Weather services in the NextGen Era

by Jennifer Harrington

The focus of the NextGen Air Transportation System has largely been on the development of satellite-based navigation systems, trajectory-based operations and the various technologies that will form the underlying structure of the nation’s future ATC system. But NextGen’s success is not dependent upon new procedures and inventions. The real key to NextGen’s success will be the ability of the aviation community to better manage weather’s impact.

This seemingly simple fact was made evident during the summer of 1996, when the NASA Ames Research Center first tested its final approach spacing tool (Fast) at Dallas/Fort Worth Airport. The tool provided landing sequences, runway assignments and speed and heading advisories to help controllers manage traffic flow, and the initial results were promising. Not only did controllers increase the aircraft arrival rate by 10 to 15 percent, but they also achieved “near-perfect runway balancing” and experienced a “sharp workload reduction,” according to NASA. In addition, a study conducted by Seagull Technology and the Logistics Management Institute estimated that the tool would save approximately $300 million annually in direct operating costs at the nation’s 10 busiest airports.

Unfortunately, Fast proved useless in hazardous weather conditions. “The system worked like a charm [in good weather],” said Bruce Carmichael, director of the Aviation Applications Program (AAP) at the National Center for Atmospheric Research (NCAR). “But throw a little weather into the middle of it, and the tool didn’t have a clue.”

A report by NASA and MIT Lincoln Labs concluded, “Fast cannot predict flight trajectories and must cease operating when hazardous weather significantly disrupts arrival routes.” Consequently, the airport suffered “unusually large residual [air traffic] queues” after the routes re-opened.

The idea that NASA would build a tool “that worked only on fair weather days is just crazy,” Carmichael said. “For years the philosophy has been to design the tools and then think about weather, but if we think of weather as the off-nominal then we miss the point.”

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The government and its industry partners realized that weather was going to be a critical component of NextGen development. As a result, when the Joint Planning and Development Office (JPDO)—a public/private partnership made up of representatives from the Departments of Transportation, Defense, Homeland Security and Commerce, as well as the FAA, NASA and the White House Office of Science and Technology Policy—began drafting the NextGen work plan, weather became the key factor.

“Weather, like embroidery, is woven throughout the fabric of the entire NextGen Integrated Work Plan,” Carmichael said. “It’s not just tucked into one chapter of the document. In every aspect of aviation, it is woven into the fabric of everything that is planned from now until 2025.”

The NextGen Vision

To understand the role that weather will play in the development of the NextGen system, it is important to understand what NextGen actually is—and more important, what it is not. It is not a program or a specific project. Rather, NextGen is the term used to describe an ongoing process to “transform” the ground-based air traffic control system of today to a satellite-based system of the future,” according to the FAA.

“So NextGen is not something that people are working on, and then suddenly in 2025 you flip a switch and you have a new system,” Carmichael said. It is a “transition from today’s world into the NextGen world, and there are lots of pieces of that transition under way.”

The FAA has targeted 2025 as the completion date for this transformation, but as Carmichael explained, that date is essentially meaningless. “[The date] 2025 is the stake in the ground, but in some ways it’s kind of bogus,” he said. “But it forces people to move forward, step by step.”

One of the primary goals of NextGen is the gradual move toward automated systems, where the human is “over the loop” as opposed to “in the loop.” Today, air traffic controllers and weather forecasters analyze data, interpret that data and make decisions based on their limited cognitive ability. “Human judgment varies, so the efficiency of the decisions varies,” explained Steve Bradford, the FAA’s chief scientist for Architecture and NextGen Development. Because of the inconsistency of these decisions, “the efficiency of each flight goes down,” he added.
To increase that efficiency, the FAA hopes to make use of automated systems, in which the controller and the forecaster become “monitors” who oversee and feed data into the systems, Carmichael explained. “There’s no way that we can continue to operate the way we do today,” he said. “That’s just not going to work in the environment we’re moving into.” The FAA estimates that air traffic will increase to more than a billion passengers a year by 2015 and double current levels by 2025. With this in mind, the NextGen vision is to triple airspace capacity requirements.

