HUDSON INSTITUTE INITIATIVE ON FUTURE INNOVATION

ORGANIZATION AND INNOVATION IN AIR TRAFFIC CONTROL

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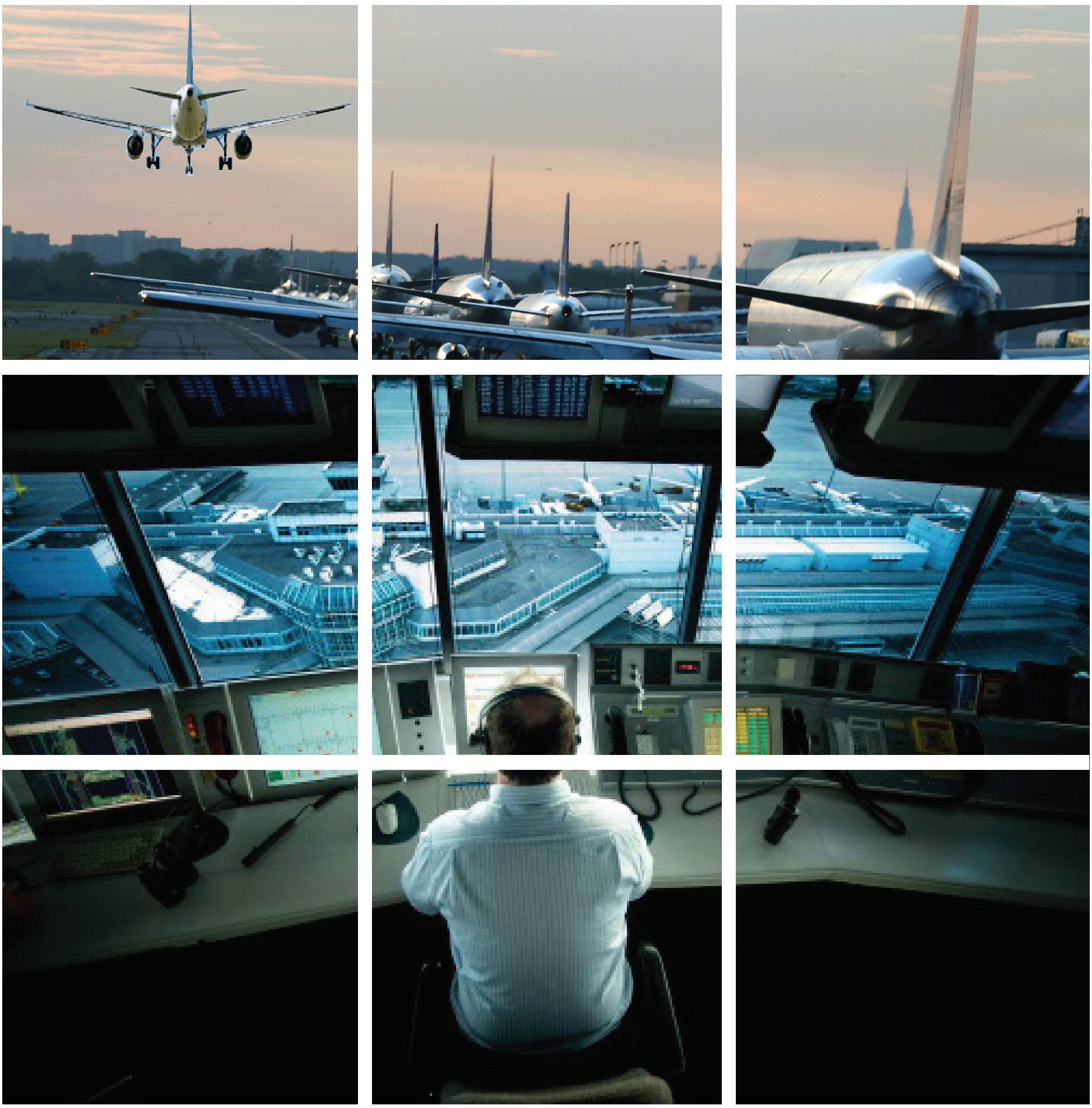

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Air travel in the United States has become safer and more reliable over the past half century. In recent years, however, our air traffic control system has fallen far behind the capacities of current information and communications technologies, even as dramatic improvements have been introduced in Europe, Canada, Australia, and elsewhere. This report documents the substantial benefits of modern air traffic management for safety, speed, reliability, and fuel-economy. Through a series of case studies, it examines the innovation failures of the American system and the causes of those failures. It ends with a detailed proposal for organizational reform.

HUDSON INSTITUTE INITIATIVE ON FUTURE INNOVATION is an effort to understand and sustain American technological innovation. Each report in the Future Innovation series examines innovation in a specific policy area, offering a detailed look at past developments, present policies, and opportunities for change.

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ORGANIZATION AND INNOVATION IN AIR TRAFFIC CONTROL

Executive Summary

Air travel requires communication between aircraft and ground facilities—to maintain safe distances between aircraft and accurate flight paths from origin to destination, and to provide pilots with current information on weather and other critical variables.

In the earliest days of aviation, flight communication consisted of little more than visual cues from the ground from directional pointers, hilltop bonfires, and airport beacons. The advent of radio in the 1920s brought voice communications between pilots and ground controllers. That was the beginning of active "air traffic control" (or ATC, an acronym used throughout this report).

By the 1950s, the federal government and local airport authorities had established an elaborate system of ground stations, radar arrays, and requirements that aircraft be equipped with standard communications equipment.

By the 1960s, the familiar features of today's ATC system were all in place: tall control towers astride airports, professional air traffic controllers focused intently on screens with moving "blips" that show planes in flight, pilots talking in jargon to controllers while flipping radio frequencies to maintain contact, and frequently, ground delays before takeoff and flying in holding patterns before landing at congested airports.

Since then, many new technologies, such as powerful computers in ATC facilities and collision avoidance systems in aircraft, have made air travel progressively safer and more reliable. But the basic features and procedures of the 1960s ATC system have remained remarkably unchanged through a half century of dramatic advances in technology and management in many other realms.

In recent years, the U.S. system has fallen well behind the capacity of new technologies to provide safer, faster, more reliable, and more fuel-efficient air travel and to keep pace with the increasing volume of air traffic.

For example:

- Most flights still fly a zigzag path to their destination because they must fly directly over a succession of ground-based radio beacons.
- Nearly all communications are still by voice radio, despite the ubiquity of text messaging and its greater ease and accuracy for routine communications.
- Radar remains the principal means of aircraft position surveillance, despite the much-greater accuracy of GPS and other systems.
- Airport control towers and other ATC facilities are still located directly beneath the airspace they manage, even though technology permits air traffic management from a much smaller number of larger and more efficient facilities that manage airspace "anywhere from anywhere."

Today, automobile drivers with smartphones and mapping, traffic, and weather apps have access to more accurate real-time information than aircraft pilots receive from our ATC system. Flight times today on high-volume, intermediate-range routes are scarcely better, and in some cases they are worse, than they were in the 1960s, when commercial flights used either propeller planes or early jetliners. Our ability to provide a vastly improved system is not in question. Over the past two decades, aviation experts have developed a new air traffic paradigm—often called air traffic *management*, or ATM, to emphasize its use of much richer information than a single locus of "control." Under this framework, technologies such as digital communications and GPS could facilitate automating much of the routine separation of aircraft, permitting far greater use of the entire airspace than the limited "airways" defined by ground-based navigation aids. New technologies and procedures would also increase the effective capacity of airport runways, improve landing protocols, transform staffed ATC facilities on the ground, and provide pilots with more accurate and timely information on weather and other variables.

The new paradigm, which we will call advanced ATM, has been embraced by the International Civil Aviation Organization, the European Commission, and ATC providers in the major developed countries—including the Federal Aviation Administration (FAA) in the United States and its counterparts in Canada, Europe, Australia, and New Zealand. Fully implemented, it would provide tremendous, wide-ranging benefits:

- savings in cost and time for aircraft operators and air travelers;
- reduced airport and airspace congestion, and hence fewer constraints on continued aviation growth;
- increased safety, thanks to more accurate information in the hands of pilots and controllers and better communications throughout the system;
- environmental benefits, as more direct routes and low-power landings reduce fuel consumption, noise, and emissions;
- increased exports of U.S.-developed technologies and services to the global air traffic market.

Unfortunately, progress toward implementing advanced ATM in the United States (where the system is called "NextGen") has been far slower than anticipated. This report uses case studies of seven critical elements of NextGen to examine the problems encountered in the U.S. effort:

1. digital communications between pilots and controllers
2. GPS-based landing as a replacement for legacy instrument landing systems
3. GPS aircraft surveillance as a replacement for ground radar (for most purposes)
4. "performance-based navigation"
5. real-time aviation weather data
6. remote airport towers employing digital imaging
7. air traffic facilities consolidation.

Several important lessons emerge from these studies. The FAA is slow to embrace promising innovations that originate in outside research organizations or private-sector companies. When the agency does embrace something new, it has a hard time defining its requirements and often delegates this task to contractors—who come up with many add-on functions that increase cost and make implementation more complex. And the FAA does a poor job of procuring new technology, with many programs eventually cancelled or emerging years late at inflated cost. The agency is particularly resistant to high-potential innovations that would disrupt its own institutional status quo—such as performance-based navigation, real-time weather, and remote towers.

This report identifies five institutional factors that account for the FAA's status-quo bias. These come from the case studies and three decades of critical reports by the Department of Transportation Inspector General and the GAO (initially known as the General Accounting Office and now called the Government Accountability Office):

1. The FAA is both the ATC service provider and the aviation safety regulator, and its self-identity as a safety agency has led to an over-cautious culture that is unlike that of aerospace companies, which are regulated for safety at arm's length by the FAA.
2. Over the years, the FAA has experienced a brain drain, losing the best and the brightest engineers to the private sector, which provides better compensation and a more challenging work culture.
3. For similar reasons, the FAA has lost program management expertise, making it overly reliant on contractors it has difficulty controlling.
4. Given the FAA's long history of problems, it must contend with oversight from the GAO, the Inspector General, a number of congressional committees, the Office of Management and Budget, and the Department of Transportation, all of which divert considerable management attention.
5. As a result, the FAA tends to focus on pleasing its various political overseers rather than its aviation customers, who are directly concerned with the quality, effectiveness, and cost of ATC.

Some ATC providers in other countries have embraced new technologies and procedures much more readily than the FAA, including providers in Australia, New Zealand, Canada, Germany, and the UK, all of which were formerly part of government aviation agencies, as the FAA is today. Over the past twenty-five years, all of them have been reorganized as self-supporting corporate entities, charging aviation customers directly for their ATC services and issuing bonds backed by their revenue streams. Independent studies have found that these providers are more customer-focused, quicker to adopt and implement new technologies and procedures, and better funded (since their revenue does not depend on the government's budget).

These findings lead to the conclusion that reform of the U.S. air traffic system's funding and governance—organizational reform—is the key to a full embrace of advanced ATM in the United States. The three necessary changes are:

1. Separate the FAA's Air Traffic Organization (ATO) from the rest of the agency, making it an ATC provider like those overseas. The new entity would be regulated at arm's length by the remaining part of the FAA, which would become exclusively an air safety regulator. This would be analogous to the highly successful 1987 divestiture of Dulles International and Washington National Airport from the FAA to a self-funded airport authority.
2. Shift from funding ATC from aviation user taxes—which must be appropriated each year as part of the federal budget—to charges paid by aviation customers directly to the revamped ATO, which could then issue revenue bonds for large-scale capital modernization as do airports, electric utilities, railroads, and other infrastructure providers.
3. Provide for a governing board that represents the key aviation stakeholders, as is done with the ATC corporations in Canada and the UK. The board, representing aircraft operators, airports, and ATC employees, would set policies for the corporation, including decisions on whether new technologies and procedures have positive business cases. A model for this kind of decision making is the role played by the current NextGen Advisory Committee, which represents a broad coalition of aviation stakeholders.

