Reason

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By Viggo Butler
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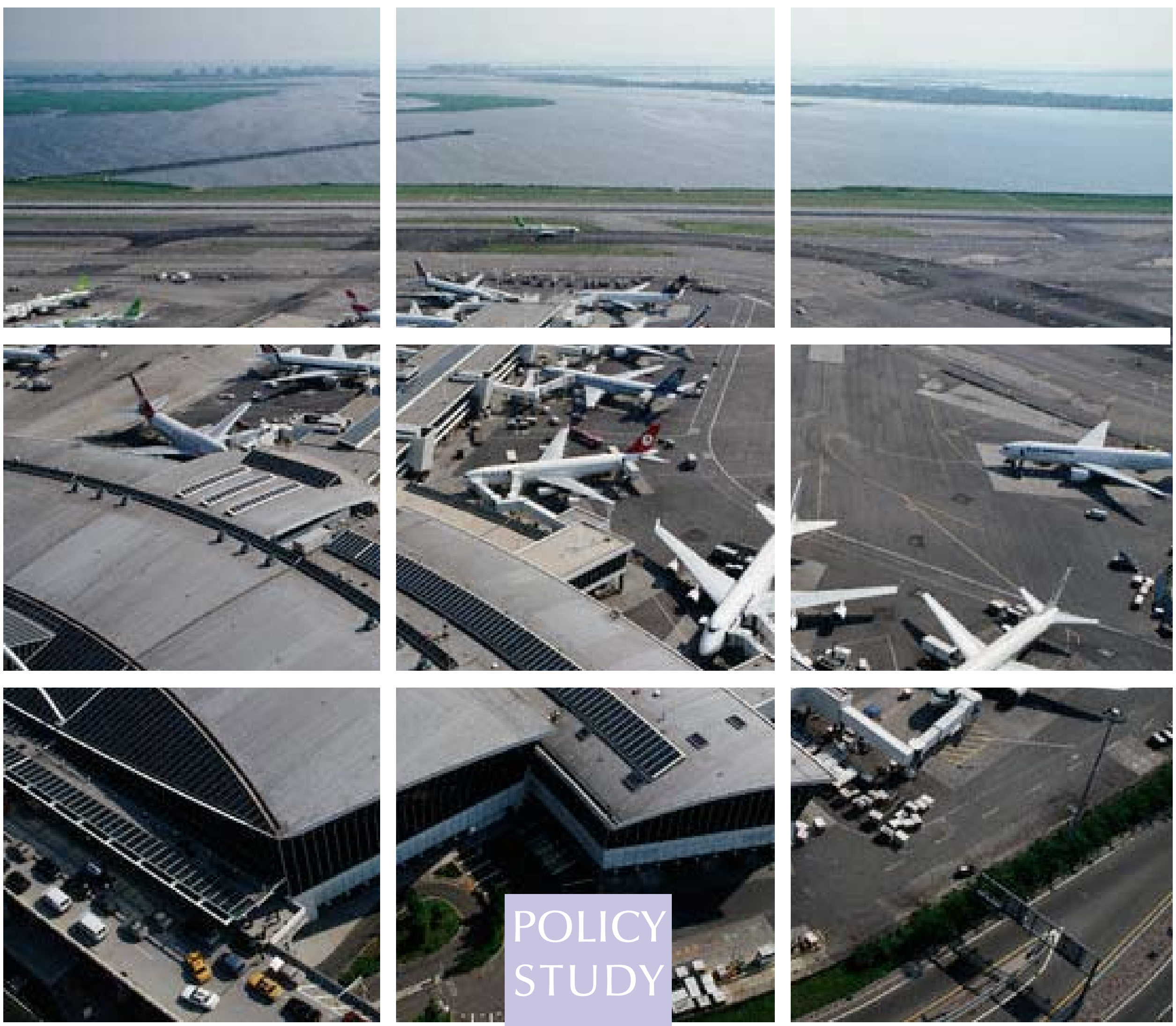

POLICY STUDY 368

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Increasing Airport Capacity Without Increasing Airport Size

By Viggo Butler and Robert W. Poole, Jr.

Executive Summary

The United States faces a real possibility of running out of airport capacity—not everywhere, but in particular at a number of the 35 most important airports in the national system. According to the Federal Aviation Administration, these are airports in large, urbanized areas such as New York, Chicago, Miami, Los Angeles, and San Francisco. The problem is seldom lack of capacity in airport terminals. Large airports are financially self-supporting, and are generally able to finance terminal expansions. Rather, the problem is one of adding needed runway capacity. Without enough runway capacity, these airports will face increasingly serious problems of delay, which already plague the New York airports.

Most of the critically important urban-area airports are hemmed in by expensive real estate. Adding a new runway of between one and two miles in length, spaced the required 4,300 feet from existing runways, typically requires large amounts of land, which many airports do not own. This often leads to divisive, protracted battles with airport neighbors to acquire the needed land. Even when the airport eventually prevails (which is often not the case), the long delay in adding the new runway can mean a decade or more of extra delays, as well as construction costs significantly increased due to inflation over the ensuing years.

What if there were ways to expand the runway capacity of an airport without expanding the airport's footprint? That would mean that an urban area could receive the economic benefits that come along with continued growth in air service without the protracted battles over land acquisition, and without the long delays attendant to such battles.

The purpose of this policy study is to explore an array of new technologies that hold significant promise for expanding the functional capacity of airport runways. These technologies—most of which already exist—are planned for incorporation into a completely new air traffic control system to replace the current system over the next 20 years. The overall concept of operations and system

architecture is being developed by a federal inter-agency planning group, the Joint Planning & Development Office, advised by aerospace/electronics industry teams. This new approach is being called the NextGen system.

Currently, runway capacity is limited by five factors:

- In-trail separation of aircraft—how closely aircraft can be spaced one after another when approaching the runway;
- Lateral separation, especially in bad weather, between aircraft approaching the same airport on parallel runways;
- The sequencing and separation of departing and landing aircraft on runways that intersect (e.g., at LaGuardia);
- The sequencing of departing and arriving aircraft on a single runway; and
- The sequencing of aircraft approaching airports located in close proximity to one another, where one aircraft must cross the path of another aircraft landing at a nearby airport (e.g., in the Chicago, Los Angeles, and New York metro areas).

In broad outline, NextGen addresses these constraints in the following ways:

- Use already developed but not fully implemented aircraft communication devices to safely reduce the physical separation of aircraft;
- Use specialized approach and departure procedures, now being implemented at a few locations, as the standard for all approaches and departures;
- Improve the management of aircraft wake turbulence in the airport vicinity; and
- Use these same technologies with central computer systems to manage aircraft movements on the ground.

This study explains the core NextGen technologies and procedures that can be used to increase airport runway capacity without expanding the airport's geographical boundaries. It then shows how these technologies could be applied to address specific types of runway capacity problems, using San Francisco International and the three main New York airports as illustrative examples.

The same technologies also offer realistic prospects for reducing the noise impact of airports on their neighbors. These benefits will be accompanied by savings for aircraft operators—on fuel use, crew time, and aircraft utilization. The reductions in fuel use and more efficient use of engines at lower altitudes will bring about noticeable reductions in emissions, producing both local and global benefits.

Airport officials, transportation planners and concerned citizens need to become aware of these new capabilities. Although full implementation of NextGen is probably 10-20 years away, the planning horizon for runway addition projects—especially if organized opposition to airport expansion is expected—is also likely to be one to two decades. Thus, planning for future expansion of runway capacity needs to begin taking into account what will be possible to do within 10-20 years that has not been possible up till now. In addition, everyone concerned about having adequate airport capacity in America's urban areas should support the timely implementation of NextGen by the federal government and the aviation industry.

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Part 1

Introduction

Air travel in the United States is projected to increase by 64 percent between 2005 and 2020, according to the Federal Aviation Administration.[1] One of the greatest constraints on that projected growth is airport capacity, especially the capacity of 35 large hub airports that the FAA identifies as capacity-constrained. Many of those airports are at or nearing the limits of their capacity, as recently described in the FAA's *Capacity Needs in the National Airspace System, 2007–2025*[2]. If those airports' capacity is not expanded, continued growth in air travel demand will lead to ever-worsening congestion, and in some cases forms of rationing, such as the "slot" systems that have been used for decades at New York's LaGuardia and Kennedy, Chicago's O'Hare, and Washington, DC's Reagan National.

The easier problem to solve is "land-side" capacity—i.e., the size and serviceability of terminals (number of gates, size of boarding lounges, amount of parking, etc.). In most cases, there is room to expand terminal capacity, and funds are readily available via airport bond issues, supported by airport revenues such as passenger facility charges (PFCs), space rentals, etc. The far more difficult problem, in many cases, is expanding "air-side" capacity—the runways which make it possible for planes to take off and land.

Runway capacity has several significant impacts on both traveler convenience and the economy. In any given city, a limit on capacity increases costs to travelers by reducing the number of flights and competitors that can serve that city. In addition, delays caused by capacity problems create passenger inconvenience, not merely at that particular city but also for other cities served by that aircraft. Thus, delays at hub airports can ripple through the system, causing inconvenience in distant cities for no locally apparent reason. In today's U.S. market, a significant increase in short-haul travel by low-cost carriers and by regional jets to hub airports means that many aircraft fly as many as eight or 10 segments a day. If the first segment is delayed significantly, those delays carry on throughout the day. In many cases, increasing capacity by reducing delays at 10 key airports may reduce delays ultimately at 50 to 100 airports. Thus, one airport's delays may be a national problem, not just a local one.

In some communities, land has been available to add runways, and the community has been generally supportive of expansion (e.g., Atlanta, Dallas/Ft. Worth, Washington Dulles). In other cases, however, bitter battles have been fought or are being fought over runway expansion. In St. Louis and Seattle, lengthy battles eventually resulted in new-runway projects going forward. By contrast, in San Francisco a multi-year battle over filling in part of San Francisco Bay to add runways to SFO ended with no new runways being developed, leaving SFO with a serious shortfall in airside capacity. As this is written, a battle over extending a parallel runway to full airliner length is under way in Fort Lauderdale.

What if it were possible to increase an airport's air-side capacity without having to expand the airport's size? While this idea might sound fanciful, new technologies being developed for the FAA's next-generation air traffic control system (NextGen) offer considerable promise. In some cases, these technologies should make much greater use of existing closely spaced parallel runways (like those at SFO) without compromising safety. In other cases, they might allow a new runway to be added much closer to existing runways than is possible under current standards, based on previous technology. And in nearly all cases, NextGen technology will make possible at least some increase in the safe, hourly throughput of every individual runway. These technologies will not eliminate the need for new runways that require expanding airport boundaries, but they should reduce the number of cases where this costly and difficult approach is needed.

The FAA's planned NextGen system represents a major step toward automation of routine aspects of air traffic control. It will safely reduce the separation between aircraft and permit more efficient routing of planes in our nation's skies. While there will be much debate over the amounts of money to be spent and the method of funding, the recognition that a new approach is needed to manage the ever-increasing number of aircraft using the nation's airspace and airports is a necessary step forward.

It is important for mayors and other elected officials, airport authority board members, and the general public to understand what these technologies can do. They will give communities new options to reduce future airport construction costs and battles over airport expansion, without having to give up the economic benefits of meeting the demand for increased air travel.

There are also realistic prospects for reducing the noise impact of airports on their neighbors. These benefits will be accompanied by savings for aircraft operators—on fuel use, crew time, and aircraft utilization. The reductions in fuel use, and more efficient use of engines at lower altitudes, will bring about noticeable reductions in emissions, producing both local and global benefits. The environmental benefits of these new technologies may well equal that of the reduced infrastructure requirements.

These benefits can be implemented and achieve the results described in this review within the time period of the FAA's planning horizon of 2025. However, the political will of both local and national leaders must be continually brought to bear on this issue. If the new technologies are not started in the near term and rigorously developed and implemented, then new pavement either at existing airports or totally new airports will be required to meet FAA forecasts. It is far cheaper for the aviation community to implement these new technologies than to build new infrastructure.

This study will focus on how these new technologies can be applied to increase the runway capacity of existing airports, without having to expand the physical land area of those airports.

Part 2

Next Generation Tools for Greater Airport Capacity

A. Air Traffic Control: An Overview

The purpose of air traffic control is to keep aircraft from running into each other—in technical terms, to provide safe separation between aircraft in all phases of operation (including on the ground). Before radar was used to keep planes safely separated, controllers on the ground used "procedural" separation methods (which are still used today over the oceans and over land in some parts of the world without radar): this means rules about how far apart planes must stay along a given flight path (in-trail separation) and between different altitudes (vertical separation). When planes and controllers can only approximately keep track of their latitude, longitude, and altitude, the rules call for huge separation margins to allow for large errors.

The introduction of radar over the land area of the United States in the 1950s and 1960s made it possible to reduce lateral and in-trail spacing, since controllers were able to determine more accurately where each plane was. More recently (within the past few years), more precise altimeters have made it possible to reduce the vertical separation required at jets' cruising altitudes, thereby increasing the number of "flight levels" for the en-route portion of flights. The increasing availability of GPS units on aircraft (airliners, corporate aircraft and light general aviation) means that pilots themselves have much more accurate information on where they are, though the current ATC system makes little use of this capability.