“The underlying problem with this is cognitive ability,” Carmichael said, adding that humans reach a point where they are unable to process any more information. “At some point, a controller says, ‘Enough, I can’t handle any more traffic.’ The automated system does not have the cognitive problem that the human does.”

An air traffic controller’s job, therefore, will be to oversee tools such as the traffic management advisor (TMA), which is similar to Fast in that it calculates precise routes and minimum safe distances between aircraft. According to NASA, the developer, TMA can sequence and schedule aircraft to the outer fix, meter fix, final approach fix and runway threshold, in addition to assigning aircraft to specific runways. It is currently deployed at 33 of the top 35 U.S. airports. The en route automation modernized (ERAM) computer, which processes flight radar data and provides safety alerts such as altitude and conflict warnings, will also be used. The FAA estimates that ERAM will be used in all 20 of the nation’s en route centers by next year.

Likewise, weather forecasters will no longer analyze reams of data in an attempt to produce a single, uncertain forecast. Instead, the forecaster of the future will oversee an automated forecasting system that will produce a “probabilistic weather forecast.” In other words, the system will produce different scenarios based on the probability of a certain weather event occurring. “Today we have only one plan, so it tends to be conservative,” Bradford said.

“The [weather] automation would run through a number of different potential futures and help us come up with a plan that would allow us to maximize the use of the airspace around an airport and minimize the chance of diversions. We could plan continuously and increase efficiency.”

The forecaster’s job would be to monitor the system. “The forecaster will watch this automated system and will input information—such as a weather boundary across the Texas Panhandle—that the system missed,” Carmichael said. “Then the system would factor that into its next forecast cycle. So the human becomes a monitor and a provider of information into that automated forecasting system.”

The traffic management system would then apply the information from the automated weather forecast to its calculations, thus eliminating the need for a human controller to analyze both traffic flow and weather to manage air traffic. “The idea is to have algorithms that translate those weather forecasts into data that automated [air traffic management] tools can use in their algorithms,” Carmichael said. “The automatic system is going to do trajectory planning based on a probability of things happening.”

So in the future, an automated system might forecast, for example, an 80-percent chance of a 30-percent airspace capacity reduction due to moderate turbulence in a single three-dimensional 10 km airspace grid above Chicago at a specific time, Carmichael said. The traffic management system, based on that 80-percent chance of lost airspace capacity, would then alter the aircraft’s route to avoid that airspace grid over Chicago. The new route information would then be sent via a datalink directly to an automated system in an aircraft cockpit, thereby eliminating the need for voice communication between the controller and the pilot.

“Humans are never going to get it right, so the idea is to get away from humans trying to analyze data and trying to figure it out,” Carmichael said. “The idea is to automate a lot of this activity, and that’s a fundamental shift from how we do business today.”

**NextGen Technology**

Much of the technology that will be used in the NextGen era is already known, according to Robert Baron, CEO and president of Baron Services, the parent company of WxWorx, which provides XM WX Satellite Weather. So the problem is not necessarily developing new technology, but rather integrating new information into the technology we use today.

Tools such as Fast and TMA are good examples. In each case, NASA developed technology that has proved to reduce delays and manage traffic flow. However, the tools are ineffective during thunderstorms or other hazardous weather conditions.

“We’ve built a lot of tools that have helped us be more efficient, but we tend to have to turn them off when we need them the most,” Bradford conceded. “We...
The Forecast for Forecasting Technology

Without the ability to understand and accurately forecast weather, NextGen technology won’t amount to much. For that reason, industry participants— including Baron Services, NCAR and the FAA—are not only working to integrate weather into the NextGen technology, but they are also working to improve forecasting techniques. One of the most significant advancements is the move from traditional Nexrad weather radars to dual-polarization Doppler radars.

In late 2007 the FAA awarded Baron Services and L-3 Communications a five-year, $43 million contract to design, develop and produce a system-wide upgrade of the 171 NWS, FAA and DoD Nexrad radars. Current radars provide storm location and intensity, as well as the movement of fronts inside the storms—the key is in the accurate interpretation of the radar image.

