

CHAPTER 1

IFR OPERATIONS IN THE NATIONAL AIRSPACE SYSTEM

Today's National Airspace System (NAS) consists of a complex collection of facilities, systems, equipment, procedures, and airports operated by thousands of people to provide a safe and efficient flying environment. The NAS includes:

- More than 750 air traffic control (ATC) facilities with associated systems and equipment to provide radar and communication service.
- Volumes of procedural and safety information necessary for users to operate in the system and for FAA employees to effectively provide essential services.
- More than 18,000 airports capable of accommodating an array of aircraft operations, many of which support instrument flight rules (IFR) departures and arrivals.
- Approximately 4,500 air navigation facilities.
- Approximately 48,000 FAA employees who provide air traffic control, flight service, security, field maintenance, certification, systems acquisitions, and a variety of other services.
- Approximately 13,000 instrument flight procedures, including over 1,000 Instrument Landing System (ILS) procedures, over 1,700 nondirectional beacon (NDB) procedures, over 2,700 VHF omnidirectional range (VOR) procedures, and over 3,500 global positioning system/area navigation procedures (GPS/RNAV).
- Procedures such as microwave landing system (MLS), localizer (LOC), localizer type directional aid (LDA), simplified directional facility (SDF), charted visual flight procedures, departure procedures (DPs), and standard terminal arrivals (STARs).
- Approximately 2,153,326 instrument approaches annually, of which 36 percent are air carrier, 27 percent air taxi, 33 percent general aviation, and 4 percent military.
- Approximately 49,409,000 instrument operations logged by FAA towers annually.

America's aviation industry is projecting continued increases in business, recreation, and personal travel. Airlines in the United States (U.S.) expect to carry twice as many passengers by the year 2015 as they do today. [Figure 1-1]



Figure 1-1. IFR Operations in the NAS.

BRIEF HISTORY OF THE NATIONAL AIRSPACE SYSTEM

About two decades after the introduction of powered flight, aviation industry leaders believed that the airplane would not reach its full commercial potential without federal action to improve and maintain safety standards. In response to their concerns, the U.S. Congress passed the Air Commerce Act of May 20, 1926, marking the onset of the government's hand in regulating civil aviation. The act charged the Secretary of Commerce with fostering air commerce, issuing and enforcing air traffic rules, licensing pilots, certifying aircraft, establishing airways, and operating and maintaining aids to air navigation. As commercial flying increased, the Bureau of Air Commerce—a division of the Department of Commerce—encouraged a group of airlines to establish the first three centers for providing air traffic control (ATC) along the airways. In 1936, the bureau took over the centers and began to expand the ATC system. [Figure 1-2] The pioneer air traffic controllers used maps, blackboards, and mental calculations to ensure the safe separation of aircraft traveling along designated routes between cities.

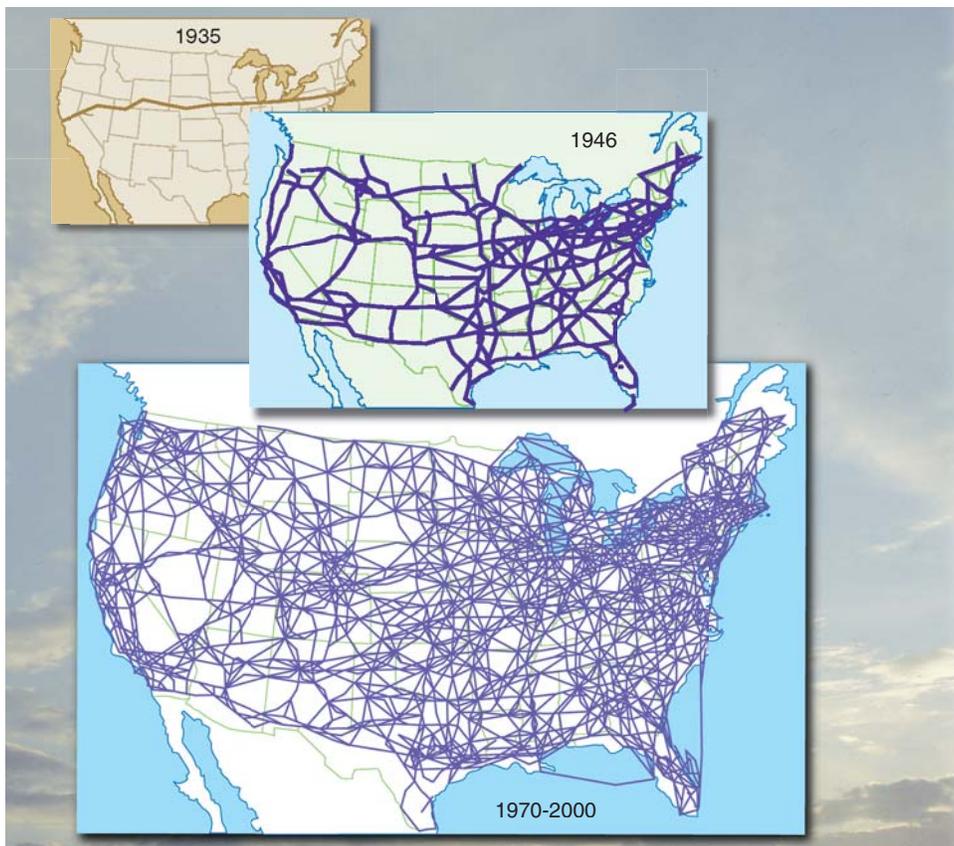


Figure 1-2. ATC System Expansion.

On the eve of America's entry into World War II, the Civil Aeronautics Administration (CAA)—charged with the responsibility for ATC, airman and aircraft certification, safety enforcement, and airway development—expanded its role to cover takeoff and landing

operations at airports. Later, the addition of radar helped controllers to keep abreast of the postwar boom in commercial air transportation.

The introduction of jet airliners, followed by a series of midair collisions, instigated the passage of the Federal Aviation Act of 1958, which transferred CAA functions to the FAA (then the Federal Aviation Agency). The act entrusted safety rulemaking to the FAA, which also held the sole responsibility for developing and maintaining a common civil-military system of air navigation and air traffic control. In 1967, the new Department of Transportation (DOT) combined major federal transportation responsibilities, including the FAA (now the Federal Aviation Administration) and a new National Transportation Safety Board (NTSB).

By the mid-1970s, the FAA had achieved a semi-automated ATC system based on a marriage of radar and computer technology. By automating certain routine tasks, the system allowed controllers to concentrate more efficiently on the task of providing aircraft separation. Data appearing directly on the controllers' scopes

provided the identity, altitude, and groundspeed of aircraft carrying radar beacons. Despite its effectiveness, this system required continuous enhancement to keep pace with the increased air traffic of the late 1970s, due in part to the competitive environment created by airline deregulation.

To meet the challenge of traffic growth, the FAA unveiled the NAS Plan in January 1982. The new plan called for more advanced systems for en route and terminal ATC, modernized flight service stations, and improvements in ground-to-air surveillance and communication. Continued ATC modernization under the NAS Plan included such steps as the implementation of Host Computer Systems (completed in 1988) that

were able to accommodate new programs needed for the future. [Figure 1-3]

In February 1991, the FAA replaced the NAS Plan with the more comprehensive Capital Investment Plan (CIP), which outlined a program for further enhancement of the ATC system, including higher levels of automation as well

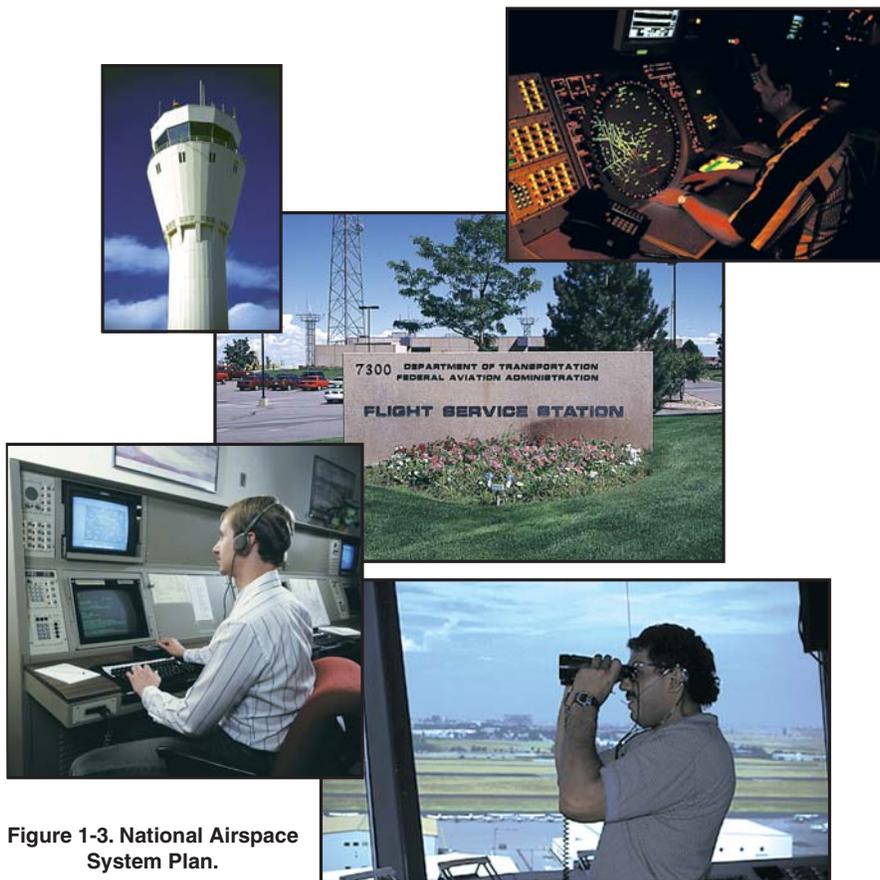


Figure 1-3. National Airspace System Plan.

as new radar, communications, and weather forecasting systems. One of the CIP's programs currently underway is the deployment of new Terminal Doppler Weather Radar systems able to warn pilots and controllers of meteorological hazards. The FAA is also placing a high priority on speeding the application of the GPS satellite technology to civil aeronautics. Another notable ongoing program is encouraging progress toward the implementation of Free Flight, a concept aimed at increasing the efficiency of high-altitude operations.

NATIONAL AIRSPACE SYSTEM PLANS

FAA planners efforts to devise a broad strategy to address capacity issues resulted in the Operational Evolution Plan (OEP)—the FAA's commitment to meet the air transportation needs of the U.S. for the next ten years.

To wage a coordinated strategy, OEP executives met with representatives from the entire aviation community—including airlines, airports, aircraft manufacturers, service providers, pilots, controllers, and passengers. They agreed on four core problem areas:

- Arrival and departure rates.
- En route congestion.

- Airport weather conditions.
- En route severe weather.

The goal of the OEP is to expand capacity, decrease delays, and improve efficiency while maintaining safety and security. With reliance on the strategic support of the aviation community, the OEP is limited in scope, and only contains programs to be accomplished between 2001 and 2010. Programs may move faster, but the OEP sets the minimum schedule. Considered a living document that matures over time, the OEP is continually updated as decisions are made, risks are identified and mitigated, or new solutions to operational problems are discovered through research.

An important contributor to FAA plans is the Terminal Area Operations Aviation Rulemaking Committee (TAOARC). The objectives and scope of TAOARC are to provide a forum for the U.S. aviation community to discuss and resolve issues, provide direction for U.S.

flight operations criteria, and produce U.S. consensus positions for global harmonization.

The general goal of the committee is to develop a means to implement improvements in terminal area operations that address safety, capacity, and efficiency objectives, as tasked, that are consistent with international implementation. In the context of this committee, terminal area means the airspace that services arrival, departure, and airport ground operations. This committee provides a forum for the FAA, other government entities, and affected members of the aviation community to discuss issues and to develop resolutions and processes to facilitate the evolution of safe and efficient terminal area operations.

Current efforts associated with NAS modernization come with the realization that all phases must be integrated. The evolution to an updated NAS must be well orchestrated and balanced with the resources available. Current plans for NAS modernization focus on three key categories:

- Upgrading the infrastructure.
- Providing new safety features.
- Introducing new efficiency-oriented capabilities into the existing system.

It is crucial that our NAS equipment is protected, as lost radar or communications signals can slow the flow of aircraft to a busy city, which in turn, could cause delays throughout the entire region, and possibly, the whole country.

The second category for modernization activities focuses on upgrades concerning safety. Although we cannot control the weather, it has a big impact on the NAS. Fog in San Francisco, snow in Denver, thunderstorms in Kansas, wind in Chicago; all of these reduce the safety and capacity of the NAS. Nevertheless, great strides are being made in our ability to predict the weather. Controllers are receiving better information about winds and storms, and pilots are receiving better information before they take off—all of which makes flying safer. [Figure 1-4]

Another cornerstone of the FAA's future is improved navigational information available in the cockpit. As the use of GPS becomes more widely accepted, the Wide Area Augmentation System (WAAS) will supplement GPS navigation and provide pilots improved accuracy and availability, which increases safety of flight. Due to the precise navigation service it provides, WAAS also enables improvements in efficiency by providing access to more runways in poor weather.

Moreover, the Local Area Augmentation System (LAAS) is being developed to provide even better accuracy than GPS with WAAS. LAAS will provide localized service for final approaches in poor weather conditions at major airports. This additional navigational accuracy will be available in the cockpit and will be used for other system enhancements. More information about WAAS and LAAS is contained in Chapters 5 and 6.

The Automatic Dependent Surveillance (ADS) system, currently being evaluated by the FAA and several airlines, enables the aircraft to automatically transmit its location to various receivers. This broadcast mode,

commonly referred to as ADS-B, is a signal that can be received by other properly equipped aircraft and ground receiver stations, which in turn feed the automation system accurate aircraft position information. This more accurate information will be used to improve the efficiency of the system—the third category of modernization goals.

Other key efficiency improvements are found in the deployment of new tools designed to assist the controller. For example, most commercial aircraft already have equipment to send their GPS positions automatically to receiver stations over the ocean. This key enhancement is necessary for all aircraft operating in oceanic airspace and allows more efficient use of airspace. Another move is toward improving text and graphical message exchange, which is the ultimate goal of the Controller Pilot Data Link Communications (CPDLC) Program.

In the en route domain, the Display System Replacement (DSR), along with the Host/Oceanic Computer System Replacement (HOCSR) and Eunomia projects, are the platforms and infrastructure for the future. These provide new displays to the controllers, upgrade the computers to accept future tools, and provide modern surveillance and flight data processing capabilities. For CPDLC to work effectively, it must be integrated with the en route controller's workstation.

RNAV PLANS

Designing routes and airspace to reduce conflicts between arrival and departure flows can be as simple as adding extra routes or as comprehensive as a full redesign in which multiple airports are jointly optimized. New strategies are in place for taking advantage of existing structures to departing aircraft through congested transition airspace. In other cases, RNAV procedures are used to develop new routes that reduce flow complexity by permitting aircraft to fly optimum routes with minimal controller intervention. These new routes spread the flow



Figure 1-4. Improved Safety of Flight.

across the terminal and transition airspace so aircraft can be separated with optimal lateral distances and altitudes in and around the terminal area. In some cases, the addition of new routes alone is not sufficient, and redesign of existing routes and flows are required. Benefits are multiplied when airspace surrounding more than one airport (e.g., in a metropolitan area) can be jointly optimized.

SYSTEM SAFETY

Although hoping to decrease delays, improve system capacity, and modernize facilities, the ultimate goal of the NAS Plan is to improve system safety. If statistics are any indication, the beneficial effect of the implementation of the plan may already be underway as aviation safety seems to have increased in recent years. The FAA has made particular emphasis to not only reduce the number of accidents in general, but also to make strides in curtailing controlled flight into terrain (CFIT) and runway incursions as well as continue approach and landing accident reduction (ALAR).

The term CFIT defines an accident in which a fully qualified and certificated crew flies a properly working airplane into the ground, water, or obstacles with no apparent awareness by the pilots. A runway incursion is defined as any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in a loss of separation with an aircraft taking off, attempting to take off, landing, or attempting to land. The term ALAR applies to an accident that occurs during a visual approach, during an instrument approach after passing the intermediate approach fix

(IF), or during the landing maneuver. This term also applies to accidents occurring when circling or when beginning a missed approach procedure.