The worsening federal budget problems in 2013, including the initial impact of the ten-year spending sequester, have led to intense discussions among aviation stakeholders about the need for funding and governance reform. At the same time, establishing a customer-funded ATC corporation would provide net savings to the federal budget. Thus, the time may be ripe for the United States to emulate the kinds of organizational reforms embraced by other developed nations.

This report is aimed at both general readers and aviation experts. It begins with a brief introduction to air traffic control procedures and technologies, followed by an account of how advanced ATM would fundamentally improve the current control system. That sets the stage for the seven case studies of air traffic innovations that have been implemented, with varying degrees of success, in the United States and abroad. The case studies show that the FAA's organizational, financial, and governance structure has left it increasingly out of step with the demands of modern air traffic management—leading to our five underlying causes of the FAA's difficulties. The final section draws on successful models from other countries that could be applied to produce a more dynamic, effective, safe, and innovation-friendly air navigation system for the United States.

Air traffic control is rife with acronyms that will be familiar only to expert readers. To assist general readers, we have provided a glossary of key terms and their acronyms at the end of the report.

ORGANIZATION AND INNOVATION IN AIR TRAFFIC CONTROL

Introduction to Air Traffic Control

Air traffic control (ATC) is essential to a safe, efficient, and effective aviation system. Its main purpose is to keep planes sufficiently separated from one another to prevent collisions, but it also serves to organize the flow of air traffic. Modern ATC began in 1929 with a non-profit company owned by several airlines. Aeronautical Radio, Inc. (ARINC) stimulated the development of airborne radios for communications, ground-based VOR radio beacons for navigation, and instrument landing systems (ILSs) for airport landings. ARINC also set up the first two ATC staffed facilities in 1935–36, serving the route linking Newark, Cleveland, and Chicago. In 1936, the Bureau of Air Commerce in the U.S. Department of Commerce took over this service from ARINC, relieving the struggling airlines of this cost.[1]

The very first air traffic guidance was provided by bonfires and later, lighted airway beacons on hilltops. These enabled pilots to follow pre-defined paths across the landscape, with periodic radio communications with ARINC controllers and airline dispatchers. The lighted beacons were subsequently replaced with VORs, and cockpits were equipped with instruments enabling pilots to follow straight-line paths to overfly each VOR using routes defined by the ATC system and assigned to each plane by controllers. In the early years, control towers were operated by airports, but starting in 1941, this function was taken over by the federal government as part of the ATC system. ILSs used equipment on planes and in the airport that enabled safe landings in low-visibility conditions.

Congress converted the Bureau of Air Commerce into the independent Civil Aeronautics Authority in 1938. The organization was responsible not only for operating ATC, but also for subsidizing and regulating the fledgling airline industry and issuing licenses to all pilots. In 1940, another reorganization split it into the Civil Aeronautics Board (CAB), which was responsible for economic regulation and subsidy, and the Civil Aviation Administration (CAA), which was in charge of ATC and safety regulation.

The costs of operating the ATC system continued to be covered out of general federal tax revenue.

Military efforts during World War II led to the development of radar for the armed forces, and as aviation expanded greatly after World War II, a series of mid-air collisions in the 1950s led the CAA to implement radar surveillance nationwide. This shift permitted controllers to see blips representing planes on scopes in ATC facilities, instead of relying on pilots' radio reports to approximate the position of each plane in a particular airspace sector. Airspace was divided into segments based on altitude and proximity to airports, and only planes equipped to fly using instruments, following an approved CAA flight plan, were allowed in such "controlled airspace" around major airports and at higher altitudes. By the early 1960s, all planes flying in controlled airspace had to be equipped with transponders—devices that send out signals, when interrogated, which identify the plane by a unique code number and report its altitude. Interrogation is done via "secondary" radar, which sends the information to the controller's radar scope as a tag that appears next to the blip from primary radar representing the plane itself.

In 1958, the CAA became the Federal Aviation Administration (FAA), which remained an independent agency until creation of the U.S. Department of Transportation (DOT) in 1967 (at which time the FAA became a modal agency within DOT).

During the 1960s, the FAA installed mainframe computers to manage and display the information at each of the 20 domestic en-route ATC Centers that monitor and direct high-altitude traffic. It also installed local computers at the nearly 200 terminal radar approach control facilities (TRACONs) that managed arrivals and departures for passenger airports. Control towers at airports handled the actual take-offs and landings.

In 1970, Congress enacted several aviation excise taxes and created the Airport and Airways Trust Fund to account for the revenues, which were to be spent only on aviation infrastructure (later expanded to include FAA operations). The FAA's three major tasks today are to operate the ATC system, make grants for airport improvements, and regulate all aspects of aviation safety (airlines, private planes, airports, aircraft manufacturers, aviation mechanics, commercial space launchers, etc.). The agency's annual budget comes from a combination of revenue from aviation excise taxes (via the Trust Fund) and general federal revenue. In recent years, the general fund portion has varied between 20 and 30 percent of FAA's total budget. Congress appropriates the FAA's budget each year and periodically reauthorizes the program and the excise taxes (typically every three-to-five years). The Airline Deregulation Act of 1978 eliminated the main function of the CAB and the agency itself in 1984. Deregulation ushered in a new era of price competition, which led to lower fares and faster growth of air travel, as well as a shift by airlines to a system largely based on hubs and spokes.

Old and New Paradigms

The Existing ATC Paradigm

Air traffic control consists of three essential functions: surveillance (confirmation of where the planes are), communications (passing data and instructions between pilots and controllers), and navigation (assisting pilots to direct their planes along safe paths). By the 1960s, these functions were provided as follows:

- **Surveillance:** Primary radar tracked the movement of all planes within a given block of airspace, with secondary radar providing more specific information about each plane. Signals from both types of radar were received by the geographically closest radar and transmitted to the nearby TRACON, or en-route Center, processed by mainframe computers, and displayed on controllers' scopes.
- **Communications:** All communications between pilots and controllers were conducted by voice radio. Pilots had to change frequencies as they moved from one sector controller to another along their routes.
- **Navigation:** In controlled airspace, planes flew under instrument flight rules (IFR). Pilots filed flight plans with the FAA for pre-flight approval by controllers. Typically, flight plans directed the plane from one VOR to another in a zigzag path from the originating airport to the destination. Controllers handed off each plane as it passed from one sector to another. Jetliners increasingly came equipped with inertial (gyroscopic) navigation systems. These separately kept track of their positions, which were reported to the pilot and to airline dispatchers. Later, onboard computers called flight management systems (FMSs) were installed on jetliners.

> Though an FMS could calculate and fly a straight-line path rather than zigzag, controllers seldom approved "going direct."

It should be noted that smaller planes operating in less congested airspace and at lower altitudes can and do fly under visual flight rules (VFR), meaning that pilots—not controllers—are responsible for separation from other aircraft.

ATC today still operates very much as it did in the 1960s, albeit on a much larger scale. The FAA reports that in 2012, its 514 control towers handled 50.6 million takeoffs and landings—21.9 million by commercial aircraft, 26.1 million by general-aviation (business and personal) aircraft, and 2.6 million by military aircraft. One major improvement was the introduction of a mandatory threat collision avoidance system (TCAS) during the late 1980s. In addition, several software tools were introduced in the 1990s. For example, Traffic Management Advisor is used to organize the transition of planes between en-route airspace and terminal-area airspace, and User Request Evaluation Tool helps controllers spot potential conflicts when authorizing pilots to take a direct route rather than zigzagging over VORs.

There is a limit to the number of planes a controller can keep track of at one time, so as air traffic has increased decade by decade, airspace has had to be subdivided into more and more sectors. Computers, displays, and software have grown more capable, but they perform the same basic functions as their predecessors in the 1960s. Despite several efforts to restructure the system to improve productivity, notably the National Airspace System (NAS) Plan during the 1980s, ATC productivity has not increased, and costs have continued to rise, along with the size of the controller workforce.

Vision of a Paradigm Shift

New technologies have opened up possibilities for dramatic improvements to the old ATC paradigm. Instead of a system that is largely "procedural," with every movement requiring specific permission from a controller, a modern air traffic system could permit flights to operate far more on user-preferred routings, optimized for user preferences, such as minimized fuel consumption or shortest overall time. Widely available GPS signals could be used to keep track of planes' locations with greater precision than radar, whether en-route at high altitudes or during airport approaches and departures. The large buffer zones separating planes in flight could thus be reduced, thereby increasing the safe capacity of specific segments of the airspace. Most communications between pilots and controllers are routine matters that could be transmitted as text messages, which would avoid frequency congestion and errors due to mis-hearing, while freeing controllers to separate and manage air traffic. Most flights could be "direct," based on the user's preferred altitudes and routing, and not constrained to pre-defined airways. Many aspects of routine separation could also be automated, with the "controller" evolving into a traffic manager. This paradigm shift from air traffic *control* to air traffic *management* would eliminate the need to place air traffic facilities directly beneath the patch of sky they deal with. With large-scale use of real-time information, facilitated by high-speed data networks, air traffic *anywhere* in a country could be managed *from anywhere* in the country.

This new paradigm originated in the 1980s and was studied during the 1990s and early 2000s by researchers at NASA, at FAA-related think tanks such as MITRE Corporation and Lincoln Laboratories, and in aerospace departments of various universities. Similar studies were taking place in Europe and elsewhere in the global aviation community. U.S. researchers came to realize that this paradigm shift could dramatically increase the capacity of the national airspace system, finally permitting significant increases in ATC productivity by making air traffic management more efficient and less labor intensive. And by eliminating the need to have facilities located directly beneath the airspace they manage, the new paradigm could lead to large-scale consolidation of ATC facilities, offering economies of scale that would further increase productivity.[2]

Those researching the new paradigm itemized the benefits that would be realized from this kind of transition. They include:

- **Savings in cost and time to airspace users:** Reduced fuel consumption—due to more direct routings, optimal altitudes, less delay in holding patterns, and other efficiencies—would reduce the largest single operating cost of aircraft today. In addition, the gains in productivity thanks to partial automation and, over time, facility consolidation, would reduce the costs of the ATC system, which are largely borne by those who use it (either via user taxes or direct fees and charges).

- **Reduced congestion, fewer constraints on growth:** The existing labor-intensive model cannot really be scaled up to manage the significantly larger volumes of air traffic that presumably would accompany continued economic growth. Without major capacity increases, the result is likely to be increased congestion and either higher air fares or some form of rationing. Direct routing will decongest existing airways. The new paradigm could also increase the effective capacity of existing runways,[3] but additional runways will still be needed for continued aviation growth.
- **Increased safety:** Throughout aviation history, every new technology (such as radio, VOR, ILS, radar, TCAS) has improved air safety. A new system using far more precise and immediate information about where planes are and where they are heading, and depending less on human visualization in three dimensions of up to a dozen moving aircraft on a two-dimensional display, would be much safer than the largely manual system it replaces. Independent safety regulation would help ensure that this is the case.
- **Environmental benefits:** The inefficiency of current ATC practices (resulting from excessive fuel consumption and hence increased emission of CO_2 and conventional pollutants) has been estimated at 12 percent by the Intergovernmental Panel on Climate Change, and that estimate is widely accepted in the aviation community. The new paradigm holds the potential to eliminate most of that.
- **Increased technology exports:** If the United States develops and implements technologies and procedures to introduce the new paradigm, our aerospace and avionics companies will be better positioned to compete with their overseas counterparts for upgrading air traffic control in the rest of the world. This will spur global adoption of the new paradigm and realization of its benefits.

