a whole series of more summers like the summer of 2000, which we never want to see a repeat of.

So let me say thank you and let's give a special hand to our panel. Thank you to all of the speakers, and thank you to a terrific audience for participation. You've made it so much better. Thanks.

APPENDIX

Biographical Summaries

G. Brant Foote
National Center for Atmospheric Research

G. Brante Foote received a Ph.D. degree in Atmospheric Sciences from the University of Arizona in 1971 and was awarded a Postdoctoral Fellowship to the Advanced Study Program at the National Center for Atmospheric Research. He has held a variety of positions in research and management at NCAR since that time, including appointment to the position of Senior Scientist in 1982. From 1994 to the present, Foote has been the Director of the Research Applications Program, a division of NCAR dealing with directed research and technology transfer, with an emphasis on applications to aviation. Foote has published over 100 papers in the fields of cloud physics, radar meteorology, severe storms, weather modification, aviation meteorology, and mesoscale meteorology. He has been a leader in the organization and conduct of large field programs such as the National Hail Research Experiment, the Cooperative Convective Precipitation Experiment, the Convective Initiation and Downburst Experiment, the Convection and Precipitation/Electrification Experiment, the Lantau Island Experiment in Hong Kong, and several other international programs. He has been active in national and international meetings and has lectured extensively abroad. He has served on several standing committees of the American Meteorological Society as well as academic thesis committees and National Academy of Science committees and served as chairman of the "Meeting of Experts on the Dynamics of Hailstorms and Related Uncertainties of Hail Suppression" for the World Meteorological Organization. He has served on advisory boards and review committees for the United States and foreign governments and has served on numerous occasions as a consultant to foreign governments. He was for 8 years a member of the Executive Committee of the International Commission on Cloud Physics of the International Association of Meteorology and Atmospheric Physics. From 1985 to 1994 he was Editor of the *Journal of the Atmospheric Sciences*. For the past 5 months he was Visiting Professor at the Universidad Nacional de Cuyo in Mendoza, Argentina.

JANE F. GARVEY
Federal Aviation Administration

Jane F. Garvey, the 14th Administrator of the Federal Aviation Administration (FAA) was sworn in August 4, 1997. She is the first Administrator confirmed by the Senate to a 5-year term. With an outstanding career in public service and extensive administrative experience, Garvey brings to the FAA a strong commitment to ensure the world's safest skies become even safer.

As Administrator, Garvey manages a 49,000-person agency with worldwide impact and presence in promoting aviation safety and security. The FAA regulates and oversees aviation safety and security, conducts cutting edge research and development, and operates the world's largest air traffic control system.

Administrator Garvey initiated Safer Skies, the U.S. aviation community's safety agenda, which focuses the agency's resources on taking the actions that safety data and analysis indicate can make the biggest difference in lowering the accident rate. She led the successful transition of the FAA's air traffic control system to January 1, 2000, with no disruptions to service. In addition, the FAA provided world leadership on Y2K transition. Under Administrator Garvey's leadership the FAA is moving forward on its phased plan to modernize the air traffic control system and has, for the first time, achieved government and industry consensus on how to proceed. To bring immediate modernization benefits, she initiated the Free Flight Phase 1 program under which the FAA reached consensus with the aviation community to deploy five specific technologies by the end of 2002.

Prior to being named FAA Administrator, Garvey was Acting Administrator of the Federal Highway Administration (FHWA). She served as Deputy Administrator of FHWA from April 1993 until February 1997. FHWA, also an agency of the U.S. Department of Transportation, has an annual budget of $20 billion and works in partnership with the states to maintain the safety and efficiency of the nation's roads and bridges. A creative leader at FHWA, Garvey chaired FHWA's Innovative Financing Initiative, which resulted in more than $4 billion in transportation investment in more than 30 states—projects that in many cases would not have otherwise been built.

Before joining FHWA, Garvey served as director of Logan International Airport, one of the nation's busiest aviation facilities. From 1988 to 1991, she was Commissioner of the Massachusetts Department of Public Works. Before that, Garvey was Associate Commissioner in the Massachusetts Department of Public Works, where she directed construction activities and developed environmental initiatives.

Garvey holds degrees from Mount Saint Mary College and Mount Holyoke College. She has participated in the Fellowship Program for Public Leaders at Harvard University.