ACCIDENT RATES

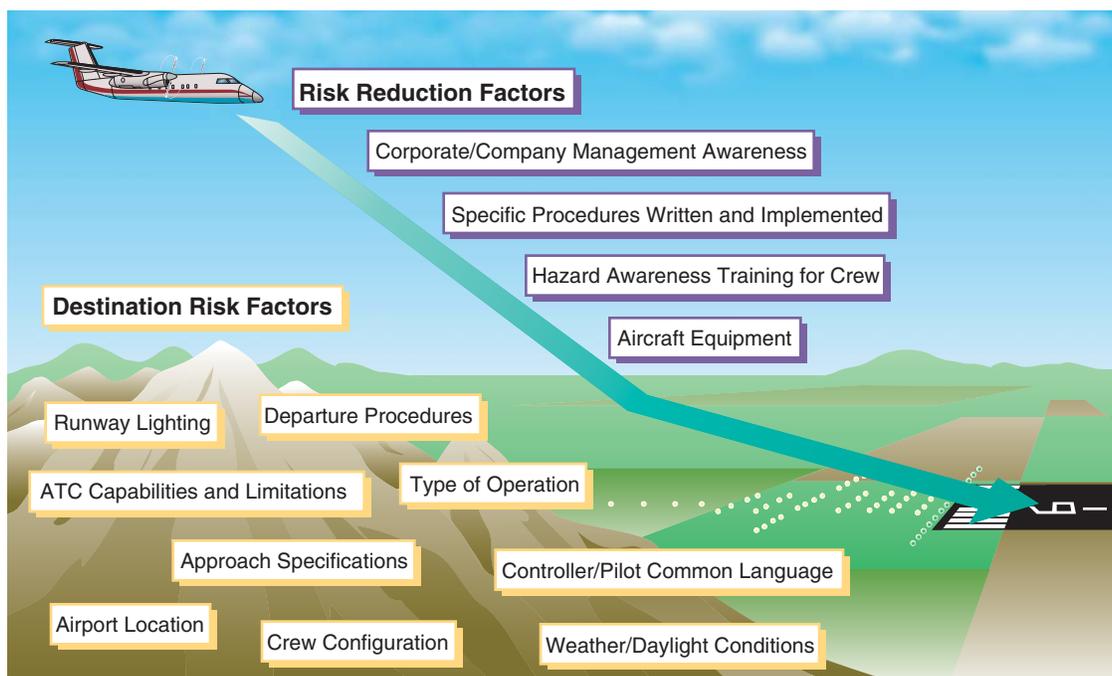
The NTSB released airline accident rate statistics for 2001 that showed a decline from the previous year. Thirty-six accidents¹ on U.S. scheduled airlines were recorded in 2001, resulting in .317 accidents per 100,000 departures. These numbers represent a decrease from 2000, when 51 accidents were reported for a rate of .463 accidents per 100,000 departures.

Accident rates for both scheduled and non-scheduled 14 CFR part 135 services also decreased in 2001. The scheduled service rate shrank from 1.965 accidents per 100,000 departures in 2000 to 1.407 in 2001. For unscheduled, on-demand air taxis, the rate decreased from 2.28 to 2.12 per 100,000 flight hours.

Despite reporting fewer accidents in 2001, the accident rate for general aviation aircraft increased slightly from 6.33 accidents per 100,000 flight hours in 2000 to 6.56 accidents in 2001. General aviation was the only category of air transportation to report an increase in its accident rate.

Among the top priorities for accident prevention are CFIT and ALAR. Pilots can decrease exposure to a CFIT accident by identifying risk factors and remedies prior to flight. [Figure 1-5] Additional actions on the CFIT reduction front include equipping aircraft with

Figure 1-5. CFIT Reduction.



¹ This figure includes the four crashes of September 11, 2001. Because the crashes of September 11, 2001 were the results of terrorist activity, those crashes are included in the totals for scheduled U.S. airline accidents and fatalities, but are not used for the purpose of accident rate computation. The accident rate of .317 per 100,000 departures is determined from the remaining 32 accidents in 2001.

state-of-the-art terrain awareness and warning systems (TAWS), sometimes referred to as enhanced ground proximity warning systems (EGPWS). This measure alone has been assessed to contribute to at least a 90 percent reduction in CFIT accidents. The total U.S. commercial fleet (excluding cargo planes) is planned to be retrofitted with TAWS by the end of March 2005.

Added training for aircrews and controllers is part of the campaign to safeguard against CFIT, as well as making greater use of approaches with vertical guidance which use a constant angle descent path to the runway. This measure offers nearly a 70 percent potential reduction. Another CFIT action plan involves a check of ground-based radars to ensure that their minimum safe altitude warning (MSAW) feature functions correctly.

Like CFIT, the ALAR campaign features a menu of actions, three of which involve crew training, altitude awareness policies checklists, and smart alerting technology. These three alone offer a potential 20 to 25 percent reduction in approach and landing accidents. Officials representing Safer Skies—a ten-year collaborative effort between the FAA and the airline industry—believe that the combination of CFIT and ALAR interventions will offer more than a 45 percent reduction in accidents.

RUNWAY INCURSION STATISTICS

While it is difficult to eliminate runway incursions, technology offers the means for both controllers and flight crews to create situational awareness of runway incursions in sufficient time to prevent accidents. Consequently, the FAA is taking actions that will identify and implement technology solutions, in conjunction with training and procedural evaluation and changes, to reduce runway accidents. Recently established programs that address runway incursions center on identifying the potential severity of an incursion and reducing the likelihood of incursions through training, technology, communications, procedures, airport signs/markings/lighting, data analysis, and developing local solutions. The FAA's initiatives include:

- Promoting aviation community participation in runway safety activities and solutions.
- Appointing nine regional Runway Safety Program Managers.
- Providing training, education, and awareness for pilots, controllers, and vehicle operators.
- Publishing an advisory circular for airport surface operations.

- Increasing the visibility of runway hold line markings.
- Reviewing pilot-controller phraseology.
- Providing foreign air carrier pilot training, education, and awareness.
- Requiring all pilot checks, certifications, and flight reviews to incorporate performance evaluations of ground operations and test for knowledge.
- Increasing runway incursion action team site visits.
- Deploying high-technology operational systems such as the Airport Surface Detection Equipment-3 (ASDE-3), Airport Movement Area Safety System (AMASS), and Airport Surface Detection Equipment-X (ASDE-X).
- Evaluating direct warning capability to flight crews using cockpit display avionics for both large and small aircraft operators.

Runway incursion statistics compiled for the first half of 2001 show that there were 243 runway incursions, two less than the same time in 2000. Of these, 48 percent were Category D (little or no risk of collision), 38 percent were Category C (there is ample time and distance to avoid a potential collision), 8 percent were Category B (there is a significant potential for collision), and 6 percent were Category A (collision avoidable only when extreme action is taken). The good news is that, when comparing the severity distribution of the combined totals of the last three years, the 2001 percentages have decreased in Categories A, B, and C.

SYSTEM CAPACITY

On the user side, there are more than 616,000 active pilots operating over 280,000 commercial, regional, general aviation, and military aircraft. That equates to 4,000 to 6,000 aircraft operating in the NAS during peak periods. Figure 1-6 depicts over 5,000 aircraft operating at the same time in the U.S. shown on this Air Traffic Control System Command Center (ATCSCC) screen.

TAKEOFFS AND LANDINGS

According to the General Aviation Manufacturer's Association (GAMA) statistics for 2000, operations at general aviation (GA) airports with FAA control towers totaled over 27 million—approximately 50,000 aircraft operations per day. Aircraft landings and departures have increased steadily with more than 11.5 million² reported for 2001. These figures do not even include operations at airports that do not have a control tower. Despite these numbers, user demands on the NAS are quickly exceeding the resources required to fulfill them. Delays for the period of

² Source: BTS publication "Air Carrier Industry Scheduled Service TRAFFIC statistics.

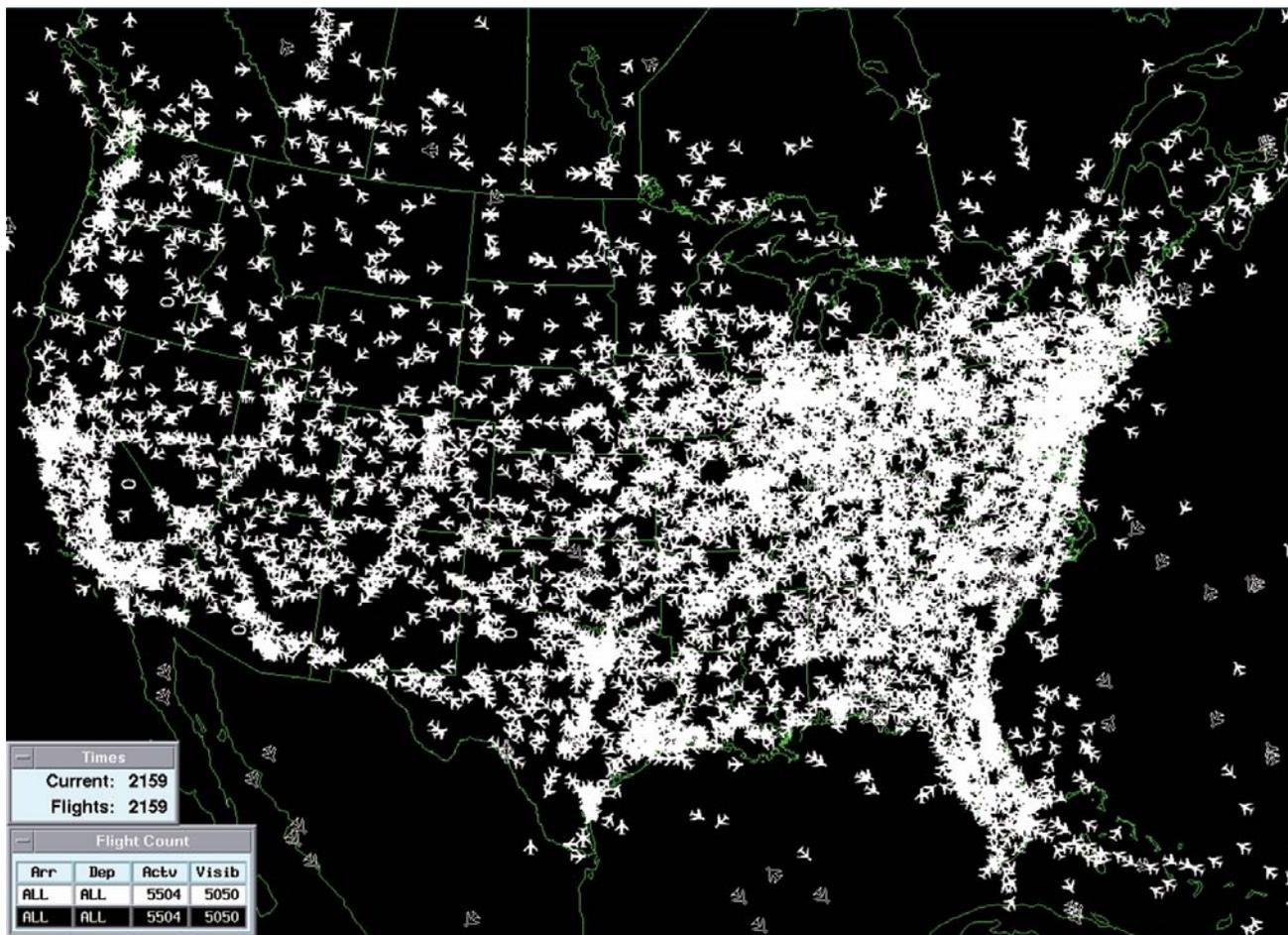


Figure 1-6. System Capacity.

January through June 2000 were almost 13.6 percent higher than in 1999. In June alone, delays increased 20 percent. Delays for May, June, and July 2000 totaled more than 86,684, a 6.8 percent increase over the previous year. This clear illustration of the NAS's growing pains provides the FAA with verification that modernization efforts currently underway are well justified. Nothing short of the integrated, systematic, cooperative, and comprehensive approach spelled out by the OEP can bring the NAS to the safety and efficiency standards that the flying public demands.

AIR TRAFFIC CONTROL SYSTEM COMMAND CENTER

The task of managing the flow of air traffic within the NAS is assigned to the Air Traffic Control System Command Center (ATCSCC). Headquartered in Herndon, Virginia, the ATCSCC has been operational since 1994 and is located in one of the largest and most sophisticated facilities of its kind. The ATCSCC regulates air traffic at a national level when weather, equipment, runway closures, or other conditions place stress on the NAS. In these instances, traffic management specialists at the ATCSCC take action to modify traffic demands in order to remain within system capacity. They accomplish this in cooperation with:

- Airline personnel.
- Traffic management specialists at affected facilities.
- Air traffic controllers at affected facilities.

Efforts of the ATCSCC help minimize delays and congestion and maximize the overall use of the NAS, thereby ensuring safe and efficient air travel within the U.S. For example, if severe weather, military operations, runway closures, special events, or other factors affect air traffic for a particular region or airport, the ATCSCC mobilizes its resources and various agency personnel to analyze, coordinate, and reroute (if necessary) traffic to foster maximum efficiency and utilization of the NAS.

The ATCSCC directs the operation of the traffic management (TM) system to provide a safe, orderly, and expeditious flow of traffic while minimizing delays. TM is apportioned into traffic management units (TMUs), which monitor and balance traffic flows within their areas of responsibility in accordance with TM directives. TMUs help to ensure system efficiency and effectiveness without compromising safety, by providing the ATCSCC with advance notice of planned outages and runway closures that will impact the air traffic system, such as NAVAID and radar shutdowns, runway closures, equipment

and computer malfunctions, and procedural changes. [Figure 1-7]

HOW THE SYSTEM COMPONENTS WORK TOGETHER

The NAS comprises the common network of U.S. airspace, air navigation facilities, equipment, services, airports and landing areas, aeronautical charts, information and services, rules and regulations, procedures, technical information, manpower, and material. Included are system components shared jointly with the military. The underlying demand for air commerce—people’s desire to travel for business and pleasure and to ship cargo by air—grows with the economy independent of the capacity or performance of the NAS. As the economy grows, more and more people want to fly, whether the system can handle it or not. Another type—realized demand—refers to flight plans filed by the airlines and other airspace users to access the system. Realized demand is moderated by the airline’s understanding of the number of flights that can be accommodated without encountering unacceptable delay, and is limited by the capacity for the system.

USERS

According to a 2000 MITRE report, between 1998 and 1999, commercial traffic grew at 4.6 percent, using up much of the capacity reserves in the system. The 2002 FAA ACE Plan showed 695.7 million passenger enplanements in 2000, while also verifying the impact of 9-11 with only 682.5 million passenger enplanements for 2001 which is the equivalent of a 1.8 percent decrease in passenger traffic. A

steady growth rate (near 3 percent per year) is predicted to resume in 2003, with projected passenger enplanements reaching the previous 2002 forecast of 740 million in 2005, or a 3 year delay in previous estimates. Likewise, the previous forecast that passenger enplanements would reach 1 billion by 2010, is now forecast for that level to be reached by 2013. Even at the lower growth rate, the system is nearing the point of saturation, with limited ability to grow unless major changes are brought about.

Adding to the growth challenge, users of the NAS cover a wide spectrum in pilot skill and experience, aircraft types, and air traffic service demands, creating a challenge to the NAS to provide a variety of services that accommodate all types of traffic. NAS users range from professional airline, commuter, and corporate pilots to single-engine piston pilots, as well as owner-operators of personal jets to military jet fighter trainees.

AIRLINES

Though commercial air carrier aircraft traditionally make up less than 5 percent of the civil aviation fleet, they account for about 30 percent of the hours flown and almost half of the total IFR hours flown in civil aviation³. Commercial air carriers are the most homogenous category of airspace users, although there are some differences between U.S. trunk carriers (major airlines) and regional airlines (commuters) in terms of demand for ATC services. Generally, U.S. carriers operate large, high performance airplanes that cruise at altitudes above 18,000 feet. Conducted exclusively under IFR, airline flights follow established schedules and operate in and

out of larger and better-equipped airports. In terminal areas, however, they share airspace and facilities with all types of traffic and must compete for airport access with other users. Airline pilots are highly proficient and thoroughly familiar with the rules and procedures under which they must operate.