The new radars will also allow forecasters to see precisely where water droplets become frozen precipitation. "We’ll be able to see the layer of supercooled droplets," Baron said. "This represents a substantial assistance to aviators because if you’re flying, you want to know exactly where you’re going to be running into icing."

NCAR is responsible for most of the aviation weather information pilots obtain from the FAA and NWS. In fact, the majority of the work completed by the Research Applications Laboratory of NCAR is devoted to aviation weather. Research areas include in-flight ice; snowfall and freezing precipitation; convective storm nowcasting and forecasting; atmospheric turbulence; numerical weather prediction; remote sensing; precipitation physics; ceiling and visibility; oceanic weather; and verification methods.

The results of most of this research can be found—practical purposes—aeronautical digital data service (ADDS) Web site and Experimental ADDS, which allows users to view and "test" new products. Once the FAA approves the products for operational use (generally as a supplemental weather product), they move to the operational ADDS Web site www.adds.aviationweather.noaa.gov; Experimental ADDS: www.weather.aero.

Among the new products on the Experimental ADDS Web site are various icing, turbulence and ceiling and visibility products that can be viewed using the Experimental ADDS flight path tool and the helicopter emergency medical services (HEMS) low-altitude flight tool.

The flight path tool displays icing, turbulence, ceiling, visibility, temperature, winds, humidity, radar and satellite information, as well as airmets, pireps, metars, and TAFs up to 44,000 feet msl. The tool lets users create vertical cross sections to view information horizontally and vertically, and the weather information is color coded for ease of use.

The HEMS tool provides ceiling, visibility, convection, icing and radar data from 500 feet agl to 5,000 feet agl. “We’re doing some really interesting things to support the helicopter EMS community,” said Marcia Politovich, deputy director of NCAR’s aviation application program and head of the icing research program. “They fly very low-altitude, short hops, so we built a tool that shows near-surface weather. It’s where we’re going to use our tools for the future.”

The tool provides “nowcast” and very short-term forecast information. “The helicopter community told us they need to know what’s happening right now or within the next hour,” Politovich said. “Almost all the rescues are an hour or less.”

NCAR is also working to improve long-term ceiling and visibility forecasts, however. “That’s an active area of research here in the lab,” she said. “There have been several major EMS accidents in the last half year that have really spurred us on to make a better product for them. The accidents were caused by low ceilings, hitting obstacles and poor visibility.”

To date, the FAA has approved the use of the HEMS tool only for “no go” decisions, which is why it has not been moved from the Experimental ADDS Web site. “That’s an important legal distinction,” Politovich said. “A pilot can’t look at the tool and say, ‘I see a hole there, so I can go.’ He can look at it and say, ‘Yikes. This looks horrible. We cannot dispatch a helicopter to that location.’”

Another tool awaiting FAA approval is the national ceiling and visibility analysis (NCVA) tool, which is available in the “Meter” section of Experimental ADDS. “This is essentially a special inter-polation, graphical representation of metar ceiling, visibility and flight information data,” Politovich said. “The information is available to you as a map with different Easter egg colors, and it represents our best estimate as to what the ceiling and visibility will be between two points, taking terrain into account.”

The NCVA tool also displays a “confidence” level along with the map view. “Usually it’s what we call ‘normal’ confidence, but there are some areas where we don’t have a lot of confidence,” she explained. “In the middle of Nevada, there aren’t any metar stations, so we would bring down the confidence a little bit to let people know that this is what we estimate but we don’t have much confidence in the data."

Finally, the FAA and NOAA (NWS) are also involved in the research for new products through the FAA’s aviation weather research program, including the development and testing of aircraft borne sensor systems that are installed on aircraft in the regional airline fleets and measure humidity, turbulence and icing in addition to wind and temperature. Two examples are the tropospheric airborne meteorological data reporting (TAMDAR) system and the meteorological data collection and reporting system (MDCRS), which collect thousands of observations per day.

