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Getting from gate to gate

UAV sector faces sweeping changes

On-orbit servicing: The new focus

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Getting from gate to gate

When growing congestion at airports forces flights to queue up for takeoffs and landings, the resulting delays can have ripple effects throughout the air traffic system. NASA has been developing technology and software aimed at streamlining aircraft departures and arrivals, including ground movements, while still maintaining safe distances between planes. 2012 will be a busy year for testing these new air traffic management tools.

by Jim Banke
Public Affairs writer, NASA Headquarters; President, MILA Solutions, a NASA contractor

Cruising more than seven miles high, most airline passengers are occupied with an in-flight movie, a good book, or a nap. They do not give much thought to the ongoing collaboration of pilots, operations centers, and air traffic controllers who guide the aircraft on its journey.

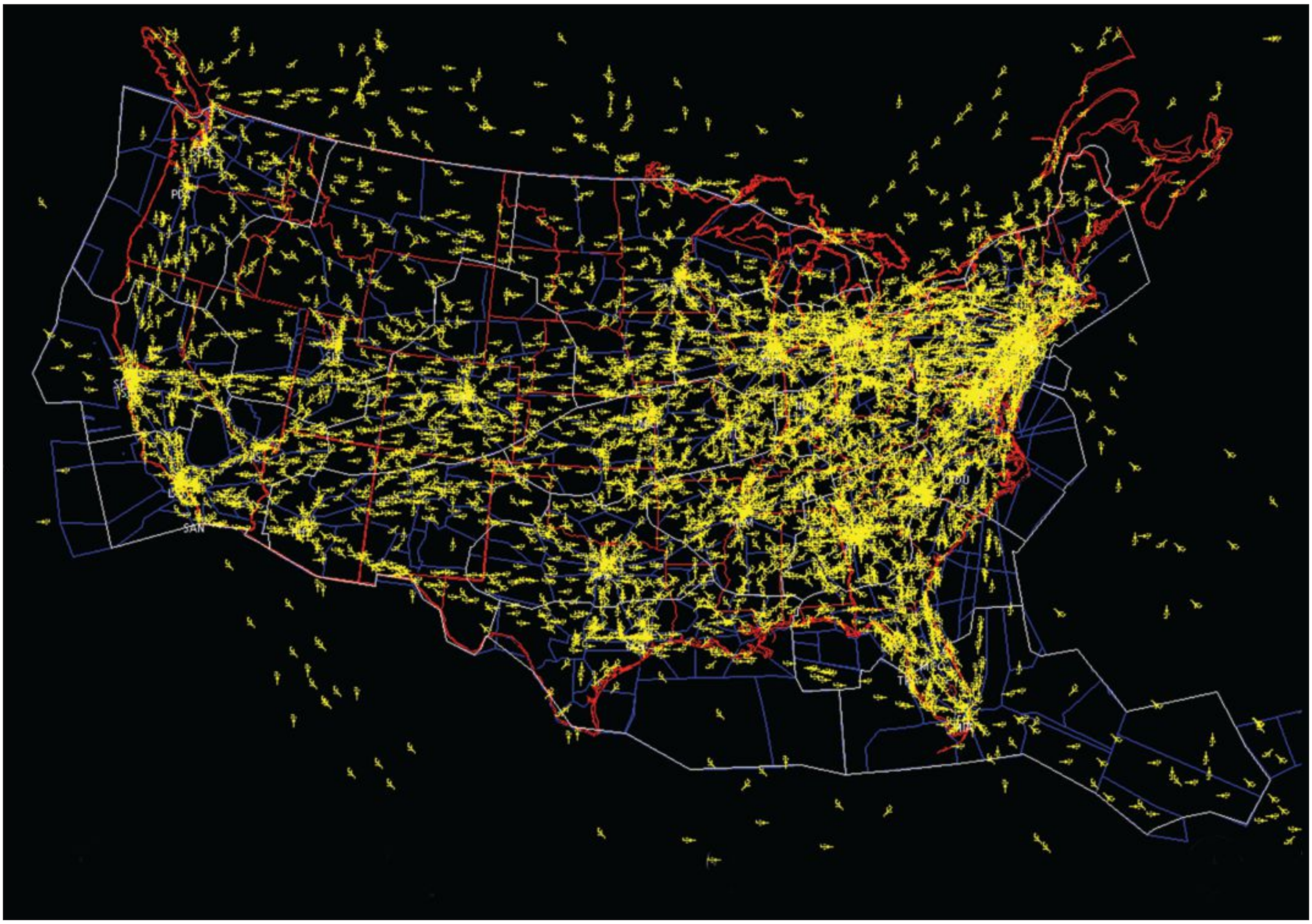
Every movement of an airplane—from the terminal gate to the runway at the departure airport, through takeoff and climb to altitude, onward to descent and landing, and the final taxi to an arrival gate—involves a complex set of tools and procedures, all of which must be managed precisely to ensure a safe voyage.