TONY HENRY
National Air Traffic Controllers Association

Tony Henry's air traffic experience started in 1974 with 5 years in the United States Navy as an operations specialist, with duties that included the following positions: air intercept controller, antisubmarine air controller, and air intercept controller supervisor. In 1981, he was hired as an air traffic controller with the FAA and was assigned to the Washington Air Route Traffic Control Center. Mr. Henry currently has 19 years 6 months experience as a Certified Professional Controller. For the past 6 years he has represented the National Air Traffic Controllers Association regarding issues concerning traffic flow management in both the Eastern Region and the nation at large.

JOHN "JACK" J. KELLY, JR.
National Weather Service

Brigadier General John J. Kelly, Jr., was appointed as Assistant Administrator for Weather Services and Director of the National Weather Service for the National Oceanic and Atmospheric Administration in February 1998.

General Kelly came into this position with 33 years of experience in all facets of the weather field, including 15 years at the senior-executive level in both government and private industry. He has broad experience in leading scientific organizations, introducing change, working in the Washington and international environments, and using and implementing technology.

Immediately prior to his current appointment, he was a senior advisor on weather services for the Department of Commerce, where he conducted a bottom-up review of the total National Weather Service operation, plus NOAA and NWS management, planning, and budget policies and processes. He also determined the resources required to operate the NWS in fiscal years 1998 and 1999 and complete its modernization and restructuring activities.

In the private sector, General Kelly was Director of Weather Systems for GTE Information Systems from 1994 to 1996. There he directed GTE's $30 million/year weather and aviation services business line, and was responsible for client satisfaction and interface, strategic planning, business development and sales, profit and loss, and program management.

General Kelly retired from the Air Force in 1994 after serving for 31 years. He began his military career on worldwide assignments, with duties covering the entire spectrum of the weather field, from operational forecaster to chief scientist to staff officer. He retired from the military as Director, Weather and Commander, Air Weather Service (1988–1994).

General Kelly holds a bachelor's degree in chemistry from Seton Hall University. He has done graduate studies in meteorology at Pennsylvania State University and holds a master's degree in public administration from Auburn University. He also completed leadership programs at the Air Force Command and Staff College and the Industrial College of Armed Forces. General Kelly is an American Meteorological Society Fellow and has been listed in *Who's Who in America*.

JACK KIES
Federal Aviation Administration

Jack Kies is the Acting Program Director for Air Traffic Tactical Operations at the Federal Aviation Administration.

Mr. Kies has more than 30 years of operational air traffic control and management experience. Since 1994, he has held the position of manager of the David J. Hurley Air Traffic Control System Command Center, where 160 personnel work to manage the flow of 137,000 commercial, business, general, and military flights a day in the U.S. National Airspace System (NAS).

Mr. Kies' strong support for the use of collaborative decision making between users and service provider has helped maintain FAA's place as the world leader in the development of traffic management tools and strategies. Under Mr. Kies' direction, the backbone of the traffic management system is based on a real-time data exchange between the airlines and FAA. This participatory process helps to ensure that the continuing growth in the number of flights will be handled safely and efficiently.

Jack is a U.S. Army Veteran of the Vietnam War. He earned a Bachelor of Science degree at Dowling College in 1977 while working as an air traffic controller in the New York Common IFR Room [predecessor of today's New York TRACON (terminal radar approach control)]. In 1997 the Air Traffic Control Association awarded Jack the Special Medallion Award for Outstanding Achievement and Contribution to Advancing the Science of Air Traffic Control.

ALLAN KRAUTER
Northwest Airlines

Allan Krauter is the Senior Instructor, Flight Dispatch at Northwest Airlines. He has 23 years experience in airline operations as an aircraft dispatcher. Al has worked on a variety of industry projects. He was a member of the Aviation Rulemaking Advisory Committee that developed the Dispatch Resource Management (DRM) Advisory Circular and later participated in an Air Carrier Working Group to rewrite Dispatch Certification regulations. His most recent industry project was to participate in a joint FAA, NATCA, and industry team that developed the S2K+1 Field Training.

Al has authored a number of training publications for Northwest Airlines, including

- *Dispatch Initial Training Student Handbook,*
- *Annual Recurrent Training Student Handbook*, and
- *International Transition Training Guide.*

He has also authored the industry's first *Job Task Analysis for Dispatch* at Northwest Airlines.