Attempts at Transition

NextGen in the United States

In response to an Aerospace Commission report[4] in 2002, the DOT, under Secretary Norman Mineta, discussed the new paradigm with leaders of several other federal agencies with an interest in the NAS—including the Departments of Defense, Homeland Security, and Commerce (National Weather Service) and NASA. They proposed a multi-agency program office to flesh out the concept and develop plans for implementation, and in 2003, Congress authorized creation of the Joint Planning & Development Office (JPDO). With DOT as the de facto lead agency, the JPDO developed a concept of operations, an enterprise architecture, and an integrated work plan for what was initially known as the Next Generation Air Transportation System. The awkward acronym NGATS was soon replaced by the catchier term NextGen. Because air traffic management was the major component, near-term planning and implementation became largely the job of the FAA.

Single European Sky

At about the same time, the European Commission undertook a similar effort in response to the new technology-based vision and to growing airline complaints. The complaints focused on much higher ATC costs in Europe and inefficient routings that led to excessive fuel consumption and made greenhouse gas reduction targets more difficult to achieve. The fragmented European ATC system was identified as a fundamental cause of inefficient routings and higher costs. With annual air traffic activity roughly comparable to that of the United States, the system had thirty-one different air navigation service providers (ANSPs) and sixty-eight en-route control Centers (compared with twenty in the United States).

The resulting program was dubbed the Single European Sky (SES). In 2004, after further study, the European Commission created the Single European Sky ATM Research program—SESAR—an industry-government body for planning implementation of the new technology and changes in procedures.

A number of other ANSPs, such as those of Australia, New Zealand, and Canada, also appreciated the potential of the new paradigm and began their own efforts to introduce new technologies and procedures. And in 2012, the International Civil Aviation Organization (ICAO) brought together the ANSPs of most of its 191 member nations to reach agreement on a phased series of air traffic "block upgrades" aimed at coordinating the improvements in what is an increasingly global aviation industry.

Disappointing Results

Unfortunately, despite extensive public relations about NextGen, SESAR, and small pilot projects, the large FAA bureaucracy (with a long and well-documented history of difficulty in carrying out technology procurements on time and on budget) has made far less progress than most of the aviation community expected. NextGen requires aircraft operators to equip their planes in parallel with FAA upgrades, and airlines and business jet operators are understandably skeptical that large investments in upgrading their planes will lead to timely benefits. That is partly because the FAA must fund its estimated $20 billion modernization program from annual appropriations from Congress, and such a major capital program is even more difficult than it would normally be because the federal budget is under increasing pressure. Also, the FAA is believed to have managers and staff who are skeptical of replacing radar with GPS-based technologies and creating systems that change traffic controllers to traffic managers.

FAA modernization programs have repeatedly failed to increase ATC productivity. Some see this as another sign of resistance to fundamental change, which leads only to replacement of older technology with newer (and costlier) technology that performs the same tasks and leaves the same flight procedures as before. Moreover, since Congress provides the FAA's funding, the agency tends to regard Congress as its customer. This situation would be very different if the aviation industry were paying directly for the FAA's services and demanding improvements that could pass a business case test.

Europe faces variations on these problems, but some of its ANSPs are more open to change than others. The largest problem is that many of the governments of the thirty-one countries involved in the SES project are highly resistant to unification of the airspace across national borders.

This is true even to the limited extent required under the plans to create nine "functional airspace blocks" within which national ATC providers would jointly streamline air routes and consolidate facilities. As a result, Europe's progress toward implementing the new paradigm has also been slow, except for a few pilot projects involving demonstrations of new technology and procedures.

Organizational Change Overseas

Most developed countries (other than the United States) have enacted fairly sweeping organizational reforms of their ANSPs over the past twenty-five years, separate from, and largely prior to, the launch of NextGen and SESAR. Until 1987, nearly all ATC was provided by a government aviation ministry or department which, like our FAA, was both safety regulator and ATC provider. Since then, beginning with Airways New Zealand in 1987, more than fifty nations have transformed their ATC providers into single-purpose corporations operated or regulated by their governments. With some variation across nations, the general pattern has been to separate ATC from safety regulation and give the provider a corporate form (in most cases government owned) with authority to charge airspace users directly for its services. The revenue streams paid directly to these ANSPs enable them to issue revenue bonds to finance large capital improvement programs. The larger ANSPs have generally obtained investment-grade bond ratings.

Financial autonomy means that these ANSPs are neither affected by government budget cuts nor subject to micromanagement by legislative bodies. Decisions to close or consolidate facilities (within national borders) are made strictly as business, not political, decisions. In addition, the direct user-pays relationship with aviation customers is intended to reorient the ANSP's focus from satisfying its former de facto customer (the legislative body) to satisfying its real (aviation) customers.[5]

Although there have been off-and-on discussions of similar reforms in the United States, and serious reform proposals during the Reagan and Clinton administrations, none has proceeded very far, and the FAA is today an outlier among the world's major ANSPs.

Innovation in Practice

We now turn to seven case studies of recent efforts to introduce innovations in the provision of air traffic services. All of these efforts have had to confront the built-in status-quo bias that has been inherent in ATC, given its historical provision by air safety organizations. A consistent finding, however, is that reformed, corporatized, customer-focused ANSPs have been far more successful in deploying major improvements than the unreformed, politicized agencies exemplified by the FAA.

Case Study 1: Digital Communications between Pilots and Controllers

The first successful concept for digital messaging between ATC and pilots originated with FAA research in the 1970s but was developed and implemented by the ICAO Special Committee on Future Air Navigation Systems (FANS), created in 1983. The committee, which included airlines and both avionics and aircraft manufacturers, developed the concept of CNS/ATM (Communications/Navigation/Surveillance for Air Traffic Management), a precursor of the paradigm shift discussed previously. The initial focus was to improve air traffic management in airspace that is out of the range of both radar and normal VHF radio communication (such as over the oceans and over large under-populated land masses). ATC in such airspace had always been "procedural"; since neither controllers nor pilots knew exactly where planes were, the practice was to create a huge margin of safety around each plane, 100 nautical miles (nm) laterally and 120 nm longitudinally, for a total of 12,000 square miles. Pilots would periodically report their estimated position via slow, long-range high-frequency radio.

CNS/ATM aimed to take advantage of GPS for navigation and surveillance, along with digital satellite communications, combined with the capabilities of existing inertial navigation systems and FMS computers on intercontinental jets. Boeing's solution, called FANS 1, was first certified on a Qantas 747 in 1995, and the following year, the first FANS 1 routes began in the Pacific airspace. As Airbus soon followed with its very similar FANS A, the overall system became known as FANS 1/A. In addition to using GPS for navigation and Inmarsat satellites for digital communications between pilots and dispatchers (a kind of data link), FANS also provided Automatic Dependent Surveillance (ADS), which used data communications to send position information to controllers.

Although the FAA accepted FANS 1/A due to its obvious improvements for oceanic airspace, it was many years before the agency's oceanic airspace software was made compatible with it so as to provide radar-like position information on controller displays. Furthermore, once FANS was operational in Pacific and North Atlantic airspace, the FAA was very slow to consider similar controller-pilot data link communications (CPDLC) for domestic airspace. Finally, in October 2002, the agency launched a pilot program at Miami Center in cooperation with American Airlines. Like FANS 1/A in oceanic airspace, this CPDLC program relied on software updates to the aircraft's FMS computer and made use of the existing text communications system, ACARS (aircraft communications addressing and reporting system), which was operated by ARINC and had previously been used only for data communications between pilots and airline dispatchers.

American initially equipped ten of its 757s and planned to add four 767s to the trial. The FAA's plan was to conduct a one-year trial and then expand CPDLC to the rest of the twenty domestic Centers by 2005. But in April 2003, the agency announced that the system would not be expanded until many years in the future because of the high cost of the ARINC messages, FAA budgetary constraints, and the fact that the benefits accrued mostly to airspace users, not the agency. (This was despite the fact that a study for the FAA showed how to expand CPDLC to all twenty Centers at lower cost.[6]) By that point, American had equipped twenty 757s, and Continental, Delta, and FedEx were planning to join the Miami program later in 2003. But the pilot program itself was terminated later that year, to the great dismay of the airlines, which saw CPDLC as "the key architectural enabler of almost any future envisioned air traffic management system."[7]

American subsequently transferred the CPDLC-equipped 757s to Europe, where Eurocontrol (a multilateral agency with European ATC responsibilities) had announced a schedule for phasing in data link, equipping key Centers and requiring all new aircraft to be equipped starting in 2009 and all in-service aircraft by 2014. That program has continued, with the 2014 deadline slipping only slightly, to February

2015. As of early 2013, the German and Swiss ANSPs (both corporatized) had equipped their principal Centers for data link, as had Eurocontrol for the airspace where it serves as the ANSP (Maastricht Upper Airspace Control). The system will provide data link communications in all phases of flight by 2015: pre-departure clearance, climb-out, en-route, approach, and landing. Honeywell, the supplier, expects the reduced workload in en-route communications alone to add 11 percent to effective capacity once 75 percent of aircraft are using it.

NAV CANADA and the UK's National Air Traffic Service (NATS), both corporatized, worked closely to provide controller-pilot data link across the North Atlantic beginning in 2003. In 2011, NAV CANADA began phasing in domestic data link in its en-route Centers across the country, with all Centers slated to be operational before the end of 2013. As of June 2013, the percentage of airliners equipped ranged from 65 percent in Gander Domestic airspace region (adjacent to Gander Oceanic airspace region) to a low of 25 percent in western Canada.

In 2012, the FAA finally relaunched CPDLC (with some added functions and renamed DataComm), awarding a contract to a team led by Harris Corporation. The initial test phase provides only pre-departure clearances to planes at the gate, and that capability will be rolled out to control towers beginning in 2016, with CPDLC at en-route Centers starting in 2019, and system-wide capacity in full operation by 2025.

What does this episode tell us? First, the introduction of data link was not led by ANSPs. Instead, it was developed and implemented under the auspices of ICAO by aircraft producers Airbus and Boeing, working with airlines. It was intended to meet a real need for improved performance in oceanic airspace, given the primitive service then offered by ANSPs. And while it made considerable use of equipment already installed on intercontinental jet airliners—FMS computers, inertial navigation equipment, and the ACARS digital text-messaging system transmitting via satellite—it still required airline investment in GPS equipment and FMS software upgrades. Eurocontrol and corporatized ANSPs, along with FMS providers like Honeywell, then took the lead in introducing data link into domestic airspace in Europe and Canada. The real laggard was the FAA, constrained by annual appropriations from Congress and apparently unable to understand the benefits to itself and its aviation customers.

Case Study 2: Replacing ILS with GPS-Based Landing Systems

In the early 1990s, several avionics companies, including Honeywell and Raytheon, used corporate funds to develop prototype airport landing systems that used GPS signals instead of traditional radio-based instrument landing systems. The idea was that if GPS signals from satellites were error corrected (augmented) using several fixed transmitters at known locations at and near an airport, they could provide precision landing guidance for all runway ends at the airport at significantly lower cost than ILSs, which require a separate system for each runway end. Thus, airports without an ILS could install a single ground-based augmentation system (GBAS), which augments GPS signals to guide planes to precision landings, and those using ILSs could gradually replace them with GBAS. FedEx spent company funds to develop and test a prototype system at its hub in Memphis, and by 1998, enough data had been gathered from prototypes to persuade the FAA to launch a development program, which it called the Local Area Augmentation System (LAAS).