Some airlines are looking toward the use of larger aircraft, such as the 555-passenger Airbus A380, with the potential to reduce airway and terminal congestion by transporting more people in fewer aircraft. This is especially valuable at major hub airports,

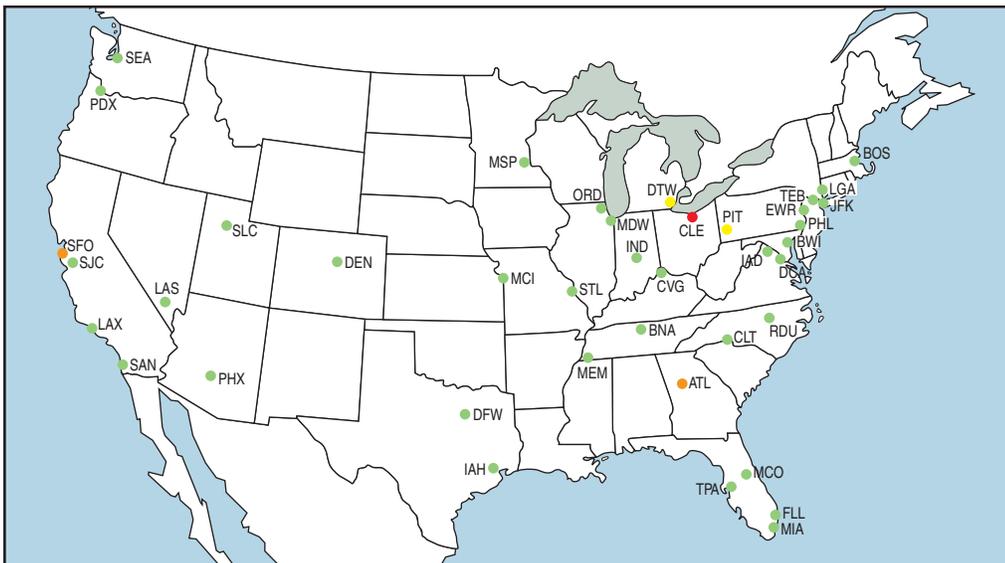


Figure 1-7. A real-time Airport Status page displayed on the ATCSCC web site (www.fly.faa.gov/flyFAA/index.html) provides general airport condition status. Though not flight specific, it portrays current general airport trouble spots. Green indicates less than five-minute delays. Yellow means departures and arrivals are experiencing delays of 16 to 45 minutes. Traffic destined to orange locations is being delayed at the departure point. Red airports are experiencing taxi or airborne holding delays greater than 45 minutes. Blue indicates closed airports.

³ Source: FAA Statistical Handbook of Aviation

where the number of operations exceeds capacity at certain times of day. On the other hand, the proliferation of larger aircraft also requires changes to terminals (e.g., double-decker jetways and better passenger throughput), rethinking of rescue and fire-fighting strategies, taxi-way file changes, and perhaps stronger runways and taxiways.

Commuter airlines also follow established schedules and are flown by professional pilots. Commuters characteristically operate smaller and lower performance aircraft in airspace that must often be shared by GA aircraft, including visual flight rules (VFR) traffic. As commuter operations have grown in volume, they have created extra demands on the airport and ATC systems. At one end, they use hub airports along with other commercial carriers, which contributes to growing congestion at major air traffic hubs. IFR-equipped and operating under IFR like other air carriers, commuter aircraft cannot be used to full advantage unless the airport at the other end of the flight, typically a small community airport, also is capable of IFR operation. Thus, the growth of commuter air service has created pressure for additional instrument approach procedures and control facilities at smaller airports. A growing trend among the major airlines is the proliferation of regional jets (RJs). RJs are replacing turboprop aircraft and they are welcomed by some observers as saviors of high-quality jet aircraft service to small communities. RJs are likely to be a regular feature of the airline industry for a long time because passengers and airlines overwhelmingly prefer RJs to turboprop service. From the passengers' perspective, they are far more comfortable; and from the airlines' point of view, they are more profitable. Thus, within a few years, most regional air traffic in the continental U.S. will be by jet, with turboprops filling a smaller role.

In 1997, the FAA's research, development, and engineering arm—the Center for Advanced Aviation Systems Development (CAASD)—investigated the underlying operational and economic environments of RJs on the ATC system. The study demonstrated two distinct trends: (1) growing airspace and airport congestion was exacerbated by the rapid growth of RJ traffic, and (2) potential airport infrastructure limitations may constrain airline business. During the spring and summer of 2000, the FAA, CAASD, major airlines, and others focused on finding mitigating strategies to address airline congestion. With more than 500 RJs in use—and double that expected over the next few years—the success of these efforts is critical if growth in the regional airline industry is to be sustained. [Figure 1-8]

CORPORATE AND FRACTIONALS

Though technically considered under the GA umbrella, the increasing use of sophisticated, IFR-equipped aircraft by businesses and corporations has created a niche of its own. By using larger high performance airplanes and equipping them with the latest avionics, the business portion of the GA fleet has created demands for ATC services

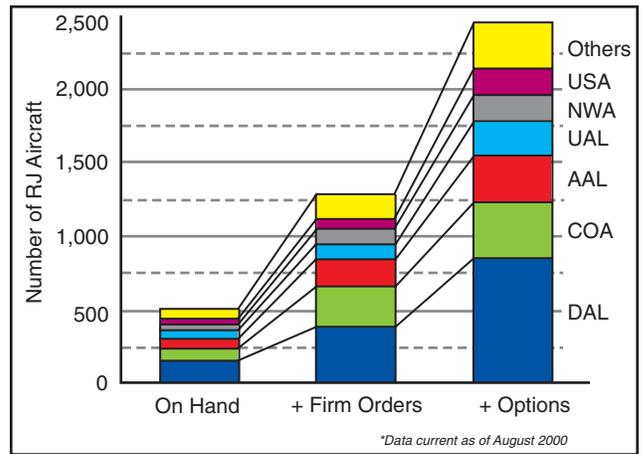


Figure 1-8. Regional Jets in the Fleet. As this chart suggests, while there are only about 500 RJs in the combined U.S. commercial airline fleet today, the major airlines have some 750 RJs on order, with options for another 1,250. As the CAASD's RJ studies demonstrate, this dramatic change from the handful of RJs that were in operation only five years ago has major implications for the NAS today and in the immediate future.

that more closely resemble commercial operators than the predominately VFR general aviation fleet.

GENERAL AVIATION

The tendency of GA aircraft owners at the upper end of the spectrum to upgrade the performance and avionics of their aircraft increases the demand for IFR services and for terminal airspace at airports. In response, the FAA has increased the extent of controlled airspace and improved ATC facilities at major airports. The safety of mixing IFR and VFR traffic is a major concern, but the imposition of measures to separate and control both types of traffic creates more restrictions on airspace use and raises the level of aircraft equipage and pilot qualification necessary for access.

MILITARY

From an operational point of view, military flight activities comprise a subsystem that must be fully integrated within NAS. However, military aviation has unique requirements that often are different from civil aviation users. The military's need for designated training areas and low-level routes located near their bases sometimes conflicts with civilian users who need to detour around these areas. In coordinating the development of ATC systems and services for the armed forces, the FAA is challenged to achieve a maximum degree of compatibility between civil and military aviation objectives.

ATC FACILITIES

FAA figures show that the NAS includes more than 18,300 airports, 21 ARTCCs, 197 TRACON facilities, over 460 air traffic control towers (ATCTs), 75 flight service stations (FSSs), and approximately 4,500 air navigation facilities. Several thousand pieces of maintainable equipment including radar, communications switches,

ground-based navigation aids, computer displays, and radios are used in NAS operations, and NAS components represent billions of dollars in investments by the government. Additionally, the aviation industry has invested significantly in ground facilities and avionics systems designed to use the NAS. Approximately 48,000 FAA employees provide air traffic control, flight service, security, field maintenance, certification, system acquisition, and other essential services.

Differing levels of ATC facilities vary in their structure and purpose. Traffic management at the national level is led by the Command Center, which essentially “owns” all airspace. Regional Centers, in turn, sign Letters of Agreement (LOAs) with various approach control facilities, delegating those facilities chunks of airspace in which that approach control facility has jurisdiction. The approach control facilities, in turn, sign LOAs with various towers that are within that airspace, further delegating airspace and responsibility. This ambiguity has created difficulties in communication between the local facilities and the Command Center. However, a decentralized structure enables local flexibility and a tailoring of services to meet the needs of users at the local level. Improved communications between the Command Center and local facilities could support enhanced safety and efficiency while maintaining both centralized and decentralized aspects to the ATC system.

AIR ROUTE TRAFFIC CONTROL CENTER

A Center’s primary function is to control and separate air traffic within a designated airspace, which may cover more than a 100,000 square miles, traverse over several states, and extends from the base of the underlying controlled airspace up to Flight Level (FL) 600. There are 21 Centers located throughout the U.S., each of which is divided into sectors. Controllers assigned to these sectors, which range from 50 to over 200 miles wide, guide aircraft toward their intended destination by way of vectors and/or airway assignment, routing aircraft around weather and other traffic. Centers employ 300 to 700 controllers, with more than 150 on duty during peak hours at the busier facilities. A typical flight by a commercial airliner is handled mostly by the Centers.

TERMINAL RADAR APPROACH CONTROL

Terminal Radar Approach Control (TRACON) controllers work in dimly lit radar rooms located within the control tower complex or in a separate building located on or near the airport it serves. [Figure 1-9] Using radarscopes, these controllers typically work an area of airspace with a 50-mile radius and up to an altitude of 17,000 feet. This airspace is configured to provide service to a primary airport, but may include other airports that are within 50 miles of the radar service area. Aircraft within this area are provided vectors to airports, around terrain, and weather, as well as separation from other aircraft. Controllers in

TRACONs determine the arrival sequence for the control tower’s designated airspace.



Figure 1-9. Terminal Radar Approach Control.

CONTROL TOWER

Controllers in this type of facility manage aircraft operations on the ground and within specified airspace around an airport. The number of controllers in the tower varies with the size of the airport. Small general aviation airports typically have three or four controllers, while larger international airports can have up to fifteen controllers talking to aircraft, processing flight plans, and coordinating air traffic flow. Tower controllers manage the ground movement of aircraft around the airport and ensure appropriate spacing between aircraft taking off and landing. In addition, it is the responsibility of the control tower to determine the landing sequence between aircraft under its control. Tower controllers issue a variety of instructions to pilots, from how to enter a pattern for landing to how to depart the airport for their destination.

FLIGHT SERVICE STATIONS

Flight Service Stations (FSSs) are air traffic facilities which provide pilot briefings, en route communications and VFR search and rescue services, assist lost aircraft and aircraft in emergency situations, relay ATC clearances, originate Notices to Airmen, broadcast aviation weather and NAS information, receive and process IFR flight plans, and monitor navigational aids (NAVAIDs). In addition, at selected locations, FSSs provide En route Flight Advisory Service (Flight Watch), take weather observations, issue airport advisories, and advise Customs and Immigration of transborder flights.

Pilot Briefers at FAA flight service stations render pre-flight, in-flight, and emergency assistance to all pilots on request. They give information about actual weather conditions and forecasts for airports and flight paths, relay air traffic control instructions between controllers and pilots, assist pilots in emergency situations, and initiate searches for missing or overdue aircraft. FSSs

provide information to all airspace users, including the military.

FLIGHT PLANS

Prior to flying in controlled airspace under IFR conditions or in Class A airspace, pilots are required to file a flight plan. IFR (as well as VFR) flight plans provide air traffic center computers with accurate and precise routes required for flight data processing (FDP⁴). The computer knows every route (published and unpublished) and NAVAID, most intersections, and all airports, and can only process a flight plan if the proposed routes and fixes connect properly. Center computers also recognize preferred routes and know that forecast or real-time weather may change arrival routes. Centers and TRACONs now have a computer graphic that can show every aircraft on a flight plan in the U.S. as to its flight plan information and present position. Despite their sophistication, center computers do not overlap in coverage or information with other Centers, so that flight requests not honored in one must be repeated in the next.

RELEASE TIME

ATC uses an IFR release time⁵ in conjunction with traffic management procedures to separate departing aircraft from other traffic. For example, when controlling departures from an airport without a tower, the controller limits the departure release to one aircraft at any given time. Once that aircraft is airborne and radar identified, then the following aircraft may be released for departure, provided they meet the approved radar separation (3 miles laterally or 1,000 feet vertically) when the second aircraft comes airborne. Controllers must take aircraft performances into account when releasing successive departures, so that a B-747 HEAVY aircraft is not released immediately after a departing Cessna 172. Besides releasing fast aircraft before slow ones, another technique commonly used for successive departures is to have the first aircraft turn 30 to 40 degrees from runway heading after departure, and then have the second aircraft depart on a SID or runway heading. Use of these techniques is common practice when maximizing airport traffic capacity.

EXPECT DEPARTURE CLEARANCE TIME

Another tool that the FAA is implementing to increase efficiency is the reduction of the standard Expect Departure Clearance Time⁶ (EDCT) requirement. The FAA has drafted changes to augment and modify procedures contained in Ground Delay Programs (GDPs). Airlines may now update their departure times by arranging their flights' priorities to meet the controlled

time of arrival. In order to evaluate the effectiveness of the new software and the airline-supplied data, the actual departure time parameter in relation to the EDCT is being reduced. This change will impact all flights (commercial and GA) operating to seven of the nation's busiest airports. Instead of the previous 25-minute EDCT window (5 minutes prior and 20 minutes after the EDCT), the new requirement for GDP implementation is a 7-minute window, and aircraft are required to depart within 3 minutes before or after their assigned Controlled Time of Departure (CTD). Using reduced EDCT and other measures included in GDPs, ATC aims at reducing the number of arrival slots issued to accommodate degraded arrival capacity at an airport affected by weather. The creation of departure or ground delays is less costly and safer than airborne holding delays in the airspace at the arrival airport.

MANAGING SAFETY AND CAPACITY

SYSTEM DESIGN

The CAASD is aiding in the evolution towards free flight with its work in developing new procedures necessary for changing traffic patterns and aircraft with enhanced capabilities, and also in identifying traffic flow constraints that can be eliminated. This work supports the FAA's Operational Evolution Plan in the near-term. Rapid changes in technology in the area of navigation performance, including the change from ground-based area navigation systems, provide the foundation for aviation's global evolution. This progress will be marked by combining all elements of communication, navigation, and surveillance (CNS) with air traffic management (ATM) into tomorrow's CNS/ATM based systems. The future CNS/ATM operating environment will be based on navigation defined by geographic waypoints expressed in latitude and longitude since instrument procedures and flight routes will not require aircraft to overfly ground-based navigation aids defining specific points. Concepts in CNS/ATM such as RNAV, GPS, and required navigation performance (RNP) provide the path for this transition.

APPLICATION OF AREA NAVIGATION

RNAV airways provide more direct routings than the current VOR-based airway system, giving pilots easier access through terminal areas, while avoiding the circuitous routings now common in many busy Class B areas. RNAV airways are a critical component to the transition from ground-based navigation systems to GPS navigation. Once established and certified, RNAV routes will help maintain the aircraft flow through busy terminals by segregating arrival or departure traffic away

⁴ FDP maintains a model of the route and other details for each aircraft.

⁵ A release time is a departure restriction issued to a pilot by ATC, specifying the earliest and latest time an aircraft may depart.

⁶ The runway release time assigned to an aircraft in a controlled departure time program and shown on the flight progress strip as an EDCT.

from possibly interfering traffic flows. Further, RNAV provides the potential for increasing airspace capacity both en route and in the terminal area in several important ways. RNAV may allow controllers to:

- Assign routes without overflying NAVAIDs such as VORs.
- Reduce the lateral separation between aircraft tracks.
- Lower altitude minimums on existing airways where VOR performance (minimum reception altitude) requires higher minimums.
- Allow the continued use of existing airways where the NAVAID signal is no longer suitable for en route navigation.