Another example is the advanced light detection and ranging (Lidar) system, which the FAA uses to measure wake turbulence. The Lidar uses laser energy to measure the amount and signature of turbulence in the air. “We use them to measure the behavior of wakes and wake conditions,” the FAA’s Steve Bradford explained. “Based on all the work we’ve done with Lidar, we know that when the wind is coming from a certain direction, wakes don’t transport from one runway to another.”

The FAA also uses Lidar to measure the signature of new aircraft to determine what the wake requirements are behind certain types of aircraft. Other agencies and private industry partners are working on various aviation weather research projects as well, but the overall focus of each project—no matter which agency or company is funding it—is to improve safety and efficiency. As Politovich explained, developing new products is often “a severe safety issue. We want to get it right. And if you can’t get it right, you want to have a conservative estimate,” she said.

“Weather is the key for us,” Bradford said. “The leading cause of delay is weather, and most of the en route problems are related to weather. We need efficiency in all weather conditions, so it’s important for us to do a better job with our programs.”

The helicopter emergency medical services tools bar, left, displays ceiling, visibility, convection, icing and radar data from 500 feet agl to 5,000 feet agl, using different colors to indicate various ceiling heights.

The national ceiling and visibility analysis tool, left, is a graphical representation of metar, ceiling, visibility and flight information data. "Weather is the key for us," Bradford said. “The leading cause of delay is weather, and most of the en route problems are related to weather. We need efficiency in all weather conditions, so it’s important for us to do a better job with our programs.”

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reroute the aircraft 200 miles out of its way every time the forecast predicted turbulence, the additional fuel and operations costs might become an issue, Gillen said.

The type of aircraft and the mission might also affect the outcome. “A UPS or FedEx aircraft might be more willing to fly through moderate turbulence because there are no passengers involved and it’s more of an issue of time, whereas a business jet with a CEO on board might make the decision to avoid turbulence altogether,” Gillen said. “So there are a lot of business rules or parameters that need to be incorporated.”

The answer might be to create a “weather acceptance level,” Gillen said. “For a particular flight, a specific aircraft might accept a ‘Level 6,’ so the route would be set up to avoid anything above a Level 6. But what does that mean exactly? It is something that would have to be figured out.”

Embryo-Riddle’s vice president for research, “This demonstration [shows] the FAA that this particular integration is feasible, practical and beneficial.”

TMA has two displays: a timeline graphical user interface (TGUI), which displays a single line of traffic coming into the airport; and a plan view graphical user interface (PGUI), which is a two-dimensional view of the air traffic coming into the airport, according to Robert Gillen, Ensco’s director of engineering. Ensco and the consortium partners were able to add weather data overlays to the PGUI display “so that as the aircraft are approaching the airport, the traffic managers will be able to see where the weather is in relation to those aircraft,” Gillen said.

The system is not fully automated—the process requires the controllers to route the aircraft manually around the weather—but the ability to “see” the weather on the air traffic management screen is a “cornerstone system enhancement and critical next step in the FAA’s Next Generation Air Transportation System,” according to Fred-erick-Recasien.

Although the FAA has the final say as to when this new development will be implemented in the field, Gillen said the ability to overlay current weather data is available today. “Getting current weather data onto the system is something that could be done fairly readily,” he said. However, integrating forecast weather into the system will take time because of the uncertainties of forecast weather. “Nobody is perfect at forecasting weather, so choosing the right products and working out the human factors is essential.”

The key to adding forecast weather to TMA and ERAM systems will be the ability to automate the weather forecasts to reduce the amount of uncertainty forecasters have today. “The accuracy of various short-term forecast automations is very good,” Gillen said. “With long-term forecasting you definitely have some uncertainty, so getting the human totally out of the loop is something that still needs to be discussed.”