With air traffic growth spawning dire predictions of traffic jams in the sky in the not-so-distant future, NASA researchers are collaborating with the FAA and its partners to develop more efficient ways to manage airliners moving from gate to gate.

Today's air traffic control system is safe but antiquated. It relies on radio and radar-based technology developed in the 1940s. Satellite-based technology, advanced avionics, and pioneering software algorithms are among the many tools being advanced by innovators from NASA's Aeronautics Research Mission Directorate to modernize the system and help create what is being called the Next Generation Air Transportation System, or NextGen.

"Our goals are to expand capacity, enable fuel-efficient flight planning, reduce the overall environmental footprint of airplanes today and in the future, reduce delays on the ground and in the sky, and improve the ability to operate in all weather conditions while maintaining the current high safety standards we demand," explains Jaiwon Shin, NASA's associate administrator for aeronautics research.

NASA and FAA facilitate the evolution of these innovations through research transition teams. Made up of experts from government, industry, and academia, the teams are responsible for ensuring that the relevant new technology needed for NextGen



Future air traffic management concepts evaluation tool (FACET) uses live air traffic feeds and real-time weather information to process thousands of aircraft trajectories across the U.S. Air dispatchers use FACET to select more efficient routes based on capacity and weather conditions.

is identified, developed, tested, and then turned over to FAA for eventual use.

"We're partnering with some of the best innovators both inside and outside of government, and together we'll lead this global change in airspace operations to meet the demands of air mobility both now and in the future," says John Cavolowsky, director of the Airspace Systems Program at NASA Headquarters. In that vein, successful research is taking place in aeronautical laboratories at NASA facilities and industry sites around the nation.

Airport surface operations

On a trip from one airport to another, sometimes the longest delay is the journey from the terminal gate to the runway as dozens of aircraft vie for their turn to take off. "We need to minimize the potential for getting stuck in 20-minute, 30-minute, or even 60-minute conga lines, which can lead to missing your connecting flights, waste fuel, and create additional emissions and noise for the neighborhoods around airports," says Cavolowsky.

In an effort to dramatically reduce departure disruptions, NASA is working on a pair of software tools aimed at better managing the flow of air traffic on the ground: the Spot and Runway Departure Advisor (SARDA) and System Oriented Runway Management (SORM).

SARDA helps determine which planes should head for the runway, when they should depart the gate, and what routes they should use so that everyone gets to leave at the right time. Tests of SARDA software in 2010 demonstrated that the amount of fuel burned and emissions released on the ground could be cut by up to 38%.

"While SARDA promises to increase the capacity and efficiency of airport surface operations, its full benefits can't be realized unless we improve how we decide which of an airport's runways to make active at any given time of day and how aircraft will be assigned to these runways. That is the role of SORM," says Parimal Kopardekar, manager of the concepts and technology development project at NASA Ames.

SORM assists controllers with runway selection. Currently they select active runways by reacting to variables such as wind direction, weather forecasts, aircraft trajectories, and requirements for maintaining safe separations as aircraft arrive or depart. SORM considers these variables and produces a proactive forecast of the best runway and aircraft assignments throughout the day, which helps prevent traffic delays.

Simulations using data from Memphis International Airport in 2010 showed that using SORM could cut traffic delays in half. Another analysis of 79 flights to and from JFK International Airport one afternoon in 2009 indicated delays could have been slashed by two hours using SORM rather than what controllers actually selected on their own that day.

So far, SORM has been tested only at individual airports, but NASA researchers envision expanding its capabilities to consider simultaneous runway use at several airports in the same metropolitan area in order to improve overall air traffic efficiency. Moreover, future versions of both the SORM and SARDA software will consider maximizing fuel efficiency and minimizing pollution from emissions and noise.