Although the accuracy of information about where planes are has increased over the decades, the fundamental concept of ATC is still the manual model developed prior to World War II. Every significant action by a pilot must receive the permission of an air traffic controller on the ground, who watches a display of traffic and tells the pilot what to do when. (The pilot himself has no such display of other planes' locations.) Even though a great deal of "intelligence" is built into most airliners' flight management system (FMS) computers, pilots are not allowed to make use of it, unless and until the controller gives permission. And although controllers' displays have for the most part been modernized, they have been given very few automation tools to predict conflicts or to manage large amounts of information in short periods of time. Thus, planes are still controlled largely "by hand." Because of the understandable limits on how much information a controller can work with at one time and the speeds at which modern aircraft fly, the system must retain very large separation margins fore and aft, to the left and to the right, and above and below each plane to ensure safe operations.

Currently air traffic at and near airports is controlled either by an air traffic controller seeing the plane from the control tower or viewing a radar display on a video screen, or by the pilot flying a prescribed approach on an instrument landing system (ILS) straight in to a runway. Each of these processes requires direct human involvement. In sequencing aircraft for arrival at the airport, an approach controller looking at a radar display accepts an aircraft approaching the airport from another controller that has handled the aircraft as it descends from its en-route altitude. The approach controller then looks at all of the other aircraft that are arriving in the same time frame that are already on his display. He gives turn and descent instructions to each plane to get them in sequence for lining up for the runway, spaced the required distance apart. In many cases, this requires multiple turns of the aircraft and speeding up and slowing down various planes to maintain the correct spacing.

The information on each plane's position is updated only every 4.8 seconds, each time the radar mechanically sweeps the sky. There is also a lag time between the controller's instruction and the pilot's action, depending on the reaction time of each pilot. To avoid errors in placing aircraft too close behind one another (which could cause problems with wake turbulence), the controller will add to the spacing, just to be safe. The result of all this work effort is an inefficient flow of aircraft with planes spaced farther apart than necessary if the controller had perfect information, thereby reducing the number of aircraft that can reach the runway each hour. There are similar problems with departing aircraft, as well as coordinating between arriving and departing aircraft on the same runway. The resulting mix is like an orchestra conductor conducting a group of musicians who can't hear or see each other.

This "by-hand" process can be replaced with procedures based on new technologies. Many of the individual components and systems have already been developed and tested, though they have not been integrated into a replacement for the current manual approach. These systems can provide precise aircraft routing without human intervention, area-wide and cockpit-to-cockpit real-time knowledge of the position of each aircraft, and more accurate separation management to mitigate wake turbulence. With such a system, aircraft can land and take off with considerably less spacing than required today, thereby maximizing the capacity of each runway.

The Next-Generation (NextGen) technologies to be presented in the following pages are being researched and developed by a federal government organization called the Joint Planning and Development Office (JPDO). Legislatively created in 2003, this body is made up of the **FAA, NASA,** the **Departments of Transportation, Defense, Homeland Security, Commerce**, and the **White House Office of Science and Technology Policy**. The group is chaired by the Secretary of Transportation and has working groups made up of industry specialists.

The JPDO is tasked with developing the various components of the NextGen air traffic control system. Its planning systems are coordinated to have a completely working system available for industry to build and install. These components include weather, networking, satellites, and security, plus the many navigational processes required for aircraft and ground control facilities. The upcoming descriptions of what is possible are based on work currently being done by the JPDO.

B. What the Future Can Look Like

Here is a brief overview of how the planned NextGen system can increase the capacity of runways and the surrounding airspace. Aircraft equipped with new communications technology and keeping track of their position via GPS transmit their exact position and their projected flight path in a real-time mode. This information is displayed on screens for controllers to monitor, and to similar display screens in aircraft cockpits. (The latter is a capability not currently in place; pilots can see a display of weather but not of the location of other planes.) This information can be used to generate precise approach and arrival paths (known as tailored arrivals), which are programmed into the aircraft's flight management system (FMS) computer. The various planes approaching an airport can be sequenced, automatically, many miles from the airport for arrival with the minimum spacing necessary.

Two aircraft can be positioned to approach closely spaced parallel runways even in bad weather (which in many cases is not allowed today). To maintain safety, since each aircraft equipped with the new technology will "know" the other's position, it can be programmed to respond, so that the approach can be abandoned automatically if one aircraft deviates from its prescribed path.

Aircraft also can be programmed to descend at the lowest power setting (engine idle) all the way from cruise altitude to touchdown, with no change in power settings and with the shortest route. This technique minimizes fuel use and also reduces the noise that would otherwise occur as the plane sped up and slowed down in response to a controller's order to follow the traditional stair-step approach pattern. This produces environmental as well as capacity benefits.

The preceding paragraphs said little about what happens when bad weather conditions (especially low visibility, requiring instrument operations) prevail. Current FAA separation requirements for a single runway are greater during such conditions, reducing the runway's hourly capacity. Similarly, the rate of landings and takeoffs using intersecting runways is significantly reduced under such conditions. And for operations on parallel runways, under low-visibility instrument conditions, simultaneous arrivals are permitted only if the runways are separated by at least 4,300 feet, or 3,000 feet with Precision Runway Monitoring (PRM) equipment. With the NextGen technologies, the in-trail sequencing of aircraft can be established hundreds of miles from the airport and from many different directions (instead of in single file), so that the aircraft arrive in the correct order and spaced correctly. In addition, as NextGen technologies are perfected, they will be able to fly precision approaches to parallel runways as close together as 750 feet in bad weather, and to land on intersecting runways in bad weather. All this will be possible because each plane's position will be known far more accurately.

These procedures can significantly increase runway capacity. Precise departure methods can be integrated into the mix by reducing the space between arriving and departing aircraft. Where airport approach and departure paths conflict, such as in the New York metro area air space, delays and spacing requirements can be reduced or eliminated. Precise flow systems can be established to keep aircraft separated between arrival and departure paths among the various airports so that they do not cross, or cross with appropriate altitude separation, so that each airport can have maximum flow to and from its runways.

These flow management capabilities can be extended to gate usage. Arriving aircraft can be sequenced to land in an order that allows them to flow to the gate without having to wait for the preceding aircraft to maneuver to its gate. Departing aircraft can be moved from the gate to the runway end in the correct order to flow from the runway in such a pattern that minimizes in-trail separation and turbulence problems.

The use of these technologies will eliminate most bad weather delays by making bad weather approach capacity similar to the good weather capacity. The delays not eliminated by these technologies will mostly be due to snow and ice on the airport surface, plus occasional severe thunderstorms and snowstorms. After complete integration of the NextGen technologies, all runways will have increased capacity, and good and bad weather capacity will be similar, allowing for much better scheduling.

In what follows, we describe the various components needed to achieve these capabilities, and the potential increases in runway capacity they could produce. The primary technologies for increasing runway capacity are also the primary components of the NextGen ATC system. They are Required Navigation Performance (RNP), Automatic Dependent Surveillance-Broadcast (ADS-B), Wide Area Augmentation System (WAAS), Continuous Descent Approach, (CDA), and Surface Area Movement Management (SAMM). The other key ingredient, on which further work is still needed, is technological improvements in managing flight through wake turbulence.

C. Key NextGen Concepts

Required Navigational Performance (RNP)

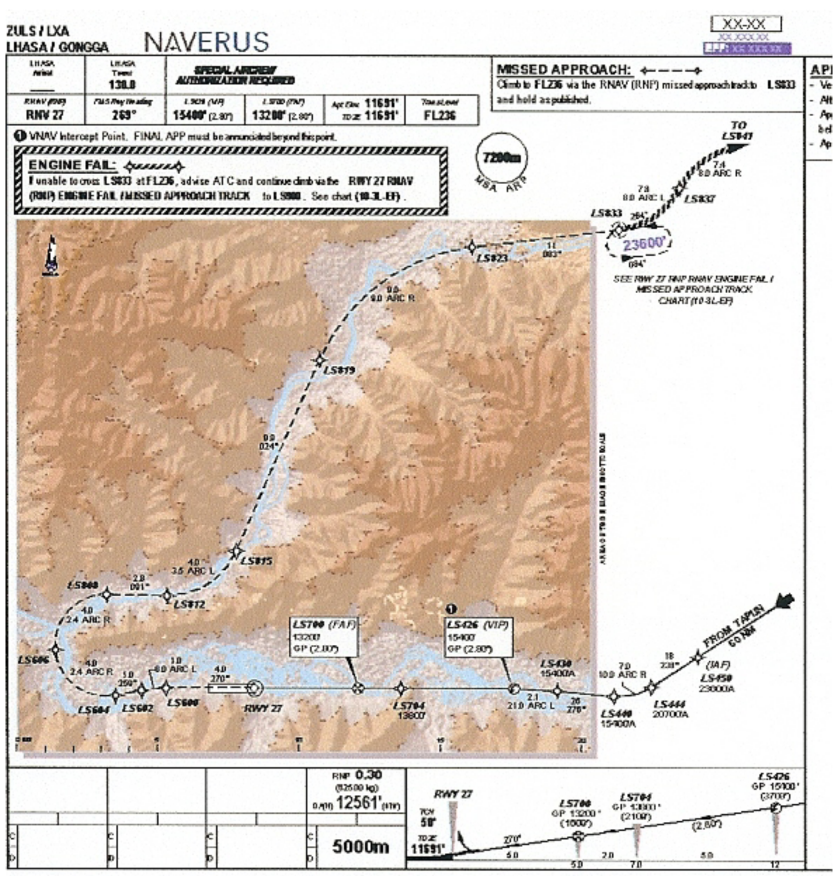
Required Navigational Performance is a functional specification from the FAA, defining a level of precision an aircraft must be able to maintain on a given flight track, but without mandating the details of the aircraft systems (hardware and software) used to achieve this. All new Boeing and Airbus aircraft built since 1995 as well as many other planes have these systems, which can be improved to achieve various higher levels of RNP precision. With a trained crew and an approved route design, an equipped plane can fly a complicated approach path very precisely by automated means. Very precise turns and altitude changes can be programmed into the aircraft. Deviations from that path are continually monitored, and there is an automated method for abandoning the approach if a deviation beyond acceptable RNP limits is detected.

Such approach techniques are currently being used at a small but growing number of airports around the world. One has been developed for Ronald Reagan Washington National Airport.

Certain RNP-qualified airlines are now using the Potomac River approach, designed to minimize noise impact on residential areas. The RNP approach allows the aircraft to follow the path of the river exactly on its entire approach to National. In Juneau, Alaska, an RNP approach allows aircraft to use, even in bad weather, the approach through mountain canyons to reach the airport. Geography precludes the use of a conventional instrument landing system (ILS) there, because there is not room for the long straight-in approach which an ILS requires. Hence, before RNP, this airport could accept landings only in good weather.

The most complicated such procedure currently in use is in the Tibet region of China, where an automated approach is made through very high mountainous terrain through multiple canyons with significant turns within the canyons, which leads to the runway that is essentially in the opposite direction to the initial approach entrance. This entire approach is flown in clouds to the point just short of the runway where the pilot takes over to land. The diagram in Figure 1 shows the routing.

Figure 1: RNP Approach to Tibet Airport



Source: Naverus Corp.

This map shows the routing of an aircraft through 20,000 foot mountain canyons to land at Lhasa, Tibet. The routing is flown automatically, by RNP methods, in bad weather. This ability can be *used at any airport to fly any track needed and to allow multiple tracks for separate aircraft to the same runway. See http://www.naverus.com/news_detail/1650.htm for a complete video of the approach. (Source: Naverus Corp.)*

RNP accuracy depends on the Global Positioning System (GPS) satellite array maintained by the Pentagon. Increasing the number of satellites accessible from any given point will increase the accuracy of the procedures used for bad weather approaches. In certain situations aircraft can be in a position where the number of satellites visible is not enough to get precise accuracy. Assuring that the system has its full capacity for the air traffic system will be an important policy issue in the near future.

RNP approaches can be created for runways (like Juneau) that have terrain obstructions that do not allow for long, straight-in ILS approaches. At some airports, this will allow secondary runways (that don't have ILSs) to be opened up for instrument approaches, allowing multiple approaches to be established where currently all aircraft must approach the airport in trail to the ILS runway.

Additionally, without full NextGen technology, an offset RNP approach called RPAT can be created to bring one aircraft in at an angle to a set of parallel runways so that two aircraft can approach the parallels at the same time. Currently, the lowest altitude to be clear of clouds and have the airport visible (minimums) for such approaches are quite high as FAA procedures require that the aircraft making the straight-in approach be protected to accommodate what is called a "blunder" of 30°, which is a significant deviation. Reevaluating this methodology and creating an RNP approach that gets lower minimums would reduce delays by more than 6 percent at San Francisco and other airports with closely spaced parallel runways.

Over the next 10 to 15 years, the primary barrier to widespread use of RNP approaches will be significantly reduced. That barrier is the equipping of all aircraft to be able to use RNP techniques. During the next decade or two, aircraft such as the 737–200 and many of the first-generation regional jets will be phasing out of domestic airline fleets. The remaining older aircraft such as the MD–80 series and 737–300 type aircraft would require relatively minor modification to meet the standards. The remaining challenge will be the equipping and approval of older business jets and of any international aircraft and that would mix with domestic traffic at international airports.