This means that the route structures can be modified quickly and easily to meet the changing requirements of the user community. Shorter, simpler routes can even be designed to minimize environmental impact, when necessary. In the future, higher levels of navigation accuracy and integrity are anticipated, which should lead to the introduction of closely spaced parallel routes. RNAV can be used in all phases of flight and, when implemented correctly, can result in:

- Improved situational awareness for the pilot.
- Reduced workloads for both controller and pilot.
- Reduced environmental impact from improved route and procedure designs.
- Reduced fuel consumption from shorter, more direct routes.

For example, take the situation at Philadelphia International Airport, located in the middle of some highly popular north-south traffic lanes carrying New York and Boston traffic to or from Washington, Atlanta, and Miami. Philadelphia's position is right underneath these flows. Chokepoints resulted from traffic departing Philadelphia, needing to wait for a "hole" in the traffic above into which they could merge. The CAASD helped USAir and Philadelphia airport officials establish a set of RNAV departure routes that do not interfere with the prevailing established traffic. Traffic heading north or south can join the established flows at a point further ahead when higher altitudes and speeds have been attained. Aircraft properly equipped to execute RNAV procedural routes can exit the terminal area faster — a powerful inducement for aircraft operators to upgrade their navigation equipment.

Another example of an RNAV departure is the PRYME TWO DEPARTURE from Washington Dulles

International. Notice in figure 1-10 the RNAV waypoints not associated with VORs help free up the flow of IFR traffic out of the airport by not funneling them to one point through a common NAVAID.

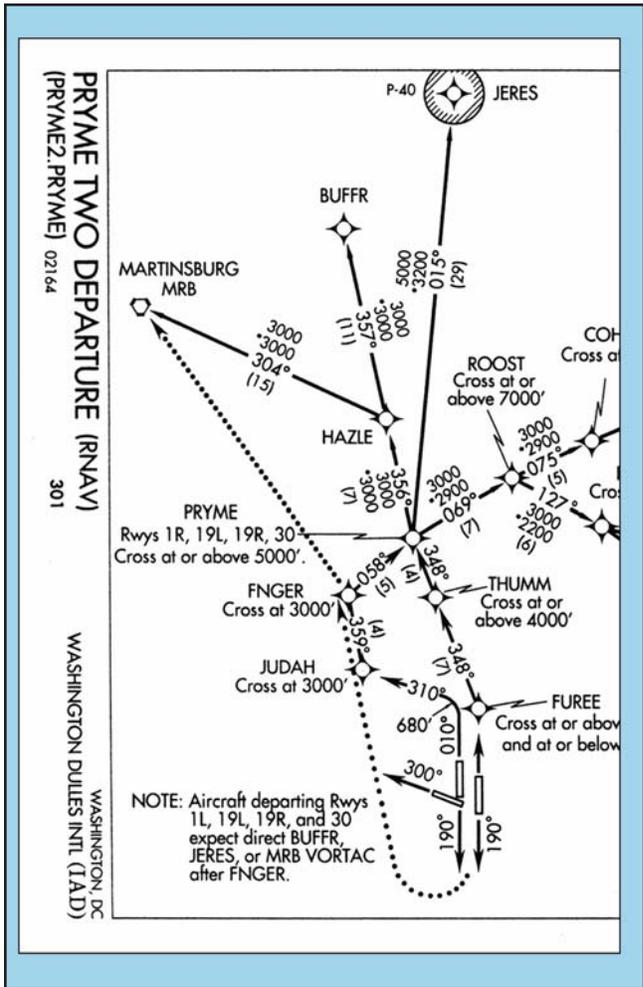


Figure 1-10. RNAV Departure Routes.

New RNAV routes were implemented through Class B airspace at Charlotte, North Carolina. IFR overflights were routinely re-routed around the Class B airspace by as much as 50 miles. Twelve new routes through the Charlotte airspace were provided for RNAV-capable aircraft to file flight plan equipment codes of /E, /F, or /G.

However, before the FAA can designate RNAV airways, the agency has to develop criteria, en route procedures, procedures for airway flight checks, and create new charting specifications. Moreover, it is essential that:

- Navigation infrastructure (i.e. the ground-based and space-based navigation positioning systems) provides adequate coverage for the proposed route/procedure.
- Navigation coordinate data meets International Civil Aviation Organization (ICAO) accuracy and

integrity requirements. This means that all the coordinates published in the *Aeronautical Information Publication (AIP)* and used in the aircraft navigation databases must be referenced to WGS 84, and the user must have the necessary assurance that this data has not been corrupted or inadvertently modified.

- Airborne systems are certified for use on the RNAV routes and procedures.
- Flight crews have the necessary approval to operate on the RNAV routes and procedures

REQUIRED NAVIGATION PERFORMANCE

RNP is a navigation system that provides a specified level of accuracy defined by a lateral area of confined airspace in which an RNP certified aircraft operates. The continuing growth of aviation places increasing demands on airspace capacity and emphasizes the need for the best use of the available airspace. These factors, along with the accuracy of modern aviation navigation systems and the requirement for increased operational efficiency in terms of direct routings and track-keeping accuracy, have

resulted in the concept of required navigation performance — a statement of the navigation performance accuracy necessary for operation within a defined airspace. RNP can include both performance and functional requirements, and is indicated by the RNP type. These standards are intended for designers, manufacturers, and installers of avionics equipment, as well as service providers and users of these systems for global operations. The minimum aviation system performance specification (MASPS) provides guidance for the development of airspace and operational procedures needed to obtain the benefits of improved navigation capability. [Figure 1-11]

The RNP type defines the total system error (TSE) that is allowed in lateral and longitudinal dimensions within a particular airspace. The TSE, which takes account of navigation system errors (NSE), computation errors, display errors and flight technical errors (FTE), must not exceed the specified RNP value for 95% of the flight time on any part of any single flight. RNP combines the accuracy standards laid out in the ICAO Manual (Doc 9613) with specific accuracy requirements, as well as functional and performance

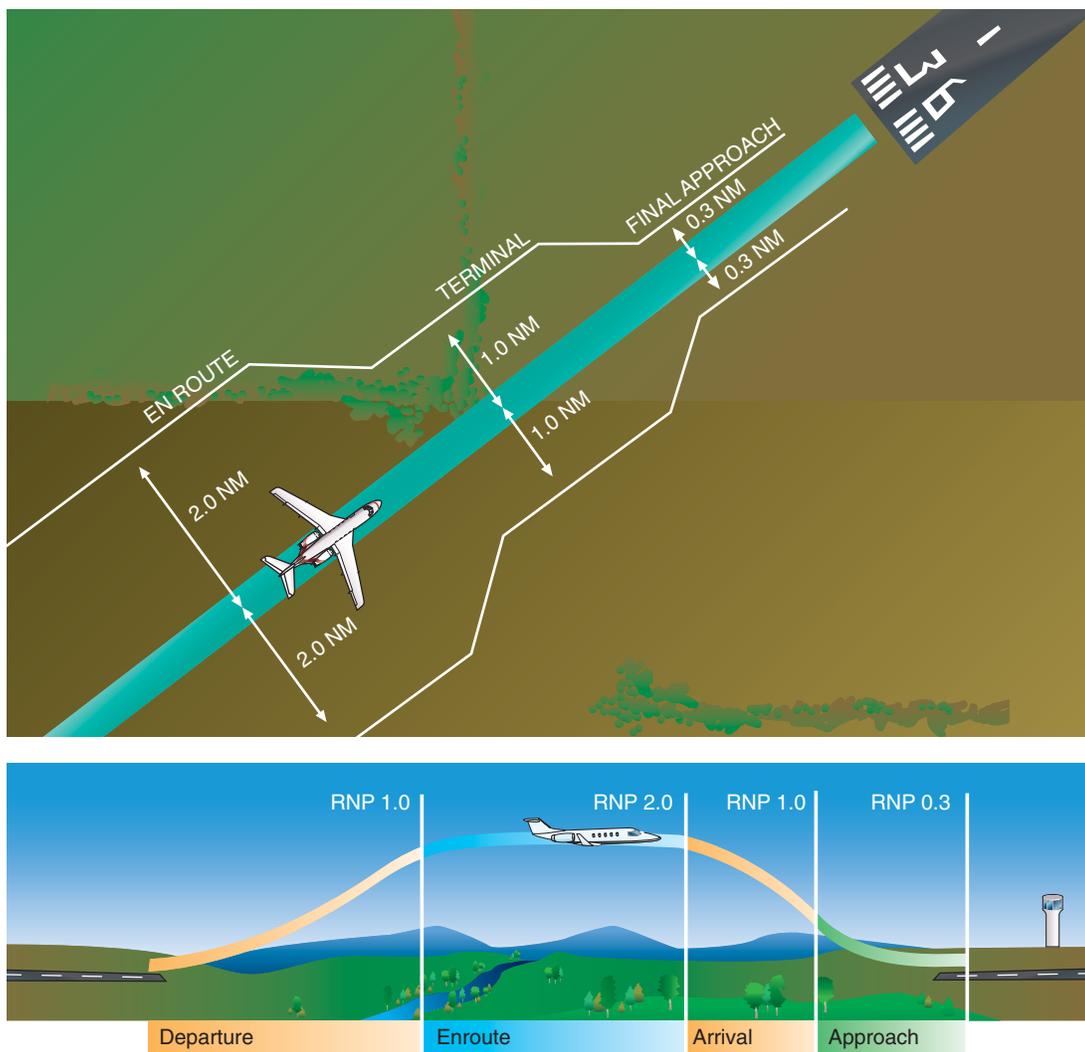


Figure 1-11. Required Navigation Performance.

standards, for the RNAV system to realize a system that can meet future air traffic management requirements. The functional criteria for RNP address the need for the flight paths of participating aircraft to be both predictable and repeatable to the declared levels of accuracy. More information on RNP is contained in subsequent chapters.

The term RNP is also applied as a descriptor for airspace, routes, and procedures — including departures, arrivals, and instrument approach procedures (IAPs). The descriptor can apply to a unique approach procedure or to a large region of airspace. RNP applies to navigation performance within a designated airspace, and includes the capability of both the available infrastructure (navigation aids) and the aircraft.

RNP type is used to specify navigation requirements for the airspace. The following are ICAO RNP Types: **RNP-1.0, RNP-4.0, RNP-5.0, and RNP-10.0**. The required performance is obtained through a combination of aircraft capability and the level of service provided by the corresponding navigation infrastructure. From a broad perspective:

Aircraft Capability + Level of Service = Access

In this context, aircraft capability refers to the airworthiness certification and operational approval elements (including avionics, maintenance, database, human factors, pilot procedures, training, and other issues). The level of service element refers to the NAS infrastructure, including published routes, signal-in-space performance and availability, and air traffic management. When considered collectively, these elements result in providing access. Access provides the desired benefit (airspace, procedures, routes of flight, etc.).

RNP levels are actual distances from the centerline of the flight path, which must be maintained for aircraft and obstacle separation. Although additional FAA recognized RNP levels may be used for specific operations, the United States currently supports three standard RNP levels:

- RNP 0.3 – Approach
- RNP 1.0 – Departure, Terminal
- RNP 2.0 – En route

RNP 0.3 represents a distance of 0.3 nautical miles (NM) either side of a specified flight path centerline. The specific performance that is required on the final approach segment of an instrument approach is an example of this RNP level. At the present time, a 0.3 RNP level is the lowest level used in normal RNAV operations. Specific airlines, using special procedures, are approved to use RNP levels lower than RNP 0.3, but

those levels are used only in accordance with their approved OpsSpecs. For aircraft equipment to qualify for a specific RNP type, it must be able to maintain navigational accuracy to within 95 percent of the total flight time.

GLOBAL POSITIONING SYSTEM

The FAA's Global Positioning System (GPS) implementation activities are dedicated to the adaptation of the NAS infrastructure to accept Satellite Navigation (SATNAV) technology through the management and coordination of a variety of overlapping NAS implementation projects. These projects fall under the project areas listed below and represent different elements of the NAS infrastructure:

- Avionics Development – includes engineering support and guidance in the development of current and future GPS avionics minimum operational performance standards (MOPS), as well as FAA Technical Standard Orders (TSOs) and establishes certification standards for avionics installations.
- Flight Standards – includes activities related to instrument procedure criteria research, design, testing, and standards publication. The shift from ground-based to space-based navigation sources has markedly shifted the paradigms used in obstacle clearance determination and standards development. New GPS-based Terminal Procedures (TERPS) manuals are in use today as a result of this effort.
- Air Traffic – includes initiatives related to the development of GPS routes, phraseology, procedures, controller GPS training and GPS outage simulations studies. GPS-based routes, developed along the East Coast to help congestion in the Northeast Corridor, direct GPS-based Caribbean routes, and expansion of RNAV activities are all results of SATNAV sponsored implementation projects.
- Procedure Development – includes the provision of instrument procedure development and flight inspection of GPS-based routes and instrument procedures. Today over 3,500 GPS-based IAPs have been developed.
- Interference Identification and Mitigation – includes the development and fielding of airborne, ground, and portable interference detection systems. These efforts are ongoing and critical to ensuring the safe use of GPS in the NAS.

To use GPS, WAAS, and/or LAAS in the NAS, equipment suitable for aviation use (such as a GPS receiver,

WAAS receiver, LAAS receiver, or multi-modal receiver) must be designed, developed, and certified for use. To ensure standardization and safety of this equipment, the FAA plays a key role in the development and works closely with industry in this process. The avionics development process results in safe, standardized SATNAV avionics, developed in concurrence with industry. Due to the growing popularity of SATNAV and potential new aviation applications, there are several types of GPS-based receivers on the market, but only those that pass through this certification process can be used as approved navigation equipment under IFR conditions. Detailed information on GPS approach procedures is provided in Chapter 5—Approach.

GPS-BASED HELICOPTER OPERATIONS

An excellent example of what can be accomplished to forge the future of helicopter IFR SATNAV is the synergy between industry and the FAA displayed during the development of the Gulf of Mexico GPS grid system and approaches. The cooperation displayed during the development of this infrastructure by the Helicopter Safety Advisory Council (HSAC), National Air Traffic Controllers Association (NATCO), helicopter operators, and FAA Flight Standards Divisions, all working together has attributed to its resounding success and accomplishment in one year. The system provides both the operational and cost saving features of flying direct to a destination when offshore weather conditions deteriorate below VFR, and an instant and accurate aircraft location capability that is invaluable for rescue operations with lives at stake.

Another success story of the further expansion of helicopter IFR service is the FAA working with EMS operators in the development of helicopter GPS non-precision instrument approach procedures and en route criteria. As a result of this collaborative effort, EMS operators have been provided with more than 200 EMS helicopter procedures to medical facilities. Before the first EMS operator (1997) invested in a GPS IFR network, they had flown 4,000 missions per year, missing 1,300 missions (30%) per year due to weather. With the new procedures and the same number of helicopters, the number of requests has grown to 10,000 but only 11% of those missions were not achieved due to weather. This provided an investment payback in less than one year with over 500 critically ill patients transported in a two-year period.

The success of these operations can be attributed in large part to the collaborative efforts of the helicopter industry and the FAA to establish criteria that will support current and future operations.

REDUCED VERTICAL SEPARATION MINIMUMS

The U.S. domestic reduced vertical separation minimums (RVSM)⁷ program is a key element of the OEP. RVSM capability reduces the vertical separation from the current 2,000-foot minimum to a 1,000-foot minimum above FL 290, which allows aircraft to fly a more optimal profile, thereby saving fuel while increasing airspace capacity. The FAA's objective is to implement RVSM between FL 290 and FL 410 (inclusive) in December 2004 in the airspace of the contiguous 48 states, Alaska, and in Gulf of Mexico airspace where the FAA provides air traffic services. The proposal is considered to be a feasible option and the FAA is developing its plans accordingly. The goal of domestic reduced vertical separation minimums (DRVSM) is to achieve in domestic airspace those user and provider benefits inherent to operations conducted at more optimum flight profiles and with increased airspace capacity. Full DRVSM will add six additional usable altitudes above FL 290 to those available with current vertical separation minimums. DRVSM users will experience increased benefits nationwide, similar to those already achieved in oceanic areas where RVSM is operational. In domestic airspace, however, operational differences create unique challenges. Domestic U.S. airspace contains a wider variety of aircraft types, higher-density traffic, and an increased percentage of climbing and descending traffic. This, in conjunction with an intricate route structure with numerous major crossing points, creates a more demanding environment for the implementation of RVSM than that experienced to this point. Nevertheless, experience gained in oceanic implementations is being considered in the DRVSM project. As airspace gets more congested, DRVSM provides the potential to reduce fuel burn and departure delays, and to increase flight level availability, airspace capacity, and controller flexibility.