NASA researcher David Wing works in the Air Traffic Operations Laboratory, which supports human-piloted simulators and finding ways to improve aircraft separation and resolve potential aircraft conflicts in the NextGen.

Departure

After determining the best timing for taxiing from the gate to the runway, the next step is to join the departing aircraft with those flying overhead. This is the job of a new tool called Precision Departure Release Capability (PDRC).

"Imagine trying to get into the busiest restaurant in town. You definitely will want a reservation, and once you have your reservation you want to make sure you don't miss it. PDRC is reducing the chances of missing that 'reservation,' which is called a slot, by determining when is the ideal time to have your flight take off so it doesn't miss its slot," says Leighton Quon, manager of the NextGen systems analysis, integration, and evaluation project at Ames.

There are specific tools for managing airport surface movements and the flow of departing aircraft, but they could not be used together for more effective air traffic control until recently. In field tests near Dallas in July 2011, NASA researchers used PDRC software to integrate existing surface traffic procedures and automate the process for timing departure releases.

Test participants offered positive feedback on the system's performance and potential benefits, which include less frequent delayed or missed departures, more departures within a given timeframe, quicker identification of departures that may be affected by changing surface traffic conditions, and reduced controller workload. Additional field evaluations are planned before the technology is transferred to the FAA later in the year.

Enroute cruising

Just as the nation is divided into states and then further into counties or parishes, the airspace is structured into sectors and areas to help air traffic controllers organize and manage the flow of airliners. Sectors are managed by radar controllers; supervisors monitor the traffic within an area encompassing six to eight sectors; and traffic managers watch over several areas, monitoring activity and coordinating information between the airlines and controllers.

Radar controllers and traffic managers operate in two different time frames: Controllers focus on a 20-min period during which aircraft are crossing their sector, while traffic managers think an hour or longer into the future as they contemplate the flow of aircraft across their areas.

Along with its partners, NASA researchers have introduced Flow-Based Trajectory Management (FBTM), a set of new tools and procedures that help flight controllers identify and deal with potential traffic issues that might occur in the 20-60-min time frame. This capability is especially handy when aircraft are trying to avoid unpredictable bad weather.

"One of the key benefits of the FBTM tool is that it allows problems to be solved as late as possible, which reduces the risk of either making corrections too early and delaying more flights than necessary, or not making any corrections at all and causing severe bottlenecks in the flow of traffic," says Cavolowsky.

Simulations between 2006 and 2010 showed the tool was effective and could be employed without adding another controller position, as initially proposed. Tests also indicated the tool would be most efficient if all aircraft were fully equipped with a suite of digital communication avionics that would allow controller instructions to be delivered to the cockpit electronically instead of vocally.

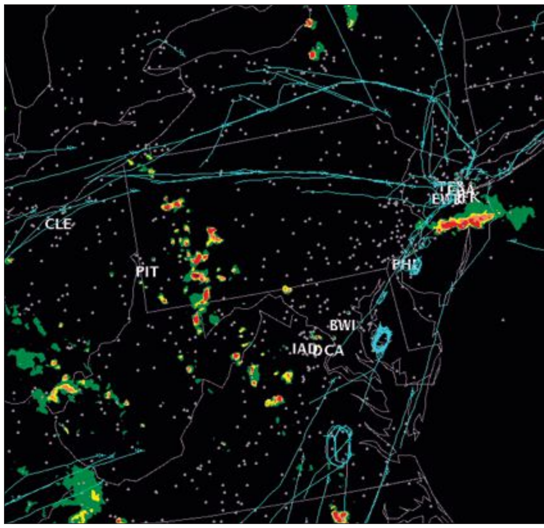
All FBTM research results were delivered to the FAA in July 2011. The FAA will perform additional testing, certification, and, eventually, operational use in the field.

Descent

As airliners descend toward the nation's busiest airports, the view below may resemble a crowd of football fans heading to a stadium for the big game. Driving in vehicles of all sizes, from stretch limousines to subcompacts, they inevitably experience traffic jams as they vie for parking spaces in hopes of being seated before kickoff.

An aircraft approaching an airport from a high cruising altitude usually has to descend in steps and occasionally fly a wide circle above the airport while waiting its turn to touch down, following verbal commands from air traffic controllers all the way. This allows controllers to keep everything from jumbo jets to light commuter aircraft a safe distance apart. However, this dive-and-drive approach wastes fuel, increases unwanted emissions, creates more noise for areas surrounding the airport, and places a heavy workload on controllers.