Currently, RNP approaches are approved on a case-by-case basis within the FAA regional offices. As part of the NextGen implementation, national standards will need to be established and methods developed to make the design and approval of RNP approaches closer to a routine process rather than the art form it is today. The FAA has taken a major step in this direction by permitting the outsourcing of RNP approach development with a recent contract with RNP pioneer Naverus Corporation.

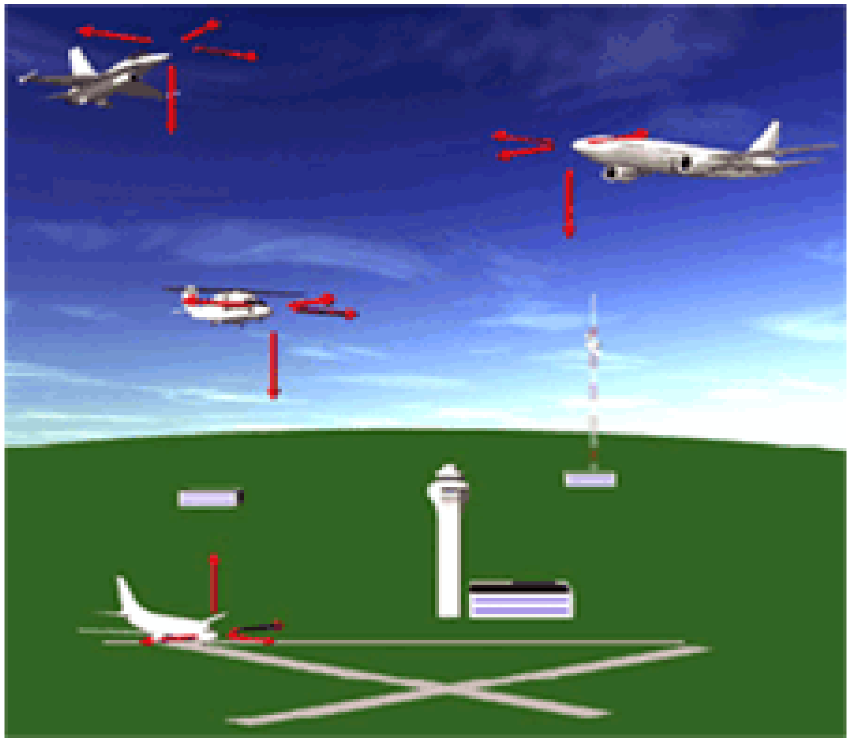
RNP procedures are also being used to create unique departure routings. For example, at Burbank, California, a departure procedure has been developed to allow an airline to increase its load capacity on a twin-engine jet aircraft. The Burbank airport is surrounded by mountainous terrain. Under traditional procedures, in the event of an engine failure the pilot must be able to climb and avoid this terrain by using manual actions or by getting the autopilot to take over control of the aircraft. This requirement reduced the plane's load capacity, because extra time must be assumed to account for the reaction time of the pilot to set the aircraft up for single engine performance and have the autopilot take over. The RNP procedure allows an aircraft to fly a prescribed route automatically, and if there is an engine failure the aircraft immediately follows a path that clears the terrain at its lowest point. Since the aircraft is assured of being able to clear the lowest point, its climb rate does not have to be as great, so it can take off at a higher gross weight.

Widespread use of RNP departures at airports will assign departing aircraft to a small number of precise dispersal routings. These routes can be designed to clearly separate departing and arriving aircraft. This will permit a higher rate of departures, since a following aircraft can avoid the previous aircraft's wake turbulence and can also be routed on a precisely created path that does not conflict with an arriving aircraft's equally precise path.[3]

Automatic Dependent Surveillance-Broadcast (ADS-B)

ADS-B is a system by which the precise position of an aircraft equipped with this technology can be monitored both on the ground and from other equipped aircraft. It makes use of GPS to determine the plane's location in real time, its transponder to provide its identity and altitude, and a datalink to broadcast and receive positioning information. The system has two basic on-board capabilities: one called ADS–B/In and the other ADS-B/Out. ADS-B/In is the ability of a plane to receive and display signals from other aircraft, while ADS-B/Out is the ability to send signals that other aircraft and ground systems can receive. When both are operational, a pilot will be able to see on a cockpit display the position of all the aircraft in the vicinity and know their speed, altitude, and direction of flight. Concurrently, on the ground, air traffic control will be able to see all details of the aircraft and project where it will be as time progresses. This technology is currently in use by United Parcel Service as ADS–B/In for many of their aircraft using their main hub at the Louisville airport. Figure 2 shows the interconnecting communication links of ADS-B providing simultaneous information to all users of the system.

Figure 2: Communications Paths in ADS-B System



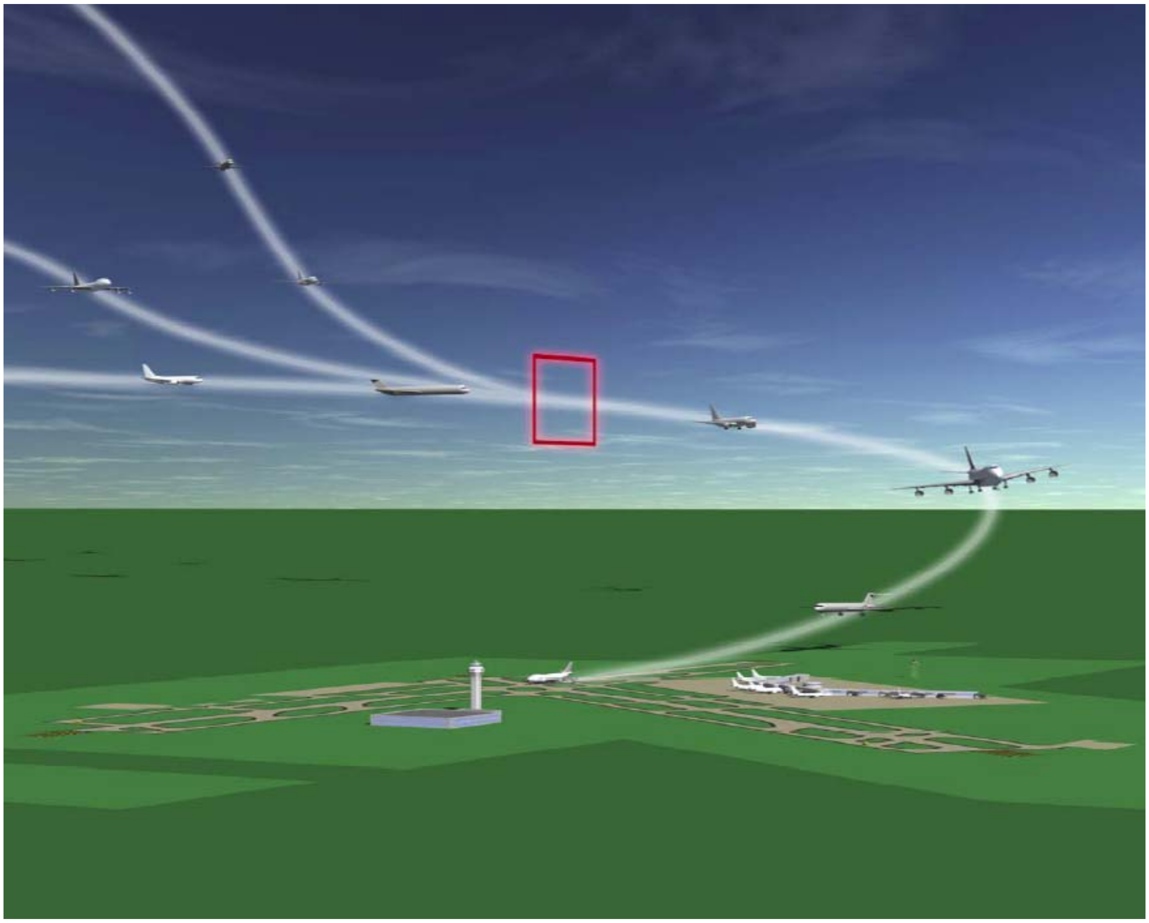
Source: FAA

This rendering depicts the multiple paths of communication used by ADS-B systems. Each aircraft knows where all other aircraft are and where they are headed. The ground has a complete picture of where the aircraft are, where each is going and how they interact.

ADS-B requires that new equipment be installed on each aircraft, and that ground or satellite stations be installed at each airport and at various en-route locations. If one aircraft in a particular airspace does not have the equipment, that plane must be placed in a traditional ATC separation environment, protected from all other aircraft in the area. To achieve the NextGen goals, all aircraft flying in controlled airspace will need to have both ADS-B/In and ADS-B/Out by some deadline date.

ADS-B is the key element in allowing aircraft to be sequenced precisely to avoid conflicts and to be closely spaced in the airport vicinity. As the technology develops, the process of separating aircraft can be automated to a great degree. Figure 3 presents a rendering of how many disparate aircraft from various directions are sequenced into one continuous flow to the runway.

Figure 3: Approach Sequencing Using ADS-B



Continuous Descent Approaches combined with automatic sequencing using NextGen technologies bring various size and speed aircraft to final approach separated for wake turbulence, speed or any other desired criteria. (Source FAA)

Wide Area Augmentation System (WAAS)

WAAS is a supplemental system for common aircraft GPS systems that provides a signal that increases the accuracy of the GPS equipment. It requires an onboard device that receives a signal from a network of ground stations placed around the country. WAAS allows reasonably precise approach paths to be created to secondary or reliever airports that do not have instrument landing systems (ILSs) or other navigational aids to assist with poor-weather approaches. WAAS can provide relief for major airports by increasing the capacity and flow rate of reliever airports, thereby reducing conflicts with the approaches to the primary airport.

Aircraft capable of RNP using a full array of satellites do not need WAAS to fly approaches independent of ground-based navigation devices. WAAS allows lesser-equipped aircraft to operate with similar capabilities to RNP-equipped aircraft. It is primarily of value to general aviation aircraft, not airliners.

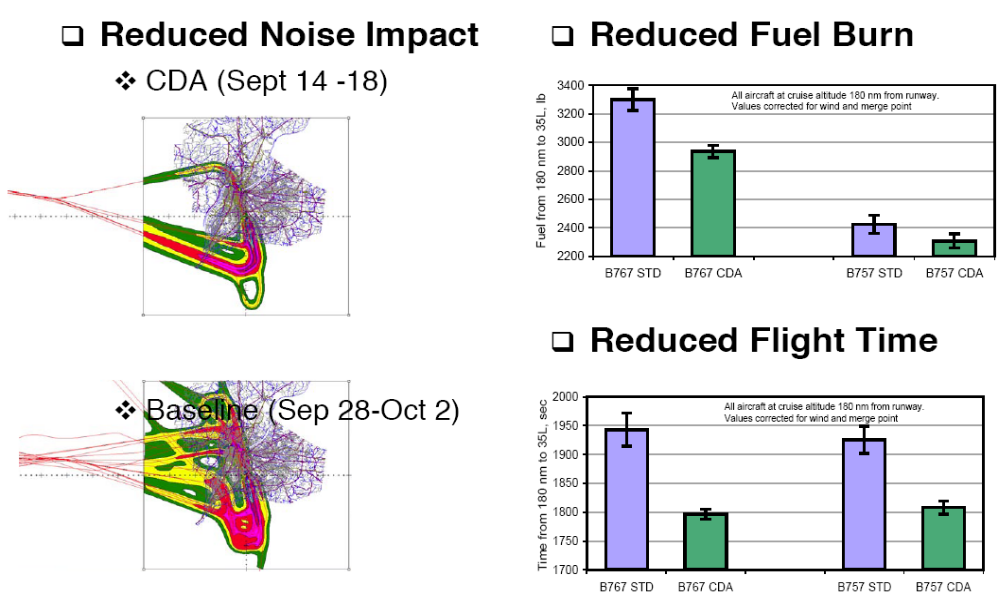
Continuous Descent Approach (CDA)

Continuous descent approach is a method of having aircraft at cruise altitude descend the entire way to the airport at the lowest power setting (engine idle) with a previously established routing requiring no leveling off at intermediate altitudes and no changes in direction once established on the designated profile. Maintaining a constant low power setting avoids the throttling up and down that is typical of conventional descents today, in which a plane makes a series of stair-step decreases in altitude at the controller's direction. Each requires acceleration and deceleration, thereby using more fuel and making more noise than what is essentially a gliding approach at minimal power. Figures 4, 5, and 6 present the difference between a CDA versus a standard stair-step approach.