FAA RADAR SYSTEMS

The FAA operates two basic radar systems; airport surveillance radar (ASR) and air route surveillance radar (ARSR). Both of these surveillance systems use primary and secondary radar returns, as well as sophisticated computers and software programs designed to give the controller additional information, such as aircraft speed and altitude.

AIRPORT SURVEILLANCE RADAR

The direction and coordination of IFR traffic within specific terminal areas is delegated to airport surveillance radar (ASR) facilities. Approach and departure control manage traffic at airports with ASR. This radar system is designed to provide relatively short-range coverage in the airport vicinity and to serve as an expeditious means of handling terminal area traffic. The

⁷ RVSM is 1,000 feet for approved aircraft operating between FL 290 and FL 410 inclusive.

ASR also can be used as an instrument approach aid. Terminal radar approach control facilities (TRACONs) provide radar and nonradar services at major airports. The primary responsibility of each TRACON is to ensure safe separation of aircraft transitioning from departure to cruise flight or from cruise to a landing approach.

Most ASR facilities throughout the country use a form of automated radar terminal system (ARTS). This system has several different configurations that depend on the computer equipment and software programs used. Usually the busiest terminals in the country have the most sophisticated computers and programs. The type of system installed is designated by a suffix of numbers and letters. For example, an ARTS-III A installation can detect, track, and predict primary, as well as secondary, radar returns. [Figure 1-12]



Figure 1-12. ARTS-III Radar Display.

On a controller's radar screen, ARTS equipment automatically provides a continuous display of an aircraft's position, altitude, groundspeed, and other pertinent information. This information is updated continuously as the aircraft progresses through the terminal area. To gain maximum benefit from the system, each aircraft in the area must be equipped with a Mode C transponder and its associated altitude encoding altimeter, although this is not an operational requirement. Direct altitude readouts eliminate the need for time consuming verbal communication between controllers and pilots to verify altitude. This helps to increase the number of aircraft which may be handled by one controller at a given time.

AIR ROUTE SURVEILLANCE RADAR

The long-range radar equipment used in controlled airspace to manage traffic is the air route surveillance radar

(ARSR) system. There are approximately 100 ARSR facilities to relay traffic information to radar controllers throughout the country. Some of these facilities can detect only transponder-equipped aircraft and are referred to as beacon-only sites. Each air route surveillance radar site can monitor aircraft flying within a 200-mile radius of the antenna, although some stations can monitor aircraft as far away as 600 miles through the use of remote sites.



The direction and coordination of IFR traffic in the U.S. is assigned to air route traffic control centers (ARTCCs). These centers are the authority for issuing IFR clearances and managing IFR traffic; however, they also provide services to VFR pilots. Workload permitting, controllers will provide traffic advisories and course guidance, or vectors, if requested.

PRECISION RUNWAY MONITORING

Precision Runway Monitor (PRM) is a high-update-rate radar surveillance system that is being introduced at selected capacity-constrained U.S. airports. Certified to provide simultaneous independent approaches to closely spaced parallel runways, PRM has been operational at Minneapolis since 1997, and four additional implementations are planned⁸. Once put into operation successfully, PRM enables ATC to improve the airport arrival rate on IFR days to one that more closely approximates VFR days; which means fewer flight cancellations, less holding, and decreased diversions.

PRM not only maintains the current level of safety, but also increases it by offering air traffic controllers a much more accurate picture of the aircraft's location on final approach. Whereas current airport surveillance radar used in a busy terminal area provides an update to the controller every 4.8 seconds, PRM updates every

⁸ PRM is planned for PHL, STL, JFK, and SFO. Other airports are under consideration.

second, giving the controller significantly more time to react to potential aircraft separation problems. The controller also sees target trails that provide very accurate trend information. With PRM, it is immediately apparent when an aircraft starts to drift off the runway centerline and toward the non-transgression zone. PRM also predicts the aircraft track and provides aural and visual alarms when an aircraft is within 10 seconds of penetrating the non-transgression zone. The additional controller staffing that comes along with PRM is another major safety improvement. During PRM sessions, there is a separate controller monitoring each final approach course and a coordinator managing the overall situation.

PRM is an especially attractive technical solution for the airlines and business aircraft because it does not require any additional aircraft equipment, only special training and qualifications. However, all aircraft in the approach streams must be qualified to participate in PRM or the benefits are quickly lost and controller workload increases significantly. The delay-reduction benefits of PRM can only be fully realized if everyone participates. Operators that choose not to participate in PRM operations when arriving at an airport where PRM operations are underway can expect to be held until they can be accommodated without disrupting the PRM arrival streams.

EQUIPMENT AND AVIONICS

By virtue of distance and time savings, minimizing traffic congestion, and increasing airport and airway capacity, the implementation of RNAV routes, direct routing, RSVM, PRM, and other technological innovations would be advantageous for the current NAS. Some key components that are integral to the future development and improvement of the NAS are described below. However, equipment upgrades require capital outlays, which take time to penetrate the existing fleet of aircraft and ATC facilities. In the upcoming years while the equipment upgrade is taking place, ATC will have to continue to accommodate the wide range of avionics used by pilots in the nation's fleet.

ATC RADAR EQUIPMENT

All ARTCC radars in the conterminous U.S., as well as most airport surveillance radars, have the capability to interrogate Mode C and display altitude information to the controller. However, there are a small number of airport surveillance radars that are still two-dimensional (range and azimuth only); consequently, altitude information must be obtained from the pilot.

At some locations within the ATC environment, secondary only (no primary radar) gap filler radar systems are used to give lower altitude radar coverage between two larger radar systems, each of which provides both primary and secondary radar

coverage. In the geographical areas serviced by secondary radar only, aircraft without transponders cannot be provided with radar service. Additionally, transponder-equipped aircraft cannot be provided with radar advisories concerning primary targets and weather.

An integral part of the air traffic control radar beacon system (ATCRBS) ground equipment is the decoder, which enables the controller to assign discrete transponder codes to each aircraft under his/her control. Assignments are made by the ARTCC computer on the basis of the National Beacon Code Allocation Plan (NBCAP). There are 4096 aircraft transponder codes that can be assigned. An aircraft must be equipped with Civilian Mode A (or Military Mode 3) capabilities to be assigned a transponder code. Another function of the decoder is that it is also designed to receive Mode C altitude information from an aircraft so equipped. This system converts aircraft altitude in 100-foot increments to coded digital information that is transmitted together with Mode C framing pulses to the interrogating ground radar facility. The ident feature of the transponder causes the transponder return to "blossom" for a few seconds on the controller's radarscope.

AUTOMATED RADAR TERMINAL SYSTEM

Most medium-to-large radar facilities in the U.S. use some form of automated radar terminal system (ARTS), which is the generic term for the functional capability afforded by several automated systems that differ in functional capabilities and equipment. "ARTS" followed by a suffix Roman numeral denotes a specific system, with a subsequent letter that indicates a major modification to that particular system. In general, the terminal controller depends on ARTS to display aircraft identification, flight plan data, and other information in conjunction with the radar presentation. In addition to enhancing visualization of the air traffic situation, ARTS facilitates intra- and inter-facility transfers and the coordination of flight information. Each ARTS level has the capabilities of communicating with other ARTS types as well as with ARTCCs.

As the primary system used for terminal ATC in the U.S., ARTS had its origin in the mid-1960's as ARTS I, or Atlanta ARTS and evolved to the ARTS II and ARTS III configurations in the early to mid-1970's. Later in the decade, the ARTS II and ARTS III configurations were expanded and enhanced and renamed ARTS IIA and ARTS IIIA respectively. The vast majority of the terminal automation sites today remain either IIA or IIIA configurations, except for about nine of the largest IIIA sites, which are ARTS IIIIE candidate systems. Selected ARTS IIIA/IIIIE and ARTS IIA sites are scheduled to receive commercial off the shelf (COTS) hardware upgrades, which replace portions of the proprietary data processing system with standard off-the-shelf hardware.

STANDARD TERMINAL AUTOMATION REPLACEMENT SYSTEM

In Spring 2002, the FAA Administrator announced operational use of the first Standard Terminal Automation Replacement System (STARS) in El Paso, Texas, an upgraded version that completely replaces the ARTS. Full STARS consists of new digital, color displays and computer software and processors that can track 435 aircraft at one time, integrating six levels of weather information and 16 radar feeds. The final version of STARS, scheduled for installation in Philadelphia, will be able to look 20 minutes into the future of a flight path while providing controllers with enhanced data blocks, including aircraft type and flight number, as well as destination and flight path information.

For the terminal area and many of the towers, STARS is the key to the future, providing a solid foundation for new capabilities. STARS were designed to provide the software and hardware platform necessary to support future air traffic control enhancements.

PRECISION APPROACH RADAR

While ASR provides pilots with horizontal guidance for instrument approaches via a ground-based radar, Precision Approach Radar (PAR) provides both horizontal and vertical guidance for a ground controlled approach (GCA). In the U.S., PAR is mostly used by the military. Radar equipment in some ATC facilities operated by the FAA and/or the military services at joint-use locations and military installations are used to detect and display azimuth, elevation, and range of aircraft on the final approach course to a runway. This equipment may be used to monitor certain non-radar approaches, but it is primarily used to conduct a precision instrument approach.

BRIGHT RADAR INDICATOR TERMINAL EQUIPMENT

Bright Radar Indicator Terminal Equipment (BRITE) provides radar capabilities to towers, a system with tremendous benefits for both pilots and controllers. Unlike traditional radar systems, BRITE is similar to a television screen in that it can be seen in daylight. BRITE was so successful that the FAA has installed the new systems in towers, and even in some TRACONS. In fact, the invention of BRITE was so revolutionary that it launched a new type of air traffic facility — the TRACAB, which is a radar approach control facility located in the tower cab of the primary airport, as opposed to a separate room.

In the many facilities without BRITE, the controllers use strictly visual means to find and sequence traffic. Towers that do have BRITE may have one of several different types. Some have only a very crude display that gives a fuzzy picture of blips on a field of green, perhaps with the capability of displaying an extra slash on transponder-equipped targets and a larger slash

when a pilot hits the ident button. Next in sophistication are BRITEs that have alphanumeric displays of various types, ranging from transponder codes and altitude to the newest version, the DBRITE (digital BRITE). A computer takes all the data from the primary radar, the secondary radar (transponder information), and generates the alphanumeric data. DBRITE digitizes the image, and then sends it all, in TV format, to a square display in the tower that provides an excellent presentation, regardless of how bright the ambient light.

One of the most limiting factors in the use of the BRITE is in the basic idea behind the use of radar in the tower. The radar service provided by a tower controller is not, nor was it ever intended to be, the same thing as radar service provided by an approach control or Center. The primary duty of tower controllers is to separate airplanes operating on runways, which means controllers spend most of their time looking out the window, not staring at a radar scope.

RADAR COVERAGE

A full approach is a staple of instrument flying, yet some pilots rarely, if ever, have to fly one other than during initial or recurrency or proficiency training, because a full approach usually is required only when radar service is not available, and radar is available at most larger and busier instrument airports. Pilots come to expect radar vectors to final approach courses and that ATC will keep an electronic eye on them all the way to a successful conclusion of every approach. In addition, most en route flights are tracked by radar along their entire route in the 48 contiguous states, with essentially total radar coverage of all instrument flight routes except in the mountainous West. Lack of radar coverage may be due to terrain, cost, or physical limitations.

New developing technologies, like ADS-B, may offer ATC a method of accurately tracking aircraft in non-radar environments. ADS-B is a satellite-based air traffic tracking system enabling pilots and air traffic controllers to share and display the same information. ADS-B relies on the Global Positioning System to determine an aircraft's position. The aircraft's precise location, along with other data such as airspeed, altitude, and aircraft identification, then is instantly relayed via digital datalink to ground stations and other equipped aircraft. Unlike radar, ADS-B works well at low altitudes and in remote locations and mountainous terrain where little or no radar coverage exists.

COMMUNICATIONS

Most air traffic control communications between pilots and controllers today are conducted via voice. Each air traffic controller uses a radio frequency different from the ones used by surrounding controllers to communicate

with the aircraft under his or her jurisdiction. With the increased traffic, more and more controllers have been added to maintain safe separation between aircraft. While this has not diminished safety, there is a limit to the number of control sectors created in any given region to handle the traffic. The availability of radio frequencies for controller-pilot communications is one limiting factor. Some busy portions of the U.S., such as the Boston-Chicago-Washington triangle are reaching toward the limit. Frequencies are congested and new frequencies are not available, which limits traffic growth to those aircraft that can be safely handled.

DATA LINK

The CAASD is working with the FAA and the airlines to define and test a controller-pilot data link communication (CPDLC), which provides the capability to exchange information between air traffic controllers and flight crews through digital text instead of voice messages. With CPDLC, communications between the ground and the air would take less time, and would convey more information (and more complex information) than by voice alone. Communications would become more accurate as up-linked information would be collected, its accuracy established, and then displayed for the pilot in a consistent fashion.

By using digital data messages to replace conventional voice communications (except during landing and departure phases and in emergencies) CPDLC is forecast to increase airspace capacity and reduce delays. Today the average pilot/controller voice exchange takes around 20 seconds, compared to one or two seconds with CPDLC. In FAA simulations, air traffic controllers indicated that CPDLC could increase their productivity by 40 percent without increasing workload. Airline cost/benefit studies indicate average annual savings that are significant in the terminal and en route phases, due to CPDLC-related delay reductions.

CPDLC for routine ATC messages, initially offered in Miami Center, will be implemented via satellite at all oceanic sectors. Communications between aircraft and FAA oceanic facilities will be available through satellite data link, high frequency data link (HF DL), or other subnetworks, with voice via HF and satellite communications remaining as backup. Eventually, the service will be expanded to include clearances for altitude, speed, heading, and route, with pilot initiated downlink capability added later.

MODE S

The first comprehensive proposal and design for the Mode S system was delivered to the FAA in 1975. However, due to design and manufacturing setbacks, few Mode S ground sensors and no commercial Mode S transponders were made available before 1980. Then, a tragic mid-air collision over California in 1986 prompted a dramatic change. The accident that claimed

the lives of 67 passengers aboard the two planes and fifteen people on the ground was blamed on inadequate automatic conflict alert systems and surveillance equipment. A law enacted by Congress in 1987 required all air carrier airplanes operating within U.S. airspace with more than 30 passenger seats to be equipped with Traffic Alert and Collision Avoidance System (TCAS II) by December 1993. Airplanes with 10 to 30 seats were required to employ TCAS I by December 1995.

Due to the congressional mandate, TCAS became a pervasive system for air traffic control centers around the world. Because TCAS uses Mode S as the standard air-ground communication datalink, the widespread international use of TCAS has helped Mode S become an integral part of air traffic control systems all over the world. The datalink capacity of Mode S has spawned the development of a number of different services that take advantage of the two-way link between air and ground. By relying on the Mode S datalink, these services can be inexpensively deployed to serve both the commercial transport aircraft and general aviation communities. Using Mode S makes not only TCAS, but also other services available to the general aviation community that were previously accessible only to commercial aircraft. These Mode S-based technologies are described below.

TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM

The Traffic Alert and Collision Avoidance System (TCAS) is designed to provide a set of electronic eyes so the pilot can maintain awareness of the traffic situation in the vicinity of the aircraft. The TCAS system uses three separate systems to plot the positions of nearby aircraft. First, directional antennae that receive Mode S transponder signals are used to provide a bearing to neighboring aircraft — accurate to a few degrees of bearing. Next, Mode C altitude broadcasts are used to plot the altitude of nearby aircraft. Finally, the timing of the Mode S interrogation/response protocol is measured to ascertain the distance of an aircraft from the TCAS aircraft. [Figure 1-13 on page 1-20]

TCAS I allows the pilot to see the relative position and velocity of other transponder-equipped aircraft within a 10 to 20-mile range. More importantly, TCAS I provides a warning when an aircraft in the vicinity gets too close. TCAS I does not provide instructions on how to maneuver in order to avoid the aircraft, but does supply important data with which the pilot uses to evade intruding aircraft.