But in October 2003, the Inspector General reported that the LAAS program was experiencing serious technical difficulties and was unlikely to be capable of handling the most precise landing approaches (so-called Category II and Category III approaches, for landing safely in conditions of very poor visibility, which some existing ILSs can achieve). The report estimated that only 20 percent of the development work needed to achieve even less-stringent Category I accuracy had been completed by that point in the contract, instead of the expected 80 percent.[8] In February 2004, after $200 million had been spent, the FAA pulled the plug on LAAS and instead continued funding large numbers of new and replacement ILSs (while continuing a small R&D contract for further work on the LAAS concept).

Honeywell was unwilling to give up, however, and began work with corporatized ANSP Airservices Australia to develop a workable Category I version of GBAS. FedEx and German ANSP DFS separately continued similar work. By 2007, an Airservices/Honeywell GBAS prototype was in test operation at Sydney, able to provide Category I service at both ends of its three runways with a single unit. Prototypes were subsequently installed and tested at Memphis for FedEx, Newark for Continental, and at Bremen, Germany and Malaga, Spain. The FAA certified Honeywell's Smartpath GBAS in September 2009, but as a "non-federal" system, meaning that the agency would not fund it or take responsibility for its performance. In 2012, air safety regulators in Australia and Germany approved Smartpath for regular (as opposed to only test) operations, and the FAA approved regular operations of the system at Newark and Houston. So far, these systems are providing only Category I approaches, although Honeywell is continuing work on achieving the precision needed to get its system certified for Category II and III landings. Encouragingly, Norwegian company Indra Navia had its prototype Category III GBAS approved for operational testing in Frankfurt, Germany, in June 2013.

In this case, we have an example of the private sector initiating the development of a new application of GPS for aviation. Evidently, the FAA misjudged how far the research had progressed when it entered into a contract to develop LAAS, then erred in the other direction after the strong criticism of the Inspector General's report. The more entrepreneurial Airservices Australia was willing to work with Honeywell to further develop the system, with positive results thus far. The only remaining question is when the more precise Category II and Category III capabilities will reach certification. Finally, the FAA's current position is rather strange. "LAAS" is now back in the agency's NextGen plans, but the only system it has certified is categorized as non-federal, which means it is being implemented only when an airport and one or more airlines are willing to pay the costs—a kind of "not invented here" attitude.

Aviation stakeholders are divided on the value of GBAS. While all new Boeing and Airbus jetliners come equipped to interface with it, only FedEx and United have embraced the technology (which is now operational at their Memphis, Houston, and Newark hubs). In September 2013, when the NextGen Advisory Committee (NAC) prioritized thirty-six NextGen capabilities at the FAA administrator's request, low-visibility approaches via GBAS were among the seventeen given the lowest priority—essentially "nice to have," but not important enough to retain funding, given the FAA's current budget pressures.[9]

Case Study 3: Using GPS for Surveillance

Since the 1950s, radar has been air traffic control's primary means of keeping track of the location of planes. Primary radar provides the basic locational information, while secondary radar picks up transponder signals that identify the plane and provide its altitude. But primary radar is slow, using a rotating dish antenna whose signals are reflected from a plane about once every twelve seconds (in en-route airspace). At 500 mph, a plane traverses about 1.7 miles in that time, so the location shown on the controller's scope could actually be that distance from the plane's real location. ADS-B is a different form of surveillance in which each plane keeps track of its position via GPS and broadcasts that information once a second to ATC and nearby aircraft (if equipped with ADS-B displays). This twelve-fold increase in positional accuracy is intended to be a building block for NextGen and its counterparts overseas.

One early concept for NextGen envisioned the replacement of all or nearly all conventional ground-based navigation aids (radar, VORs, etc.) with GPS, thereby eliminating extensive ongoing maintenance costs as well as replacement costs. But primary radar has one key advantage that will lead to its retention: it locates planes that do not want to be seen and therefore turn off their transponders. In the post-9/11 age, the inability to identify "uncooperative targets" is not acceptable. However, since ADS-B replaces today's transponders, it would still make obsolete the secondary radars (whose job is to read transponder data), and most of the business case for domestic ADS-B was based on savings from eliminating secondary radars.

In the late 1990s, the FAA began an ADS-B demonstration program in Alaska, where radar coverage is difficult due to mountainous terrain, but where private planes provide much-needed transportation. The main focus was to reduce their high accident rate by providing more-accurate surveillance, including in-cockpit displays of nearby air traffic (which later became known as ADS-B/In). The first phase of the program, called Capstone, was in operation by 2000.

During the same time period, the air cargo industry promoted the use of ADS-B, funding initial efforts that included a fly-in demonstration at the Wilmington, Ohio, airport in 1999. Thereafter, the JPDO embraced ADS-B as part of the NextGen vision. After much debate within the aviation community, the FAA mandated that by 2020, all aircraft flying in airspace that requires a transponder must install ADS-B/Out, in which each plane sends out its GPS position once per second. This benefits the ATC system via faster, more accurate surveillance, but it offers no immediate benefits to aircraft operators.

Those benefits accrue only to those who invest in equipment for ADS-B/In, in which information is *received* from both ATC and nearby aircraft. An in-cockpit display screen permits pilots, for the first time, to see other air traffic, instead of having to rely on controllers (or their onboard collision avoidance systems). It should therefore allow reduced separation distances. The display screen can also give updates on weather and other general information from the ATC system. UPS is pioneering the use of ADS-B/In in its nightly flights to its main hub in Louisville, enabling it to engage in synchronized merging and spacing and permitting more landings per hour, which minimizes delay.

Most U.S. airlines, however, are hesitating to invest in the equipment needed for ADS-B/Out until closer to the 2020 deadline for a variety of reasons. Firstly, they are waiting to see when the FAA will have trained controllers and will offer services like merging and spacing, which would allow the airlines to add ADS-B/In and Out functions at the same time and save money. They also want to see whether the performance gains in domestic airspace justify the expense of equipping their planes. Moreover, due to a likely decline in unit costs as production volumes increase, late adopters are likely to get a better deal on price. Lastly, the FAA's ADS-B program costs more than programs in Australia, Canada, and Europe because the agency requires compatibility with two different communications links, one for commercial users and another for private planes, and this is an additional source of delays.

The business case for ADS-B/Out is far stronger for portions of the globe that lack radar coverage—over the Gulf of Mexico, the oceans, the polar regions, and portions of large but sparsely-populated countries such as Australia, Canada, and Russia. Consequently, ANSPs such as Airservices Australia and NAV CANADA have been early adopters of ADS-B. Likewise, airlines have been equipping their planes to take advantage of more "radar-like" separation on polar routes within NAV CANADA's airspace and across much of Australia and the North Atlantic (in a joint effort by NATS and NAV CANADA). This allows planes to operate safely with less spacing, which means more of them can fly at altitudes optimal for reduced fuel consumption. Europe's SES effort has also mandated that airlines and business jets equip for ADS-B/Out by 2017.

Since no ANSP currently has plans to provide ADS-B surveillance over most oceanic airspace, the private sector has come up with a solution. In 2012, communications provider Iridium announced the creation of Aireon, a joint venture with avionics companies Harris Corp. and ITT Exelis that will offer global ADS-B coverage to ANSPs using the next version of Iridium's sixty-six-satellite constellation. NAV CANADA has been announced as both the launch customer and an investor in Aireon. Airlines in polar and oceanic airspace can expect to save $6–8 billion per year in fuel thanks to more direct routes and the ability to fly at the most fuel-efficient tracks and altitudes as a result of radar-like surveillance in these portions of the airspace.

It is important to note that initially, Iridium approached the FAA to offer it the opportunity to be the launch customer and an investor.[10] However, the talks dragged on for many months without an FAA decision, and when Iridium offered NAV CANADA the same opportunities, it evaluated the business proposition and made a timely decision.

Why was the FAA's response to Iridium's offer so different from that of NAV CANADA? First, as a government agency, the FAA is subject to numerous regulations and to oversight by external agencies. Any FAA investment decision must go through a complex and time-consuming decision process for which the agency must conduct considerable competitive due diligence. (In this case, a start-up company in Alaska—ADS-B Technologies—had also announced plans for space-based ADS-B, but with a number of differences from Aireon's plans.) And any FAA spending must be part of the agency's annual budget approved by the Office of Management and Budget (OMB), with funds duly authorized and then appropriated by Congress. Under all those constraints—and especially with the dire budgetary situation in 2012–13—the FAA was unable to make what to NAV CANADA was a simple business decision. (The agency did finally, in mid-2013, sign an agreement to work with NAV CANADA on space-based ADS-B.)

ADS-B remains a promising technology for areas that lack radar coverage, which is the vast majority of the earth's surface. It can also offer more-precise surveillance than radar in controlled airspace. However, the aviation community is apparently still not certain that the benefits justify the cost in domestic airspace, when there are other ways of enabling aircraft to fly closer together safely that appear to have stronger business cases (see the discussion of performance-based navigation, below). The NAC, in its September 2013 prioritization report to the FAA, identified one ADS-B/Out capability as Tier 1A (highest) and another as Tier 1B. But the ADS-B/In capabilities were among the seventeen that placed last, in the "nice-to-have" category.

Finally, most of the business case for ADS-B in domestic airspace depends on the retirement of existing secondary surveillance radar systems. But under the FAA's recently adopted plan for GPS backup, it intends to retain a large complement of ground-based navigation aids, including about half of all VORs and *all* secondary surveillance radar systems.[11] This seriously undercuts the business case for domestic ADS-B. At the time of this writing, the main proponents of ADS-B in radar airspace are the FAA and the European Commission, not aircraft operators or self-supporting ANSPs.

Case Study 4: Performance-Based Navigation (PBN)

The idea that navigation procedures should be based not on specific kinds of equipment but on navigation performance requirements is a key aspect of the new ATC paradigm. Historically, air traffic control was based on detailed equipment requirements (VORs, ILSs, etc.) and the associated flight procedures. But the PBN concept developed in the early 1990s recognized that with GPS and onboard FMS computers, aircraft could more easily navigate “off the grid,” flying direct routes not dependent on the locations of VORs on the ground. This “area navigation” (RNAV) concept had begun to see limited use in the 1970s with early navigation systems, such as Omega/VLF, which used early on-board computers and later, FMS computers, prior to the widespread availability of accurate GPS signals for non-military use.

The PBN concept defines navigation in terms of the accuracy, integrity, availability, and functionality needed to operate in a specific airspace, given the navigational aids available and specific pilot training. While the longer-term implications include the ability of aircraft to operate mostly on user-preferred routes between origin and destination, with time-based arrivals, called “trajectory-based operations,” this discussion concentrates on the most-developed aspect, commonly referred to as Required Navigation Performance (RNP).

RNP is a form of area navigation in which the key onboard systems monitor their own performance in real time and can alert the flight crew and controllers if the defined performance levels are not being attained (in which case, the flight must revert to procedures that can be handled at a lower level of precision). RNP 5 means the plane’s navigation system can maintain its intended flight track within 5 nautical miles; RNP 0.5 means the ability to be within 0.5 nm of the intended position or track. The amount of separation between planes depends on their RNP levels; the more precise the RNP capability, the less spacing needed. The best current systems can achieve RNP 0.1 (the technical equivalent of ILS), permitting a precise three-dimensional curved path for landing or take-off (instead of the long, straight-line approach required with ILS) while avoiding terrain obstacles, noise-sensitive areas, and the like.