In addition to his duties and responsibilities at Northwest, Al has delivered FAR 121 Initial Dispatch training programs to emerging 121 Carriers and has trained Chinese dispatchers through a joint effort with the Civil Aviation Administration of China (CAAC). He is currently working with KLM Royal Dutch Airlines to assist in their transition to an operational control system similar to that which exists in the United States.

Al is President of Operational Control Consultants (OCC), an aviation consulting firm, and is also the Director of Training for the Airline Dispatcher's Federation.

Michael S. Lewis
National Aeronautics and Space Administration

Michael S. Lewis, Director of the NASA Aviation Safety Program, has worked with the National Aeronautics and Space Administration since 1983.

He began work with the Army Aeroflightdynamics Directorate at NASA Ames conducting helicopter flight control and handling qualities studies from 1983 to 1988. From 1988 to 1989, he worked at NASA Headquarters as Program Manager for Aeronautical Guidance and Controls. He joined NASA Langley Research Center in 1989 as Wind Shear Flight Test Project Engineer and was later named Deputy Wind Shear Program Manager. The Wind Shear Program pioneered the development of forward-looking airborne sensors to detect hazardous wind shear conditions. His most recent position was Program Manager for Flight Deck Systems on NASA's High Speed Research Program, which aims to develop technologies for a Mach 2.4 supersonic transport aircraft.

Mr. Lewis is the author of 15 scientific journal articles, conference papers, and other technical reports.

Mr. Lewis graduated with honors from Princeton University with a BSE in Mechanical and Aerospace Engineering in 1983. He earned an MS in Aeronautics and Astronautics from Stanford University in 1987.

He has been awarded the Robert Lichten Award by the American Helicopter Society, the American Institute of Aeronautics and Astronautics San Francisco Chapter Young Engineer of the Year Award, and numerous NASA individual and group achievement awards. He is a member of the Commercial Aviation Safety Team, the U.S. organization leading a national strategy aimed at reducing the aviation accident rate.

Mr. Lewis, his wife Kathleen, and their three children live in Smithfield, Virginia.

JOHN MCCARTHY
Naval Research Laboratory

Dr. John McCarthy is the Manager for Scientific and Technical Program Development at the Naval Research Laboratory in Monterey, California. Previously, Dr. McCarthy served as Special Assistant for Program Development to the Director of the National Center for Atmospheric Research (NCAR), in Boulder, Colorado. Prior to that position, he served as the Director of the Research Applications Program (RAP) at NCAR. As Director of RAP, he directed research associated with aviation weather hazards including NCAR activities associated with the Federal Aviation Administration (FAA) Aviation Weather Development Program, the FAA Terminal Doppler Weather Radar Program, and a national icing/winter storm research program. Previously, he directed NCAR activities associated with the Low-Level Windshear Alert System (LLWAS) project, which addressed the technical development of sensing systems to detect and warn of low-altitude wind shear; the Joint Airport Weather Studies (JAWS) and the Classify, Locate and Avoid Wind Shear (CLAWS) project at NCAR. Additionally, Dr. McCarthy was the principal meteorologist associated with the development of the FAA Wind Shear Training Aid.

Dr. McCarthy is the recipient of the 1992 Flight Safety Foundation Admiral Luis de Florez Flight Safety Award for outstanding contribution to aviation safety. He is corecipient of the 1989 Aerospace Laurels Award presented by Aviation Week and Space Technology, recipient of the 1987 Losey Atmospheric Sciences Award of the American Institute of Aeronautics and Astronautics (AIAA); recipient of the 1987 Edgar S. Gorrell Award of the Air Transport Association; and recipient of the Boeing Commercial Airplane Group 1997 President's Award for Contributions to Aviation Safety. In January 2000, Dr. McCarthy was named a Fellow of the American Meteorological Society.

Dr. McCarthy received his B.A. in Physics from Grinnell College (1964), his M.S. in Meteorology from the University of Oklahoma (1967), and his Ph.D. in Geophysical Sciences from the University of Chicago (1973). He is a private pilot holding single-engine land, glider, and instrument ratings. Additionally, he has been an official member of the crew as an observer on more than 500 commercial jet transport flights.