UPS has been experimenting at Louisville, Kentucky with this procedure with the results shown below. As expected, there is less fuel burned, fewer emissions, less noise, and a reduction in flight time.[4]

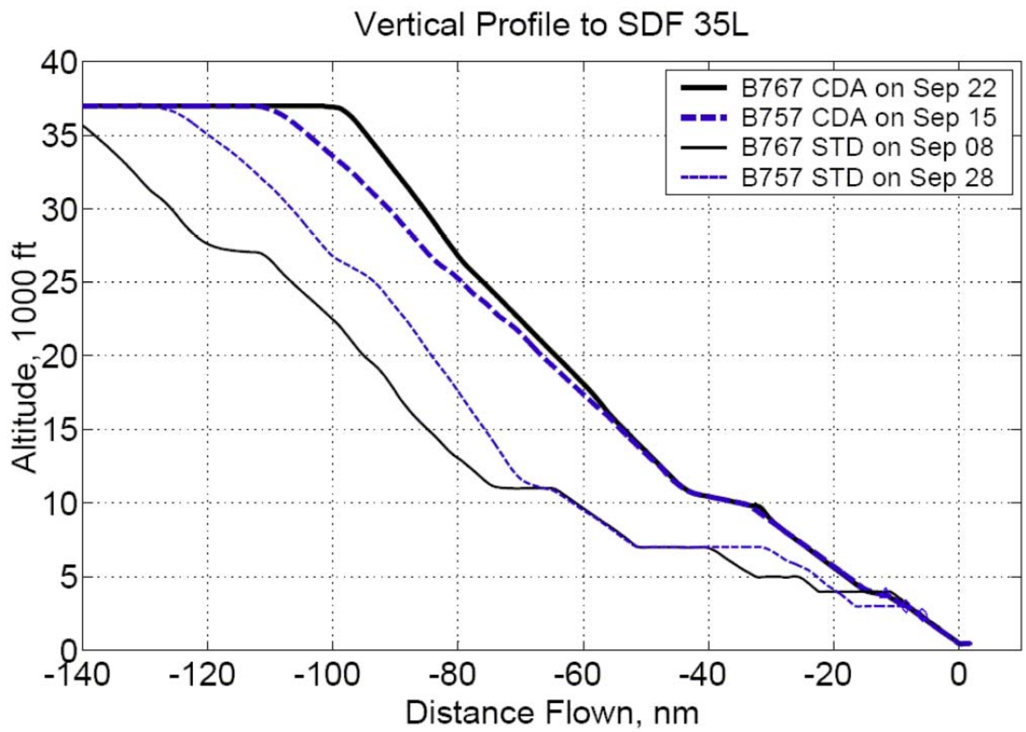
Figure 4: Continuous Descent Approach at Louisville

Noise Impact, Fuel and Time Savings



The benefits of Continuous Descent Approaches include reduced fuel usage, noise and flight time. These benefits magnified by tens of thousands of flights can be very significant for both the environment and the economy. (Source: Bob Hilb, UPS Airlines)

Figure 5: Continuous vs. Standard Descent Approach

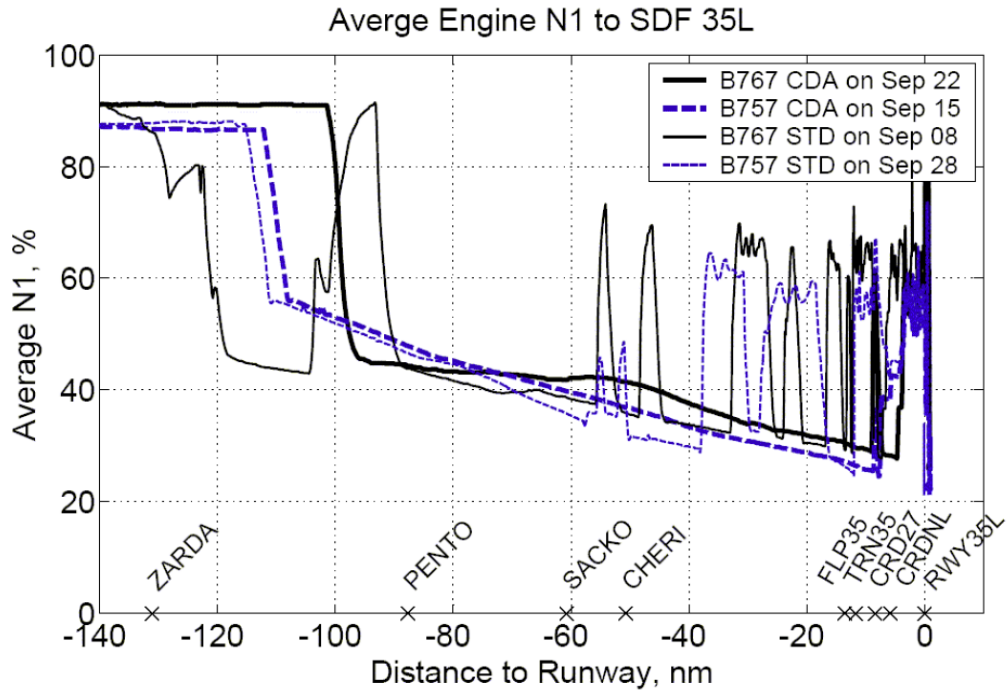


Comparison of continuous vs. standard descent altitude changes on approach, showing the lack of changes in altitude settings. (Source: Bob Hilb, UPS Airlines)

In the example above, the noise reduction was 30 percent. The reduction in emissions was 34 percent in nitrogen oxides (NOx) below 3,000 feet.

San Francisco is experimenting with this concept with aircraft approaching from the west over the ocean. This is already having a beneficial result on noise impact for communities south of San Francisco.

Figure 6: Engine Power in Continuous Descent Approach



Comparison of continuous vs. standard descent engine power changes on approach, showing the significant reduction of engine power settings, providing a much smoother approach that reduces noise and provides other benefits. (Source: Bob Hilb UPS Airlines)

The combination of RNP, ADS-B and CDA will create a streamlined flow of aircraft on precise approaches from en-route to landing that are automated, predictably separated to give correct spacing, sequenced for most efficient use of the airfield and gates, and spaced to maximize the use of the runway(s) to increase their capacity.

Surface Area Movement Management (SAMM)

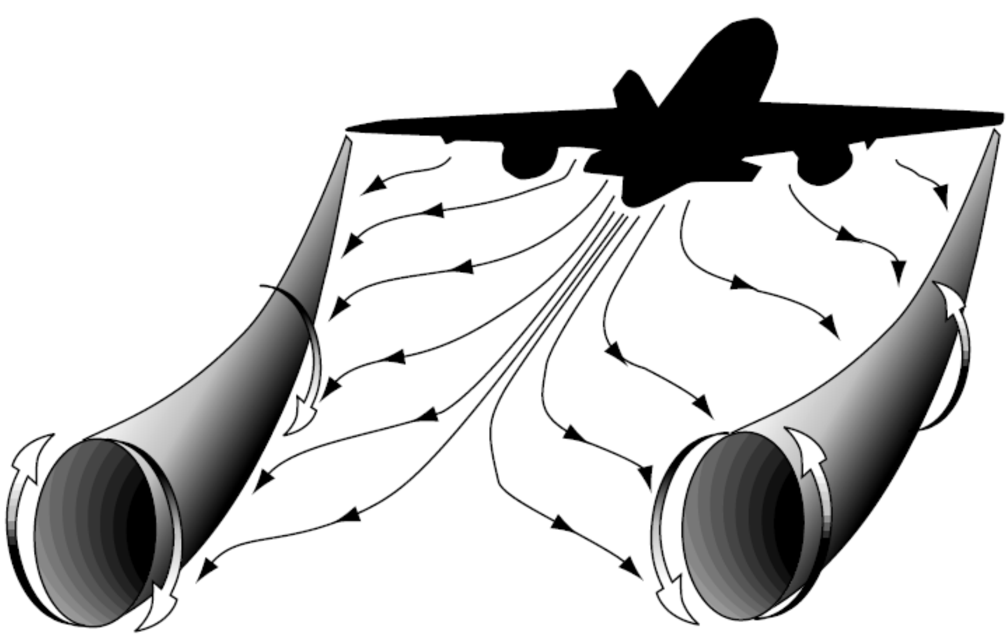
Methods to maximize the use of the gates and to minimize taxi distances, hold times, and separation between aircraft on arrival can all be integrated into one system. One tool for this is Surface Area Movement Management (SAMM). Displaying the airport map and the traffic moving on the airport in the cockpit alerts crews of potential conflicts and possible runway incursions. This in-cockpit information, coupled with central systems that know the arrival times one or more hours before that aircraft arrives at the airport, can sequence the aircraft to arrive in the correct order to flow the landing aircraft and taxi it to its gate so that it does not conflict with other aircraft approaching the same gate area. This will allow the airline to have the appropriate ground equipment in place to move the aircraft into the gate immediately and avoid blockage of the taxi area. Concurrently, departing aircraft can be directed to the end of the runway in sequence to minimize wake turbulence on departure or insert an aircraft departing on a different routing between those that may be departing in the same direction and would have to experience a delay to maintain separation. Common use gates with centralized management systems can further increase the efficient flow of taxiing aircraft.

D. Wake Turbulence Mitigation

The biggest hurdle to the implementation of reduced separation in the vicinity of airports is that of wake turbulence. There are ongoing studies and field experiments to better understand how close aircraft can be placed both laterally and in trail to make the maximum use of the technology described in this study.

Wake turbulence is the disturbance in the air left after the passing of an aircraft. The primary effect is tornado-like vortexes generated at the wing tips, powerful enough in some cases to upset a following aircraft, even causing it to crash. Figure 7 shows this powerful effect trailing off the wings.[5]

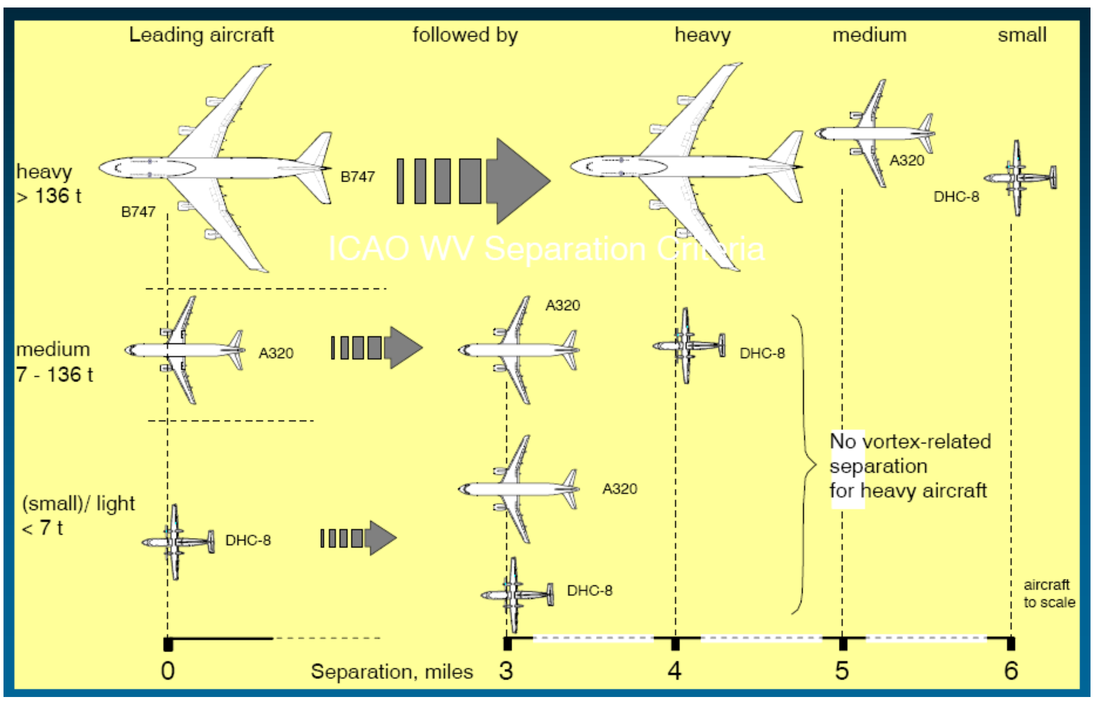
Figure 7: Wake Turbulence Affects Following Aircraft



The picture reveals the expanding outward impact of disrupted air that trails behind a large aircraft and disrupts the stability of a following aircraft. (Source: FAA)

Being able to "see" these disturbances, or knowing if they have dissipated or moved out of the flight path, will in many cases allow following aircraft to get closer. Currently, the distance between aircraft is set by rule, based on worst-case scenarios. This restricts the capacity of a runway in many cases that are less than worst-case, since no changes to mandated spacing are allowed. And in actual practice, controllers tend to err on the side of increased separation, further reducing capacity. Field observation studies have shown that as much as 20 percent of runway capacity is lost to inaccurate spacing.[6] Figure 8 indicates the distances required for various aircraft following larger aircraft. The top row shows that a heavy aircraft following another heavy aircraft requires four miles distance while a small commuter airplane needs six. The second row shows the distances needed behind a medium-size jet.