Developing an RNP approach or departure and getting it approved by an ANSP takes time and money to pay for the work of highly skilled people. Many of the RNP approaches at terrain-challenged airports are proprietary, paid for by the principal airline user at that airport (e.g., Alaska at Juneau, Qantas at Brisbane, LAN in South America). Far more beneficial would be public-use procedures, paid for by the ANSP to save its customers time and money while reducing carbon emissions and noise exposure.

Alaska Airlines pioneered the development of RNP in the United States, making the first RNP approach into Juneau in 1996. Until RNP, the approach to this airport could be made only in clear weather, since the airport's location at the end of a curved fjord made it impossible to accommodate the long, straight approach required by an ILS. With RNP, Alaska's planes could get into and out of Juneau in much lower visibility conditions, thanks to the capabilities of their GPS/FMS systems, monitored in real time. Recognizing the major benefits of RNP in such circumstances, the FAA cooperated with Alaska in approving its development and use of this capability. Alaska Airlines went on to develop more than thirty RNP approaches in the state, and it later obtained FAA approval to develop these approaches to other U.S. airports (such as Reagan National, where its approach precisely follows the Potomac River to minimize noise exposure over houses).

RNP's potential is so great that Airbus and Boeing have been including this capability in all their commercial aircraft since the mid-1990s, but the actual development of RNP approaches and departures that take advantage of these capabilities has lagged far behind. The FAA's practice has been to embrace the *idea* of RNP and assign staff to develop hundreds of approaches to give pilots and controllers the opportunity to get familiar with them. But nearly all such approaches have simply been "overlaid" on top of existing, traditional approach and departure paths, which does not shorten the flight track and therefore does not save time or reduce fuel use or noise exposure. However, for the FAA, it does have the advantage of avoiding objections and political pressures from Congress over revised flight tracks that change the location of noise exposure. As a result, airlines that have retrofitted large portions of their fleets, such as Southwest, have complained publicly that they have realized only a very small fraction of the expected fuel and time savings from RNP.

Meanwhile, "real" RNP approaches and departures have been growing rapidly overseas, especially at terrain-challenged airports such as Queenstown, New Zealand, and Lhasa, Tibet. To date, more than twenty-five RNP approaches and departures have been developed for airports in mountainous locations in Chile, Ecuador, and Peru. Like Juneau, these airports could not use ILS and had suffered numerous flight cancellations due to low visibility prior to the implementation of RNP procedures.

In 2003, the RNP experts at Alaska Airlines spun off an RNP development company, Naverus, to develop both proprietary RNP procedures for airlines and public-use procedures for ANSPs. Naverus was acquired by GE Aviation in 2009, and it now competes in this business with Boeing's Jeppesen subsidiary. While both have been certified by the FAA as RNP procedure developers, the agency declined until very recently to hire them to develop any public-use procedures. That changed in 2012, when Congress required the agency to begin contracting with certified providers to develop such procedures at five medium-size airports. The FAA complied, while claiming (based on dubious cost estimates[12]) that it could develop RNP procedures at lower cost than the private sector.

In the same 2012 legislation, Congress addressed industry concern about local objections to changed patterns of noise exposure. The law provides a categorical exclusion from standard, highly time-consuming environmental-impact-study requirements where new RNP procedures produce meaningful reductions in fuel consumption, CO_2 emissions, and noise. For the largest airports, Congress also required the FAA to consider "extraordinary circumstances" in deciding whether a categorical exclusion is warranted. But in a hyper-cautious decision, the agency decided that, in its Metroplex (major hub) initiative involving NextGen improvements for airspace near major metro-area airports, it would not even consider pursuing new RNP approaches that would require route changes below 3,000 feet or very near the airport. Those are the very approaches—such as short, curved approaches instead of long, straight-in ILS approaches—that offer aircraft operators and airport neighbors the greatest benefits. The GAO joined airlines in criticizing the FAA's conservatism.[13]

Even in its showcase RNP project, Greener Skies Over Seattle, the FAA has both enabled and impeded progress. That effort, involving Boeing, Sea-Tac Airport, Alaska Airlines, and local FAA controllers and managers, has developed and tested twenty-seven short, curved RNP over-water public-use approaches as an alternative to the long, straight ILS approaches that are mostly over land. Despite highly successful tests since 2012, as of mid-2013 the FAA has still not been able to certify the new approaches for regular use by equipped aircraft because it has yet to complete the time-consuming process of revising the controller handbook. And this is an airport where about 80 percent of airliners (Alaska, Horizon, and Southwest, in particular) are already RNP-capable.

The RNP experience illustrates the difference between FAA's lofty NextGen rhetoric and the ingrained conservatism that impedes its implementation of a proven concept that is highly desired by its aviation customers. More innovative ANSPs and airlines overseas have contracted with GE/Naverus and Boeing/Jeppesen to develop RNP procedures, while the FAA resisted such contracting until required by Congress and has been very slow to implement the kinds of RNP approaches that deliver real benefits. This also illustrates the difference between the aviation-customer focus of overseas ANSPs and the congressional focus of the FAA.

The NAC ranked airspace redesign for PBN/RNP as its top priority, with PBN/RNP for Metroplex airports in its top Tier 1A priorities and the use of PBN/RNP en-route in Tier 1B.

Case Study 5: Real-Time Weather Data

One of NextGen's key objectives is to give pilots and airline dispatchers more accurate and timely weather information for the altitudes where planes fly. Weather modeling has improved over the decades, thanks to supercomputers and more sophisticated software, but the basic limitation is the input data. A primary source of U.S. high-altitude aviation weather data is twice-daily weather balloons. (Lower-altitude data are provided by a network of ground-based NEXRAD weather radars.) The National Weather Service Aviation Weather Center launches sixty-nine balloons at twelve-hour intervals, each of which covers 45,000 square miles. They provide data on temperature, air pressure, winds, humidity, and latitude/longitude. Critically important data on icing comes only from pilot reports, which vary markedly in timeliness and quantity. The Weather Service uses these data inputs to create three-dimensional weather models, portions of which can be as much as twelve hours out of date by the time pilots access their outputs.

What is really needed is *real-time* high-altitude weather modeling that would add the critical fourth dimension: time. For the past five years, a start-up company called AirDat has been providing such data collection and modeling. Its model, TAMDAR, was invented by two atmospheric physicists and developed by AirDat with early support from the FAA and the National Oceanic and Atmospheric Administration (NOAA). The company installs a multi-function sensor on aircraft, along with a two-way voice and data link transmitting via the Iridium satellite system. TAMDAR provides more-timely versions of the weather balloon data, supplemented with data on icing, turbulence, time, and GPS position. These data are continuously relayed to the company's data center in Orlando, where they feed a set of real-time and forecast models in both 3- and 4-D.

As of early 2013, TAMDAR sensors had been installed on over 300 airliners in the United States, Europe, and Mexico. Aircraft operators that install the sensing device gain access to real-time weather data and predictions, and the communications device can also report real-time aircraft systems and performance data to airline headquarters. A four-year, FAA-funded study of the potential benefits of TAMDAR data used for NOAA's NCEP 3-D model found that it increased forecast accuracy by 30 to 50 percent; when used with a 4-D model, TAMDAR doubled forecast accuracy.[14]

An important potential benefit of real-time data such as provided by TAMDAR is to enable the current manual system for pilot reports to be replaced with real-time electronic pilot reports. With thousands of planes equipped with weather sensors and broadcast capability, electronic pilot reports (ePireps) could be sent not only to ground stations, but also to surrounding aircraft. This would allow non-equipped aircraft to gain real-time knowledge of winds, turbulence, icing, and other conditions, increasing both safety and convenience.

Raytheon and Metron have announced a teaming arrangement with AirDat to bid on the two key NextGen weather programs: NextGen Network Enabled Weather and NextGen Weather Processor. Those competitions have yet to be held, and in early 2013, AirDat was acquired by Panasonic, which plans its own satellite communications network. What all this will mean for the NextGen weather program remains to be seen.

In this case, the FAA spotted the potential of AirDat's concept early on, and along with NOAA, assisted the company in commercializing the technology. However, it seems to be taking the FAA a long time to define what it actually wants for the NextGen weather program. There may also be something of a "not invented here" syndrome at work in NOAA's Aviation Weather Services Branch, since AirDat's real-time aviation weather data and forecasting qualifies as a "disruptive technology."

Case Study 6: Remote Towers

A basic principle of the new ATC paradigm is that there no longer needs to be a direct spatial relationship between a sector of airspace and the ground beneath it. With the right real-time information, air traffic can be managed anywhere from anywhere. One application of this principle, enunciated in the JPDO's planning documents, is remote (or virtual) control towers. Instead of locating a tall structure at each airport, with controllers in a top-floor control room, an array of sensing devices—including video cameras and communications antennas—can be installed at the airport, with the data transmitted to a remote location staffed by

ATC personnel.

The concept could be applied to airports ranging from the very small to the very large. Small, low-activity airports that do not have enough traffic to warrant twenty-four-hour staffing could share the functions with other small airports at a single remote facility. There would then be enough total traffic to justify staffing and a large enough workload to keep controllers productively engaged. At very large airports, such as Dallas/Ft. Worth, Los Angeles International, and Chicago O'Hare, where controllers cannot see all the runways from a single tower, cameras and surveillance systems such as wide-angle multilateration (WAM) could cover the more-distant runways, obviating the need to construct and maintain a second tower (or, in the case of O'Hare, the planned third tower).

In 2007, the FAA's research facility in Atlantic City conducted a demonstration project to test the idea with controllers, using a prototype remote tower cab with a variety of display screens. For comparison, they used the facility's tower cab simulator, which provides 360-degree out-the-window video views of the Atlantic City Airport. Researchers recruited three retired controllers and one instructor to deal with six different control tower situations, comparing controller performance under both visual and instrument flight operations, both day and night. The results showed that controllers not only performed better with the remote tower but also perceived their workload as being lighter, leading the researchers to conclude that providing tower functions with a remote tower is feasible and that such a tower demonstrates "superior performance when visibility deteriorates."[15]

Alas, since then, there has been very little heard from the FAA about remote towers, despite exposés about sleeping controllers at small-airport towers with very little night-shift activity and the revelations that more than 100 such towers no longer meet FAA minimum traffic requirements to operate at night. These are cases where the functions of several low-activity towers could be operated from a single remote tower, with enough workload to justify a midnight shift.

Overseas, innovative ANSPs have been working with private-sector firms such as Saab-Sensis to develop and certify remote towers. The Swedish ANSP, LFV, began testing prototype remote towers in 2009 and expects certification of the first ones in 2013. Norway's Avinor is nearing certification of its first remote tower, for a low-activity helicopter airport serving North Sea oil platforms. Saab and LFV are also working with Airservices Australia on a prototype virtual tower to serve Alice Springs, in the middle of the Outback, which will be monitored from Adelaide, over 900 miles to the south. Germany's DFS is developing a remote tower function to oversee the new third runway at Munich and plans tests of the concept for several low-activity airports. Saab-Sensis is also discussing the idea with the Airports Authority of India. Searidge Technologies, an affiliate of NAV CANADA, has implemented partial remote tower functions for Malta Air Traffic Services.