Since the beginning of his tenure at NRL, Dr. McCarthy has developed programs in improving ceiling and visibility forecasting, flight operations risk assessment, and a broad program effort to improve short-term weather information to the Navy battle group, entitled “NOWCAST for the Next Generation Navy.”

John E. O'Brien
Air Line Pilots Association

John E. O'Brien has been the Director of the Engineering and Air Safety Department for the Air Line Pilots Association (ALPA) since 1982. In this position he is responsible for all aspects of the ALPA air safety structure, which consists of 5 technical groups, 19 geographical regions, the safety committees of 46 airlines and several project teams, and special programs supported by over 700 pilot volunteers. He has served in a variety of senior positions at ALPA between 1975 and 1982 including Deputy Director of Operations and Manager of Engineering and Operations.

Mr. O'Brien joined ALPA in 1972 as staff engineer in the Engineering and Air Safety Department. He was the staff coordinator for ALPA's All Weather Flying, Air Traffic Control, and Pilot Training Committees as well as serving as staff coordinator for many accident investigations between 1972 and 1982.

While performing in these capacities, he also served on or chaired a number of industry and government advisory committees and special programs. He chaired the Executive Committee for the FAA Aviation Rulemaking and Advisory Committee 1992–1993 and currently serves as Chairman of the Radio Technical Commission for Aeronautics Board of Directors and is a Member of the Flight Safety Foundation Board of Governors.

His credentials include a master's degree in business administration from Stetson University and a B.S.A.S. from Embry-Riddle Aeronautical University.

Prior to joining ALPA, Mr. O'Brien was employed by Pan American World Airways for 7 years as an engineer at the Pan American Special Projects Office in Cocoa Beach, Florida. In addition to flying for Pan American, he was the project engineer for a NASA contract to study margins for space shuttle design, operations, and safety from an airline perspective.

JEFFREY N. SHANE
Hogan & Hartson
Moderator

Jeffrey N. Shane is a partner in the Washington, D.C., office of Hogan & Hartson L.L.P. and a member of the firm's Aviation Group. He has a domestic and international transportation practice, with a major emphasis on regulatory, legislative, and transactional issues arising in aviation and aerospace. He has focused particular attention on licensing and enforcement proceedings, regulatory compliance, aircraft transactions, rulemakings, and airport development projects.

Mr. Shane served as Assistant Secretary for Policy and International Affairs at the U.S. Department of Transportation (1989–1993), Deputy Assistant Secretary of State for Transportation Affairs (1985–1989), and in a number of other transportation-related positions.

He currently serves as Chairman of the Commission on Air Transport of the International Chamber of Commerce (based in Paris) and as Chairman of the Military Airlift Committee of the National Defense Transportation Association. From 1985 through 1989, he was Adjunct Professor of Law at Georgetown University, teaching a course in International Transportation Law.

Mr. Shane received his A.B. from Princeton University and his L.L.B. from Columbia University, where he was Articles Editor of the *Columbia Journal of Law and Social Problems*. He is a member of the District of Columbia Bar.

Agam N. Sinha
MITRE Corporation

Dr. Sinha is the Director of Air Transportation Systems (U.S. FAA Projects) and Regional Director of the Americas (International Projects) at the Center for Advanced Aviation System Development (CAASD). On the FAA projects, his responsibilities include Free Flight, NAS performance, and Spring/Summer 2000–2001 projects as well as providing strategic guidance on research, engineering, and operational aspects of all projects. As the Regional Director, he is responsible for all international projects in the Americas. Current international projects include Canada, Brazil, Argentina, Mexico, and Panama.

Since joining MITRE in the early 1970s, Agam has worked extensively on several FAA projects dealing with engineering the evolution of the National Airspace System, en route and terminal area operations related to airport and airspace capacity, wake vortex, Air Traffic Control (ATC) automation, and weather systems. He has participated in many industry task forces dealing with the problems of major U.S. airports. He has also been involved internationally in supporting other governments on airport, terminal area operations, and ATC system design and acquisition. In addition, he has managed several projects in support of the National Oceanic and Atmospheric Administration in weather and satellite systems.

Agam holds a Ph.D. (1974) and a M.S. (1970) in Operations Research from the University of Minnesota. He also has a M.S. degree in Management of Technology from American University (1985). His bachelor's degree (1968) is in Mechanical Engineering from the Indian Institute of Technology, Bombay, India.

APPENDIX

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