NASA offers a potential solution to the problem in Efficient Descent Advisor (EDA) software, which helps controllers make sure aircraft of all sizes can perform continuous descents from cruising altitudes at quieter, less fuel-thirsty power levels and remain safely separated. EDA alerts controllers to potential conflicts all along an aircraft's planned approach path, which improves flight management efficiency and reduces controller workload.



NASA is developing sophisticated computer algorithms to reduce delays and reroutes caused by bad weather, especially approaching busy airports like those near New York City.

"Think of EDA this way: Imagine being in your car, cruising down your street on your way home, and being able to take your foot off the gas at the perfect time to roll to a stop in your driveway without having to use the gas and brake—smooth, efficient, and quiet," says Quon.

EDA works by considering variables such as the size, speed, and trajectories of neighboring aircraft; the time required for descending to the runway; and input from other information sources. Using the flight data that airplanes are already transmitting to each other and to the ground, EDA computes how a particular aircraft can maintain safe separation from others in the sky while flying a continuous descent, and recommends any adjustments to avoid conflicts.

EDA shows the solution to controllers, who radio the pilot with voice approval of the proposed new flight path. If EDA is deployed as envisioned, controllers could approve the continuous descent solution electronically. This would enable the aircraft's flight management system to effectively fly the efficient approach on autopilot.

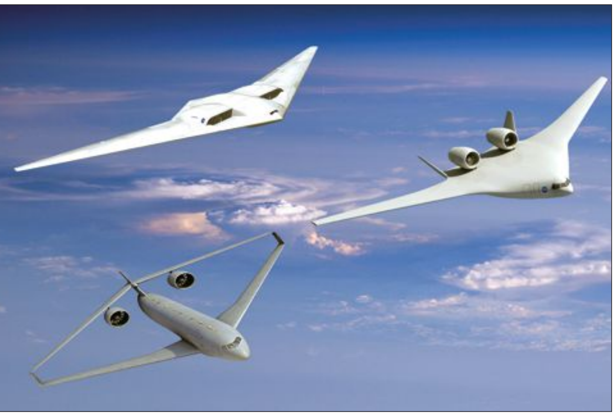
Tests in 2005 at the Air Route Traffic Control Center (ARTCC) in Fort Worth demonstrated the benefits of EDA. Another set of simulations in 2009 at the Denver ARTCC validated results of the earlier exercises and showed that while the tool was specifically designed for high-density traffic situations, other, less busy airports could benefit as well. Based on simulations, NASA estimates $300 million in fuel savings during descents if EDA is implemented fleet-wide at the nation's busiest airports.

In January results of the research were turned over to the FAA, which is responsible for certifying and implementing the technology.

Approach and arrival

With the flight nearly complete, the final leg of the journey from gate to gate presents its own challenges, as every airport has its own runway configuration and unique weather characteristics. This is especially true in San Francisco.

The city's storied summertime fog conjures up thoughts of romance and mystery for some, but for air traffic controllers, it



The NextGen system will be able to take on the 'green' aircraft of the future, regardless of their configuration.

means only chaos. Low, thick stratus clouds roll in off the Pacific Ocean almost daily from May through October, blanketing runways and approach lanes at San Francisco International Airport. They reach the ground as fog, delaying local air traffic for hours at a stretch and triggering other flight delays across the U.S.

Compounding this problem are the airport's parallel runways, built before the jet age and situated very close together. When the stratus layer is in place pilots cannot see each other, so the FAA is forced to limit the number of aircraft landing or taking off. This effectively cuts arrival capacity from 60 planes per hour to 30. The aircraft are held on the ground at their departure points and again in the air if the stratus does not clear as forecast.

"The key to improving this situation is to know more precisely when the stratus will dissipate and then communicate that information to the controllers—who are not meteorologists—in a way that is useful to them," says Kopardekar.

A new forecasting procedure developed under a NASA research contract does just that. It uses an improved weather model for forecasting when fog will lift and conveys data to traffic managers in a way that helps them minimize the number of holds around the country for flights heading to San Francisco. NASA and its research partner Mosaic ATM put the tool to a successful test in summer 2011.

"Without the tool, they may send too many planes too early or perhaps might hold planes back all over the country, unnecessarily causing delays to you and me during our travels," says Kopardekar.