Here at home, the closest we have come to remote tower implementation is emerging from the Colorado Surveillance Project, a Colorado DOT effort to improve air service at airports in the mountainous ski resort country.[16] WAM, a triangulation system to keep track of airplanes' positions via their transponder signals, has already been installed at several of these airports that do not have control towers, and FAA's Denver Center is providing limited ATC service for those airports. Phase 3 of the project is exploring the addition of video surveillance at these airports to provide more complete remote tower capability for controllers. While this Colorado DOT project has gained support, as an experiment, from the FAA's regional office, the agency has turned it into a two-year study rather than a pilot program for deployment.

The remote tower concept is yet another disruptive technology which, despite growing evidence of effectiveness, has yet to be embraced by FAA leadership, apart from rhetoric in NextGen planning documents. Controllers are certainly concerned that jobs in low-activity towers may be put at risk if remote towers become mainstream, but there is also the potential for growing communities to obtain the safety benefits of control tower functions if they can be provided more economically using the remote tower model. Here again, the more entrepreneurial ANSPs overseas are leading the way.

Case Study 7: Facility Consolidation

Both the ability to manage air traffic anywhere from anywhere and the use of remote towers have major implications for increasing ATC productivity, beyond what advanced technology and procedures can provide, through economies of scale. A 2013 Reason Foundation study analyzed the productivity of all 20 U.S. domestic en-route Centers and 167 TRACONs, finding a wide range in annual operations per controller that correlates with size.[17] Economies of scale are also evident in comparisons of the U.S. and European ATC systems. As noted earlier in this paper, Europe has 31 ANSPs operating 68 en-route Centers. The geographic areas are comparable in size, but the volume of air traffic is higher in the United States. The ATC cost per IFR flight hour, averaged across Europe, is about double the average level in the United States.

The Reason study developed a proposal to consolidate the 187 Centers and TRACONs into five high-altitude Centers; eight Integrated Control Facilities (ICFs), which combine en-route and terminal airspace in the busiest areas; and 38 geographically consolidated TRACONs providing radar approach and departure control to sets of smaller airports. While constructing these new facilities would entail significant costs, it would also avoid the extensive costs of rehabilitating or replacing the FAA's 20 aging Centers and 167 TRACONs and their ongoing high maintenance costs. Moreover, the new facilities could be located in areas with lower real estate costs (and cost of living) than places like urban Long Island and urban California.

The FAA created a special Program Management Office to lead a facility consolidation effort, and in 2010, it began developing a plan that included replacing most existing Centers with a handful of high-altitude Centers and blending en-route and terminal airspace in high-traffic areas to be served by ICFs. However, that effort was significantly downsized in 2012, with no further work done on an overall nationwide consolidation plan.[18] Instead, all near-term effort is being devoted to creating the first ICF in the very complex and politically charged New York metro area.

Experts, including the Reason study authors, consider this to be a high-risk approach. A lower-cost and lower-risk approach would be to develop the initial ICF in an easier environment, such as Houston. In any event, as of mid-2013, the FAA has failed to provide Congress with the long-range facility consolidation plan required by the 2012 reauthorization law.

This impending debacle is not the first time the FAA has included large-scale facility consolidation in its planning as a means to the end of increased ATC productivity. The highly touted NAS Plan of the early 1980s promised major productivity gains thanks to a combination of new technology, streamlined ATC procedures, and consolidation of TRACONs and Centers into just twenty-three new Area Control Facilities. But as those plans were revised from one budget year to the next, the consolidation aspect gradually faded from sight, as did major changes in how the system would operate, and the idea evolved into little more than upgrading equipment and software—though not without large schedule slips and cost overruns.

The FAA *has* accomplished four large-scale TRACON consolidations, combining a number of smaller facilities into a single regional TRACON for Southern California, Northern California, the Washington, DC metro area (Potomac), and Atlanta (incorporating Columbus and Macon). A number of other efforts to combine several smaller TRACONs into one have floundered, generally due to opposition from unionized employees and private pilots, who have enlisted the local congressional delegation to pressure the FAA to save these local jobs or legislatively forbid it from spending money on the proposed consolidation. In recent years the National Air Traffic Controllers Association (NATCA), has taken a more constructive approach, supporting (for example) consolidation of the Dayton and Columbus TRACONs and of Reno with Northern California, while opposing consolidation of Boise with Salt Lake City and of West Palm Beach with Miami.

The experience overseas is generally more positive. Several of the entrepreneurial ANSPs have succeeded in large-scale facility consolidations. In February 2010, NATS completed the second of two major consolidations, replacing four Centers with two new ones covering the entire UK, one in Swanwick, England, and the other in Prestwick, Scotland. Airservices Australia consolidated its six Centers into two new, identical facilities, each of which is capable of handling all the ANSP's domestic and oceanic traffic. Germany's DFS integrated its approach control facilities with its existing Centers and then consolidated them into two new Centers, Dusseldorf and Frankfurt. France, however, has faced serious opposition to consolidation from its controllers' union. In addition, consolidation of ATC facilities across borders in Europe is proving to be very difficult, with political and controller resistance greater than what we have seen in the United States.

The lesson from overseas is that successful consolidations have been the result of business decisions by the ANSPs in consultation with their customers and controllers. The problem of controller opposition still exists—some controllers may have to relocate, and others may become redundant—but management and employees have incentives to work out win-win solutions. There is no opportunity for elected officials to become involved and politicize the decisions because the commercialized ANSPs obtain their revenues not from the government's budget, but from payments for services from their aviation customers. Furthermore, when opponents claim that a consolidation plan would reduce aviation safety, there is an independent aviation safety regulator to assess the facts and approve or disapprove. By contrast, in this country the FAA (as the ANSP) is both the proponent of consolidations and the safety regulator, an inherent conflict of interest.

Assessment: Why Is There a Status-Quo Bias?

Some common themes emerge from our seven case studies. Many of the innovations that are part of the proposed paradigm shift from twentieth-century air traffic control to twenty-first-century air traffic management originated in the private sector (or in various research labs such as NASA, MITRE, and Lincoln Laboratories) but have been slow to be embraced and implemented by the FAA. Even when the agency does seek to procure new technology, it seems to have a hard time defining what it wants, which leads to very long development times with unpredictable operational dates and often large cost over-runs. The agency resists disruptive innovations such as GBAS, RNP, real-time weather, and remote towers in practice, despite enthusiastic rhetoric in NextGen documents and FAA leadership speeches.

What accounts for this risk-averse organizational culture? Five factors are discussed below.

1. Identity as a Safety Agency

From the outset, the FAA has combined aviation safety regulation and ATC service provision in a single entity. The attempt to partially separate these two functions by creating the Air Traffic Organization as an entity within the agency—proposed by the Mineta Commission and mandated by Congress—has been steadily reversed under the two most recent FAA administrators, with their "one FAA" theme and their forbidding use of the term "customers" when referring to airlines using ATC services.

ICAO recommended in 2001 that all signatory states (including the United States) separate air traffic control operations from aviation safety oversight and regulation within two years.[19] Nearly all developed countries have complied, as part of ATC reforms that have split their former aviation ministry into a safety regulatory agency and a separate, generally self-supporting air navigation service provider. This organizational change explicitly acknowledges a growing aviation consensus that safety regulation and ATC service provision are very different functions—and indeed, that ATC service provision ought to be regulated at arm's length, just like all the other entities in the aviation system (airports, airlines, manufacturers, repair stations, pilots, mechanics, etc.). The United States, however, has yet to comply with the ICAO recommendation.

The FAA's continued self-concept as a "safety agency" contributes to a highly risk-averse, status-quo organizational culture within its Air Traffic Organization. By contrast, numerous innovations are proposed and developed by airframe manufacturers and avionics companies, whose engineers and managers are willing and able to think outside the box, while knowing that the innovations they propose must eventually pass muster with the independent air safety regulator.

The FAA's Research, Engineering, and Development Advisory Committee (REDAC) was asked by the FAA Administrator in 2010 to "identify cultural issues that could impact successful implementation of NextGen."[20] It found that real transformation would require all aviation stakeholder groups to embrace a common vision for the new paradigm, but that even with such a shared vision, strong leadership over a long period would be needed to get it implemented. Such a change in culture would be unprecedented for a large government bureaucracy like the FAA.

Evidence for the cultural hypothesis comes from the post-corporatization cultures we observe in several well-run ANSPs. Airservices Australia, DFS, NATS, and NAV CANADA, for example, have been far more willing than the FAA to develop new technologies and flight procedures, and they have avoided the chronic problems of large cost overruns and schedule delays that have plagued the agency since at least the 1980s. The more entrepreneurial ones, such as DFS and NAV CANADA, have disclosed that while they have brought about cultural change among their controllers, over time they have had to replace the 40 to 50 percent of their managers who could not make the transition to a customer-focused business model.[21]

2. Loss of Technical Expertise

For several reasons, it appears that the FAA's technical capabilities are far below what they should be when it comes to figuring out new technologies and procedures. A key symptom of this is what observers describe as "requirements creep." All too often, as we saw with the LAAS example, the FAA has only a general idea of what it wants a new system to do. Instead of defining this in detail before issuing a contract, it turns over much of the initial development work to a contractor, who is only too happy to explore all kinds of things that the notional system might do. In this manner, "requirements" evolve over time, often becoming far more elaborate than what was initially intended. When it comes time to procure the more complex system, the cost is likely to be considerably higher than the initial estimate.

In addition, more often than not, the FAA has failed to involve field-level controllers and managers in thinking through the requirements. As a result, when initial prototypes reach the field, there are often unanticipated problems that must then be resolved at considerable additional cost, leading to further schedule slips. FAA leadership also shies away from field trials because when they succeed, controllers at the field site wish to continue using the prototypes, and over time, this leads to an array of different hardware and software modifications at nominally identical facilities. As an example, large amounts of time and money have been needed to customize the new ERAM software for each of the twenty en-route Centers. Similar problems exist with replacing the highly modified CARTS displays at TRACONs with the newer STARS displays.[22]

ANSPs that are paid directly by their aviation customers seem to have a far more disciplined process. First, they have higher-level technical expertise in-house. Second, they confer with controllers and customers when developing requirements for new systems. Third, because they must develop a business case that the new system is worth its cost, they are more hard-nosed about eliminating nice-to-have but inessential bells and whistles from the requirements. Fourth, their business case analysis focuses on benefits to the users, rather than benefits to the ATC provider (as is often the case with the FAA). And fifth, they are more disciplined about specifying requirements and resisting requirements creep during development and production.

Why does the FAA lack sufficient technical expertise (despite having some very talented engineers)? First, it is a large and cumbersome bureaucracy and is known to be one. Innovative engineers generally find such places less attractive to work in than aerospace companies, especially smaller ones. Second, government civil service rules make it very difficult to hold FAA engineers and managers accountable for performance. Third, civil service pay scales are often not competitive with the private sector—at least for highly talented engineers. Evidence for this premise can be found in the continual migration of talented engineers and managers from the FAA to the private sector. One avionics company CEO, reviewing a draft of this paper, commented that "I have hired many good people away from the FAA. Usually their reason for leaving is the stultifying civil service culture and the pervasive mediocrity that drives the good ones out." Fourth, as the FAA experiences budget pressures, it has tended to hire engineers straight out of college, with few or no years of actual aviation experience, who are more affordable than engineers and procurement managers with decades of experience.

By contrast, self-supporting ANSPs are not constrained by civil service rules or pay scales, so they hire and retain experienced engineers and program managers. They can also hold program managers accountable for results, pay performance bonuses, and do other things that are difficult or impossible in a civil service environment.