TCAS II provides pilots with airspace surveillance, intruder tracking, threat detection, and avoidance maneuver generations. TCAS II is able to determine



Figure 1-13. Traffic Alert and Collision Avoidance System.

whether each aircraft is climbing, descending, or flying straight and level, and commands an evasive maneuver to either climb or descend to avoid conflicting traffic. If both planes in conflict are equipped with TCAS II, then the evasive maneuvers are well coordinated via air-to-air transmissions over the Mode S datalink, and the commanded maneuvers do not cancel each other out.

TCAS and similar traffic avoidance systems provide safety independent of ATC and supplement and enhance ATC's ability to prevent air-to-air collisions. Pilots currently use TCAS displays for collision avoidance and oceanic station keeping (maintaining miles-in-trail separation). TCAS technology improvements, currently in development, will enable aircraft to accommodate reduced vertical separation above FL 290 and the ability to track multiple targets at longer ranges.

TRAFFIC INFORMATION SERVICE

Traffic Information Service (TIS) provides many of the functions available in TCAS; but unlike TCAS, TIS is a ground-based service available to all aircraft equipped with Mode S transponders. TIS takes advantage of the Mode S data link to communicate collision avoidance information to aircraft. Information is presented to a pilot in a cockpit display that shows traffic within 5 nautical miles and a 1,200-foot altitude of other Mode S-equipped aircraft. The TIS system uses track reports provided by ground-based Mode S surveillance systems to retrieve traffic information. Because it is available to all Mode S transponders, TIS offers an inexpensive alternative to TCAS. The increasing availability of TIS makes collision avoidance technology more accessible to the general aviation community.

TERRAIN AWARENESS AND WARNING SYSTEM

The Terrain Awareness and Warning System (TAWS), an enhanced ground proximity warning capability is also being installed in many aircraft. TAWS uses position data from a navigation system, like GPS, and a digital terrain database to display surrounding terrain. TAWS equipment is mandatory for all U.S registered turbine powered airplanes manufactured after March 2002 with six or more passenger seats. For airplanes manufactured earlier, compliance is required by March 2005. FAA and National Transportation Safety Board (NTSB) studies show that in 14 CFR part 91 aircraft with six or more passengers, ground proximity warning systems (GPWS) could have avoided 33 of the 44 controlled flight into terrain (CFIT) accidents with 96 fatalities, and enhanced GPWS (EGPWS) could have avoided 42 of the 44 accidents with 126 fatalities.

GRAPHICAL WEATHER SERVICE

The Graphical Weather Service provides a graphical representation of weather information that is transmitted to aircraft and displayed on the cockpit display unit. The service is derived from ground-based Mode S sensors and offers information to all types of aircraft, regardless of the presence of on-board weather avoidance equipment. The general aviation community has been very pro-active in evaluating this technology, as they have already participated in field evaluations in Mode S stations across the U.S.

AVIONICS AND INSTRUMENTATION

The proliferation of advanced avionics and instrumentation has substantially increased the capabilities of aircraft in the IFR environment.

FLIGHT MANAGEMENT SYSTEM

A flight management system (FMS) is a flight computer system that uses a large database to allow routes to be preprogrammed and fed into the system by means of a data loader. The system is constantly updated with respect to position accuracy by reference to conventional navigation aids, inertial reference system technology, or the satellite global positioning system. The sophisticated program and its associated database ensures that the most appropriate navigation aids or inputs are automatically selected during the information update cycle. A typical FMS provides information for continuous automatic navigation, guidance, and aircraft performance management, and includes a control display unit (CDU). [Figure 1-14]

ELECTRONIC FLIGHT INFORMATION SYSTEM

The electronic flight information system (EFIS) found in advanced aircraft cockpits offer pilots a tremendous amount of information on a colorful, easy-to-read display. Glass cockpits are a vast improvement over the earlier generation of instrumentation. The latest flat panel screens



Courtesy of Universal Avionics Systems Corporation

Figure 1-14. FMS Control Display Unit. This depicts an aircraft established on the Atlantic City, NJ, RNAV (GPS) Rwy 13 instrument approach procedure at the Atlantic City International Airport, KACY. The aircraft is positioned at the intermediate fix UNAYY inbound on the 128 degree magnetic course, 5.5 nautical miles from PBIGY, the final approach fix.

are about half the size of the cathode-ray tube (CRT) screens first used for EFIS displays. [Figure 1-15]

Primary flight, navigation, and engine information are presented on large display screens in front of the flight crew. Flight management CDUs are located on the center console. They provide data display and entry capabilities for flight management functions. The display units generate less heat, save space, weigh less, and require less power than traditional navigation systems. From a pilot's point of view, the information display system is not only more reliable than previous systems, but also uses

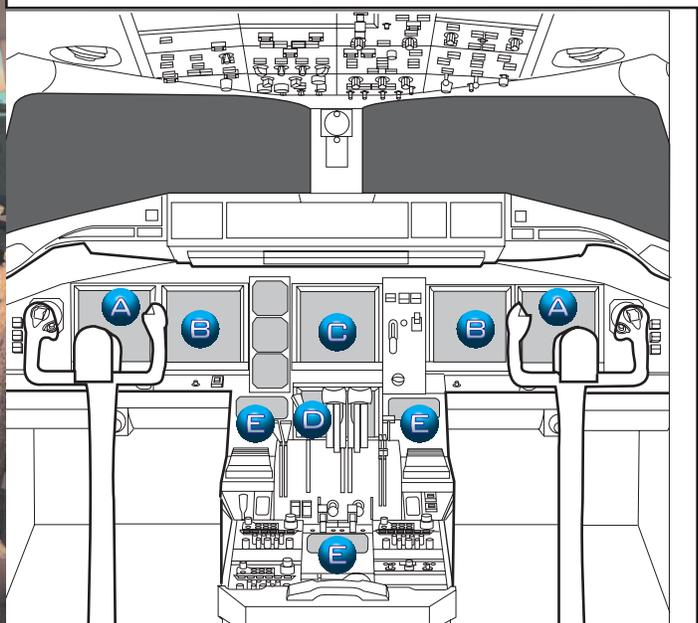
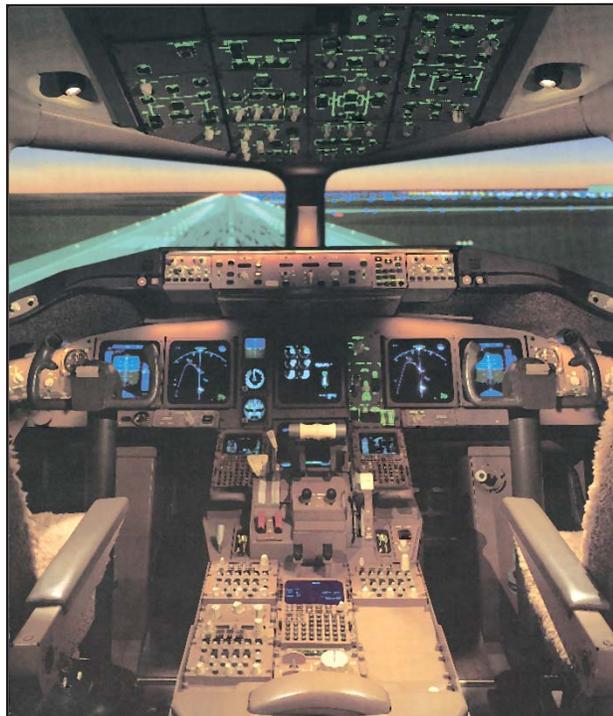
advanced liquid-crystal technology that allows displayed information to remain clearly visible in all conditions, including direct sunlight.

NAVIGATION SYSTEMS

Navigation systems are the basis for pilots to get from one place to another and know where they are and what course to follow. Since the 1930s, aircraft have navigated by means of a set of ground-based NAVAIDs. Today, pilots have access to over 2,000 such NAVAIDs within the continental U.S., but the system has its limitations:

- Constrained to fly from one NAVAID to the next, aircraft route planners need to identify a beacon-based path that closely resembles the path the aircraft needs to take to get from origin to destination. Such a path will always be greater in distance than a great circle route between the two points.
- Because the NAVAIDs are ground-based, navigation across the ocean is problematic, as is navigation in some mountainous regions.
- NAVAIDs are also expensive to maintain.

Since the 1980s, aircraft systems have evolved towards the use of SATNAV. Based on the GPS satellite constellation, SATNAV provides better position information than a ground-based beacon system.



- A** Primary Flight Displays (PFD)
 - B** Navigation Displays (ND)
 - C** Engine Indicating and Crew Alerting System (EICAS)
 - D** Multifunction Display (MFD)
 - E** Flight Management Control Display Units (CDU)
- Photo and graphic courtesy of Boeing Commercial Airplane Group

Figure 1-15. Airline Flight Deck Instrument Displays

GPS is universal so there are no areas without satellite signals. Moreover, a space-based system allows “off airway” navigation so that the efficiencies in aircraft route determination can be exacted. SATNAV is revolutionizing navigation for airlines and other aircraft owners and operators. A drawback of the satellite system, though, is the integrity and availability of the signal, especially during electromagnetic and other events that distort the Earth’s atmosphere. In addition, the signal from space needs to be augmented, especially in traffic-dense terminal areas, to guarantee the necessary levels of accuracy and availability.

The CAASD is helping the navigation system of the U.S. to evolve toward a satellite-based system. The CAASD analysts are providing the modeling necessary to understand the effects of atmospheric phenomena on the GPS signal from space, while the CAASD is providing the architecture of the future navigation system and writing the requirements (and computer algorithms) to ensure the navigation system’s integrity. Moving toward a satellite-based navigation system allows aircraft to divorce themselves from the constraints of ground-based NAVAIDs and formulate and fly those routes that aircraft route planners deem most in line with their own cost objectives.

With the advent of SATNAV, there are a number of applications that can be piggybacked to increase capacity in the NAS. Enhanced navigation systems will be capable of “random navigation,” that is, capable of treating any latitude-longitude point as a radio navigation fix, and being able to fly toward it with the accuracy we see today, or better. New routes into and out of the terminal areas are being implemented that are navigable by on-board systems. Properly equipped aircraft are being segregated from other aircraft streams with the potential to increase volume at the nation’s busy airports by keeping the arrival and departure queues full and fully operating.

The CAASD is working with the FAA to define the nation’s future navigation system architecture. By itself, the GPS satellite constellation is inadequate to serve all the system’s needs. Augmentation of the GPS signal via WAAS and LAAS are necessary parts of that new architecture. The CAASD is developing the requirements based on the results of sophisticated models to ensure the system’s integrity, security, and availability.

SURVEILLANCE SYSTEMS

Surveillance systems are set up to enable the ATC system to know the location of an aircraft and where it is heading. Position information from the surveillance system supports many different ATC functions. Aircraft positions are displayed for controllers as they watch over the traffic to ensure that aircraft do not violate separation criteria. In the current NAS, surveillance is

achieved through the use of long-range and terminal radars. Scanning the skies, these radars return azimuth and slant range for each aircraft that, when combined with the altitude of the aircraft broadcast to the ground via a transceiver, is transformed mathematically into a position. The system maintains a list of these positions for each aircraft over time, and this time history is used to establish short-term intent and short-term conflict detection. Radars are expensive to maintain, and position information interpolated from radars is not as good as what the aircraft can obtain with SATNAV. ADS-B technology may provide the way to reduce the costs of surveillance for air traffic management purposes and to get the better position information to the ground.

New aircraft systems dependent on ADS-B could be used to enhance the capacity and throughput of the nation’s airports. Electronic flight following is one example: An aircraft equipped with ADS-B could be instructed to follow another aircraft in the landing pattern, and the pilot could use the on-board displays or computer applications to do exactly that. This means that visual rules for landing at airports might be used in periods where today the airport must shift to instrument rules due to diminishing visibility. Visual capacities at airports are usually higher than instrument ones, and if the airport can operate longer under visual rules (and separation distances), then the capacity of the airport is maintained at a higher level longer. The CAASD is working with the Cargo Airline Association and the FAA to investigate these and other applications of the ADS-B technology.

OPERATIONAL TOOLS

Airports are one of the main bottlenecks in the NAS, responsible for one third of the flight delays. It is widely accepted that the unconstrained increase in the number of airports or runways may not wholly alleviate the congestion problem and, in fact, may create more problems than it solves. The aim of the FAA is to integrate appropriate technologies, in support of the OEP vision, with the aim of increasing airport throughput.

The airport is a complex system of systems and any approach to increasing capacity must take this into account. Numerous recent developments contribute to the overall solution, but their integration into a system that focuses on maintaining or increasing safety while increasing capacity remains a major challenge. The supporting technologies include new capabilities for the aircraft and ATC, as well as new strategies for improving communication between pilots and ATC.

IFR SLOTS

During peak traffic, ATC uses IFR slots to promote a smooth flow of traffic. This practice began during the late 1960s, when five of the major airports (LaGuardia Airport, Ronald Reagan National Airport, John F.

Kennedy International Airport, Newark International Airport, and Chicago O'Hare International Airport) were on the verge of saturation due to substantial flight delays and airport congestion. To combat this, the FAA in 1968 proposed special air traffic rules to these five high-density airports (the "high density rule") that restricted the number of IFR takeoffs and landings at each airport during certain hours of the day and provided for the allocation of "slots" to carriers for each IFR landing or takeoff during a specific 30 or 60-minute period. A more recent FAA proposal offers an overhaul of the slot-reservation process for JFK, LaGuardia, and Reagan National Airport that includes a move to a 72-hour reservation window and an online slot-reservation system.

The high density rule has been the focus of much examination over the last decade since under the restrictions, new entrants attempting to gain access to high density airports face difficulties entering the market. Because slots are necessary at high density airports, the modification or elimination of the high density rule could subsequently have an effect on the value of slots. Scarce slots hold a greater economic value than slots that are easier to come by.

The current slot restrictions imposed by the high density rule has kept flight operations well below capacity, especially with the improvements in air traffic control technology. However, easing the restrictions imposed by the high density rule is likely to affect airport operations. Travel delay time might be affected not only at the airport that has had the high density restrictions lifted, but also at surrounding airports that share the same airspace. On the other hand, easing the restrictions on slots at high density airports should help facilitate international air travel and help increase the number of passengers that travel internationally.

Slot controls have become a way of limiting noise, since it caps the number of takeoffs and landings at an airport. Easing the restrictions on slots could be politically difficult since local delegations at the affected airports might not support such a move. Ways other than imposing restrictions on slots exist that could diminish the environmental impacts at airports and their surrounding areas. Safeguards, such as requiring the quietest technology available of aircraft using slots and frequent consultations with local residents, have been provided to ensure that the environmental concerns are addressed and solved.

GROUND DELAY PROGRAM

Bad weather often forces the reconfiguration of runways at an airport or mandates the use of IFR arrival and departure procedures, reducing the number of flights per hour that are able to takeoff or land at the affected airport. To accommodate the degraded arrival

capacity at the affected airport, the ATCSCC imposes a ground delay program (GDP), which allocates a reduced number of arrival slots to airlines at airports during time periods when demand exceeds capacity. The GDP suite of tools is used to keep congestion at an arrival airport at acceptable levels by issuing ground delays to aircraft before departure, as ground delays are less expensive and safer than in-flight holding delays. The FAA started GDP prototype operations in January 1998 at two airports and expanded the program to all commercial airports in the U.S. within 9 months.

Ground Delay Program Enhancements (GDPE) significantly reduced delays due to compression—a process that is run periodically throughout the duration of a GDP. It reduces overall delays by identifying open arrival slots due to flight cancellations or delays and fills in the vacant slots by moving up operating flights that can use those slots. During the first 2 years of this program, almost 90,000 hours of scheduled delays have been avoided due to compression, resulting in cost savings to the airline industry of more than \$150 million. GDPE also has improved the flow of air traffic into airports; improved compliance to controlled times of departure; improved data quality and predictability; resulted in equity in delays across carriers; and often avoided the necessity to implement FAA ground delay programs, which can be disruptive to air carrier operations.