Controllers in San Francisco and FAA's System Command Center in Warrenton, Va., received the data as they decided when to release commercial aircraft from distant cities on flights to San Francisco, timing the departures so that when the planes arrived at the West Coast hub their pilots would have clear approaches to the runway.

The shadow evaluation, so called because the new procedure merely backs up decision tools already in place, affirmed early benefit assessments indicating that unnecessary ground delays for San Francisco International arrivals could be reduced by 29%, saving more than $5 million a year in airline operating costs.

The procedure will undergo an operational evaluation this summer. If the upcoming test is successful, the technology will be transferred to the FAA.

Putting it all together

As NASA works with the FAA and other partners to devise better ways of managing the national airspace system, many air traffic control tools and procedures currently in use will be upgraded or replaced for use in NextGen. This will enable the system to benefit from satellite navigation, digital communications, increased airport throughput, and reduced controller workload. "All of these technologies working together will help make air travel from gate to gate more dependable and efficient," says Quon.

To this end, NASA will begin planning this year for an Air Traffic Management Technology Demonstration (ATD-1) that will evaluate how well these emerging tools will work together in managing arrivals of aircraft at major airports with heavy traffic while enabling fuel-efficient, environmentally friendly approaches and landings.

"We need to bring together the multiple ground-based and airborne control tools needed to efficiently achieve and maintain safe spacing and reduce delay. The critical challenge will be to achieve these operational and environmental benefits simultaneously," says Cavolowsky.

When demonstrated together in ATD-1, software and procedures should allow arriving aircraft to maintain safe separation in heavy traffic and enable controllers to react better to changing conditions. The demonstration also will address terminal area congestion and how well the air traffic management tools work when not all aircraft have the same avionics equipment.

NASA's hope is that, in addition to environmental benefits, ATD-1 will demonstrate significant potential fuel savings and provide airlines a business case for equip-

NASA innovations improve journey from gate to gate

- *Airport surface operations: Reducing delays while safely increasing the number of aircraft taxiing between the terminal gate and runway.*
- *Departure: Efficiently merging aircraft as they taxi, take off, and climb to join other traffic flying overhead.*
- *Cruise: Streamlining air traffic controller workload and procedures as aircraft fly at cruising altitude.*
- *Descent: Enabling aircraft to more efficiently descend and approach an airport, saving fuel and reducing emissions.*
- *Arrival: Engaging satellite navigation; digital communications with new software and procedures to increase airport capacity.*

ping more of their aircraft with the avionics needed to take full advantage of NextGen.

Many of the tools to be showcased with ATD-1 rely on whether a plane has advanced avionics such as ADS-B (Automatic Dependent Surveillance-Broadcast) available in the cockpit. ADS-B gives flight crews a greater awareness of other traffic in the area, allowing them to improve safety and efficiency. It will enable an aircraft to transmit its location and receive the locations of others. The FAA considers this capability the 'cornerstone' of NextGen and has mandated that most aircraft be outfitted with the transmission technology by 2020.

The ATD-1 effort will start with computer simulations this year and progress to simulations with pilots and flight controllers assessing the new tools and procedures. The activity will conclude with field demonstrations using aircraft operations at a major airport during 2015.

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ATD-1 and the other technology programs just detailed are just a handful of the many research programs NASA is conducting in an effort to increase the efficiency and safety of air travel, save fuels, shrink its environmental footprint, and improve the flight experience for passengers. These enhancements to air traffic management, along with work to design aircraft and engines that burn less fuel, emit fewer noxious fumes, fly more quietly, and make the whole air transportation system safer, comprise NASA's aeronautics research portfolio.

Says Jaiwon Shin, "These investments in cutting-edge aeronautics research were selected to meet the future needs of an aviation industry that plays such an important role in so many aspects of our daily lives and serves as a major engine for our nation's economy."

Editor's note: *This is the last feature in our series describing the challenges associated with trying to invent a truly 'green' airplane. The first feature (March 2011) covered research into reducing nuisance noise around airports. The second (May 2011) concerned efforts in lowering aircraft emissions and improving air quality. The third (July-August 2011) looked at efforts to reduce fuel consumption.* ▲

For more information, download the free ebook, NASA's Contributions to Aeronautics, Volume 2, *edited by Richard P. Hallion, at http://www.aeronautics.nasa.gov/ebooks/index.htm*