3. Loss of Management Expertise

During the 1980s and 1990s, numerous reports from the General Accounting Office and the Inspector General faulted FAA procurement methods for chronic problems of cost overruns and schedule delays. As a result, "procurement reform" became a mantra in Congress, which legislated on this subject in 1996. Today, the FAA has a formal Acquisition Management System, which requires an investment analysis before a major new program can be launched. It also includes many detailed procedural steps, all of which slow down the decision-making process (as illustrated by the agency's inability to make a timely decision on involvement with the Aireon venture for space-based ADS-B). Despite this formal process, programs still get redefined along the way and "rebaselined" with higher expected costs. Today's GAO and Inspector General reports on FAA procurement and program management still read very much like those of the 1980s and 1990s.

The problem is not fundamentally with the process but rather with the issues discussed above: an inability within a civil service system to empower strong managers and hold them accountable. And because FAA typically requires numerous approvals of key decisions, any number of people are able to say no. There are also the problems of inability to pay market compensation to successful program managers. One former FAA manager, now an FAA consultant, told the author that "making decisions imparts risk, and risk is to be avoided in what is a risk-averse organization. That is why we see interminable delays in deciding, as well as the propensity to study at length or recurrently to avoid making decisions." He went on to add that these problems "have created an unresponsive and ineffective organization whose major objective is maintaining the status quo. This has resulted in personnel selection for advancement which does not reward the brightest and those driven by a desire to lead and accomplish, but rather personnel who are politically adept at talking the talk but unable to walk the walk."

Another former FAA manager wrote that "there is an additional highly perverse factor at work here. Because of the dreadful lack of technical and managerial talent at the FAA, they are completely dependent on outside consultants. They are de facto long-term employees whose interests are not aligned with the FAA, but rather with job preservation, delay, fostering dependence, and self-promotion. Worse yet, many of these consultants are former FAA employees who are well-versed in subverting an efficient and transparent acquisition process to the benefit of their masters. The revolving door problem at the FAA is huge, and it is rife with examples of blatant conflict of interest."

One related problem is a trend that some have called "creeping privatization." In two recent large procurements—involving the nationwide ground station network for ADS-B and implementation of DataComm—instead of simply procuring the equipment, FAA procured provision of the new service using company-owned equipment. The agency apparently adopted this course because of its very limited annual capital budget. The advantage of this is that rather than buying modest numbers of these systems in annual purchases over many years, it is able to acquire the entire needed complement in just a few years, paying the providers an annual fee to produce, install, operate, and maintain them. The downsides are that FAA loses control of these assets and creates time-limited monopolies for the contractors in question (while also eliminating maintenance jobs for its technicians' union). To the best of this author's knowledge, this method of procurement exists at no other ANSP.

4. Excessive Oversight

As a government agency spending taxpayers' money, the FAA comes under ongoing scrutiny not only from GAO and the Inspector General, but also from a number of congressional committees, the Secretary of Transportation, and OMB. This extensive oversight is positive in that it calls attention to numerous shortcomings that might otherwise not become known, either to aviation stakeholders or to members of Congress. But it also has the downside of focusing FAA leadership's attention on responding to all its overseers. By contrast, self-supporting ANSPs focus on delivering what their aviation customers want and are willing to pay for.

Congress gives directions to the FAA in ways that are often well-meaning but sometimes self-serving. In the latter category are legislative provisions requiring specific equipment to be purchased even if the agency has not requested it and a legislated mandate on the number of maintenance technicians the agency must employ. In addition, Congress has intervened a number of times to prevent proposed facility consolidations to protect even small numbers of jobs in a particular member's district. A Bloomberg News investigation in 2012 found that some members of Congress put pressure on the FAA Administrator to prevent the elimination of midnight shifts at numerous low-activity towers that no longer met established FAA criteria for being open overnight.[23]

In the well-meaning category of congressional intervention are various mandates and deadlines for NextGen projects that may or may not make sense in terms of timely and efficient system modernization. Sometimes such mandates serve to overcome internal FAA resistance, as when the agency is required to start contracting with certified RNP procedure developers. Another positive example is the 2012 requirement that the FAA produce a long-range plan for facility consolidation, a requirement the agency had not yet met by the end of fiscal year 2013.

One former FAA Administrator told the author that even though air traffic control represents over 80 percent of the agency's staff and budget, the Administrator must devote the majority of his interactions with Congress to air safety issues. At the very least, this diverts his attention away from ATC, which definitely needs full-time management.

The recent budget pressures resulting from sequestration have been a further distraction for FAA management. An FAA consultant (and former manager) says that "FAA management [in 2013] has been in constant turmoil attempting to deal with these budget initiatives. The result is they have turned away from routine daily management activities to focus on constant budget drills. It is painful to see an agency that moves slowly under normal circumstances virtually grind to a stop due to budget distractions."

The frequent audit reports by GAO and the Inspector General have been vitally important in pointing out management failures and shortcomings; in the absence of a more effective governance model, they remain critical. But they also serve to draw management attention away from operating and managing the ATC system and toward responding to long lists of findings and recommendations. As valuable as these reports are, most of them address issues at the micro level, rather than raising broader institutional questions about the governance and funding of the ATC system. As such, they fail to address larger questions, such as why both the failed NAS Plan of the 1980s and potentially the current NextGen effort end up focusing not on transforming how air traffic is managed but simply on upgrading the infrastructure to continue business as usual under an increasingly obsolete paradigm.

A 2003 paper for the Transportation Research Forum addressed the question of how the FAA "could invest billions of dollars to modernize and increase its operations, but not reduce its costs per operation."[24] It found that "NAS modernization architecture and project designs have been consistently subverted by requirements growth, development delays, cost escalations, and inadequate benefits management. But all these things were symptomatic of the fact that FAA didn't think it needed to reduce its operating costs." And when it comes to the current (NextGen) efforts, the same authors concluded that "FAA is trying to modernize its infrastructure rather than its services."

When Clinton administration legislation on converting the ATC system to a self-funded corporate entity, the U.S. Air Traffic Services Corporation (USATS), was before Congress, a senior staffer on the House Aviation Subcommittee told this author that "We always give FAA the money they ask for." That claim rings hollow since the FAA, as part of the DOT, may ask only for what the Office of Management and Budget will allow it to request, regardless of what the agency's ATC management may believe is necessary. Likewise, during the 2013 sequester, the FAA had no choice but to toe the administration's line about the inflexibility of OMB's budget cutback rules, rather than seeking ways to make the required cuts in the least damaging manner.

5. Lack of Customer Focus

As noted at many points in this paper, the FAA's de facto customer is Congress, which provides the agency's funding and mandates most of its GAO and Inspector General oversight. That fundamental fact shapes the boundaries of what FAA leadership can and cannot do. As we have seen, Congress has often prevented the agency from consolidating facilities or eliminating night shifts at "zombie towers." It has required the agency to procure certain hardware and encouraged it to select certain contractors. The FAA has been averse to implementing RNP approaches and departures for major airports, which would lead to the greatest user benefits, because it fears that Congress would overreact to constituent complaints about changed noise exposure. Some have speculated that the agency has failed to implement the policy of "best equipped, best served"—that is, rewarding aircraft operators that are early adaptors of RNP or ADS-B/In with better service—due to fear that operators planning to be late adaptors would claim discrimination.

The self-supporting ANSPs provide a dramatic contrast. They are free to make business decisions without concern that elected officials will countermand them. ANSPs like NAV CANADA and NATS have implemented best equipped, best served by giving preference for fuel-minimizing altitude requests to planes equipped for ADS-B and data link, even offering discounts on their ATC charges in some cases. Decisions about when and where to introduce such changes, as well as RNP procedures, are made in consultation with customers. A business case for such changes is developed cooperatively, and only if the case is sufficiently positive does the change get implemented. When the case for converting Canada's government ATC operation to self-supporting NAV CANADA was being developed by a coalition of aviation groups in the 1990s, their mantra was that "user pay means user say," and that has been borne out in practice.

Remedies

The organizational model for air traffic control still in use in the United States is poorly suited to the task. This has been known for several decades. The first published studies proposing a U.S. ATC corporation appeared in the early 1980s.[25] We now have a number of empirical studies documenting the superior performance of the self-funded ANSP model, which has been embraced by over fifty countries since Airways New Zealand was formed in 1987.[26]

No business enterprise can be expected to run efficiently and effectively if it needs continual outside direction. The superior approach is to create an institutional environment that provides the proper incentives and let the enterprise decide how best to meet its objectives for cost, efficiency, quality, and safety. Like all other components of aviation, the enterprise will still need safety regulation, but this does not require detailed directions about every aspect of its business.

The key changes needed are the following:

First, separate ATC (the current Air Traffic Organization within FAA) from the government aviation safety function and set it up as an ATC provider focused on serving its aviation customers. Allow the remaining part of the FAA to regulate it for safety at arm's length, just as Boeing, Pratt & Whitney, United Airlines, Miami International Airport, and all the other entities providing aviation infrastructure and aviation services are regulated. The new ANSP could be a government corporation, either within the DOT (per the USATS proposal) or separate and independent (like the Tennessee Valley Authority). Alternatively, it could be a private non-profit organization such as NAV CANADA. There are successful ANSP examples of each.

Second, shift from user-tax funding to direct user charges. This model is similar to that employed by airports (apart from modest federal airport grants) and by electric, gas, and other public utilities. Users are charged for the services they receive, and the revenues flow directly to the provider, not passing through the government's budget or the legislative process. This financial independence removes the principal Congressional lever of micromanagement: "safeguarding taxpayers' money." In turn, the ANSP's dependable revenue stream is bondable, making it possible to finance large capital modernization programs outright rather than have to pay for them in bits and pieces out of (increasingly uncertain) annual appropriations. Revenue bonds subject investments to a market test, reinforcing the need for sound business cases that reduce costs and produce net benefits for customers. And, of particular relevance to the FAA and NextGen, well-established public utility principles provide that the costs of new investments cannot enter the rate base for cost recovery until the project is "used and useful." That guards against requirements creep and the attendant cost escalation and schedule delays. The ANSP will have to *deliver* new systems in order to recover the costs of developing and operating them.

Third, change the governance model. The two best ANSP models include aviation stakeholders on the corporation's governing board, setting overall policy. NATS in the UK has airlines and airports owning 46 percent, employees 5 percent, and the government 49 percent. Nonprofit NAV CANADA's stakeholder board includes representatives of airlines, business aviation, employees, and the government. Because NATS is nominally a for-profit entity, its monopoly en-route services are subject to governmental price-cap regulation. With NAV CANADA's stakeholder governance model—analogous to a user co-op—there is no need for explicit government price regulation (although an appeal process is available for customers who contend that a rate decision was not consistent with the statutory charging principles that apply to NAV CANADA).

A reform that embodies these three principles represents the best practice currently available for organizing, paying for, and governing a provider of air traffic management—and for pursuing the many opportunities to greatly improve air traffic safety and efficiency that modern technology provides.

Transitioning to a U.S. ATC Corporation

Previous efforts to shift U.S. air traffic control to a self-funded corporate entity failed for several reasons. First, the various aviation stakeholders were divided and did not come together to argue for major reform, which was crucial to Canada's successful transition to NAV CANADA in 1996. Second, the debate was basically an inside-the-Beltway issue, without wider support from either the national media or the business community. And third, there were powerful members of Congress staunchly opposed to any such change, and they succeeded in blocking, in particular, the Clinton administration's 1994 ATC corporation legislation.