Figure 8: Standard Aircraft Separations
(ICAO's Weight Class Dependent Separation Criteria)



Separation distances between various aircraft as currently applied. The top row shows the following distances behind a large jet for a medium jet and a commuter airplane. For example an A320 needs to follow a 747 by five miles. The center and lower rows show the same for small jets and aircraft. (Source: Bram Elsenaar, WakeNet2-Europe)

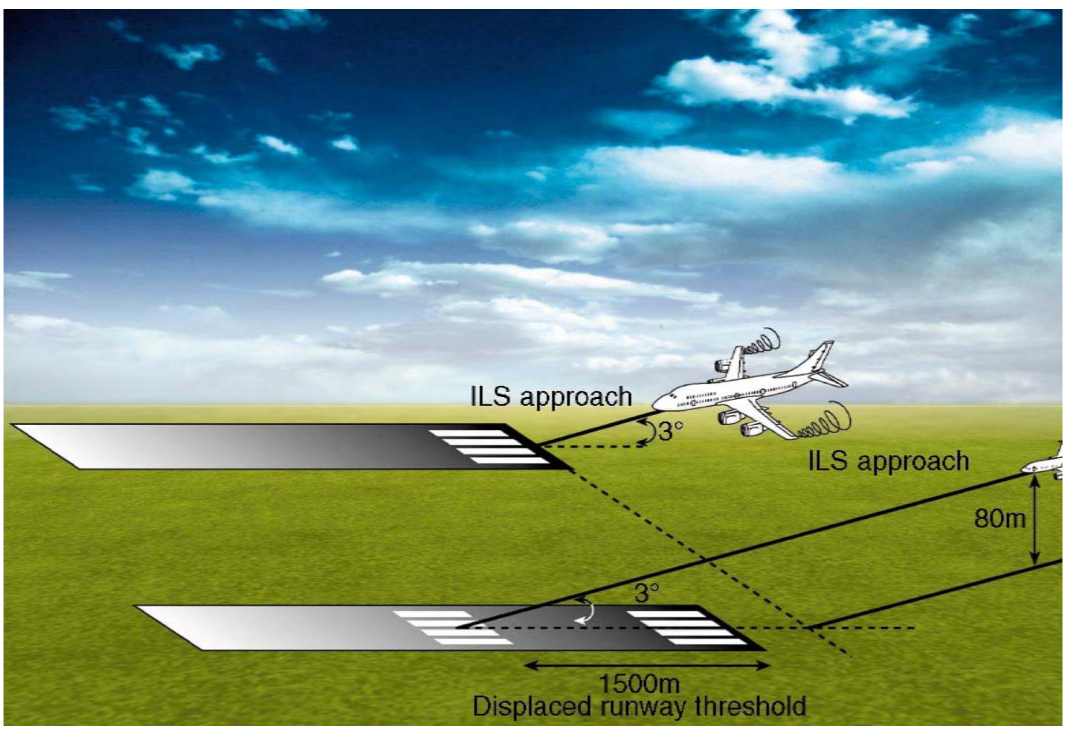
Solutions to this problem are being researched in the United States and Europe. Studies include wind pattern forecasting, ground and airborne radar, and laser real-time analysis and display.

At the San Francisco airport (SFO), for example, wind studies may be able to predict the rate of dispersal of the aircraft wake, so that on windy days the turbulence will not be a factor affecting closely spaced parallel approaches.[7] Experiments with laser systems (LIDAR) that can analyze vortex and turbulence in real time are ongoing and may create a predictable model that both pilots and controllers can use to warn when turbulence exceeds a safe limit. That would permit closely spaced approaches to be used routinely, except when warnings occur.

Also at SFO a new concept for the near-term management of turbulence is a program called Wake Protection Zone. This creates a defined box around an aircraft that the aircraft must stay in on final approach. The controller and pilot know where the plane is within the box and another airplane's box can be established behind it. If a plane moves out of its box, it is removed from final approach and must go around again. [8]

The Frankfurt, Germany airport has been testing and is now implementing a process that displaces the threshold (the point at which pilots aim to touch down) of one of the parallel runways, so that smaller arriving jet aircraft can fly a higher approach path than the parallel larger jet is flying, avoiding its vortexes, as shown in Figure 9. The processes are called High Approach Landing System (HALS) and Dual Threshold Operations (DTOP).[9] This allows the jets to land simultaneously without having turbulence interfere with the approach. The runway with the displaced threshold can also be used at other times at full length for arriving large jets.

Figure 9: Frankfurt Displaced Runway Threshold For Reduced Wake Turbulence

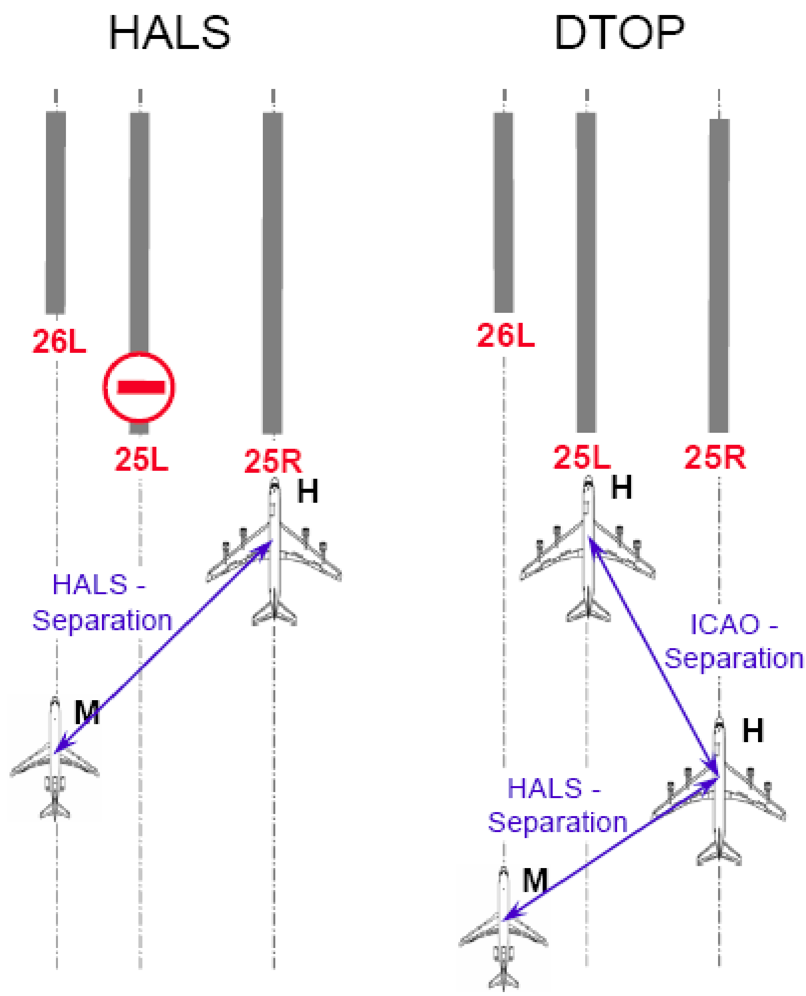


This shows that if a smaller jet flies on a higher approach path that lands farther down the runway it is not affected by wake turbulence from the larger jet. (Source: Bram Elsenaar, WakeNet2-Europe).

Figure 10: Frankfurt's Two Landing Zones

This represents the displaced threshold being lit and the beginning portion of the runway unlit so that the arriving aicraft is directed to displaced portion for landing. (Source: Frankfurt Airport Capacity Enhancement Program the Role of Wake Vortex Reducing Measures 2nd WakeNet 2 - Europe Workshop, 30.11. – 01.12.2004)

Figure 11: HALS (High Approach Landing System) and DTOP (Dual Threshold Operations) Used Simultaneously



The aircraft on the left is flying higher than the others and can thus fly closer behind the others. H stands for heavy jet and M stands for medium jet. (Source: Frankfurt Airport Capacity Enhancement Program the Role of Wake Vortex Reducing Measures 2nd WakeNet 2 - Europe Workshop, 30.11. – 01.12.2004)

This procedure could be applied at most airports with long parallel runways, especially those with a high percentage of regional jets that can use less runway length for landing.

Current and future programs dealing with turbulence include Weather-Dependent Aircraft Spacing, ATC-Wake, Time-Based Separation, and Crosswind-Reduced Separations for Departure Operations (CREDOS). From these programs, singly or in conjunction with each other, reduced separation can be achieved.

A reduction of one mile of in-trail separation or in offset approaches to closely spaced parallels can increase runway capacity by 20 percent. Research and development of wake turbulence reduction or management has the most significant potential for runway capacity increase. Figure 2-12 below shows the increase in capacity at some major European airports that should be available if wake turbulence can be managed via one or another of these techniques. The chart indicates the annual number of added flights that can be achieved over current activity using various alternate solutions.

Figure 12: Potential European Airport Capacity Gains

Annual totals for "Extra Movements" as estimated from the Eurocontrol / Nats / UKMO "Euroben" study for some of the studied CONOPS

	ATC-Wake		CREDOS		TBS
Airport	*3Nm*	*2.5Nm*	*90s*	*80s*	
Heathrow	10,858	26,280	6,843	9,490	1,788
Frankfurt	3,923	11,315	0	91	2,801
Schiphol	1,277	5,565	547	638	431
Paris CdG	638	1,916	0	0	0
Madrid	547	4,653	273	456	169
Munich	0	0	0	0	0
Rome	0	0	0	0	26
Zurich	0	365	0	0	0
Barcelona	0	0	0	0	0
Gatwick	0	0	0	0	0
Manchester	0	0	0	0	0

The chart shows that, for example, Heathrow could expect 26,280 more flights per year (72 per day) if they could achieve a 2.5 nm separation between arriving aircraft. (Source: European Research on Wake Turbulence, Vienna 2006, Bram Elsenaar)

An aggressive research and development program run in conjunction with NextGen development and implementation is imperative. NextGen can significantly improve traffic flows, but the addition of wake turbulence management will have the most impact on airport capacity.

Wake turbulence management will come in increments over a multi-year period. Each improvement can be implemented as it is approved, bringing small but measurable capacity increases each time. By the time NextGen systems are fully deployed the ability to maximize their capabilities will be much improved by the piecemeal turbulence advances.

Part 3

Expanding Airport Capacity via NextGen

While each distinct piece of the new technologies discussed in the previous section may marginally improve the capacity of any given airport, only the complete deployment of the NextGen system will have a comprehensive impact on airport capacity. The combination of ADS-B and RNP plus wake turbulence management will appreciably increase runway capacity. The ability to sequence aircraft much closer together, to use closely spaced parallel runways in good or bad weather, and to better time and sequence arriving and departing aircraft on intersecting runways or closely spaced parallels are all possible, and will have different impacts on different airports. In addition, the ability to position aircraft ready for takeoff in a timely fashion so as to better sequence them with arriving aircraft will also increase capacity. Moving aircraft on the ground with no delays and in the correct sequence will improve taxiway and gate usage, reducing delay times in waiting for gates as well as long waits for takeoff. Thus, gate-to-gate times for passengers, aircraft utilization, and crew duty time can all be reduced.

Each airport is unique in its layout of runways and local procedural needs. However, some characteristics are similar at various airports, enough so that some solutions can be generalized to other airports with similar capacity limitations. In this section, we will illustrate how NextGen technologies can address several types of airport capacity problems.

A. Capacity-Constrained Airports

The FAA's 2007 Capacity Needs report analyzed the 35 busiest airports (the ones it tracks in its Operational Evolution Plan) plus 13 more that will fall short of needed capacity between now and 2025. After reviewing all 48 of these airports, the researchers identified 18 that would still have capacity needs in 2025 even after currently planned or proposed improvements were made. If those improvements are not made, the total could rise to 27 airports. Many of the airports that plan to meet capacity or cannot meet capacity have characteristics that this study indicates may be able to improve capacity by using technology. The airports listed in Table 1 are those that have future capacity problems, with indications as to whether they have closely spaced parallel runways or other factors that can be managed by technology.

Table 1: Airports Needing Additional Capacity by 2025

Airport Name	Airport Code	After Planned Improvements	Without Planned Improvements	Single Runway*	Closely Spaced Parallels	Infill Runway Potential**
Baltimore-Washington International	BWI		X			
Boston Logan	BOS		X		X	X
Charlotte Douglas	CLT		X			
Ft. Lauderdale-Hollywood	FLL	X	X			X
George Bush Intercontinental	IAH		X		X	X
Hartsfield-Jackson Atlanta	ATL	X	X		X	
JFK International	JFK	X	X		X	X
John Wayne-Orange County	SNA	X	X	X		
LaGuardia	LGA	X	X	X		
Long Beach	LGB	X	X			
Los Angeles International	LAX		X		X	
McCarran International	LAS	X	X		X	
Memphis International	MEM				X	
Miami International	MIA				X	
Midway Airport	MDW	X	X		X	
Minneapolis-St. Paul	MSP		X		X	
Newark Liberty	EWR	X	X		X	
O'Hare International	ORD		X			
Oakland International	OAK	X	X			
Orlando International	MCO				X	X
Palm Beach International	PBI		X	X		
Philadelphia International	PHL	X	X		X	
Phoenix Sky Harbor	PHX	X	X		X	
Pittsburgh International	PIT				X	
Portland International	PDX				X	
Ronald Reagan Washington National	DCA		X		X	
San Antonio International	SAT		X			
San Diego International	SAN	X	X	X		
San Francisco International	SFO	X	X		X	
Seattle-Tacoma International	SEA		X		X	
T.F. Green	PVD		X	X		
Tucson International	TUS		X	X		
Washington Dulles International	IAD		X			X
William P. Hobby	HOU		X			

Source: FAA Roadmap for Performance Based Navigation 2006-2025 and ACI-NA.[10]

*or intersecting single runways ** Creating runway separations as little as 750 feet.

In addition, the FAA has identified eight metropolitan areas that will need additional capacity perhaps beyond what is possible at their existing airports by 2025: Atlanta, Las Vegas, Los Angeles, New York, Philadelphia, Phoenix, San Diego, and San Francisco.