Ensco, independent of the test facility, is addressing the issue of long-term forecasting. Scientists are comparing automated forecasts—such as those produced by ensemble forecast models—with human-produced forecasts. Ensemble forecasts incorporate the results of numerous forecast models to determine if there is a consensus among the different models. These forecasts are sometimes used to predict hurricane tracks, for example. “If all the different models are in agreement, then the forecasters can say that a particular hurricane is moving toward a certain location. But there are times when the models deviate greatly, so it gives the forecaster a feeling of uncertainty about the forecast,” Gillen said. He added that the results of the comparison study are still being analyzed.

As well as adding weather information to traffic management and en route systems, the test facility is also researching the integration of weather information into trajectory-based operations, in which automated traffic management systems route aircraft to operate at the most efficient routes and altitudes. Test aircraft using trajectory-based operations saved 330 gallons of fuel and 6,730 pounds of carbon dioxide emissions, according to the FAA.

The only weather information air traffic controllers used during the tests, however, was wind data to determine aircraft ground-speed. “The next logical step is to incorporate turbulence and convection into these automation systems, so air traffic managers could preplan routes around forecast weather or turbulence conditions,” Gillen said.

Other NextGen concepts are also being explored. “Is weather a component of this? That’s the question we have to ask with every task that flows through the consortium. We recognize the importance of this and in most cases we see a need for it,” Lester said.

There are some potential problems with incorporating automated weather information into these new systems and procedures, however. If an automated system rerouted an aircraft 200 miles out of its way every time the forecast predicted turbulence, the additional fuel and operations costs might become an issue, Gillen said.

The type of aircraft and the mission might also affect the outcome. “A UPS or FedEx aircraft might be more willing to fly through moderate turbulence because there are no passengers involved and it’s more of an issue of time, whereas a business jet with a CEO on board might make the decision to avoid turbulence altogether,” Gillen said. “So there are a lot of business rules or parameters that need to be incorporated.”

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Cockpit Technology

In addition to improving weather technology and integration on the ground, the FAA has also established a weather technology in the cockpit (WTIC) research and development program. The focus of the program is to establish the requirements of a cockpit weather display that could be used for operational purposes. The weather information pilots receive today—such as XM WX Satellite Weather—is used for general situational awareness only, Bradford explained.

The WTIC program is a component of NNEW. “The idea here is that anyone in aviation who is making a decision is going to be using the same data source,” NCAR’s Carmichael said. “Pilots, dispatchers and controllers are all going to have a common understanding of the weather. That’s critical if automated systems are providing the decision support.”

Researchers will attempt to define the amount and quality of weather data needed for safety and planning purposes, the type of display best suited for operational purposes and the quality of the weather information. “Pilots get quite a bit of information today, but what’s not well understood is the full range of weather a pilot might want in the cockpit for safety and planning,” Bradford said. “More important, if we’re going to set standards for this, we need to know the reliability, integrity and accuracy of the information. We don’t want to represent the weather in the cockpit display as more benign than it actually is.”

Researchers will also develop new ways to transmit the information to the aircraft. “There are a number of initiatives to get weather data into the cockpit, but the limiting factor tends to be the bandwidth between the ground and the aircraft,” Gillen said. “There’s very limited bandwidth available to produce weather graphics, such as radar data. Even if it’s compressed, it tends to be difficult.”

The research could take five to seven years, Bradford said. Based on this research, the FAA will establish standards and make prototypes that vendors will use to build their own systems that meet the display and weather requirements for operational use.

There are some questions, however, as to whether this research is necessary. “My personal feeling is that we ought to facilitate what’s already available,” said Wx Worx CEO Baron. “The availability and acceptance of [XM Weather] has been phenomenal. I’m not sure how many in the GA community are going to be willing to give up what they currently have.”

Baron said it would be years before the FAA is able to provide anything more than basic information, such as TAFs, metars and notams. XM Weather, on the other hand, already offers 29 products, ranging from Nexrad radar and metar and TAF information, to turbulence and icing products, convective outlooks and hurricane tracks. “The [FAA’s] system will certainly not provide all this additional information that I believe the aviation community has come to expect,” he said.

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—Bruce Carmichael, NCAR