FLOW CONTROL

ATC provides IFR aircraft separation services for NAS users. Since the capabilities of IFR operators vary from airlines operating hundreds of complex jet aircraft to private pilots in single engine, piston-powered airplanes, the ATC system must accommodate the least sophisticated user. The lowest common denominator is the individual controller speaking to a single pilot on a VHF voice radio channel. While this commonality is desirable, it has led to a mindset where other opportunities to interact with NAS users have gone undeveloped. The greatest numbers of operations at the 20 busiest air carrier airports are commercial operators (airlines and commuters) operating IFR with some form of ground-based operational control. Since not all IFR operations have ground-based operational control, very little effort has been expended in developing ATC and Airline Operations Control Center (AOC) collaboration techniques, even though ground-based computer-to-computer links can provide great data transfer capacity. Until the relatively recent concept of Air Traffic Control-Traffic Flow Management (ATC-TFM), the primary purpose of ATC was aircraft separation, and the direct pilot-controller interaction was adequate to the task. Effective and efficient traffic flow management now requires a new level of control that includes the interaction of and information transfer among ATC, TFM, AOCs, and the cockpit. [Figure 1-16]



Figure 1-16. Flow Control Restrictions.

As the first step in modernizing the traffic flow management infrastructure, the FAA began reengineering traffic flow management software using commercial off-the-shelf products. In FY 1996, the FAA and NASA collaborated on new traffic flow management research and development efforts for the development of collaborative decision making tools that will enable FAA traffic flow managers to work cooperatively with airline personnel in responding to congested conditions. Additionally, the FAA provided a flight scheduling software system to nine airlines.

LAND AND HOLD SHORT OPERATIONS

Many older airports, including some of the most congested, have intersecting runways. Expanding the use of Land and Hold Short Operations (LAHSO) on intersecting runways is one of the ways to increase the number of arrivals and departures. Currently, LAHSO operations are permitted only on dry runways under acceptable weather conditions and limited to airports where a clearance depends on what is happening on the other runway, or where approved rejected landing procedures are in place. A dependent procedure example is when a landing airplane is a minimum distance from the threshold and an airplane is departing an intersecting runway, the LAHSO clearance can be issued because even in the event of a rejected landing, separation is assured. It is always the pilot's option to reject a LAHSO clearance.

Working with pilot organizations and industry groups, the FAA is developing new LAHSO procedures that will provide increased efficiency while maintaining safety. These procedures will address issues such as wet runway conditions, mixed commercial and general

aviation operations, the frequency of missed approaches, and multi-stop runway locations. After evaluating the new procedures using independent case studies, the revised independent LAHSO procedures may be implemented in 2005.

SURFACE MOVEMENT GUIDANCE AND CONTROL SYSTEM

To enhance taxiing capabilities in low visibility conditions and reduce the potential for runway incursions, improvements have been made in signage, lighting, and markings. In addition to these improvements, airports have implemented the Surface Movement Guidance and Control System (SMGCS),⁹ a strategy that requires a low visibility taxi plan for any airport with takeoff or landing operations with less than 1,200 feet RVR visibility conditions. This plan affects both aircrew and airport vehicle operators, as it specifically designates taxi routes to and from the SMGCS runways and displays them on a SMGCS Low Visibility Taxi Route chart. SMGCS airports may have several or all of the following features:

- **Stop bars** consist of a row of red unidirectional, in-pavement lights installed along the holding position marking. When extinguished by the controller, they confirm clearance for the pilot or vehicle operator to enter the runway.
- **Taxiway centerline lights**, which work in conjunction with stop bars, are green in-pavement lights that guide ground traffic under low visibility conditions and during darkness.
- **Runway guard lights**, either elevated or in-pavement, will be installed at all taxiways that provide access to an active runway. They consist of alternately flashing yellow lights, used to denote both the presence of an active runway and identify the location of a runway holding position marking.
- **Geographic position markings**, used as hold points or for position reporting, enable ATC to verify the position of aircraft and vehicles. These checkpoints or "pink spots" are outlined with a black and white circle and designated with a number, a letter, or both.

⁹ SMGCS, pronounced "SMIGS," is the Surface Movement Guidance and Control System. SMGCS provides for guidance and control or regulation for facilities, information, and advice necessary for pilots of aircraft and drivers of ground vehicles to find their way on the airport during low visibility operations and to keep the aircraft or vehicles on the surfaces or within the areas intended for their use. Low visibility operations for this system means reported conditions of RVR 1,200 or less.

- **Clearance bars** consist of three yellow in-pavement lights used to denote holding positions for aircraft and vehicles. When used for hold points, they are co-located with geographic position markings.

SMGCS is an increasingly important element in a seamless, overall gate-to-gate management concept to ensure safe, efficient air traffic operations. It is the ground-complement for arrival and departure management and the en route components of free flight. The FAA has supported several major research and development efforts on SMGCS to develop solutions and prototype systems that support pilots and ATC in their control of aircraft ground operations.

EXPECTATION OF ATC

Aircraft safety is based on the adherence to a set of rules based on established separation standards. Air traffic controllers follow established procedures based upon specific routes to maintain the desired separations needed for safety. The current ATM system has an excellent safety record for aircraft operations. Use of the free flight approach—where aircraft operators select paths, altitudes, and speeds in real time—can maximize efficiency and minimize operating costs. New technologies and enhanced aircraft capabilities necessitate changes in procedures, an increase in the level of automation and control in the cockpit and in the ground system, and more human reliance on automated information processing, sophisticated displays, and faster data communication.

DISSEMINATING AERONAUTICAL INFORMATION

The system for disseminating aeronautical information is made up of two subsystems, the Airmen's Information System (AIS) and the Notice to Airman (NOTAM) System. The AIS consists of charts and publications. The NOTAM system is a telecommunication system and is discussed in later paragraphs. Aeronautical information disseminated through charts and publications includes aeronautical charts depicting permanent baseline data and flight information publications outlining baseline data.

IFR aeronautical charts include en route high altitude conterminous U.S., and en route low altitude conterminous U.S., plus Alaska charts and Pacific Charts. Additional charts include U.S. terminal procedures, consisting of departure procedures (DP's), standard terminal arrivals (STAR's), and standard instrument approach procedures (SIAP's).

Flight information publications outlining baseline data in addition to the *Notices to Airmen Publication* (NTAP), include the *Airport/Facility Directory* (A/FD), a Pacific Chart Supplement, an Alaska Supplement, an

Alaska Terminal publication, and the *Aeronautical Information Manual* (AIM).

PUBLICATION CRITERIA

The following conditions or categories of information are forwarded to the National Flight Data Center (NFDC) for inclusion in flight information publications and aeronautical charts:

- NAVAID commissioning, decommissioning, outages, restrictions, frequency changes, changes in monitoring status and monitoring facility used in the NAS.
- Commissioning, decommissioning, and changes in hours of operation of FAA air traffic control facilities.
- Changes in hours of operations of surface areas and airspace.
- RCO and RCAG commissioning, decommissioning, and changes in voice control or monitoring facility.
- Weather reporting station commissioning, decommissioning, failure, and nonavailability or unreliable operations.
- Public airport commissioning, decommissioning, openings, closings, and abandonments and some airport operating area (AOA) changes.
- Aircraft Rescue & Fire Fighting (ARFF) capability, including restrictions to air carrier operations.
- Changes to runway identifiers, dimensions, threshold placements, and surface compositions.
- NAS lighting system commissioning, decommissioning, outages, and change in classification or operation.
- IFR Area Charts.

A wide variety of additional flight information publications are available. Electronic flight publications include electronic bulletin boards, the FAA home page, advisory circulars, the AC checklist, federal aviation regulations, the Federal Register, including the notices of proposed rulemaking (NPRM). Printed publications include the *Guide to Federal Aviation Administration Publications*, which is intended to help pilots identify and obtain other FAA publications, as well as aviation-related materials issued by other federal agencies. This Guide is published annually and is available at no charge. To order, request the Guide by name and number, FAA-APA-PG-13, from: DOT, M-443.2, General

Services Section, 400 7th St. S.W., Washington, D.C. 20590.

AERONAUTICAL CHARTS

Pilots can obtain most aeronautical charts and publications produced by the FAA National Aeronautical Charting Office (NACO), by subscription or one-time sales through a network of FAA chart agents primarily located at or near major civil airports. Additionally, opportunities to purchase or download aeronautical publications online are expanding, which provides pilots quicker and more convenient access to the latest information. Civil aeronautical charts for the U.S. and its territories, and possessions are produced according to a 56-day IFR chart cycle by NACO, which is part of the FAA's Office of Aviation Systems Standards (AVN). Comparable IFR charts and publications are available from commercial sources, including charted visual flight procedures, airport qualification charts, etc.

Most charts and publications described in this Chapter can be obtained by subscription or one time sales from NACO. Public sales of charts and publications are also available through a network of FAA chart agents primarily located at or near major civil airports. A listing of products and agents is printed in the free FAA catalog, Aeronautical Charts and Related Products (FAA Stock No. ACATSET). A link to obtain publications is accessible through <http://www.naco.faa.gov>. Below is the contact information for NACO.

FAA, National Aeronautical Charting Office
Distribution Division AVN-530
6303 Ivy Lane, Suite 400
Greenbelt, MD 20770

Telephone

(301) 436-8301

(800) 638-8972 toll free, U.S. only

FAX

(301) 436-6829

E-mail

9-AMC-Chartsales@faa.gov

Retail Sales

See [Agent Listings Page](#)

IFR charts are revised more frequently than VFR charts because chart currency is critical for safe operations. Selected NACO IFR charts and products available include IFR navigation charts, planning charts, supplementary

charts and publications, and digital products. IFR navigation charts include the following:

- **IFR En route Low Altitude Charts**
(Conterminous U.S. and Alaska): En route low altitude charts provide aeronautical information for navigation under IFR conditions below 18,000 feet MSL. This four-color chart series includes airways; limits of controlled airspace; VHF NAVAIDs with frequency, identification, channel, geographic coordinates; airports with terminal air/ground communications; minimum en route and obstruction clearance altitudes; airway distances; reporting points; special use airspace; and military training routes. Scales vary from 1 inch = 5 NM to 1 inch = 20 NM. The size is 50 x 20 inches folded to 5 x 10 inches. The charts are revised every 56 days. Area charts show congested terminal areas at a large scale. They are included with subscriptions to any conterminous U.S. Set Low (Full set, East or West sets). [Figure 1-17]
- **IFR En route High Altitude Charts**
(Conterminous U.S. and Alaska): En route high altitude charts are designed for navigation at or above 18,000 feet MSL. This four-color chart series includes the jet route structure; VHF NAVAIDs with frequency, identification, channel, geographic coordinates; selected airports; and reporting points. The chart scales vary from 1 inch = 45 NM to 1 inch = 18 NM. The size is 55 x 20 inches folded to 5 x 10 inches. Revised every 56 days. [Figure 1-18]
- **U.S. Terminal Procedures Publication (TPP):**
TPPs are published in 20 loose-leaf or perfect bound volumes covering the conterminous U.S., Puerto Rico, and the Virgin Islands. A Change Notice is published at the midpoint between revisions in bound volume format. [Figure 1-19]

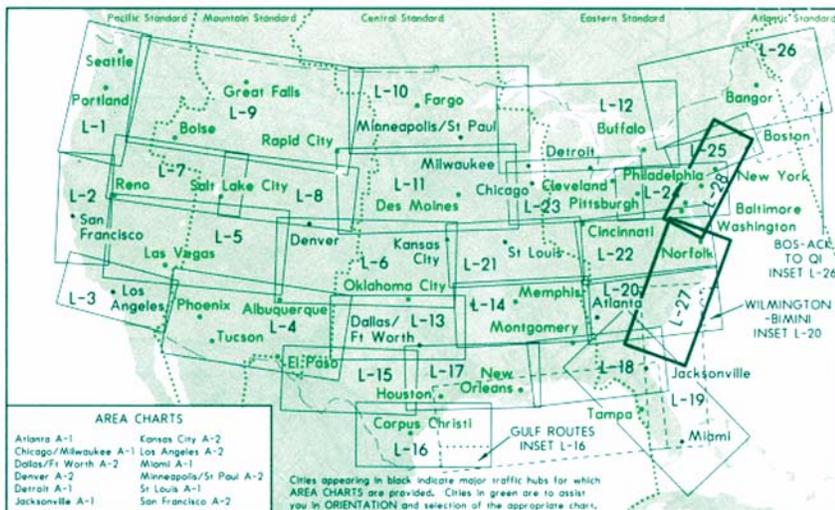


Figure 1-17. En route Low Altitude Charts.

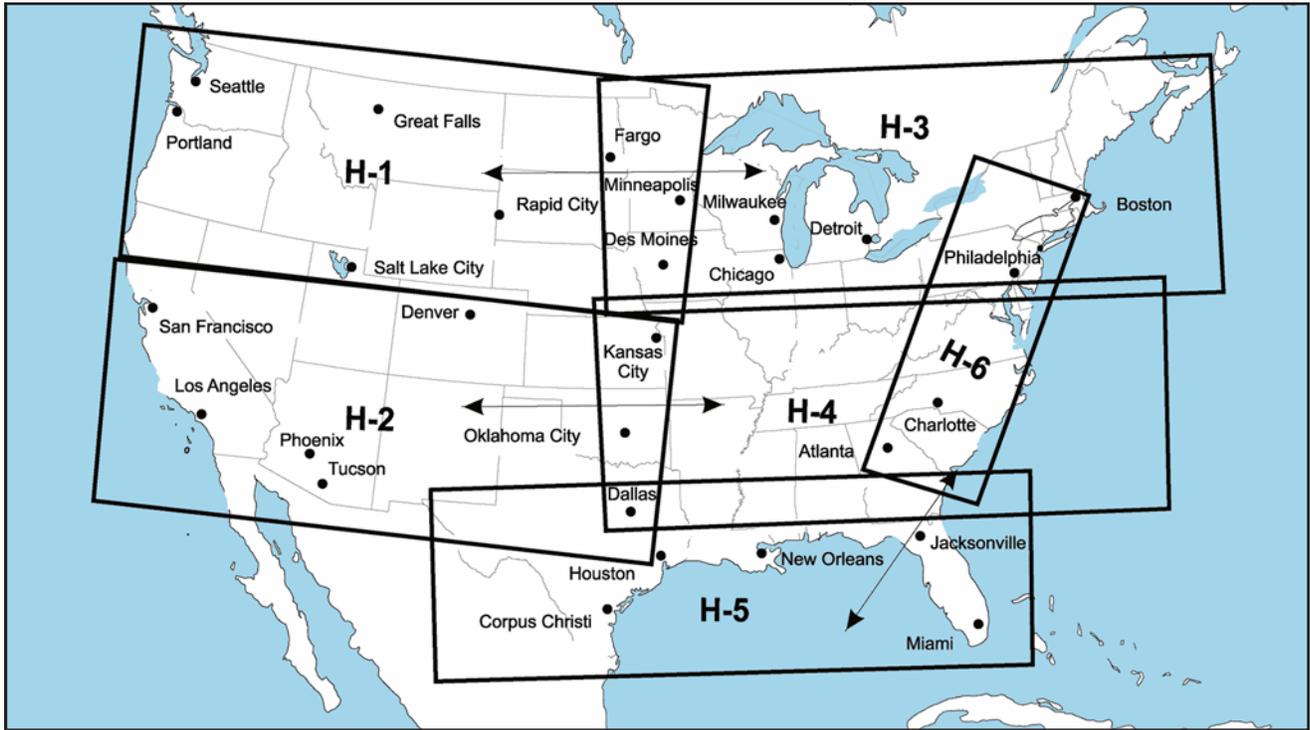


Figure 1-18. En route High Altitude Charts.

- Instrument Approach Procedure (IAP) Charts:** IAP charts portray the aeronautical data that is required to execute instrument approaches to airports. Each chart depicts the IAP, all related navigation data, communications information, and an airport sketch. Each procedure is designated for use with a specific electronic navigational aid, such as an ILS, VOR, NDB, RNAV, etc.
- Instrument Departure Procedure (DP) Charts:** There are two types of departure procedures; Standard Instrument Departures (SIDs) and Obstacle Departure Procedures (ODPs).