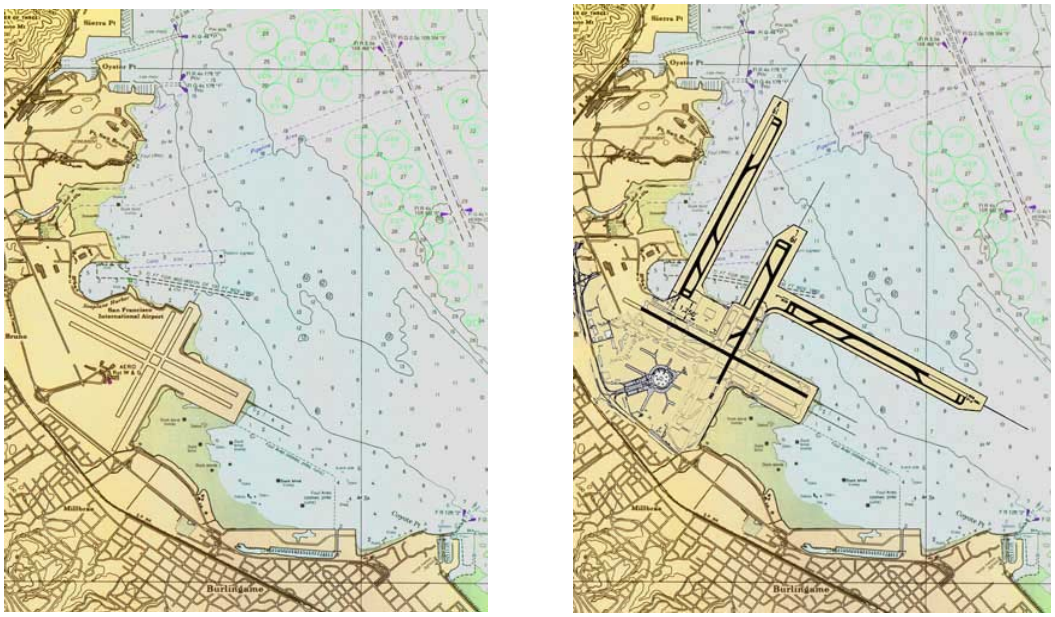
In this section, we will look at several approaches that can be used to address various types of capacity limitations, illustrating them with specific airports that exemplify that particular problem.

Capacity Problem #1: Closely Spaced Parallel Runways

As noted in the previous section, under current FAA regulations, simultaneous landings on parallel runways under low-visibility conditions are only permitted if those runways are nearly a mile apart (the actual spacing required is 4,300 feet). Many airports have parallel runways that are much closer to each other than that, which means those airports' capacity can be cut as much as in half under low-visibility conditions. San Francisco International (SFO) is an extreme case, with its parallel runways only 750 feet apart. Other airports on the FAA's list with closely spaced parallels include Boston, Las Vegas, Kennedy, Los Angeles, and Newark. Our case study for this discussion will be SFO, but similar approaches should be considered for the others with this problem.

During visual conditions at SFO, aircraft fly parallel approaches to the 750-foot separated runways. When bad weather sets in (and SFO is subject to frequently occurring foggy conditions), only one runway can be used for landings. In an attempt to solve this problem, the city developed a plan to fill in an adjacent portion of San Francisco Bay, so as to build a new runway separated by 4,300 feet from the existing ones. This plan became the subject of fierce political debate for years—and was eventually abandoned. This leaves SFO with having to make maximum use of the existing facilities for the foreseeable future. Fortunately, a considerable increase in capacity is possible with new technology.

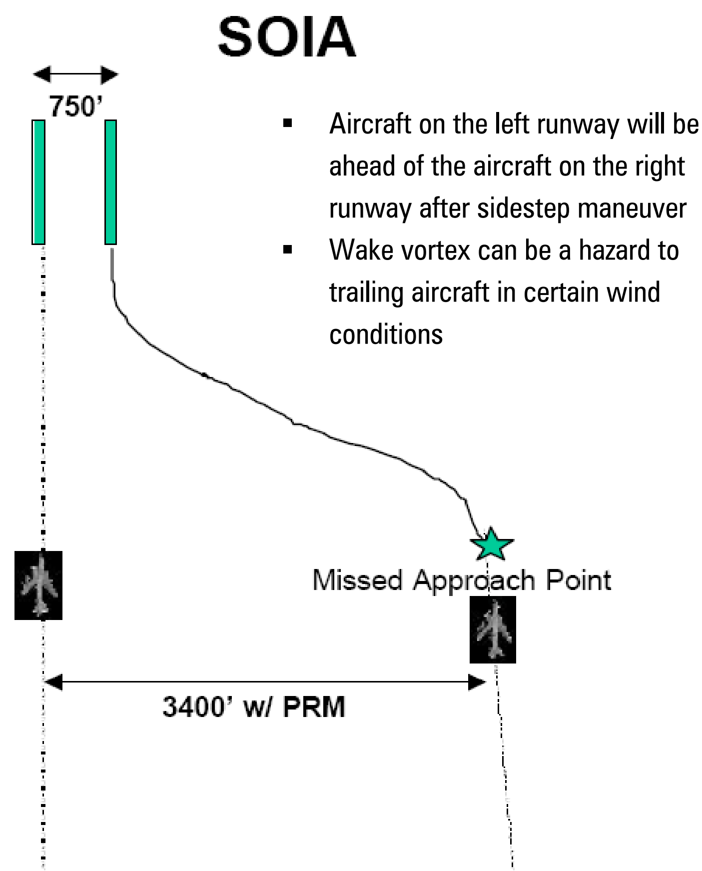
Figure 13: SFO's Proposed Runway Expansion



The complex of runways at the top of the picture (right) were proposed to be built on fill extended into the Bay. (Source: San Francisco International Airport)

SFO's current effort is a system called Simultaneous Offset Instrument Approach (SOIA). It makes use of a precision radar system, under which a separate radar is installed, capable of making aircraft position readings every second (compared with every 4.8 seconds with a conventional radar). This radar requires a separate air traffic controller position to monitor it, to observe the closure rate of two aircraft, one of which is flying a standard instrument (ILS) approach to the left runway (28L) and the other approaching the right runway (28R) from an angle that gradually approaches the straight-in arriving aircraft. If the controller observes a deviation, he instructs the pilots to take corrective action. This currently requires that there be enough time for a controller to observe the deviation and advise the aircraft to take corrective action. Because of this time delay, the lowest possible altitude for the aircraft to achieve visual separation from the parallel aircraft is 2,200 feet. While this procedure has incrementally increased the capacity of San Francisco's runways, it comes at considerable expense in both equipment and workforce.

Figure 14: Simultaneous Offset Instrument Approach (SOIA) at SFO



This figure shows the approaching aircraft on the right maintaining a path 3,400 feet or more separated from the left aircraft until the aircraft can maintain visual separation below clouds after the missed approach point indicated by the green star. (Source: FAA)

This system cannot maximize runway usage in the prevailing weather conditions during much of the year in San Francisco. SFO often has a marine layer (low-level clouds) that generally requires getting down to 1,600 feet to be able to see the airport, but SOIA only achieves 2,200 feet. By using a variation of RNP called RNP with Parallel Transition (RPAT), this ceiling restriction can be overcome in the near future. A major benefit to SFO of using NextGen would be Continuous Descent Approaches feeding various sized aircraft in the proper sequence to separate them from each other for proper spacing for turbulence and to allow takeoff windows for the crossing runways. This sequencing, RPAT parallel arrivals, would provide quieter, lower-emission approaches, fully automated to maximize runway capacity with no extra turns or speed adjustments for approaching aircraft.[11]

According to a MITRE study[12], the use of RNP systems alone can increase the overall capacity of the San Francisco airport by as much as 54 percent over current bad weather capacity. If all the technologies discussed in this study are used, parallel approaches exceeding the capacity of the current visual approaches could be achieved, further increasing total aircraft and passengers using the facility.

This capacity increase can be extrapolated to apply at the other airports with similar separation. The MITRE study looked at a few airports with varying layouts and showed that all would benefit from RNP alone as shown in the chart below.

Table 2: Capacity Gain Once All Aircraft Are RPAT-Capable

Site	Applicable Runways	Fraction of Time RPAT is Applicable	Approximate Capacity Increase
Atlanta	26R/27L, 8L, 9R (Triples)	17%	40%
Boston	4L/R	6%	35%
Cleveland	24L/R, 6L/R	14%	59%
Detroit	21L/R, 22L/R, 3L/R, 4L/R (Triples)	18%	25%
JFK	4R/L 22 R/L	5%	20%
Las Vegas	25R/L, 19R/L, 7R/L, 1 R/L	3%	43% (limited WX application)
Newark	4L/R 22 L/R (possibly)	11%	45%
Philadelphia	26/27R	7%	16%
Portland	10 R/L, 28R/L	23%	17%
San Francisco	10s, 28s, 1s, 19s	14%	54%
Seattle	16 R/L, 34 R/L	23%	18%
St. Louis	12R/L 30 R/L (SOIA today)	16%	24%

Source: MITRE Corporation

This table shows that significant improvements can achieved from the application of RNP technology alone. Even greater increases are achievable when ADS-B is added. Studies conducted by Boeing and others indicate a 45 percent increase in capacity using the various technologies of NextGen.[13]

Capacity Problem #2: Needing a New Parallel Runway But Having Limited Space

A related problem to that of airports like SFO and EWR, whose existing parallel runways are closer together than 4,300 feet, is that of an airport which needs an additional parallel runway but is unable to expand the airport boundary enough to space it 4,300 feet from one of the existing runways. A possible answer is what some NextGen advocates call "paving down the middle." In other words, with the development of technologies that will permit safe operation of runways as close together as 750 feet, there may be space within the airport boundary to add a closely spaced parallel runway. A recent technical paper makes a persuasive case that use of ADS-B along with advanced cockpit displays will make it feasible to reduce runway spacing to 750 feet.[14]

John F. Kennedy International is one airport on the FAA's list where this may be possible. If a new runway were built between runways 4R and 4L at Kennedy, the three parallel runways would have separations greater than SFO and similar to Boston (see Figure 15) . Capacity at Kennedy could be increased by much more than 50 percent on those runways if every NextGen technology were applied. Kennedy already has more airside capacity than the other two major New York airports. Managed well through new technology, a very significant increase in New York area capacity can be achieved, allowing the metropolitan area to meet demand for many years to come.

Figure 15: JFK Airport Layout with Proposed New Parallel Runway

The altered photo shows JFK runways 4 Right and 4 Left as they are now and as the airport would be with a new parallel runway "paved down the middle." Those three runways would have greater separation than the current parallel runways at SFO, and would be similar to what exists today at BOS.

Other airports in Table 1 where capacity could be expanded by adding a closely spaced parallel runway include Atlanta, Ft. Lauderdale, Houston Intercontinental, and Washington Dulles.

Capacity Problem # 3: Limited Landing Capacity of a Single Runway

For airports with a single runway or only one runway available during certain wind conditions (e.g., LaGuardia, Washington National), the primary means of increasing capacity is by reducing in-trail separation between aircraft. The critical problem in achieving reduced separation once new technology has been applied is wake turbulence. As discussed in Part 2, methods to sequence various size aircraft can be implemented that will create an arrival flow that places larger aircraft closer behind smaller aircraft to reduce the separation between them. Also, different approach glide path angles can allow smaller aircraft to operate slightly higher than larger aircraft, thereby avoiding the larger plane's wake turbulence. This principle can be used to create different runway landing thresholds or touchdown points, whereby two aircraft occupy different points on the runway at the same time with one turning off at the far end as the second aircraft is touching down. The previously described Frankfurt International Airport method is one example, but this particular method requires a runway in the 10,000-foot range. Airports with shorter runways, such as LGA and DCA, cannot use this method.

For shorter, single-landing-runway airports such as LaGuardia, the most promising methods of improving capacity are using the NextGen systems to place aircraft in the closest possible sequencing while managing wake turbulence to ensure this is done safely. Additionally, NextGen technologies can also reduce delays in sequencing takeoffs on intersecting runways. The FAA estimates that LaGuardia peak-hour capacity can be increased by 10 percent using these methods, or nine flights per hour. Over a year this is approximately 59,000 flights not currently using the nation's most constrained airport. This type of improvement can also be expected at other similar airports (such as Reagan National and San Diego). Also, because approaches can be flown more precisely and wake turbulence can be better managed, larger aircraft can be used with closer separation than current operations, thereby expanding the number of seats available.

Capacity Problem # 4: Intersecting Runways

The use of ADS-B in the future can increase capacity in managing takeoffs and landings on runways that intersect. At La Guardia, the slowest operational mode is the use of runway 4 for departures and 31 for landings. Because of the configuration, the controller has to wait until it can be clearly determined by visual means that the landing aircraft can stop before the crossing runway or has cleared the crossing runway before allowing the departing aircraft to takeoff. With full use of new technologies the pilot of the departing aircraft will be able to see the landing capability of the arriving aircraft and its braking situation; he can then determine its stopping point. With the ADS-B information, the pilot can be given windows of time in which takeoff is safe, either before the aircraft touches down or as it is coming to a stop. Having this ability will increase, over the course of a day, the arrival and departure flow. This use of the technology would be at the later stages of implementation, once all aircraft and crews are totally capable of using and trusting the systems and it becomes the norm for aircraft operation.