The 2013 sequester, which led to controller furloughs and a plan to shut down 149 control towers, was a wake-up call to aviation stakeholders, sparking serious reform discussions at aviation conferences and behind the scenes. These discussions have included ideas such as corporatization, user funding, revenue bonds, and a governing body made up of aviation stakeholders. Indeed, the FAA's own Management Advisory Council sent a unanimous letter to aviation leaders in Congress arguing for reform of both funding and governance, calling the current system unsustainable.[27] In addition, the chairman of the House Aviation Subcommittee, Rep. Frank LoBiondo (R-NJ), has been quoted as having lost confidence in the FAA's ability to implement NextGen and as being open to "big ideas" to change things.

Aviation stakeholder groups also appear willing to take a fresh look at corporatization. In online forums and at 2013 aviation conferences, leaders of airline trade association A4A, controllers' union NATCA, and private pilots' group AOPA have all stated that the current funding system is broken and needs to be replaced with one that is sustainable and not subject to politics.[28] The former editor of *Flying* magazine asked in a blog post whether it is time to privatize the ATC system and cited NAV CANADA's low annual charge for private planes to use its system.[29]

Assuming that an aviation-business coalition were assembled that supported removing the Air Traffic Organization from the FAA and converting it into a self-funding corporation, what would be involved in making this change? Congress would need to enact enabling legislation authorizing the divestiture of the ATO and its conversion to either a government corporation or a non-profit stakeholder-controlled corporation. The legislation would transfer ownership of the FAA's air traffic facilities (Centers, TRACONS, towers, etc.) to the corporation. It would also authorize it to charge fees for its services and to issue revenue bonds in the same way as airports, seaports, railroads, and electric utilities do, backed by the revenue from customer payments.

An example of such a divestiture is the 1987 transfer of the two Washington airports, Washington National (today called Ronald Reagan Washington National) and Dulles International, from the FAA to a newly created airports authority. Since their creation after World War II, both airports had been part of the FAA, with their budgets appropriated each year by Congress. Revenues from landing fees, space rentals, and other sources went to the U.S. Treasury and were not connected to subsequent appropriations for the airports. In addition, National and Dulles, alone among U.S. airports, lacked the ability to issue revenue bonds for major capital expenditures. Consequently, National's terminal was small and outdated, and Dulles was under-utilized. Divestiture transformed the two airports, thanks to self-government in the interests of their users and the ability to control their revenues and bond major runway and terminal projects.[30] Similar examples have occurred with the corporatization of ATC systems in more than fifty countries since 1987.

The enabling legislation could spell out the composition of a governing board representing all aviation stakeholders, comparable to NAV CANADA's board. Direct aviation stakeholders could include airlines, regional/commuter carriers, cargo carriers, business aviation, air taxis/fractionals, general aviation (private pilots), controllers and other employees, and airports. Several citizen members might be appointed directly by Congress to represent the traveling public. And, as in Canada, the government might be directly represented, as a user of the airspace for civil and military purposes, by the secretaries of defense and transportation or their designees.

The ATC corporation would be regulated at arm's length for safety by the remaining FAA, and for security purposes by the Transportation Security Administration. In times of war, the Defense Department would have the same control over the national airspace as it does today.

There would need to be a transition period of perhaps two years, during which the new corporation would be set up, the initial governing board appointed, and a CEO hired. For most or all of this period, until the board had agreed upon a fair and reasonable set of fees and charges and these were implemented, the corporation would receive the ATO's current share of the FAA's annual budget to cover its capital and operating costs. (The funding transition period for NAV CANADA, for example, was two years.) Once the transition to ATC fees occurred, the existing aviation user taxes would sunset. Congress could fund the FAA's safety regulation and miscellaneous functions (e.g., commercial space launch) from general revenues, as is de facto the case today. It would need to implement a new funding source for the Airport Improvement Program (AIP), whose grant-making would continue as an FAA function.

In broad outline, the above description is what the Clinton-

Gore legislation called for with its proposed U.S. Air Traffic Services Corporation.[31] It is also similar to what took place in the transition that created NAV CANADA.

Reform along these lines would address all five problems identified earlier in this report. By creating an ATC provider that is regulated for safety by the FAA yet wholly separate from it, such reform would permit the development of a corporate culture suitable to a high-tech business, like the culture at Boeing, Honeywell, and other innovative firms regulated for safety by the FAA. This kind of cultural transformation has, in fact, occurred at such corporatized ANSPs as Airservices Australia, DFS, NATS, and NAV CANADA.

The ATC corporation, by removing its employees from the constraints of the civil service system, could seek and attract highly skilled engineers and program managers, compensating them at market rates—and holding them accountable for delivering results. The technical expertise at NAV CANADA has led to a thriving business marketing innovative ATC hardware and software and advising other ANSPs on modernization.

A shift in funding from congressional appropriations to customer payments would allow the ATC corporation's management to refocus on delivering cost-effective services to its aviation customers and correct the FAA's lack of customer focus, which persists to this day (former Administrator Randy Babbitt even banned the word "customer"). Under the changed funding system, the principle of "user pay means user say" would come into being, as it has in other self-funded ANSPs, especially those with aviation stakeholders on their governing boards (as in Canada and the UK).

Customers, in their role as members of the governing board, would be overseeing the CEO and management because *their* money, not taxpayer money, would be involved. Congressional committees, the GAO, the Inspector General, OMB, and other government bodies would no longer be needed for that kind of oversight. They would retain oversight of the tax-funded FAA, the safety regulator responsible for regulating the safety of the self-supporting ATO.

The idea that the highly diverse group of aviation stakeholders could work together to reach decisions about ATC fees and charges, which new upgrade programs are worth the cost, and similar issues may seem hard to believe to those who recall the fights among such groups in the 1990s and 2000s. Yet the experience of the NAC, organized by the non-profit federal advisory committee RTCA, suggests otherwise. All factions of the aviation community have worked together in the NAC to set priorities for the FAA's NextGen efforts, to the surprise of many aviation observers. Those years of working together on NAC committees seem to have laid the groundwork for the emerging consensus on the need for ATC funding and governance reform.

Glossary

ACARS: Aircraft communications addressing and reporting system, a digital data link system for communications between airline dispatchers and cockpit crews.

ADS: Automatic Dependent Surveillance, a form of surveillance in which an aircraft automatically provides information about its position via a data link. The most common form is ADS-B, with the B referring to "broadcast," meaning that the position information is broadcast at regular intervals.

AIP: Airport Improvement Program, a grant program available to commercial and general aviation airports. AIP money comes from the FAA Aviation Trust Fund, whose source of money is aviation excise taxes.

ANSP: Air navigation service provider, the term generally applied to self-supporting air traffic control providers organized as corporate entities. In recent years, the term has evolved to include all entities that provide ATC services, including the FAA's Air Traffic Organization.

ATC: Air traffic control, the equipment and procedures to keep aircraft safely separated from one another while in flight.

ATO: Air Traffic Organization, the branch of the FAA responsible for developing and operating the ATC system.

ATM: Air traffic management, the general term for the new paradigm that is expected to replace manual 20th-century air traffic control with changes in airspace, procedures, and technologies.

CANSO: Civil Air Navigation Services Organization, the trade association for ANSPs (counterpart of IATA for airlines and ACI for airports).

CARTS: Common Automated Radar Terminal System, the software system used to manage and display aircraft positions on scopes at most TRACONs.

Center: Abbreviated form of air route traffic control center, the kind of ATC facility responsible for en-route (high-altitude) flights.

CNS/ATM: Communications, Navigation, Surveillance/Air Traffic Management, an early term for the ATM paradigm now embodied in modernization efforts such as NextGen and SES.

CPDLC: Controller-pilot data link communications, a system for digital text messaging between air traffic controllers and cockpit crew.

DFS: Deutsche Flugsicherung, Germany's self-supporting air navigation service provider.

ERAM: En Route Automation Modernization, the replacement for the software used to manage en-route airspace at the FAA's 20 en-route Centers.

FAA: Federal Aviation Administration, the agency that regulates aviation safety and operates the U.S. air traffic control system.

FANS: Future air navigation system, a system implemented in the 1990s for improved air traffic control in oceanic airspace.

FMS: Flight management system, an onboard computer system that automates much of an aircraft's flight path, based on inputs from the flight crew and air traffic control.

GBAS: Ground-based augmentation system, a system that augments GPS signals to guide planes to precision landings.

GPS: Global positioning system, a global satellite constellation that provides information for positioning, navigation, and timing; a key enabler for the NextGen ATC concept.

ICAO: International Civil Aviation Organization, the UN agency responsible for coordinating international aviation.

ICF: Integrated control facility, proposed new type of ATC facility dealing with a blend of en-route and terminal airspace, encompassing functions of both Centers and TRACONs.

IFR: Instrument flight rules, rules requiring pilots to file and comply with a flight plan in order to use certain portions of the airspace under ATC control.

ILS: Instrument landing system, a 1940s technology that provides for precision landings.

JPDO: Joint Planning & Development Office, a multi-agency body created to develop the Next Generation Air Transportation System concept.

LAAS: Local Area Augmentation System, an FAA program to develop a replacement airport landing guidance system using local augmentation of GPS signals.

NAC: NextGen Advisory Committee, a group of aviation stakeholders convened by non-profit FAA advisory body RTCA to develop consensus recommendations for the FAA on implementing NextGen.

NAS: National Airspace System, the airspace, both domestic and oceanic, for which the FAA has air traffic control responsibility.

NATS: National Air Traffic Service, the UK's self-supporting air navigation service provider.

NextGen: FAA's name for the overall effort to implement the next-generation air traffic management system, which includes new facilities, procedures, and technologies.

NOAA: National Oceanic and Atmospheric Administration, parent agency of the National Weather Service.

OMB: Office of Management and Budget, the White House budget office.

PBN: Performance-based navigation, an emerging concept in which the paths aircraft may travel are based on their self-monitored performance capabilities, rather than purely on equipment requirements. RNAV and RNP are forms of PBN.

RNAV: Area navigation, flight paths that go directly from a point A to a point B defined by an onboard computer, rather than having to overfly individual ground navigation signals such as VORs.

RNP: Required navigation performance, a more-advanced form of PBN defined by how precisely an aircraft can fly a given path (e.g., RNP 0.3

means it can reliably stay within 0.3 nautical miles of a defined path).

RTCA: A federal advisory committee (originally named the Radio Technical Committee for Aeronautics) created in 1935.

SES: Single European Sky, the term for the European Union's program to implement advanced ATM while consolidating airspace and reducing unit costs.

SESAR: Single European Sky ATM Research, the EU counterpart to the U.S. NextGen program.

STARS: Standard Terminal Automation Replacement System, the much-delayed replacement for the CARTS software in all US TRACONs.

TAMDAR: Tropospheric airborne meteorological data reporting, a real-time aviation weather data reporting system.

TCAS: Threat collision avoidance system, a collision warning and avoidance system, required on all planes operating in controlled airspace.

TRACON: Terminal radar approach control, FAA ATC facility responsible for departure and arrival airspace near airports.

USATS: U.S. Air Traffic Services Corporation, Clinton administration Department of Transportation proposal for an air traffic control corporation in 1994.

VFR: Visual flight rules, rules requiring pilots in uncontrolled airspace to see and avoid other air traffic; no flight plan is required for planes flying under these rules.

VOR: VHF omnidirectional radio, a ground-based navigation aid identifying a specific geographical location on aeronautical charts.

WAM: Wide-area multilateration, a ground-based system that tracks the position of vehicles by triangulating on signals from their transponders or ADS-B units.

Endnotes

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