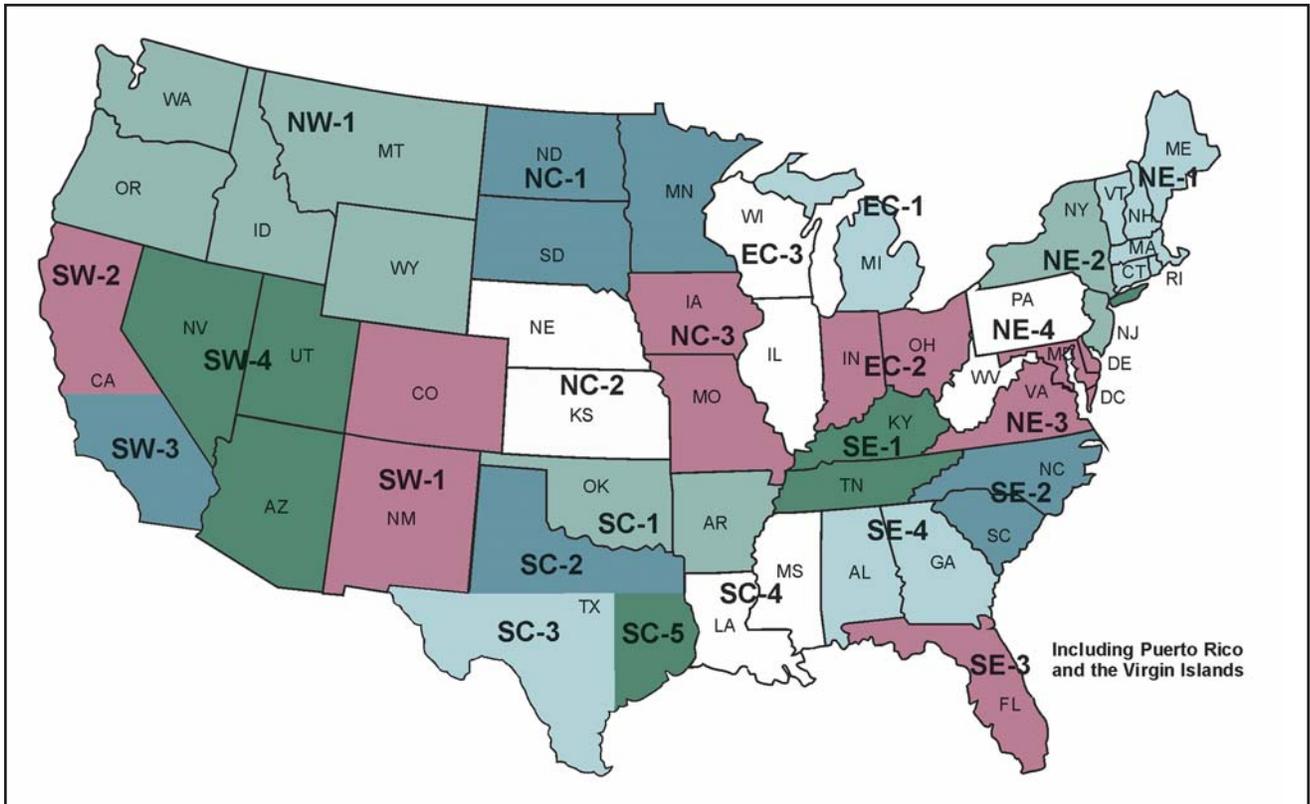


Figure 1-19. Terminal Procedures Publication.

SIDs will always be in a graphic format and are designed to assist ATC by expediting clearance delivery and to facilitate transition between take-off and en route operations. ODPs are established to insure proper obstacle clearance and are either textual or graphic, depending on complexity.

- **Standard Terminal Arrival (STAR) Charts:** STAR charts are designed to expedite ATC arrival procedures and to facilitate transition between en route and instrument approach operations. They depict preplanned IFR ATC arrival procedures in graphic and textual form. Each STAR procedure is presented as a separate chart and may serve either a single airport or more than one airport in a given geographic area.
- **Airport Diagrams:** Full page airport diagrams are designed to assist in the movement of ground traffic at locations with complex runway and taxiway configurations and provide information for updating geodetic position navigational systems aboard aircraft.
- **Alaska Terminal Procedures Publication:** This publication contains all terminal flight procedures for civil and military aviation in Alaska. Included are IAP charts, DP charts, STAR charts, airport diagrams, radar minimums, and supplementary support data such as IFR alternate minimums, take-off minimums, rate of descent tables, rate of climb tables and inoperative components tables. The volume is 5-3/8 x 8-1/4 inches top bound, and is revised every 56 days with provisions for a Terminal Change Notice, as required.
- **U.S. IFR/VFR Low Altitude Planning Chart:** This chart is designed for preflight and en route flight planning for IFR/VFR flights. Depiction includes low altitude airways and mileage, NAVAIDs, airports, special use airspace, cities, time zones, major drainage, a directory of airports with their airspace classification, and a mileage table showing great circle distances between major airports. The chart scale is 1 inch = 47 NM/1:3,400,000, and is revised annually, available either folded or unfolded for wall mounting.

Supplementary charts and publications include:

- **Airport/Facility Directory (A/FD):** This seven volume booklet series contains data on airports, seaplane bases, heliports, NAVAIDs, communications data, weather data sources, airspace, special notices, and operational procedures. The coverage includes the conterminous U.S., Puerto Rico, and the Virgin Islands. The A/FD shows

data that cannot be readily depicted in graphic form; e.g., airport hours of operations, types of fuel available, runway widths, lighting codes, etc. The A/FD also provides a means for pilots to update visual charts between edition dates, and is published every 56 days. The volumes are side-bound 5-3/8 x 8-1/4 inches.

- **Supplement Alaska:** This is a civil/military flight information publication issued by the FAA every 56 days. This booklet is designed for use with appropriate IFR or VFR charts. The Supplement Alaska contains an airport/facility directory, airport sketches, communications data, weather data sources, airspace, listing of navigational facilities, and special notices and procedures. The volume is side-bound 5-3/8 x 8-1/4 inches.
- **Chart Supplement Pacific:** This supplement is designed for use with appropriate VFR or IFR en route charts. Included in this booklet are the airport/facility directory, communications data, weather data sources, airspace, navigational facilities, special notices, and Pacific area procedures. IAP charts, DP charts, STAR charts, airport diagrams, radar minimums, and supporting data for the Hawaiian and Pacific Islands are included. The manual is published every 56 days. The volume is side-bound 5-3/8 x 8-1/4 inches.
- **North Pacific Route Charts:** These charts are designed for FAA controllers to monitor transoceanic flights. They show established intercontinental air routes, including reporting points with geographic positions. The Composite Chart scale is 1 inch = 164 NM/1:12,000,000. 48 x 41-1/2 inches. Area Chart scales are 1 inch = 95.9 NM/1:7,000,000. The size is 52 x 40-1/2 inches. All charts shipped unfolded. The charts are revised every 56 days.
- **North Atlantic Route Chart:** Designed for FAA controllers to monitor transatlantic flights, this five-color chart shows oceanic control areas, coastal navigation aids, oceanic reporting points, and NAVAID geographic coordinates. The full size chart scale is 1 inch = 113.1 NM/1:8,250,000, shipped flat only. The half size chart scale is 1 inch = 150.8 NM/1:11,000,000. The size is 29-3/4 x 20-1/2 inches, shipped folded to 5 x 10 inches only, and is revised every 56 weeks.
- **FAA Aeronautical Chart User's Guide:** A booklet designed to be used as a teaching aid and reference document. It describes the substantial amount of information provided on the FAA's aeronautical charts and publications. It includes

explanations and illustrations of chart terms and symbols organized by chart type.

- **Airport/Facilities Directory (A/FD)**

Digital products include:

- **The NAVAID Digital Data File:** This file contains a current listing of NAVAIDs that are compatible with the NAS. Updated every 56 days, the file contains all NAVAIDs including ILS and its components, in the U.S., Puerto Rico, and the Virgin Islands plus bordering facilities in Canada, Mexico, and the Atlantic and Pacific areas. The file is available by subscription only, on a 3.5-inch, 1.4 megabyte diskette.
- **The Digital Obstacle File:** This file describes all obstacles of interest to aviation users in the U.S., with limited coverage of the Pacific, Caribbean, Canada, and Mexico. The obstacles are assigned unique numerical identifiers, accuracy codes, and listed in order of ascending latitude within each state or area. The file is updated every 56 days, and is available on 3.5-inch, 1.4 megabyte diskettes.
- **The Digital Aeronautical Chart Supplement (DACS):** The DACS is a subset of the data provided to FAA controllers every 56 days. It reflects digitally what is shown on the en route high and low charts. The DACS is designed to be used with aeronautical charts for flight planning purposes only. It should not be used as a substitute for a chart. The DACS is available on two 3.5-inch diskettes, compressed format. The supplement is divided into the following nine individual sections:

Section 1: High Altitude Airways, Conterminous U.S.

Section 2: Low Altitude Airways, Conterminous U.S.

Section 3: Selected Instrument Approach Procedure
NAVAID and Fix Data

Section 4: Military Training Routes

Section 5: Alaska, Hawaii, Puerto Rico, Bahamas, and
Selected Oceanic Routes

Section 6: STARs, Standard Terminal Arrivals

Section 7: DPs, Instrument Departure Procedures

Section 8: Preferred IFR Routes (low and high altitude)

Section 9: Air Route and Airport Surveillance Radar
Facilities

NOTICE TO AIRMEN

Since the NAS is continually evolving, Notices to Airmen (NOTAM) provide the most current essential flight operation information available, not known sufficiently in advance to publicize in the most recent aeronautical charts or A/FD. NOTAMs provide information on airports and changes which affect the NAS that are time critical and in particular are of concern to IFR operations. Published FAA domestic/international NOTAMs are available by subscription and on the internet. Each NOTAM is classified as a NOTAM (D), a NOTAM (L), or an FDC NOTAM. [Figure 1-20]

A NOTAM (D) or distant NOTAM is given dissemination beyond the area of responsibility of a Flight Service Station (AFSS/FSS). Information is attached to hourly weather reports and is available at AFSSs/FSSs. AFSSs/FSSs accept NOTAMs from the following personnel in their area of responsibility: Airport Manager, Airways Facility SMO, Flight Inspection, and Air Traffic. They are disseminated for all navigational facilities that are part of the U.S. NAS, all public use airports, seaplane bases, and heliports listed in the A/FD. The complete NOTAM (D) file is maintained in a computer database at the National Weather Message Switching Center (WMSC) in Atlanta, Georgia. Most air traffic facilities, primarily AFSSs/FSSs, have

NOTAM (D)

DEN 09/080 DEN 17L IS LLZ OTS WEF 0209141200-0210012359

NOTAM (L)

TWY C (BTN TWYS L/N); TWY N (BTN TWY C AND RWY10L/28R); TWY P (BTN TWY C AND RWY10L/28R) - CLSD DLY 1615-2200.

FDC NOTAM

FDC 2/9651 DFW FI/P DALLAS/FORT WORTH INTL, DALLAS/FORT WORTH, TX CORRECT U.S. TERMINAL PROCEDURES SOUTH CENTRAL (SC) VOL 2 OF 5. EFFECTIVE 8 AUGUST 2002, PAGE 192.
CHANGE RADIAL FROM RANGER (FUZ) VORTAC TO EPOVE INT TO READ 352 VICE 351.

Figure 1-20. NOTAM Examples.

access to the entire database of NOTAM (D)s, which remain available for the duration of their validity, or until published.

A NOTAM (L) or local NOTAM requires dissemination locally, but does not qualify as NOTAM (D) information. These NOTAMs usually originate with the Airport Manager and are issued by the FSS. A NOTAM (L) contains information such as taxiway closures, personnel and equipment near or crossing runways, and airport rotating beacon and lighting aid outages. A separate file of local NOTAMs is maintained at each FSS for facilities in the area. NOTAM (L) information for other FSS areas must be specifically requested directly from the FSS that has responsibility for the airport concerned. *Airport/Facility Directory* listings include the associated FSS and NOTAM file identifiers. [Figure 1-21]

FDC NOTAMs are issued by the National Flight Data Center (NFDC) and contain regulatory information such as temporary flight restrictions or amendments to instrument approach procedures and other current aeronautical charts. FDC NOTAMs are available through all air traffic facilities with telecommunications access. Information for instrument charts is supplied by Aviation System Standards (AVN) and much of the other FDC information is extracted from the NOTAM (D) System.

The *Notices to Airmen Publication* (NTAP) is published by Air Traffic Publications every 28 days and contains all current NOTAM (D)s and FDC NOTAMs (except FDC NOTAMs for temporary flight restrictions) available for publication. Federal airway changes, which are identified as Center Area NOTAMs, are included with the NOTAM (D) listing. Published NOTAM (D) information is not provided during pilot briefings unless requested. Data of a permanent nature are sometimes printed in the NOTAM publication as an interim step prior to publication on the appropriate aeronautical chart or in the A/FD. The NTAP is divided into four parts:

- Notices in part one are provided by the National Flight Data Center, and contain selected

NOTAMs that are expected to be in effect on the effective date of the publication. This part is divided into three sections:

- a. Airway NOTAMs reflecting airway changes that fall within an ARTCC's airspace;
 - b. Airports/facilities, and procedural NOTAMs;
 - c. FDC general NOTAMs containing NOTAMs that are general in nature and not tied to a specific airport/facility, i.e. flight advisories and restrictions.
- Part two contains revisions to minimum en route IFR altitudes and changeover points.
 - Part three, International, contains flight prohibitions, potential hostile situations, foreign notices, and oceanic airspace notices.
 - Part four contains special notices and graphics pertaining to almost every aspect of aviation; such as, military training areas, large scale sporting events, air show information, and airport-specific information. Special traffic management programs (STMPs) are published in part four.

If you plan to fly internationally, you can benefit by accessing Class I international ICAO System NOTAMs, that include additional information. These help you differentiate IFR vs VFR NOTAMs, assist pilots who are not multilingual with a standardized format, and may include a "Q" line, or qualifier line that allows computers to read, recognize, and process NOTAM content information.

NAVIGATION DATABASES

The FAA has committed resources to the development and distribution of a navigation database to be implemented and distributed over the next few years. To this end, the FAA has sought to implement the use of GPS and WAAS to replace the current ground-based infrastructure within the NAS. A major hurdle for this effort is the cost of acquiring and updating the navigation database, especially for pilot/owners who also have to update their flight deck with RNAV equipment.

The FAA has developed an implementation and development plan that will provide users with data in acceptable, open-industry standard for use in GPS/RNAV systems. The established aviation industry standard database model,

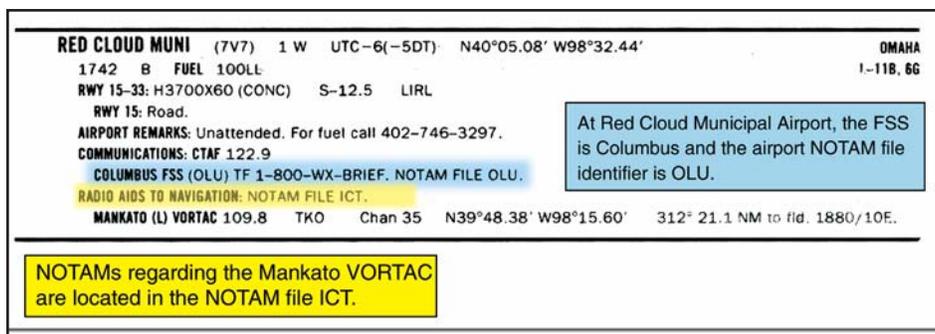


Figure 1-21. NOTAM File Reference in A/FD.

Aeronautical Radio, Incorporated (ARINC 424) format, includes the essential information necessary for IFR flight in addition to those items necessary for basic VFR navigation. As part of Phase I of the process, existing en route data is entered and verified in the ARINC 424 database while Phase II includes the verification and population of the procedural information. Ultimately, this will allow manufacturers the ability to provide several options to consumers. One option would be to allow the end user to download the FAA database utilizing the hardware/software

interface, while another option allows database subscribers access not only to the FAA database but also value-added data such as FBO/airport services, fuel costs, or a plug-and-play database card. Essentially the new FAA database will fulfill requirements for operations within the NAS while still providing the opportunity for private entities to build upon the basic navigation database and provide users with additional services when desired. Refer to Appendix A, Airborne Navigation Databases for more detailed information.