Capacity Problem #5: Separate Takeoff and Arrival Dual Runways

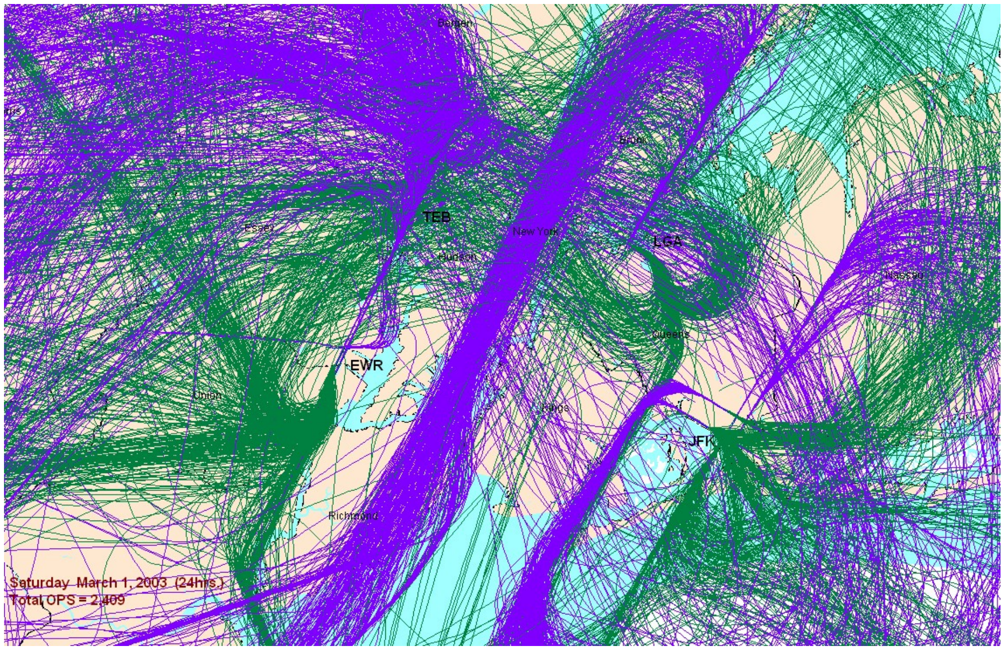
At Newark, with closely spaced parallels, one runway is generally used for takeoffs and the other for landings, making the landing runway the equivalent of a single runway operation. In addition to the above solutions, technology can be used to increase both the arrival and departure rates of both runways. Throughout the day schedules vary from having a large number of takeoffs and fewer arrivals in any given hour to the opposite. During these cycles, when there are fewer departures, arriving aircraft can be sequenced to use both runways for landing, filling the gaps in the departure traffic. The same principle can be used for heavy departure periods. As with all of the above techniques these aircraft will be separated by size and turbulence differences automatically. The increase in capacity using this capability is in addition to any created by the previously discussed means.

Capacity Problem #6: Conflicts with Nearby Airports

The FAA's Capacity Needs report identified eight metro areas with regional airport capacity shortfalls likely in 2025. In three of these—Los Angeles, New York, and the San Francisco Bay Area—one source of the problem is conflicts in traffic flow among the several major airports. Such conflicts limit the capacity of each individual airport, over and above its own capacity problems.

The most significant current example is that of the New York metropolitan area. While each airport can achieve individual capacity increases as discussed above, conflicts among the approach and departure paths of the three Port Authority airports (Kennedy, LaGuardia and Newark) plus their surrounding airports (Teterboro and Westchester among others) create the biggest barrier to traffic growth. Currently, the methods of routing aircraft to and from the airports is a very complex, high-workload (labor-intensive) environment whereby each aircraft has to be threaded through the approach and departure paths of the other airports. In some cases entire runway complexes cannot be used during certain weather conditions, and even using the NextGen systems to place aircraft in the closest possible sequencing for an airport would directly conflict with the procedures of another airport. Figure 16 shows the extreme complexity of the current situation.

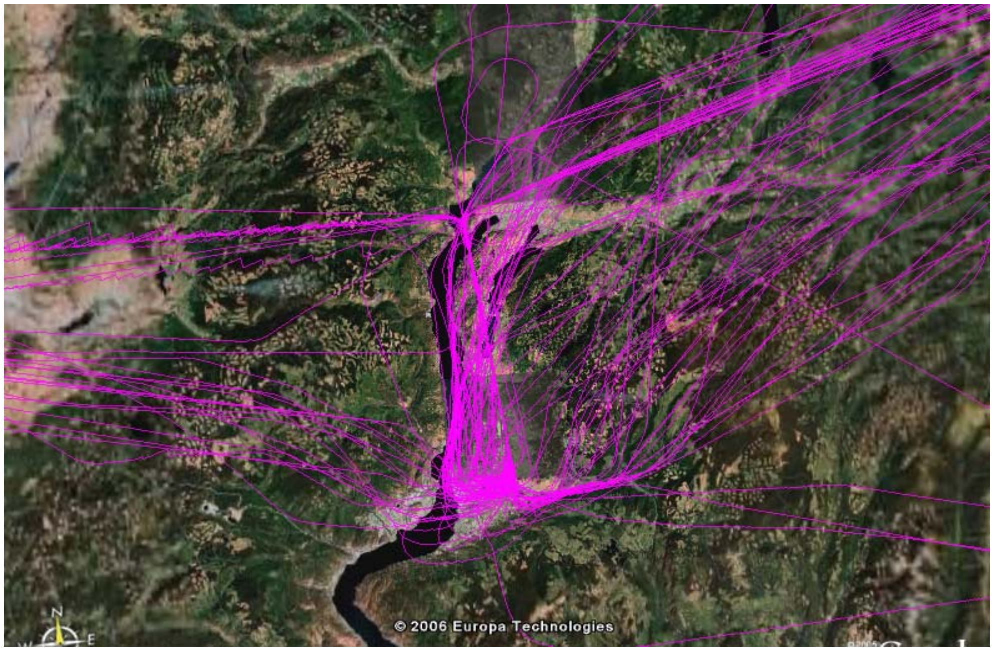
Figure 16: Current Approach and Departure Routings for New York Airports



This representation is a recording of actual flight tracks on one day in 2003. The complexity of this interlacing of arriving and departing aircraft at all the New York-area airports is a major cause of delays. (Source: Port Authority of New York and New Jersey)

A few single lines approaching and departing each runway can replace all of the spaghetti shown in Figure 16. The next illustrations, Figures 17 to 20, which were developed by Naverus for a project in British Columbia, show how RNP procedures can simplify formerly haphazard pilot and controller-managed flight activity. These routings shown in the after pictures can be designed to follow any path that is desired—curved, angled, and at various altitudes—so as always to cross another pattern at the same altitude.

Figure 17: Current Approach Paths in British Columbia

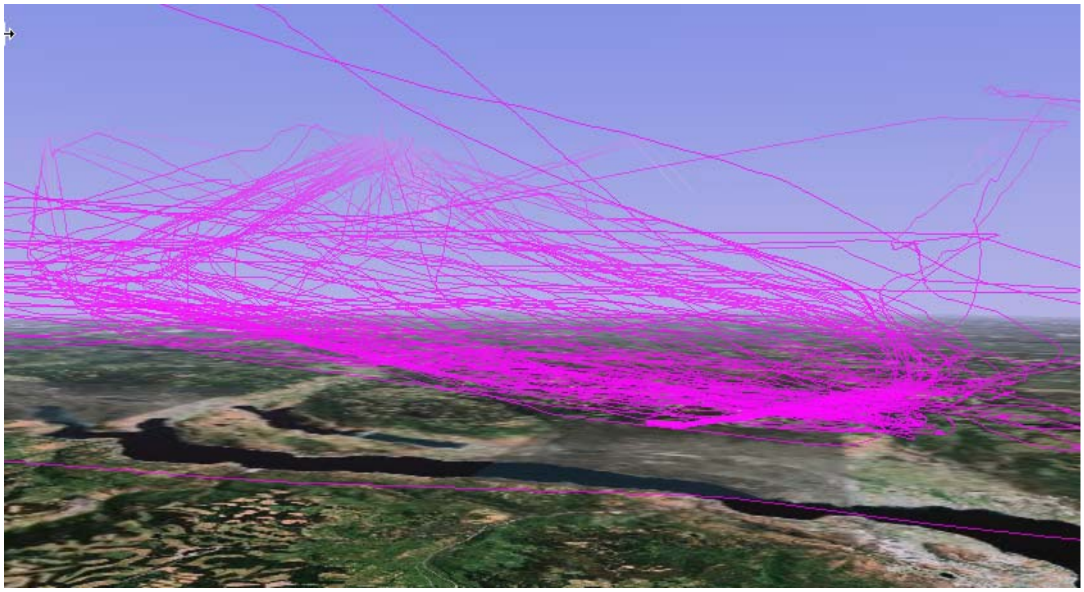


This top-down view is analogous to what the previous figure showed for New York, but for a test in British Columbia. Compare with what is shown in Figure 18 below.(Source: Naverus Corp.)

Figure 18: B.C. Approach Paths Using RNP

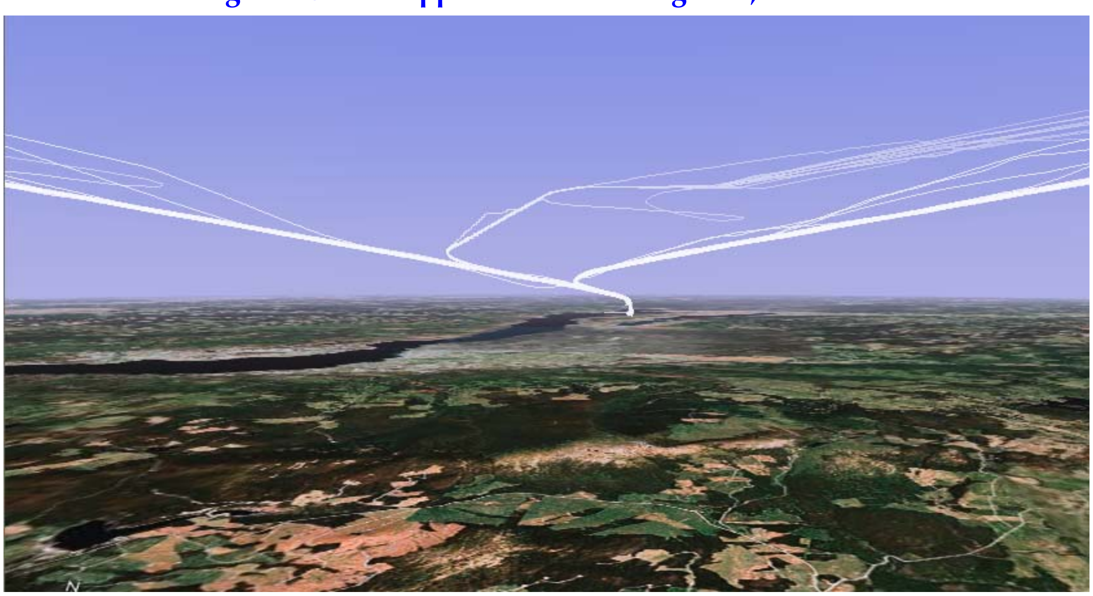
This figure shows the precise and repetitive nature of this new technology. Every aircraft follows the same path all day long. These paths can be designed to follow any routing. (Source: Naverus Corp.)

Figure 19: Current B.C. Approach Paths, Side View



The same recording of current approach paths in British Columbia, shown from the side. (Source: Naverus Corp.)

Figure 20: B.C. Approach Paths Using RNP, Side View



Side view of the same approach paths after the RNP Approach System is implemented. The same results can be achieved in New York with a resulting flow of single lines replacing the many different lines shown in Figure 19. (Source: Naverus Corp.)

Where routings must conflict because of physical constraints, the position of each aircraft can be predicted and each aircraft sequenced so that separation standards are maintained without having to manually route and reroute each aircraft. This can have very beneficial impacts on noise, emissions, fuel usage, and on pilot and controller fatigue. Future users and operators will look back in amazement that the current procedures were even manageable.

As can be seen in the illustrations, the approach can be designed to meet a very precise route that each aircraft will follow. These pictures suggest what the New York airport complex routings could look like in the future. Each airport would have tailored arrival and departure routings for each runway. These routings would be designed to remove conflicts between airports. They also would be designed to minimize noise. When weather conditions create arrival or departure patterns that physically conflict because one airport's departure pattern crosses another's arrival pattern, the system can be designed to assign aircraft so that they will be sequenced correctly and operate over the minimum distance required with the correct separation vertically or horizontally. The New York airport complex would have lines as simple as those in the pictures, with single lines approaching each runway and similar single lines showing departures.

The Port Authority has for some years done flow studies to minimize these conflicts but has had no success in getting them implemented due to the significant efforts required. A new effort is being made with the initiation of the New York, New Jersey, Philadelphia Airspace Redesign Program. With the various technologies emerging, especially RNP, very precise approach and departure routings can be established that allow every aircraft to be sequenced to eliminate circuitous routing and delay as well as reducing fuel consumption and emissions. These routings can also be established to minimize noise by using over river, lake or ocean approaches to the maximum extent possible.

The use of new technologies to improve bad weather approaches to Teterboro (a reliever airport) could substantially increase the capacity of Newark airport. Currently many of the aircraft using Teterboro must divert to Newark when the weather is bad, because Teterboro has less precision approach equipment to allow operations in very low ceiling and visibility conditions. These diversions use up Newark's runway capacity on the ground as well as its approach capacity, requiring greater hold times for aircraft approaching the New York area. If Teterboro had improved technologies, Newark's own bad-weather capacity would be significantly increased, and the capacity of the entire New York airport complex would be increased.

The use of improved technologies, including WAAS, for secondary airports in many metropolitan areas can have a positive impact on major airport capacity by keeping the regional airport traffic in a separate flow from the major airports and making them more attractive for business aircraft, as they will be available in much poorer weather conditions than currently. This will have even more importance in the near future as new very light jets enter the airspace. These jets can be sequenced at altitude and on descent to be separated from and sequenced with faster airline aircraft automatically.

Part 4

Other Issues

Previous sections have focused on how NextGen technology will make it possible to expand the capacity of existing airports in cases where it is physically or politically impossible to expand the airport's land area to add a new runway. In this section, we focus on several additional issues that may affect the policy debates on moving forward expeditiously to implement these technologies.

A. The Environment

While this study has focused on increasing airport capacity, it may well be that the major benefit of this emerging mix of technologies will be on the environment. Some of that improvement will be in the area of noise abatement, as discussed in connection with Continuous Descent Approaches (CDAs). However, the primary environmental impact will come from reduced fuel usage and hence reduced emissions.

If departing aircraft are given very precise departure routings, prescribed turns are optimally sequenced with other aircraft in the area and are separated from arriving aircraft, then the distance covered to altitude while using takeoff and climb power will be reduced. Without having to constantly level off, reduce power then increase power again, fuel consumption at the highest burn rate portion of the flight can be reduced along with the resulting emissions.

The same is true of arriving aircraft, which now at most airports descend in stages of varying speeds and have repetitive changes in power settings. The CDA procedure will lead to major reductions in emissions. If each of the principal airports in the Los Angeles basin (Los Angeles, Burbank, Ontario, and Long Beach) had automated departure and arrival systems that allowed each aircraft's arrival and departure to be totally integrated with the others, the amount of emissions below 10,000 feet in the Los Angeles basin would decline sharply. The efficiencies of these procedures would equal or exceed any new engine technology that could be implemented across the entire fleet within the same time period. The cost of the technology, both in the air and on the ground, is far less than acquiring entirely new fleets of aircraft for the purpose of reducing emissions. At some point in the future, global implementation of these technologies will have a significant impact on total national emissions.

B. Super-Jumbo Jets

Many airport managers are concerned about the advent of very large (super-jumbo) jets, including the Airbus A-380 and Boeing 747-8. These aircraft have wing spans and tail heights that infringe on current clearances between taxiways and runways and between closely spaced parallel runways. A landing or departing super-jumbo may infringe on the wing space of an aircraft taxiing or operating on an adjacent runway. Under currently planned procedures, aircraft must be held clear of the path of the super-jumbo so as to let it land or take off without causing interference. With the addition of the wake turbulence problem (which is even more severe than wake turbulence from current wide-body airliners), a super-jumbo must currently be isolated for many miles from the airport with its own space, separated in trail and from parallel aircraft by inefficient radar sequencing. Ground aircraft movements must be held out of the clear zones for the super-jumbo by visual means, causing delays to aircraft waiting for takeoff.

With NextGen technologies, the super-jumbo can be sequenced from enroute altitude to fit with the optimal spacing with the other aircraft approaching the airport. With new technology on the ground, taxiing aircraft can sequenced to arrive at predetermined points on the airfield that do not obstruct the clear area and be ready to continue taxiing once the super-jumbo passes. These taxiing aircraft can continue to their takeoff position or gate as soon as the super-jumbo passes, even if it is not visible from the control tower in inclement weather.

The ability to handle a number of super-jumbo aircraft with this technology will prolong the viability of existing runway complexes. It is important to repeat that all of this can be done by automated means.

C. International Considerations

Much of what is being discussed in this study may well be implemented internationally before implementation in the United States. Australia, Canada, China, and Thailand are all actively implementing new processes. Australia is now installing ADS-B systems nationwide, Canada and the U.K. are implementing ADS-B and controller-pilot data link communications (CPDLC) on the North Atlantic, and Thailand, India, and others are installing airport surface management systems.

China’s rapidly expanding aviation system has had to rely on existing runways that have very little technological support, such as radar, instrument landing systems, and related legacy systems. By skipping a generation and using technologies now emerging, they can create an automated system that will require significantly fewer people to operate and maintain, less training of personnel to staff control towers and approach facilities, and possess a much higher level of safety than is currently the norm within China.

With the previously described RNP approach to the Tibet airports as an early and dramatic example of what the future may hold, the FAA has recognized China's emergence in this area with the opening of an office in Shanghai to coordinate technology transfer between the United States and China. While some of the technology involved is currently U.S.-developed, as China implements new systems, it will undoubtedly create new methods and procedures at home. If the United States lags in implementation of the systems it needs to create the NextGen capability, it may need to rely on jointly developed products in the future on which it may not have first call.

Historically, the United States has been the technological leader in air navigation systems, i.e. GPS, RNP, inertial navigation, etc., but it may soon be faced with having to share improvements that will be made elsewhere.

D. Human Factors

Overcoming resistance to and relying on technical systems to carry out previously manual procedures has been a challenge for almost two centuries. Invariably, the technology becomes relied on, and the people involved move to a new level of performance. It was once famously said after direct dialing and area codes were developed for the phone system, that if automatic switching and direct dialing had not been implemented, every woman in the United States would eventually have to have been a telephone operator. Today, with a hugely larger volume of telephone activity, telephone operators are rarely accessed, so their numbers have shrunk to a fraction of that needed in the 1950s.

The significance of aviation's coming air traffic management technology is similar. Automation will replace much of the routine process of moving an aircraft from point to point. Pilots today, while relying on many new automated support features in their aircraft, still fly and manage the aircraft and are responsible for avoiding unwanted situations. Air traffic controllers have been operating with the same basic procedures in the same basic environment since the establishment of radar in the 1950s; they are still charged with maintaining separation and routing of aircraft, essentially by hand. They do so in a real-time environment where human intervention is required to instruct pilots on altitude changes, direction, and speed to avoid other aircraft and to sequence aircraft for departure or arrival.

The total integration of the technologies described in this study will greatly increase automated processes to guide aircraft through the entire trip. It will require a great deal of trust in the technology to (1) have each aircraft know where every other aircraft in the area is at all times; (2) allow for centralized processors to know the intentions of every aircraft at all times and for that information to be used to move the aircraft through the airspace efficiently; and (3) be able to sequence aircraft hundreds if not thousands of miles away from their destination airport so that they arrive as closely spaced as possible in an efficient manner and to approach the airport in a closely spaced environment. The change in mindset of the human beings involved in this process is a key challenge that must be managed. It means moving from hands-on, minute-by-minute decision-making to true systems management.

There is an opportunity for the FAA to carefully mange this transition. Over the next 15 years, about two-thirds of the current air traffic control workforce will retire. Developing the implementation schedule for NextGen to include a new approach to recruiting and training replacement controllers would allow for a gradual and seamless transition to a smaller and more efficient workforce. This will require significant changes in selection criteria (e.g., a requirement for a college degree or advanced technical skills) and in training curriculum.[15]

Part 5

Conclusion

The rapid emergence of new technologies as described in this paper can lead to a new way of looking at airport capacity challenges. Depending on the airport, a new runway might not be needed after all, or a new runway could be created inside the current property line, or new aircraft routings can open up existing airports that have previously been constrained.

Additionally, new ways of looking at aviation funding can be achieved. Looking at the entire infrastructure as a whole can bring a more focused analysis of where spending will have the greatest impact. Increased use of technology may reduce fixed capital costs at airports, as well as measurably reducing fuel and crew costs, as well as providing the major benefits of less delay and aggravation on the part of passengers.

For airport planners, the developments discussed in this study warrant taking another look at how best to approach airport capacity expansion. Conventional approaches might suggest spending large sums on fixed facilities that may not be needed as soon, as well as planning for protracted battles with airport neighbors. If NextGen is truly on the way within the planning horizon for new runway projects, airport planners would be derelict in their duties not to consider the impact of those new technologies on airport capacity.

Needless to say, for this new way of planning to take place, airport owners and their consultants must have confidence that the technologies will be delivered over the next 10 to 20 years. That includes not just the FAA's portion but also the timely equipage of the entire fleet of aircraft that will be operating in controlled airspace. Ground-based elements, space-based elements, and on-board elements must all be implemented in a timely, coordinated manner. The federal government must make a strategic commitment to implement the system by a date in the not-too-distant future so that the entire industry can plan now on how to meet the capacity needs poised to overwhelm aviation.

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Joshua Kendrick, Manager, Production Flight Operations, Naverus, Kent, WA, Jan. 26, 2007

John J. Gottsman, UPROAR: Air Traffic Noise in the Bay Area, Jan. 22, 2007

David Smith, Senior Planner, Seattle-Tacoma Int'l Airport, Jan. 25, 2007

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Endnotes

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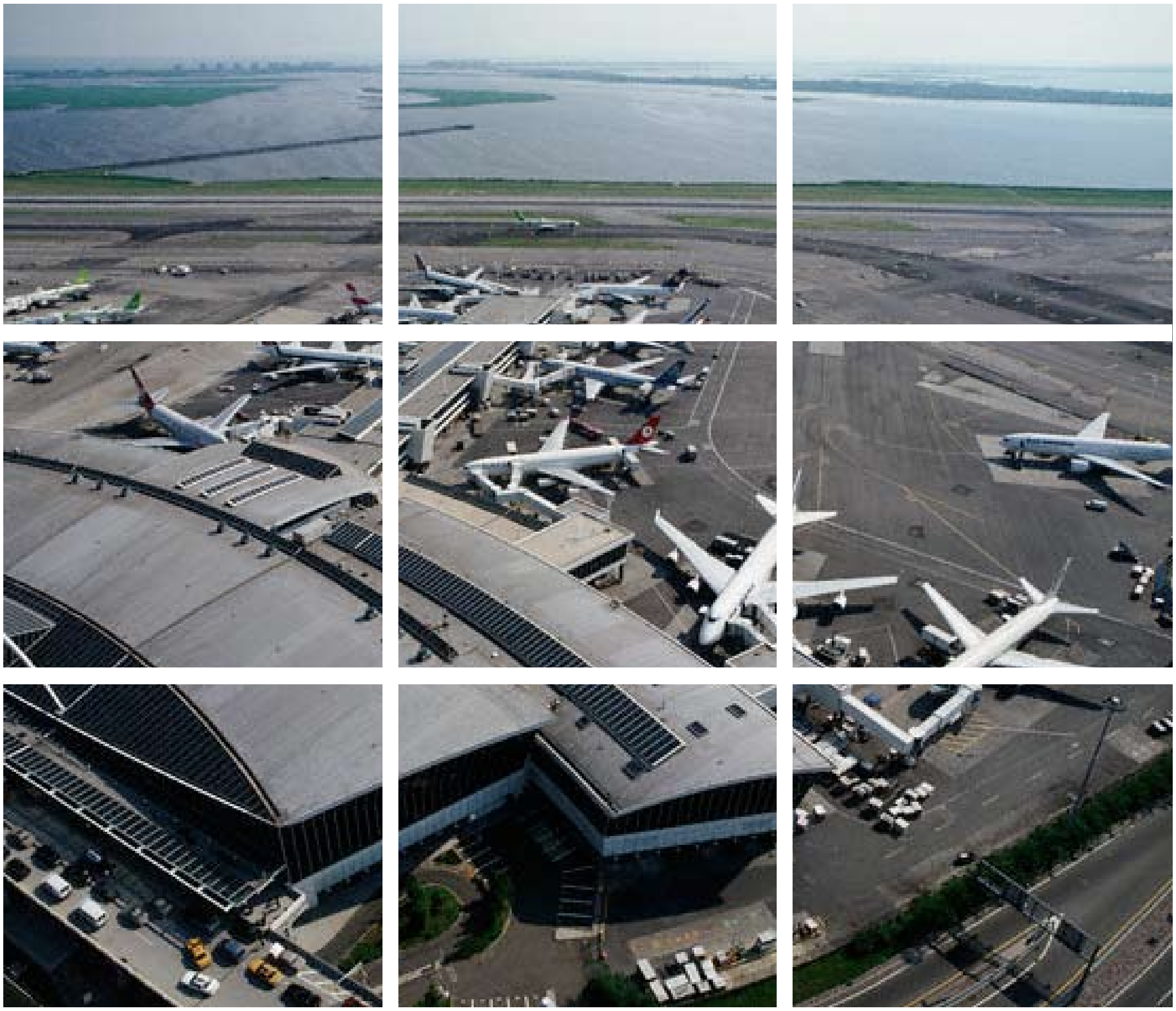

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